Promoting the Use of Tropical Legumes as Cover Crops in Puerto Rico

By

Sonia I. Carlo Acosta

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Approved by:

James S. Beaver, Ph.D. Chair, Graduate Committee	Date
Elide Valencia Chin, Ph.D. Member, Graduate Committee	Date
Felix Roman, M.S. Member, Graduate Committee	Date
Miguel A. Muñoz, Ph.D. Chairperson of the Department	Date
Joseph Robinson, M.S. Representative of Graduate Studies	Date

Abstract

Degradation and misuse of agricultural land has made it necessary to identify solutions to address this serious problem. Cover crops have long been used in the tropics to increase soil and water conservation, especially on steep land, and to improve soil structure. This investigation involved two types of experiments; experiment station studies and on-farm trials. Seed density trials were conducted at the Isabela Substation to identify appropriate production practices for seed production of jack bean (*Canavalia ensiformis)* and velvet bean (*Mucuna pruriens*) variety V- 90. On-farm trials were conducted on 20 citrus farms in the central mountain region of Puerto Rico to evaluate the performance of jack bean, velvet bean, cowpea (*Vigna unguilata*) and sunn hemp (*Crotolaria juncea)* as cover crops. An additional objective of this research was to inform farmers of the advantages of using green manures to improve their cropping systems. At the Isabela Substation, a determinate velvet bean cultivar produced an average seed yield of 900 kg ha^{-1}. An indeterminate velvet bean cultivar produced a seed yield of 2,400 kg ha^{-1} and the jack bean cultivar produced a mean seed yield of 3,810 kg $ha^{-1.}$ Canopy cover was estimated in the on-farms trials at 6, 9 and 12 weeks after planting. At flowering (102 days after planting), the jack bean had a mean canopy coverage of 60%. Velvet bean flowered at 67-days after planting and produced an average canopy cover of 82%, whereas the sunn hemp flowered at 96-days after planting and had a mean canopy cover of 73%. Biomass (kg dry weight /ha) and nitrogen accumulated in the biomass was determined at 120 DAP. Jack bean produced the greatest amount of biomass and nitrogen (2,477 kg/ha; 93 kg/ha), followed by velvet bean (1,817 kg/ha; 69 kg/ha) and sunn hemp (1,849 kg/ha; 60 kg/ha*).*The amount of biomass produced by each legume during a specific period of time, did not necessarily correspond to the amount of area covered by the canopy of leaves. The use of legume cover crops in farming systems can be a viable management practice for Puerto Rico. Citrus producers expressed willingness to use legume cover crops to improve their production practices and reduce soil loss.

Resumen

La degradación del suelo y sus múltiples efectos negativos han creado la necesidad de buscar soluciones que ayuden enfrentar esta problemática y sus consecuencias para la agricultura. Una alternativa son las plantas cobertoras que durante y al final de su ciclo se convierten en "abonos verdes", reintegrándose al suelo y mejorando sus características físicas y químicas. El uso de abonos verdes ha sido una de las técnicas más acogidas por los agricultores en Puerto Rico por su fácil establecimiento, bajo costo y gran aporte al mejoramiento de la fertilidad y productividad del suelo. Se llevó a cabo 2 experimentos, un experimento de densidad en la estación experimental de Isabela y otro en 20 fincas de cítricas bajo condiciones similares de clima y geografía en el área montañosa central de Puerto Rico. Se evaluó el comportamiento de tres especies de leguminosas anuales [jack bean (*Canavalia ensiformis)*, sunn hemp (*Crotolaria juncea)* y velvet bean (*Mucuna prurience*)]. En la estación experimental de Isabela, velvet bean determinada obtuvo un rendimiento de 900 kg ha^{-1}, velvet bean indeterminada obtuvo 2,400 kg ha^{-1} y jack bean 3,810 kg ha^{-1}. Para cada una de las especies, se estima la superficie de terreno cubierta por la cobertora a la fecha de floración. En promedio, Jack bean, velvet bean y sunn hemp cubrieron respectivamente, 60% (102 días), 82% (67 días) y 73% (96 días). Además, a los 120 días, se determinó la biomasa en kg de peso seco/ha y el contentido de nitrógeno acumulado en la biomasa producida por cada especie en cada finca. Jack bean, velvet bean y sunn hemp produjeron promedios de 2,477kg/ha, 1,816 kg/ha y 1,849 kg/ha de biomasa y 93 kg N/ha, 69 kg N/ha y 60 kg N/ha, respectivamente. Estos resultados preliminares muestran que la cantidad de biomasa producida en un determinado tiempo, no necesariamente corresponde a una mayor o menor superficie cubierta por las tres especies. Jack bean produjo la mayor cantidad de biomasa en 120 días, mientras que el velvet bean tuvo el mayor cobertura de área en 67 días. El uso de abonos verdes como alternativa fue acogida con gran entusiasmo por los productores quienes se motivaron a continuar con esta práctica agrícola sostenible.

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Introduction

Cover crops have long been used in the tropics for soil and water conservation, especially on steep land, and to improve soil structure. The introduction of inexpensive nitrogen fertilizers and herbicides encouraged many farmers to discontinue this practice. However, soil degradation, erosion, and weed problems are leading farmers to re-consider the integration of cover crops into their farming systems. Cover crops can contribute to pest management and reduce the use of pesticides. When managed properly, legume cover crops can decrease dependence on external inputs such as fertilizer. Although, the principal benefits of a cover crop lies in the control of soil erosion and their ability to suppress weeds, intercropping trees with cover crops is a well-known strategy in several cash-crop production systems in the tropics (Coulloudon et al., 1999) . In tropical Asia, cover crops are frequently planted in oil palm plantations (Broughton, 1976), as well as with coconut (Aldaba, 1995) and rubber trees (Watson, 1989).

Cover crops may fulfill several purposes in agro-forestry systems by providing permanent soil cover, reducing erosion, increasing soil nutrient concentration and increasing organic matter. Integrating cover crops into farming systems is not a common practice in Puerto Rico. Citrus growers face many challenges including competition in global markets. Soil erosion is one of the most chronic environmental problems on citrus farms in Puerto Rico. Farms in many municipalities have steep slopes and high annual rates of rainfall (means of 1,500 mm in the north and 508 mm in the central mountain area) that can cause severe soil erosion. The use of legume cover crops in farming systems can be a viable management practice in Puerto Rico. Citrus producers have expressed a willingness to adopt new production practices to reduce soil loss due to lack of ground cover and intensive tillage practices.

The identification of proper management techniques and availability of seed are needed to initiate the incorporation of legumes cover crops into farming systems on the island. The results of this research could be used to develop management plans for the use of legume cover crops on citrus farms in Puerto Rico.

Proper management and adaptation of the legumes may be specific to certain regions or production systems. Since there are diverse cropping systems within the island, the use of different legume cover crops may be required. The legumes in this study may be used as cover crops, green manures or as forage crops. The use of these tropical legumes cover crops can generally be applied to citrus as well as other farming systems in Puerto Rico. This research will help the University of Puerto Rico, Agricultural Experiment Station to produce legume seed more efficiently and provide farmers with access to seed of cover crops that are adapted to a range of climate conditions. The use of these legume cover crops would allow farmers to reduce operating cost and environmental risk.

This study measured the performance of various leguminous cover crops in the principal citrus production region of Puerto Rico. Adaptation, flowering date, canopy cover, biomass yield, nitrogen accumulation and other contribution of the cover crops were the criteria used to evaluate the performance of the legumes on the citrus farms.

Objectives

- Identify tropical legumes that may have potential as cover crops or alternative crops for citrus producers in Puerto Rico.
- Conduct on farm-validation trials of the most promising tropical legumes to identify appropriate management practices.
- Document potential benefits and limitations of the use of tropical legumes as cover crops for citrus producers in Puerto Rico.
- Collect agronomic and seed production data needed to formally release the most promising tropical legumes as cultivars.

Literature Review

The use of cover crops is a sustainable management practice used to enhance soil fertility improve soil, and water quality, manage weed, pest and pathogen populations, and preserve biodiversity in agro-ecosystems (Lu et al. 2000). Although cover crops can perform multiple functions in an agro-ecosystem, they are most often grown to prevent soil erosion. Soil erosion is a process that can irreparably reduce the productive capacity of an agro-ecosystem. Dense cover crop physically slows down the velocity of rainfall before it contacts the soil surface, preventing soil splashing and erosive surface runoff (Romkens *et al.* 1990). Additionally, cover crop root networks help anchor the soil in place and increase soil porosity, creating suitable habitat networks for soil macro fauna (Tomlin et al*.,* 1995). By reducing soil erosion, cover crops can improve soil quality by increasing soil organic matter levels through the input of cover crop biomass over time. Legume cover crops can reduce both the rate and quantity of water that drains off the field that would normally pose environmental risks to waterways and ecosystems downstream (Dabney et al*.,* 2001).

When the cover crop is incorporated into the soil, or left on the soil surface, it often increases soil moisture. Where water for crop production is in short supply, cover crops can be used as a mulch to conserve water by shading and cooling the soil surface. This reduces evaporation of soil moisture. Successful cover cropping requires the selection of a species that will provide specific desired benefits and that will be compatible with the overall farming system. Growers who use cover crops gain multiple benefits from them. Cover crops should be rotated periodically to avoid the buildup of plant-specific pests.

Furthermore, cover cropping, like any new practice, should be approached slowly and methodically. It is important to test several species or mixtures to find the most appropriate cover crop for individual farms. Farmers should consider starting on a small scale in order to learn from mistakes without incurring unnecessary expenses. With persistence and creativity, cover cropping can provide many benefits at little or no extra cost.

Cover crops increase soil organic matter, enhance soil structure and improve the water and nutrient holding and buffering capacity of soils (Patrick et al., 1957). Their use can also lead to increased soil carbon sequestration, which has been promoted as a mitigation strategy to help offset the rise in atmospheric carbon dioxide levels (Kuo et al., 1997; Sainju et al., 2002;, Lal, 2003).

Cover crop biomass acts as a physical barrier between rainfall and the soil surface. Cover crop root growth also results in the formation of soil pores, which in addition to enhancing soil macro fauna habitat, provides pathways for water to filter through the soil profile rather than draining off of the field as surface flow. With increased water infiltration, the potential for soil water storage and the recharging of aquifers can be improved (Joyce et al., 2002).

Some cover crops suppress weeds both during growth and after death (Blackshaw et al., 2001). During growth these cover crops compete vigorously with weeds for available space, light, and nutrients, and after death they smother weeds by forming a mulch layer on the soil surface. Blackshaw et al.,(2001) found that *Melilotus officinalis* (yellow sweetclover) used as a cover crop in an improved fallow system (where a fallow period is intentionally improved by any number of different management practices, including the planting of cover crops), weed biomass only constituted between 1-12% of total standing biomass at the end of the cover crop growing season. Furthermore, after cover crop termination, the yellow sweetclover residues suppressed weeds to levels 75-97% lower than in fallows without yellow sweetclover.

Cover crops are used to manage a range of soil macronutrients and micronutrients. The impact of cover crops on nitrogen management has received by far the most attention by researchers and farmers, because nitrogen is often the most limiting nutrient in crop production. In addition to biological nitrogen fixation, legume cover crops serve as "catch crops" retaining and recycling soil nitrogen already present in the agro-ecosystem. Catch crops take up surplus nitrogen remaining from fertilization of the previous crop, preventing it from being lost through leaching or volatilization (Morgan et al., 1942). Catch crops are typically fast-growing annual cereal species adapted to scavenge available nitrogen efficiently from the soil (Ditsch and Alley 1991). The nitrogen tied up in catch crop biomass is released back into the soil once the catch crop is incorporated as a green manure or otherwise begins to decompose.

Cover crops known as "green manures" are grown and incorporated (by tillage) into the soil before reaching full maturity, and are intended to improve soil fertility and quality. Leguminous cover crops are typically high in nitrogen and can often provide the required quantity of nitrogen for crop production that might normally be applied as chemical fertilizer (Thiessen-Martens et al., 2005). Biological nitrogen fixation, achieved mainly through the use of cover crops, is a sustainable alternative to the use of chemical fertilizers derived which are mostly derived from industrial nitrogen fixation: a process that requires petroleum and the intensive use of energy (Thiessen-Martens et al*.,* 2005).

Velvet bean [*Mucuna pruriens* (syn. *Dolichos pruriens*)] is known worldwide as a tropical legume cover crop or green manure. Velvet bean has proven to be successful for maintaining soil fertility and controlling weeds. The numerous advantages of velvet bean have led to widespread adoption in many parts in Central America and Africa. Velvet bean was introduced to Florida in the 1870s and by early 1900 many Florida orange growers planted velvet bean in orchards to improve soil fertility (Buckles, 1995). Velvet bean was domesticated in tropical regions of India (Tateishi, 1987). The velvet bean has been reported to fix up to 150 kg N/ha as well as produce 35 tons of organic matter per year and, when integrated with corn, can increase seed yields up to 2500 kg/ha (Bunch, 1990). The velvet bean is used as a green manure that is considered an inexpensive source of organic fertilizer to build up organic matter. In Nigeria, velvet bean increased the availability of phosphorus in the soil after rock phosphate was applied (Vanlauwe et al., 2000). Hundreds of farmers in the northern coast of Honduras use velvet bean with excellent results, producing maize (*Zea mays* L.) yields of about 3,000 kg/ha, more than double their national average. Additional advantages include erosion reduction, weed suppression and lower land preparation costs. The use of slash/mulch systems based on the traditional "tapado" system, used on the Central American hillsides, have been reported to increase bean and maize yields and reduce labor inputs as cover crops smother aggressive weeds, thus minimizing the need for weeding. Another advantage is that the use of drought resistant mulch legumes such as velvet bean provides good forage for livestock (Thurston et. al., 1994). Some velvet bean cultivars can produce nearly 30 t/ha of biomass per year, or about 90-100 kg of N/ha per year (Flores, 1989). The velvet bean has been reported to control root-knot nematodes (*Meloidogyne incognita*) (McSorley et al., 1992)

Velvet beans usually have an indeterminate growth habit that produces vines 3 to 18 m in length. Plants have royal purple flowers that hang in long clusters. The plant also produces clusters of pods which contain seeds known as mucuna beans. The seed pods are covered with dark hairs that are readily dislodged and can cause irritation to the skin. The species name "pruriens" (from the Latin, "itching sensation") refers to the results to be had from contact with the seed pod hairs South America (Sridhar et al., 2007).

Another promising legume cover crop is the jack bean (*Canavalia ensiformis).* The genus *Canavalia* consists of 4 genera with 51 species (Smartt 1990). Agronomic studies in Cuba reported that jack bean produced a total biomass of 5.3 t/ha (Martin et al., 1998). Due to its tolerance to shade, jack bean is used in Honduras as a cover crop in association with coffee. It has been reported to fix more than 200 kg/ha of N per year. The jack bean can be used as a green manure or as forage crop for ruminant animals. The legume grows in elevations as high as 1,800 m. Very young pods are edible, but mature beans are highly toxic, although heat treatment can eliminate the toxic effects. This variety is very drought-tolerant and can be useful as a cover crop. The ideal pH for development is 5-6 and although the jack bean will grow on degraded tropical soils where other legumes will not grow. It has proven to be a useful species in tropical soil reclamation efforts because of its deeply penetrating root system provides high drought tolerance (Price, 2005)

Cowpea [*Vigna unguiculata* (L.) Walp.] is a grain legume grown mainly in the savanna regions of the tropics and subtropics in Africa, Asia, and South America. The value of cowpea lies in its high protein content, and its ability to tolerate drought. Cowpea seed can be consumed green or dry and the plant can be used as fodder or as a green manure. Cowpeas are tolerant to high temperatures and this legume has been reported to fix up to 100 kg of N per year and improve poor soils (Wilson, 1982). The cowpea is a fast growing, cover crop that is adapted to a wide range of soil conditions. A long taproot allows cowpeas to obtain moisture from deep in the soil profile, thus it is well adapted to drought conditions. Vigorous cowpea varieties compete well against weeds. A high nitrogen producer, cowpea yields an average of 3,000 to 4,000 lb/acre of dry biomass containing. This average biomass can be achieved 60 to 90 days after planting. Residues are succulent and decompose readily when incorporated into the soil. Plants normally grow up to 2 ft tall, but some cultivars can climb when planted in mixtures with other species. When killed mechanically, cowpeas can have considerable re-growth after mowing and undercutting in some years (Harrison et al., 2004).

Sunn hemp (*Crotalaria juncea* L.) is a legume that when grown as a summer annual can produce over 2268 kg of biomass and can fix over 45 kg N ha^{-1} (Cook and White, 1996). Sunn hemp originated in India where it has been grown since the dawn of agriculture. It has been utilized as a green manure, livestock feed, and as a non-wood fiber crop. It has also been grown in Brazil and Bangladesh as a soil-improving crop.

Research with sunn hemp has been conducted in the United States since the 1930s, where it was reported to be excellent in improving soil conditions (Cook and White, 1996). However, suitable areas for seed production are limited to mostly southern Texas. The difficulty in producing seed in other parts of the United States caused many farmers to abandon growing the crop. The USDA-NRCS and the University of Hawaii Institute of Tropical Agriculture and Human Resources cooperatively released the cultivar 'Tropic Sun' sunn hemp in 1983. Sunn hemp has been used extensively to improve soil or as green manure crop in the tropics because of its ability to produce large amounts of biomass in as little as 60 to 90 days. Because of this, it has the potential to build organic matter levels and sequester carbon. Also, as a legume, it can fix large amounts of nitrogen. Used as a cover crop, sunn hemp can improve soil properties, reduce soil erosion, conserve soil water, and recycle plant nutrients. The sunn hemp variety 'Tropic Sun' is also resistant to root-knot nematodes. Other potential uses for sunn hemp are forage, paper fiber, and as alternative fuel crop (Rotar and Joy, 1983).

Materials and Methods

Seeds of the legume species used in this research were obtained from Honduras, Central America and the U.S. Determinate and indeterminate velvet bean varieties (cv. Vine 90-d) were obtained from the Educational Concern for Hunger Organization (ECHO), based in Ft. Meyers, FL. Because these velvet bean varieties reach maturity within 100 days after planting and have more limited vegetative growth, they were considered to be good candidates for intercropping with citrus (*Citrus sinensis),* bananas and plantains (Musa *spp*). The jack bean line was obtained from the Panamerican School of Agriculture in Honduras. The determinate cowpea variety 'Gorda' was obtained from the University of Puerto Rico, Agricultural Experimental Station (UPR, AES) and the sunn hemp "var. Tropic Sun" was provided by Dr. Bryan Brunner, UPR Mayaguez campus.

Studies were conducted at the Isabela Substation, UPR, AES. This station is located in the northwest sub-humid region of Puerto Rico at a longitude of 67.3° W and latitude of 18.28° N. The research site is 128 m above sea level and the soil is classified as an Oxisol within the Coto series. The average annual precipitation ranges from 1,000 to 1,500 mm, and its distribution is defined by a wet season from July to December and a dry season from January to April (Howorth, 1934). An average monthly rainfall of 144 mm of rainfall occurs during the wet season and a monthly average of 94 mm of precipitation occurs during the dry season (SERCC, 2004).

The experiments conducted at the experimental station focused on seed production, adaptation and overall performance of the legume species, as well plant density trials. Legumes that were considered to be potential cover crops for citrus farms were narrowed down to the jack bean, velvet bean, Gorda and Tropic Sun. The Isabela Substation density experiments evaluated the jack bean and velvet bean varieties at three different densities. The determinate and indeterminate velvet bean varieties were hand planted using within row distances (0.15 m, 0.3 m, 0.45 m) and a spacing of 0.6 m between rows. Since jack bean's growth is so vigorous, the within-row spacing in this experiment was (0.6 m, 0.9 m, and 1.2 m between plants) and a spacing of 1.2 m between rows. The experimental designs were Randomized Complete Blocks with 4 replications, with experimental units consisting of 3 rows, 5m in length.

The experiments were planted in January 2008 for dry season and a second planting in May 2008 for the wet season. Fertilizer, insecticide or irrigation was not applied after planting or during the growing season.

Variables measured in the density trials were plant population (based on the number of plants per experimental unit), flowering date (50% or more of the plants with at least 1 flower), percentage of canopy cover at flowering date, harvest date (when seed pods matured), seed yield (kg/ha), and 100 seed weight. Data were analyzed with INFOSTAT (2007), analysis of variance (ANOVA) and means were compared using Least Significant Differences ($p < 0.05$).

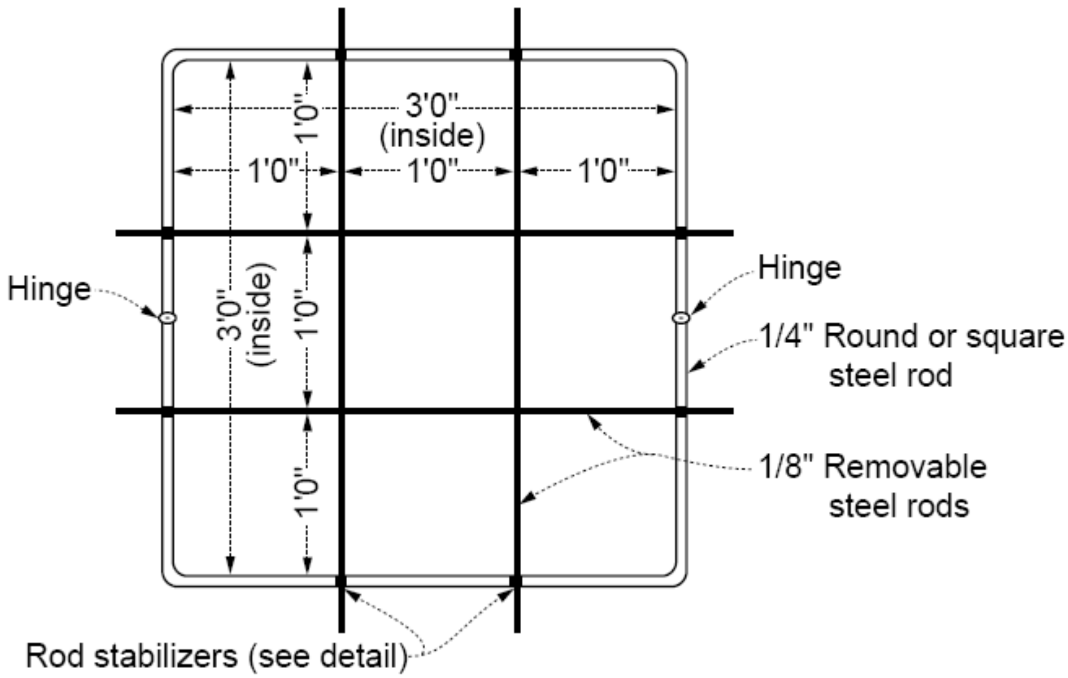
Planting of indeterminate velvet beans in citrus in 2006 was unsuccessful because of its aggressive growth habit. As a result, determinate velvet bean was assessed, along with Gorda and jack bean for their potential as cover crops. Legumes were eliminated as treatments for the on-farm trials in subsequent years if they demonstrated to have poor performance during the previous years of testing. New legume species were included as entries in the on-farm trials if their performance on the Isabela Substation proved to be promising.

The sites for the on-farm trials were selected with the assistance of local agents of the Agricultural Extension Service of the University of Puerto Rico. Participants were educated about cover crop usage and the benefits of integrating these legumes into their farming system. The on-farm trials were conducted to correspond to the wet and dry seasons. The planting dates were established in June through August for the wet season and in January through May for the dry season. The experiments were planted using a Randomized Complete Block design with two replications for each legume species. Treatments were planted as monocultures of velvet bean, cowpeas and Jack bean. The on-farm trials were conducted on at least 5 farms per growing season over a two-year period, resulting in a total of 20 trials. The dimensions of the experimental units were 5 m x 3 m. Spacing between rows for velvet bean, Gorda and Tropic sun was 0.5 m between rows. Seeding rates were 5-6 seed m^{-1} for velvet bean, 7-8 seed m^{-1} for cowpea and 9-10 seed m^{-1} for sunn hemp. Between row spacing for the jack bean was 0.6 m with a seeding rate of approximately 2 seed m^{-1} of row length. An additional treatment was planted with the velvet bean intercropped with cowpea (spaced at 0.25 m between rows) to enhance weed control.

No inorganic fertilizer was used in the on-farm trials. In addition, there was no control of insects or diseases and no weeding in order to evaluate the legumes potential in controlling these biotic factors. Soil samples were taken from each trial before planting. Since all treatments were planted without tillage; weeds were killed before planting with Glyphosate (N-(phosphonomethyl) glycine) at a rate of 1L/ha. The USDA soil survey catalog of central and northern Puerto Rico and a GPS device (Garmin E-trex legend) was used to determine the exact location and soil series of each farm. An inclinometer to estimate the average length and percentage of slopes of each on-farm trial was also used. Each trial site was visited three weeks prior to planting date and was under observation for 120 days after planting. A micro-plot was established for each trial using a 1 x 1 m^2 quadrant. This frame is build of 0.2 x 0.2 m segregated squares that were constructed of plastic. Each square was assigned a number that afterwards was converted into a percentage that allowed an area from each treatment to be selected and identified for evaluating frequency, cover, density and production (Coulloudon et al., 1999).

The cover crop plants present in each sampling unit was counted to measure frequency. Cover percentage was also collected at the same time frequency data was gathered. Frequency data was collected for all plant species except the species used as a cover. To calculate the percent frequency for species we determined the number of occurrences of each species per 0.2 x 0.2

m unit in each plot (Figure 1). The total number of occurrences of each species was divided by the total number of quadrants sampled and multiplied by 100 to determine the percentage of frequency per trial.



(Coulloudon et al., 1999)

Figure 1: Monitoring Frame 1 x 1 m

The Daubenmire method was used to determine canopy cover. This method consists of systematically placing the quadrant frame along the permanently located micro plots in each trial (Coulloudon et al., 1999). The estimation of vegetative cover was similar to the frequency sampling only that the cover is categorized using the Daubenmire cover crop standards. Plant species, bare soil, and structures (plant residue) were assigned cover class values based on the development of the cover up to 120 days after planting. Using the Daubenmire method, the following cover were classified as (CC) values are used for this study; CC1 (5% or less), CC2 (5-25%), CC3 (25-50%), CC4 (50-75%), CC5 (75-95%), and CC6 (95% or greater) (Coulloudon et al., 1999). This data was observed at 3, 6, 9, 12, 15 and 18 weeks after planting or until the cover reached 90% (Coulloudon et al., 1999).

The Dry Weight Rank method was used to estimate biomass production. This method consists of harvesting the 1 x 1 m micro plot at 120 days after planting from each trial. Samples were dried at a constant temperature of 60˚C for two days and weighed (Coulloudon et al., 1999). Nitrogen concentration was analyzed using the Kjeldahl method. Accumulated nitrogen was calculated by multiplying biomass with the N concentration.

Insect/disease damage were monitored using a general disease and pest evaluation scale that are used for evaluating bean disease and pest damage. The incidence of plants with disease symptoms was obtained by counting the number of healthy and diseased plants in a plot. The Modified Cobb scale was used for estimating the amount of leaf area infected by a disease or pest (Table 1).

Table 1: Modified Cobb scale for intensity of infection.

Description	
0	No visible infection
1	1-5% leaf area infected or damaged
2	6-10% leaf area infected or damaged
3	11-25% leaf area infected or damaged
4	26-40% leaf area infected or damaged
5	65-100% leaf area infected or damaged

Source: Stavely (1985).

All cooperating farmers were requested to take a survey for this research. This survey attempted to identify the barriers to adoption of cover cropping in citrus orchards in Puerto Rico (Annex 1). Farmers were asked to indicate which legume was most suited for their particular farming system. The subject of selecting proper legume cover crops for citrus growers included questions concerning the difficulty of managing the legumes. It is interesting to note that many of the farmers that were interviewed were aware of the potential benefits of cover cropping such as the increased presence of beneficial insects including pollinators, reduced weed problems, increased water holding capacity, increased nutrient availability to the following crop, and reduced soil compaction.

Results and Discussion

Seeding rate trials planted at the Isabela Substation

For determinate velvet bean, there were no significant differences ($p>0.05$) among plant densities for seed yield, 100 seed weight, day to first flower and % canopy cover (Table 3). There were, however, significant differences between seasons for days to first flower. When compared with the January 2008 planting date, the mean flowering date of the determinate velvet bean was 15 days later when planted in May 2008 (Table 2).

Mean seed yield ranged from 756 kg ha^{-1} to 871 kg ha^{-1} for the January planting date and from 844 kg ha^{-1} to 1117 kg ha^{-1} for the May planting date. The determinate velvet bean could be planted at the lowest seeding rate for seed production at the Isabela Substation. Hundred seed weight was approximately 60 g. At the lowest seeding rate, approximately, 67 kg of seed would be needed to plant one ha of determinate velvet bean. At an average seed yield of 900 kg ha^{-1}, one ha should produce sufficient seed to plant an additional 12 ha of determinate velvet bean.

Although there was a two-week difference in flowering date between the January and May plantings, determinate velvet beans reached maturity and were harvested within 120 days after planting. There were no significant problems with disease or pests during both growing seasons. However, it would be better to produce seed of the determinate velvet bean variety during the dry season because many of the pods touch the surface of the soil and began to decay.

Table 2: Analysis of variance for seed yield, 100 seed weight, days to first flower and % canopy cover at flowering of determinate velvet bean planted at Isabela, Puerto Rico in January 2008.

Source of Variation	df	Mean Square			
		Seed yield	100 seed weight	Days to first flower	% canopy cover at flowering
Seasons	1	121553	70.0	1410.7**	160.2
Block/Seasons	6	20013	23.8	26.1	175.3
Density	2	53502	30.3	32.7	162.7
Density x Seasons	2	37961	5.0	50.7	155.2
Error	12	48744	34.4	65.4	252.0
CV (%)		24.55	9.56	12.61	19.76

*Significant at 5%, **Significant at 1%

Table 3: Means of seed yield, 100 seed weight, days to flowering and canopy cover in spacing trial for determinate and indeterminate velvet bean planted at Isabela, Puerto Rico in January and May 2008.

Plant density	Determinate velvet bean		Indeterminate velvet bean	
	Seed yield (kg/ha)			
	January	May	January	May
60 cm x 15 cm	756	951	2131	2780
60 cm x 30 cm	871	1117	1996	2544
60 cm x 45 cm	858	844	1702	3090
Mean	828	971	1943	2804
LSD (0.05)	NS		NS	
	100 seed weight (g)			
	January	May	January	May
60 cm x 15 cm	57	62	71	67
60 cm x 30 cm	62	65	71	71
60 cm x 45 cm	61	63	68	68
Mean	60	63	69	68
LSD (0.05)	NS		NS	
	Days to first flower			
	January	May	January	May
60 cm x 15 cm	57	73	57	89
60 cm x 30 cm	56	76	54	87
60 cm x 45 cm	57	67	55	88
Mean	57	72	55	88
LSD (0.05)	NS		NS	
	Canopy cover (%)			
	January	May	January	May
60 cm x 15 cm	77	75	91	88
60 cm x 30 cm	78	93	81	84
60 cm x 45 cm	80	81	78	88
Mean	78	83	83	86
LSD (0.05)	NS		NS	

For indeterminate velvet bean, there were no significant differences among plant densities for seed yield, 100 seed weight, days to first flower and % canopy cover (Table 3). There were significant differences between seasons for days to first flower. When compared with the January 2008 planting date, the mean flowering date of the indeterminate velvet bean was 33 days later when planted in May 2008 (Table 3). Mean seed yield ranged from 1702 kg ha^{-1} to 2131 kg ha^{-1} for the January planting date and from 2,544 kg ha^{-1} to 3,090 kg ha^{-1} for the May planting date. The indeterminate velvet bean could be planted at the lowest seeding rate for seed production at the Isabela Substation. Hundred seed weight was approximately 68 g. At the lowest seeding rate, approximately, 76 kg of seed would be needed to plant one 1 ha of indeterminate velvet bean. At an average seed yield of 2,400 kg ha^{-1}, 1 ha should produce sufficient seed to plant an additional 31 ha of indeterminate velvet bean. Although there was a five-week difference in flowering date between the January and May plantings, seed of the indeterminate velvet beans reached maturity and were harvested within 120 days after planting. There were no significant problems with disease or pest during both growing seasons. This variety of velvet bean was more abundant in seed yield than the determinate variety.

Table 4: Analysis of variance for seed yield, 100 seed weight, days to first flower and % canopy cover at flowering of indeterminate velvet bean planted at Isabela, Puerto Rico in January 2008.

Source of Variation	df	Mean Square			
		Seed yield	100 seed weight	Days to first flower	% canopy cover at flowering
Seasons	1	4453955	7.1	6468.2**	51.0
Block/Seasons	6	948397.8	28.0	33.3	154.0
Density	2	71858	23.0	11.2	126.0
Density x Seasons	2	420428	18.0	0.17	95.0
Error	12	514158	32.1	21.0	113.2
CV (%)		30.21	8.23	6.38	12.55

*Significant at 5%, **Significant at 1%

For jack bean, there were no significant differences among plant densities for seed yield, 100 seed weight and % canopy cover (Table 4). There was a significant density *seasons interaction for days to first flower ($p < 0.05$). When compared with the January 2008 planting date, the mean flowering date of jack bean was 36 days later when planted in May 2008 (Table 5). Mean seed yield ranged from 3,531 kg ha^{-1} to 4,330 kg ha^{-1} for the January planting date and from 3,244 kg ha^{-1} to 4,092 kg ha^{-1} for the May planting date. The jack bean could be planted at the lowest seeding rate for seed production at the Isabela Substation. Hundred seed weight was approximately 144 g. At the lowest seeding rate, approximately, 14 kg of seed would be needed to plant 1 ha of jack bean. At an average seed yield of 3,810 kg ha^{-1}, 1 ha should produce sufficient seed to plant an additional 272 ha of jack bean. Although there was a five-week difference in flowering date between the January and May plantings, both seed of jack beans reached maturity and were harvested six to eight weeks after planting. There were no significant problems with disease or pest during both growing seasons.

Table 5: Analysis of variance for seed yield, 100 seed weight, days to first flower and % canopy cover at flowering of jack bean planted at Isabela, Puerto Rico in January 2008.

Source of Variation	df	Mean Square			
		Seed yield	100 seed weight	Days to first flower	% canpoy cover at flowering
Seasons	1	54150	80.7	7704	26
Block/Seasons	6	1220397	30.4	170	293
Density	2	1101873	29.3	55	70
Density x Seasons	2	426394	5.5	332*	51
Error	12	1396735	54.8	94	203
CV (%)		31.0	5.1	11.0	18.4

Table 6: Means of seed yield, 100 seed weight, days to flowering and canopy cover in spacing trial for jack bean planted at Isabela, Puerto Rico in January and May 2008.

Plant density	Jack Bean	
	Seed yield (kg/ha)	
	January	May
120 cm x 60 cm	3531	3952
120 cm x 90 cm	3713	3244
120 cm x 120 cm	4330	4092
Mean	3858	3763
LSD (0.05)	NS	NS
	100 seed weight (g)	
	January	May
120 cm x 60 cm	144	143
120 cm x 90 cm	146	141
120 cm x 120 cm	149	144
Mean	146	143
LSD (0.05)	NS	NS
	Days to flowering	
	January	May
120 cm x 60 cm	80	101
120 cm x 90 cm	65	109
120 cm x 120 cm	65	107
Mean	70	106
LSD (0.05)	23	23
	Canopy cover (%)	
	January	May
120 cm x 60 cm	76	81
120 cm x 90 cm	76	72
120 cm x 120 cm	77	82
Mean	77	79
LSD (0.05)	NS	NS

Results of On-Farms Trials

First growing season (June – October 2007)

During the first growing season (June-October, 2007), the on-farm trials were planted in a region important for the production of citrus. Four legumes (velvet bean, sword bean, sunn hemp and cowpea) were evaluated as potential cover crops for citrus producers in Puerto Rico, In the combined Analysis of Variance the effects of farm and farm*species interaction was significant for all traits except plant population. The effect of species was significant for all of the traits (Table 7).

Table 7: Analysis of Variance for biomass, days to first flower, % canopy cover at flowering and plant population for on-farm trials planted northwestern Puerto Rico from June to October 2007.

Source of variation	Df	Mean square					
		Plant population	Days to flowering	% canopy cover			Biomass
				Week 6	Week 9	Week 12	
Farm	3	745	342*	1217**	2286*	3333**	1241478**
Rep (Farm)	4	768	51	2	109	55	12207
Species	2	17422**	7615**	2102**	3099**	3362**	853351**
Farm*species	6	409	215*	808**	574**	441**	92080*
Error	8	205	56	18	21	48	16161
CV (%)		20.3	9.7	14.2	10.2	11.7	13.8

*Significant at 5%, **Significant at 1%

FARM 1

This farm is located in Moca, P.R. Barrio (Bo) Cano Gordo, Road (Rd) 495. The elevation was 97 m and the coordinates were Lat. 18°.34”, N; Log. 67°.08”,W. The farm was recently planted with two year old citrus trees (aprox. 2.4 ha planted), and also was planted with plantain, bananas, yams (*Dioscorea spp.)* and other minor vegetables. This 13-ha farm owned by Norma Santiago, is new farm land that is being developed for crop production. We observed that soil erosion was already a serious problem on the farm. The soil series is Consumo (CoE), Ultisol with 35% slope. The average precipitation in this area is normally 15 to 25 mm for this time period. Results from the soil analysis reported high levels of organic matter: intermediate levels of P, K, and Ca; and low levels of NO_3^-N, Mg and exchangeable Al (Table 9). The legume with the greatest biomass production was the jack bean with an average of 2,170 kg/ha, followed by cowpea and velvet bean with average biomasses of 1,461 and 1,064 kg/ha, respectively (Table 8). Cowpea was the legume that produced the greatest amount of canopy cover at 6, 9, and 12 week after planting. The cowpea canopy completely covered the soil surface at 9 weeks after planting, followed by velvet bean that covered 80% of the of the soil surface at 12 weeks after planting and jack bean that covered only 35% of the area at 12 weeks after planting. The cowpea was the legume with the earliest flowering date (42 days after planting) followed by velvet bean (63 days after planting) and jack bean (116 days after planting), (Table 8). In general, the farmer was pleased with the growth of the legumes on her farm. There were some concerns with the tendency of the jack bean to climb up the citrus trees. To insure that no damage would be caused to the citrus trees, we pruned the vine growth of the jack bean.

Table 8: Means of plant population, flowering date, canopy cover, biomass and soil nutrient content for velvet bean and jack bean and cowpea on the farm of Norma Santiago, Moca, Puerto Rico, June-October 2007

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days
			6 Weeks	9 weeks	12 weeks	
Velvet Bean	92.4	63.0	25.0	55.5	79.5	1064
Jack Bean	22.0	115.5	9.5	24.0	34.5	2170
Cowpea	135.8	42.0	92.5	100.0	100.0	1461
LSD (0.05)	NS	17.3	9.9	10.6	16.0	293
CV (%)	20.3	9.7	14.2	10.2	11.7	13.8

Table 9: Results from the soil test from the farm of Norma Santiago, Moca, Puerto Rico June 2007

Fertility factor	pH	OM	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_c kg^{-1}$--				%
Mean	4.6	5.5	4.6	11.6	4.6	1.4	0.4	0.1	2.0
Level in soil*	L	H	L	M	M	L	M	L	---

*Level in soil according to Sotomayor-Ramírez (2006): L=low, M=medium, H= high.

FARM 2

This trial was located on the experimental station in Adjuntas, P.R. Bo Limani, Rd. 525. The elevation was 1824 m and the coordinates were Lat,18°.15" N; Long, 66°.47", W. The citrus trees on this farm are older (a 5-6 year old planting) than in the Moca trial. Citrus and coffee are the main crops produced in this area. We chose the station because of easy access to the citrus orchard. We chose a "Valencia" variety as the site for the experiment because this is the variety most commonly used in Puerto Rico. The soils are mostly Ultisols, series Consumo (CoE) with a 40% slope. Average precipitation for this time period ranges from 64 to 76 mm. Results from the soil test indicated high levels of exchangeable Al and low levels of P, K, Ca, NO_3^-N, Mg, pH and organic matter (Table 11). We observed that the cowpeas had a severe infestation of aphids *(Aphis fabae)* that may have may adversely affected growth and development of the canopy cover

Similar to the results from the other on farm trials, the jack bean had the greatest amount of biomass production at flowering with an average of 993 kg/ha, followed by velvet bean with an average of 596 kg/ha and cowpea with an average of 340 kg/ha. In spite of the aphid infestation the cowpeas produced the greatest amount of amount of canopy cover at 6, 9, and 12 week after planting, with average coverage of 43%, 62% y 91% respectively. In week 9 and 12, the velvet bean had more canopy cover than the jack bean (Table 10).

Table 10: Means of plant population, flowering date, canopy cover and biomass for velvet bean, jack bean and cowpea on the farm of the in the Adjuntas experimental station, Puerto Rico, June-October 2007.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days
			6 weeks	9 weeks	12 weeks	
Velvet Bean	71.4	85.0	22.0	42.5	70.0	596
Jack Bean	25.7	126.0	18.0	24.0	42.0	993
Cowpea	80.7	43.0	43.0	62.0	90.5	340
LSD0.05	33.0	17.3	9.9	10.6	16.0	293
CV (%)	20.3	9.7	14.2	10.2	11.7	13.8

Table 11: Results from the soil test from the farm of the Adjuntas experimental station, Puerto Rico June 2007

Fertility factor	pH	MO	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---			--$cmol_c kg^{-1}$--			%
Mean	5.1	1.4	3.0	2.0	0.8	0.9	0.2	8.2	10.2
Level in soil*	L	L	L	L	L	L	L	H	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

FARM 3

This experiment was conducted in Lares, Puerto Rico on Mr. Victor Delgado's banana farm, Bo. Buenos Aires, Rd. 129. The elevation was 616 m and the coordinates were Lat 18°.23", N; Long 66°82", NW. This farm is known for production of finger link bananas (guineos enanos). Because of reduced banana yields and increased production costs due to Black Sigatoka caused by *Mycosphaerella fijiensis* Morelet, Mr. Delgado is planning to convert his farm to citrus production. The farm already has 2 acres of 3-year-old tangerines on the farm. This farm has roughly 21 hectare of cultivated bananas and coffee. Soils are generally composed of Ultisols, soil series Consumo (CoF) and a 35% slope.

Average precipitation for this time of year ranges from 127 to 165 mm. Results from the soil test indicated high levels of Ca, K and exchangeable Al; average pH, organic matter and Mg levels; and low level of NO_3^-N, and P (Table 13). Mr. Delgado expressed a willingness to continue the use of cover crops in his farm. However he commented that the cowpea may be a difficult crop to manage on his farm. He also expressed concern about the possibility that cowpeas may serve as a host for non-beneficial insects.

Jack bean had the greatest yield of biomass producing an average of 1,206 kg/ha, followed by velvet bean with an average of 950 kg/ha and cowpea with an average of 610 kg/ha. The canopy cover of cowpea and velvet bean was similar at 6, 9 and 12 weeks after planting. The mean % canopy cover of cowpeas and velvet bean was 45%, 65% y 85% at 6, 9 y 12 weeks after planting, respectively. Jack bean produced the lowest % canopy cover for all three evaluation dates (Table 11). Mean flowering dates of velvet bean (62 days after planting) and cowpea (52 days after planting) were similar to the results from trials 1 and 2. The mean flowering date of jack bean was 94 days after planting (Table 12).

Table 12: Means of plant population, flowering date, canopy cover and biomass for velvet bean, jack bean and cowpea on the farm of Victor Delgado, Lares, Puerto Rico, June-October 2007.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days
			6 weeks	9 weeks	12 weeks	
Velvet Bean	82.0	62.0	44.5	66.0	85.5	950
Jack Bean	16.4	94.0	27.5	35.5	46.0	1206
Cowpea	128.4	51.5	47.5	67.5	88.5	610
$LSD_{0.05}$	33.0	17.3	9.9	10.6	16.0	293.2
CV (%)	20.3	9.7	14.2	10.2	11.7	13.8

Table 13: Results from the soil test from the farm of Victor Delgado, Lares, Puerto Rico, June 2007

Fertility factor	pH	OM	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--cmol$_c$kg^{-1}--				%
Mean	6.0	3.2	4.8	2.0	4.1	1.8	0.5	0.8	0.0
Level in soil*	M	M	L	L	H	M	H	H	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

FARM 4

The fourth trial was planted on a farm owned by Mr. Emilio Jaramillo at Bo. Culebrina, San Sebastian, P.R. Rd.119. The farm was located at an altitude of 150 m and the coordinates were Lat 18° 30", N; Long 67°.00", NW.. Mr. Jaramillo is the producer of the popular Jaramillo syrups used to flavor juices. This 10 hectare farm was a banana farm that is currently planted with 3 year old lemons trees of the varieties "Taiti" and "Limón criollo". Because herbicide is heavily used on his farm, Mr. Jaramillo interested in using cover crops to lower production costs. The experiment was conducted in the "limón criollo" field because it is the variety that is most consumed in Puerto Rico. Soils were generally Ultisols, series Humatus (HmE2) with a 30% slope. Rainfall during this time of year ranges from 76 to 102 mm. Results from the soil test indicated high levels of Ca, and exchangeable Al; average organic matter and P levels; and low levels of NO_3^-N, Mg, K and pH (Table 15). The farmer expressed the most interest in cowpea because of the potential benefit of having an additional crop. The cowpea in this trial had less pest damage than other farms which helped to demonstrate the potential of this legume as a cover crop. The jack bean had highest production of biomass with an average of 822 kg/ha. The velvet bean (482 kg/ha) and cowpea (383 kg/ha) produced similar amounts of biomass. The % canopy cover at flowering of the legumes was similar at 6, 9 and 12 after planting, with averages of 11%, 17% y 24%. The velvet bean flowered at 73 days and the cowpea flowered at 62 days at flowering whereas the jack bean flowered at 126 days after planting (Table 14).

Table 14: Means of plant population, flowering date, canopy cover and biomass for velvet bean, jack bean and cowpea on the farm of Emilio Jaramillo, San Sebastian, Puerto Rico, June-October 2007.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days
			6 weeks	9 weeks	12 weeks	
Velvet Bean	79.4	72.5	16.0	22.0	32.5	482
Jack Bean	12.6	126.0	9.0	14.0	20.5	822
Cowpea	97.4	62.0	8.5	14.5	18.5	383
$LSD_{0.05}$	33.0	19.1	9.9	10.6	16.0	293.2
CV (%)	20.3	16.3	14.2	10.2	11.7	13.8

Table 15: Results from the soil test from the farm of Emilio Jaramillo, San Sebastian, Puerto Rico, June 2007

Fertility factor	pH	MO	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_ckg^{-1}$--				%
Mean	4.8	3.5	5.2	16.0	7.6	0.6	0.2	4.8	21.0
Level in soil*	L	M	L	M	H	L	L	H	---

*Level in soil according to Sotomayor-Ramírez (2006): L=low, M=medium, H= high.

FARM 5

The fifth trial planted during the first growing season was conducted at the Isabela Substation. The elevation was 128 m and the coordinates were Lat, 18°.15”, N; Long, 66°94”, NW. This trial was planted in a five-year-old avocado field that was not sprayed with insecticide. Only one replicate was established due to lack of space. Unlike previous experiments, we tested in this trial the growth of the legume around the trees. We chose the experimental station instead of an actual farm to minimize concerns of farmers about incorporating these legumes in their cropping systems. Soils at the Isabela Substation are an Oxisol, series Coto(CuB2) with a 5% slope. Average precipitation during the growing season ranges from 25 to 64 mm. In this trial, the legumes had a uniform germination and complete canopy cover around the avocado plants. Jack bean had to be pruned due to the tendency of climbing up the avocado trees.

Table 16: Means of plant population, flowering date, canopy cover and biomass for velvet bean, jack bean and cowpea in the Isabela experimental station, Puerto Rico, June-October 2007.

Species	Plant pop (1000 pl/ha)	Flowering date	Cover (%) at Flowering	Biomass (kg/ha) at 120 days
Velvet Bean	100.1	80.0	72.0	1504
Jack Bean	21.3	101.0	68.0	1716
Cowpea	108.7	59.0	70.0	1305
$LSD_{0.05}$	35.3	18.5	15.6	314

Table 17: Results from the soil test from the farm of the Isabela experimental station, Puerto Rico June 2007.

Fertility factor	pH	OM	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_c kg^{-1}$--				%
Mean	6.9	5.5	5.2	9.7	6.8	0.8	0.5	0.5	21.0
Level in soil*	H	H	L	M	H	L	H	L	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

This growing season June-October 2007 was considered to be relatively dry although rainfall can vary considerably in the central mountain area of the island. The performance of the legumes was similar on all of the farms. Some farmers expressed concern about the potential of the jack bean to climb on the citrus trees. However, Jack bean can be easily pruned to avoid injury to the citrus trees. Farmers had mix feelings about cowpea. On some farms, the cowpea was considered a potential source of income or food. Other farmers found it difficult to use cowpeas in their cropping systems and questioned if the legume my attract pests such as aphids or rats. Velvet bean was the most popular legume. However, some farmers were concerned because of the similarity in appearance of velvet bean with the weed locally known as “pica pica” (*Mucuna* spp.). Pica pica can cause significant irritation if contacted with the skin.

On the farm of Norma Santiago, the legumes produced the greatest amount of biomass (1,064 kg/ha for velvet bean, 2,170 kg/ha for jack bean, 1,461 kg/ha for cowpea). This farm had a greater amount of organic matter and a lower content of exchangeable Al than other farms which may have favored biomass production. This was followed the farm of Victor Delgado that produced average biomasses of 950 kg/ha for velvet bean, 1,206 kg/ha for jack bean and 610 kg/ha for cowpea. The Substation at Adjuntas and the farm of Emilio Jaramillo produced least amount of biomass. These farms had more elevated amounts of exchangeable Al, and low to average levels organic matter in the soil. Good levels of growth of legumes on these farms may require the application of lime to increase pH. In week 9 and 12 there were no significant differences between velvet bean and cowpea in % canopy cover on farms 1, 2 and 3 with the legumes velvet bean and jack bean. Farm 4 had a lower % canopy cover in weeks 6, 9, and 12 for all legumes. Velvet bean and jack bean flowered the latest on farm 2 with an average of 85 days and 126 days, cowpea flowered the latest on farm 4 (62 days). Farm 2 had the highest altitude which may have delayed flowering date. Cowpea was the least desirable cover crop due to its short life cycle, low biomass production and susceptibility to insects.

In general, the jack bean produced the highest amount of biomass (1,298 kg/ha) on all four farms. Velvet bean and cowpea had similar averages of biomass production (773 kg/ha and 698 kg/ha) and in week 12 these legumes had produced similar % canopy covers (69% and 74%) The jack bean had the lowest % canopy cover at 12 weeks after planting (36%). However, the jack bean continued to provide complete canopy cover after the cowpea and velvet bean had matured. The jack bean flowered the latest (115 days after planting), followed by velvet bean (71 days after planting) and cowpea (50 days after planting). The velvet bean had the best combination of biomass production and % canopy cover during this growing season.

Cowpea biomass production from the farm of Norma Santiago in Moca (1,461 kg/ha) was similar to the levels of biomass production (1,050 kg/ha) in Zimbabwe (Jeranyama et al. 2000). The low amount of biomass production on farms 2, 3 and 4, may have been caused by an elevated content of exchangeable Al and the limited amount of N and P in these soils. Fosu (1999) reported an elevated biomass of 8,400-9,800 kg/ha of biomass for a late variety of indeterminate velvet bean planted in the dry season of northern Ghana. The low production of biomass (773 kg/ha) production during the first growing season may have been due to the absence of inputs such as fertilizer and irrigation in the on-farm trials.

Second growing season January-May 2008

San Sebastian has an ideal landscape and climate for citrus production. During this growing season, trials were conducted on two lemon and three orange farms. The farms had different varieties, years and scale of production. Average temperatures in this region range from 23° to 27° C and precipitation ranges from an average of 112 to 140 mm during the period when the on-farm trials were conducted.

There were significant differences in the interaction of farm*species for plant population and days to flowering. There were significant differences among the legumes for all of the traits except N accumulation in the biomass (Table 18).

Table 18: Analysis of Variance for biomass, days to first flower, % canopy cover at flowering and plant population for on-farm trials planted in San Sebastian Puerto Rico from January-May 2008.

Source of variation	df	Mean square						
		Plant population	Flowering	% canopy cover			Biomass	N accumulation in the biomass
				Week 6	Week 9	Week 12		
Farm	3	3378**	1017**	774*	1067**	610**	622514	869
Rep (Farm)	4	643	18	152	117	23	303742	328
Species	2	23284**	3115**	1163*	1524	3975**	2368639*	946
Farm*species	6	1445*	1033**	394	269	1165	667016	835
Error	8	304	18	307	480	408	335758	396
CV (%)		24.2	4.8	43.4	32.7	26.6	25.6	22.0

*Significant at 5%, **Significant at 1%

FARM 6

Due to the Mr. Jaramillo’s interest in integrating the legumes into his production system, a second trial was conducted on his farm. During the second growing season, sunn hemp replaced cowpea. The farmer expressed interest in the performance of sunn hemp due to its rapid growth and resemblance to pigeon peas (*Cajanus cajan* L.).

There were no significant differences in biomass production of the velvet bean (2,241 kg/ha) and sunn hemp (1,951 kg/ha). The biomass production of the jack bean was lower (1,360 kg/ha). The jack bean, however, produced the highest % N and the greatest amount of nitrogen in the biomass. The % canopy cover of the legumes was similar at 6, 9 and 12 weeks after planting. Jack bean and sunn hemp flowered about 106 days after planting, whereas the velvet bean flowered at 75 days (Table 19).

Table 19: Means of plant population, flowering date, canopy cover and biomass for velvet bean, jack bean and sunn hemp on the farm of Emilio Jaramillo, January-May 2008.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days	N content kg/ha
			6 weeks	9 weeks	12 weeks		
Velvet Bean	66.7	75.0	29.0	60.5	84.5	2241	54.5
Jack Bean	6.6	106.0	26.5	43.0	58.0	1360	106.5
Sunn Hemp	81.7	106.0	13.0	29.0	60.5	1951	68.5
$LSD_{0.05}$	38.9	9.4	NS	NS	NS	NS	NS
CV (%)	24.2	4.8	43.4	32.7	26.6	25.6	22.0

Table 20: Results from the soil test from the farm of Emilio Jaramillo, San Sebastian Puerto Rico January 2008

Fertility factor	pH	OM	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_c kg^{-1}$--				%
Mean	4.8	3.5	5.2	16.0	7.6	0.6	0.2	4.8	21.0
Level in soil*	L	M	L	M	H	L	L	H	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

FARM 7

The site of the second on-farm trial is located in Bo. Hoya Mala, sector Varela Rd.119, San Sebastian. The elevation of the farm is 221 m and the coordinates are Lat 18°.36” N; Long, 66°96” W. This 2.5 ha farm has a natural grass cover growing between the citrus and lemon trees. Mr. Jimenez controls the weeds on his farm with the grazing of sheep and mowers. The use of herbicides is limited in his cropping system. Soils are generally composed of Ultisols, series Cidral (CfC2) with a 15% slope. Results from a soil test reported high levels of organic matter, Ca and Mg; intermediate pH, P and K levels; and low levels of NO_3^-N, and exchangeable Al (Table 22). Mr. Jimenez was already using a permanent grass cover on his farm. He was particularly interested in the jack bean due to vigorous growth and prolonged life cycle. We did not observe any climbing from the jack bean planted on his farm.

Jack bean and velvet bean had greater levels of production of biomass (3,233 and 2,214 kg/ha) and nitrogen content (94 and 129 kg/ha) than sunn hemp which produced 1,634 kg/ha of biomass and accumulated 64 kg/ha of N. At 6 weeks after planting, the velvet bean and sunn hemp had greater % canopy cover than jack bean. At weeks 9 and 12 after planting, the legumes produced similar amounts of canopy cover. Sunn hemp and jack bean flowered between 105 and 110 days after planting whereas velvet bean flowered at 86 days after planting (Table 21).

Table 21: Means of plant population, flowering date, canopy cover and biomass for velvet bean, jack bean and sunn hemp on the farm of Gilberto Jimenez, January-May 2008.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days	N content kg/ha
			6 weeks	9 weeks	12 weeks		
Velvet Bean	113.8	86.0	40.5	82.0	100.0	2214	129
Jack Bean	19.0	106.0	22.5	68.0	97.0	3233	94
Sunn Hemp	87.7	107.0	41.5	74.5	100.0	1634	64
$LSD_{0.05}$	38.9	9.4	NS	NS	NS	NS	NS
CV (%)	24.2	4.8	43.4	32.7	26.6	25.6	22.0

Table 22: Results from the soil test from the farm of Gilberto Jimenez, San Sebastian, Puerto Rico, January 2008

Fertility factor	pH	OM	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_ckg^{-1}$--				%
Mean	6.2	9.1	2.6	17.4	15.6	2.6	0.4	0.1	0.0
Level in soil*	M	H	L	M	H	H	M	L	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

FARM 8

The site of the third on-farm trial is a small 1.6 hectare citrus farm owned by Mr. Francisco Rodriguez that is mostly planted with the variety "China del Pais". The farm is located in Bo. Juncal, Rd. 438, San Sebastian. The elevation of the farm is 300 m and the coordinates are Lat, 18°.31", N; Long, 66°93" S. His farming systems are similar to Mr. Jaramillo. The frequent use of herbicides has resulted in little vegetative cover. As a consequence, soil erosion is a serious problem on the farm. Soils are generally composed of Mollisols, series Colinas (CIF2) with a 24% slope. Results from the soil test indicate high levels of organic matter, Ca, P and Mg; intermediate pH and K levels; and low levels of NO_3^-N, and exchangeable Al (Table 24). This field trial was the most difficult to establish due to free range chickens that roamed the area, The legumes still managed to germinate and grow in this challenging atmosphere. Jack bean and sunn hemp had good growth, but velvet had a poor plant population due to damage caused by the chickens.

Jack bean produced the greatest amount (3,643 kg/ha) and accumulated the most nitrogen (101 kg/ha) in the biomass. Velvet bean had the highest % canopy cover at 6, 9, and 12 weeks after planting. Jack bean was the latest to flower at 105 days, followed by sunn hemp 101 days and velvet bean 62 days after planting (Table 23).

Table 23: Means of plant population, flowering date, canopy cover and biomass for velvet bean, jack bean and sunn hemp on the farm of Francisco Rodriguez, January-May 2008.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days	N content Kg/ha
			6 weeks	9 weeks	12 weeks		
Velvet Bean	107.4	62.0	75.0	97.5	100.0	2540	68.0
Jack Bean	22.0	105.0	45.0	65.0	75.0	3648	100.5
Sunn Hemp	98.0	101.0	22.5	50.0	62.5	1931	77.5
$LSD_{0.05}$	38.9	9.4	NS	NS	NS	NS	NS
CV (%)	24.2	4.8	43.4	32.7	26.6	25.6	22.0

Table 24: Results from the soil test from the farm of Francisco Rodriguez, San Sebastian Puerto Rico February 2008

Fertility factor	pH	OM	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_ckg^{-1}$--				%
Mean	6.0	9.7	2.3	22.6	18.0	2.9	0.4	0.1	0.0
Level in soil*	M	H	L	H	H	H	M	L	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

FARM 9

Another trial was planted on the farm owned by Mr. Rodriguez which is located in Bo. Cidral, Rd. 438, San Sebastian. The elevation is 252 m and the coordinates are Lat, 18°.32", N; Long, 66°.94" E. This farm has approximately 14 hectare of "Valencia" variety oranges that are about 6 to 7 years old. Agro. Rodriguez's management practices include a combination of mowing and application of herbicide. Soils are generally composed of Vertisols, series Percha (PeD2) with a 23% slope. Results from the soil test indicate high levels of P, Ca, Mg, K and exchangeable Al; intermediate levels of organic matter; and low levels of NO_3^-N, and pH (Table 26). Since Agro. Rodriguez is educated in the field of agriculture; he readily recognized the benefits of the legume cover crops. However, he had no previous knowledge of the legumes used as treatments in the on-farm trial. He expressed particular interest in incorporating velvet bean into his cropping system because of its short life cycle. This farm was ideal for using these legumes since the trees are planted on the contour and the trees in the orchard are older.

Jack bean and sunn hemp produced > 2,000 kg/ha of biomass whereas the biomass yield of velvet bean was slightly lower. N accumulation in the biomass was statistically the same for all three legumes. At 6, 9, and 12 weeks after planting the % canopy cover of the legumes was not statistically different. Sunn hemp flowered the latest at 101 days after planting. Jack bean flowered at 82 days and velvet bean flowered at 61 days after planting (Table 25).

Table 25: Means of plant population, flowering date, canopy cover and biomass for velvet bean, jack bean and sunn hemp on the farm of Pablo Rodriguez, January-May 2008.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days	N content Kg/ha
			6 weeks	9 weeks	12 weeks		
Velvet Bean	40.4	61	48.0	78.0	93.0	1631	103.5
Jack Bean	15.4	82	35.0	68.5	84.5	2512	105.5
Sunn Hemp	95.1	101	56.5	86.5	95.0	2084	113.0
$LSD_{0.05}$	38.9	9.4	NS	NS	NS	NS	NS
CV (%)	24.2	4.8	43.4	32.7	26.6	25.6	22.0

Table 26: Results from the soil test from the farm of Pablo Rodriguez, San Sebastian Puerto Rico February 2008.

Fertility factor	pH	OM	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_c kg^{-1}$--				%
Mean	4.8	3.9	6.1	30.0	23.5	4.5	1.0	4.3	14.0
Level in soil*	L	M	L	H	H	H	H	H	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

FARM 10

A trial was planted on a farm located in Bo. Perchas, Rd. 435, San Sebastian. The elevation was 291 m and the coordinates were Lat, 18°.29”, N; Long, 66°93”, NW. This 8.9 hectare farm has bananas intercropped with tangerines and other varieties of oranges. The owner of this commercial farm is Mr. Enrique Rivera. His farming practices include the use of herbicide on relatively flat land (< 15% slope inclination) and weeding the more steep areas (> 15% slope) with manual labor. Soils are generally composed of Ultisols, series Humatas (HmE2) with an average slope of 22%. Results from the soil tests indicate high levels of P, Ca, Mg, K, organic matter and exchangeable Al and low levels of NO_3^-N, and pH (Table 28). The performance of sunn hemp was exceptional compared with its performance in other trials conducted during the second growing season. The farmer was impressed by the rapid growth of this legume. The velvet bean and jack bean also performed well on this farm. As a result, the farmer expressed interest in continued use of legumes for his cropping system.

Jack bean (3,141 kg/ha) and velvet bean (2,372 kg/ha) produced slightly higher yields of biomass and than the sunn hemp (1,459 kg/ha). N accumulation in the biomass was statistically the same for all three species. At 6, 9, and 12 weeks after planting, the % canopy cover of the velvet bean was superior to jack bean and sun hemp. Jack bean and sunn hemp flowered at 127 days after planting and the velvet bean flowered at 66 days after planting (Table 27).

Table 27: Means of plant population, flowering date, canopy cover and biomass for velvet bean, jack bean and sunn hemp on the farm of Enrique Rivera, January-May 2008.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days	N content Kg/ha
			6 weeks	9 weeks	12 weeks		
Velvet Bean	109.8	66.0	68.5	87.5	97.5	2372	86.0
Jack Bean	26.4	127.0	34.5	58.0	72.0	3141	100.0
Sunn Hemp	190.1	127.0	46.5	57.0	61.0	1459	88.5
$LSD_{0.05}$	38.9	9.4	NS	NS	NS	NS	NS
CV (%)	24.2	4.8	43.4	32.7	26.6	25.6	22.0

Table 28: Results from the soil test from the farm of Enrique Rivera, San Sebastian, Puerto Rico, February 2008

Fertility factor	Ph	MO	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_c kg^{-1}$--				%
Mean	4.6	4.5	2.8	54.2	14.6	4.2	0.6	6.7	21.0
Level in soil*	L	H	L	H	H	H	H	H	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

Due to the problems with aphid infestations during the first growing season, sunn hemp substituted cowpea in the trials planted during the second and subsequent growing seasons. However, it should be noted that the cowpeas in the first growing season received no fertilizer or pesticide applications. If the farmers were interested in producing cowpeas for seed or green-shell production, the aphid populations could be easily be controlled with the application of an insecticide such as Sevin (Carbaryl). Moderate levels of fertilization and the timely application of insecticide should permit the cowpeas to produce good seed yields

On some farms, an additional treatment of cowpea intercropped with velvet bean was planted to examine if there were an advantage of using the cowpea to obtain rapid ground cover as velvet bean plants developed. This treatment did not show an advantage over monocroping of the legume. The farmers were impressed with the rapid growth of the sunn hemp and the Jack bean did not climb onto the citrus trees. During the second growing season, we had an opportunity to establish trials on 2 large citrus farms and obtained a better idea of the potential of these legumes in a commercial operation. The growth and development of the legumes benefited from above-average precipitation during the second growing season.

The velvet bean on farms 6, 7, 8 and 10 produced > 2,000 kg/ha of biomass. Although the velvet bean on Farm 9 produced less biomass (1,631 kg/ha) than the other farms, it produced a large amount of accumulated nitrogen (104 kg/ha). On farms 7, 8 and 10, the jack bean produced the highest yields of biomass averaging > 3,000 kg/ha. The accumulated nitrogen in the biomass of the jack bean (101 kg/ha) was similar on all five farms. Sun hemp on farms 6, 8 and 9 produced almost 2,000 kg/ha of biomass. All three legumes accumulated > 100 kg/ha on farm. At 12 weeks after planting, the canopy cover for velvet bean was similar (95% average) on all 5 farms. Jack bean and sunn hemp produced more canopy cover on farms 7 and 9 at 12 weeks after planting. Jack bean produced the greatest mean biomass (2,779 kg/ha), followed by velvet bean (2,200 kg/ha average) and sunn hemp (1,872 kg/ha). Jack bean also accumulated the most nitrogen in the biomass (101 kg/ha). Sunn hemp (105 days after planting) and jack bean (108 days after planting) had similar flowering dates. Velvet bean produced the most canopy cover at 12 weeks after planting (95%), Jack bean and sunn hemp had similar % canopy cover at 12 weeks after planting (77% and 76%).

The average biomass collected in the 5 farms in this season for velvet bean was 2,157 kg/ha. Ramos et al. (2001) reported similar yields of 2,100 kg/ha in Cuba, but were harvested after a shorter period of time at 60 days after planting (DAP). Conversely, these results were below the 3,000 kg/ha average of reported by Carsky (1989) in Nigeria, Bowen (1987) in Brazil, (4,300 kg/ha) Quntana (1987) and Anthofer and Kroschel (2005) in the forest-savannah transitional zone in Ghana (> 4,500 kg/ha). The average nitrogen accumulated in the biomass of velvet bean for this growing season was 110 kg/ha, that is similar to the 130 kg/ha reported by Carsky (1989). In addition, Bowen (1987) and Quintana (1987) reported higher production of nitrogen levels in the biomass.

The mean biomass collected of Jack bean on farms 7 (3,230 kg/ha), 8 (3,648 kg/ha) and 10 (3,141 kg/ha) are similar to the biomass yields reported by Ramos et al. (2001), but less than the data reported by Quintana (1987) and Carsky (1989). The average nitrogen content accumulated in the biomass in all 5 farms for jack bean in this growing season was 102 kg/ha which is more than the 58 kg/ha reported by Ramos et al. (2001) but less than the 177 kg/ha reported by Quintana (1987) and the 170 kg/ha reported by Carsky (1989)..

Biomass production of sunn hemp in farm 9 (2,084 kg/ha) was similar to the 2,860 kg/ha reported by Jeranyama et al. (2000) but significantly less than yields reported by Ramos et al., (2001), Quintana (1987) and Carsky (1989). However, sunn hemp varieties that are later in maturity than 'Tropic Sun' could produce more biomass and accumulate more nitrogen. The average nitrogen accumulation in the biomass for all five farms of sunn hemp was 82 kg/ha, which is very similar to the nitrogen accumulation reported by Jeranyama et al. (2000).

Third growing season July-November 2008

The third growing season was conducted in Las Marias which is known in Puerto Rico for producing the sweetest oranges. The field experiments included a local orange tree nursery and a farmer that is the head of the citrus producers' growers association. The common cropping system in Las Marias is to intercrop the citrus with coffee and bananas. Average temperature in Las Marias ranges from 21° to 29° C and average precipitation ranges from 89 to 102 mm during this growing season.

In the combined ANOVA, the farm*species interaction was significant for days to flowering and % canopy cover at 9 and 12 weeks after planting (Table 29). There were significant differences among legumes for all of the traits evaluated in the trial.

Table 29: Analysis of Variance for biomass, days to first flower, % canopy cover at flowering and plant population for on-farm trials planted Las Marias, Puerto Rico, from July-November 2008

Source of variation	df	Mean square						
		Plant pop	Flowering	% canopy cover			Biomass	N accumulation in the biomass
				Week 6	Week 9	Week 12		
Farm	3	2716	479**	1228**	1360**	1747**	2502278**	2477*
Rep (Farm)	4	463	13	36	16	1	897720	374
Species	2	18647**	4275**	3520**	4877**	2932**	7743943**	8616**
Farm*sp	6	1216	266**	288	260**	264**	7724937	1177
Error	8	876	34	179	32	46	402026	495
CV (%)		49.1	6.6	33.0	10.3	10.2	24.5	34.0

*Significant at 5%, **Significant at 1%

FARM 11

The first trial was planted on a farm located in Bo. Maravilla Este, Las Marias. The elevation was elevation 229 m and the coordinates were Lat, 18°.27”, N; Long, 66°.98”. The farm is owned by Mr. Gorge Mendez, the current head of the citrus growers association of Puerto Rico. Mr. Mendez operates a 22.3 ha farm that produces different varieties of citrus. The trees in the grove are at least 5 years old and are intercropped with coffee and bananas. Most weeds are shaded out or are controlled with the use of herbicide. Soils are generally Ultisols, series Humatas (HmF2) with an average slope of 15%. Results from the soil test indicate high levels of organic matter, P, Ca, and Mg; an intermediate level of pH; and low levels of NO_3^-N, K and exchangeable Al (Table 31). Mr. Mendez expressed interest in all of the legumes. Although the citrus was intercropped with banana we did not experience difficulties establishing the field trials.

Jack bean produced the highest yield of biomass (4,175 kg/ha) and accumulated the greatest amount of nitrogen (123 kg/ha). At 6, 9, and 12 after planting the % canopy cover for velvet bean was greater than jack bean and sun hemp. The number of days to flower was similar for all three species (Table 30).

Table 30: Means of plant population, flowering date, canopy cover, biomass and nitrogen content for velvet bean, jack bean and sunn hemp on the farm of Gorge Mendez, Las Marias, July-November 2008.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days	N content Kg/ha
			6 weeks	9 weeks	12 Weeks		
Velvet Bean	49.1	94	75.0	95.0	100.0	2714	65.5
Jack Bean	21.3	94	35.0	50.0	55.0	4175	122.5
Sunn Hemp	137.1	97	37.5	55.0	75.0	2509	42.0
$LSD_{0.05}$	NS	13.1	NS	12.5	15.1	NS	NS
CV (%)	49.1	6.6	33.0	10.3	10.1	24.5	34.6

Table 31: Results from the soil test from the farm of Gorge Mendez, Las Marias, Puerto Rico, August 2008

Fertility factor	pH	OM	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_c kg^{-1}$--				%
Mean	6.1	4.2	4.0	2.0	10.3	4.3	0.2	0.1	1.0
Level in soil*	M	H	L	H	H	H	L	L	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

FARM 12

This on-farm trial was located on the "Vivero de Chinas de Las Marias" or Las Marias orange tree nursery, in Bo. Buena Vista, Las Marias. The elevation was 182 m and the coordinates were Lat, 18°.25", N; Long, 66°.98", NW. The 13.4 hectare farm is administered by Mr. Jaime Lopez. The citrus trees are approximately 7-8 years old. The nursery is a source of different varieties of citrus including "Taiti" lemon and "Valencia" oranges. Due to the steep landscape, the use of herbicide is the only weed control used for this farm. Soils are generally composed of Ultisol, series Humatas (HmE2) with a 17% slope.

Results from the soil test indicate high levels of organic matter and exchangeable Al; intermediate levels of NO_3^-N and K; and low levels of, P, Ca, Mg and pH (Table 33) . Because this farmer was especially interested in the velvet bean, we planted an extra treatment using cowpea intercropped with velvet bean. We did not observe any benefit intercropping these legumes due to an aphid infestation on the cowpeas. Therefore, we decide not to employ this treatment in future plantings. Mr. Lopez expressed concern about the growth of jack bean, which tended to climb on the citrus trees on this farm.

The legumes produced similar amounts of biomass with an average of 2,417 kg/ha for velvet bean, 2,877 kg/ha for jack bean and 2,008 kg/ha for sunn hemp. Velvet bean and jack bean accumulated approximately 70 kg/ha of nitrogen in the biomass whereas the N accumulation of the sunn hemp was much lower. At 6, 9, and 12 weeks after planting, the % canopy cover for velvet bean was superior to jack bean and sun hemp. Jack bean flowered at 100-days and sunn hemp at 91-days, while velvet bean flowered at 52-days (Table 32).

Table 32: Means of plant population, flowering date, canopy cover, biomass and nitrogen content for velvet bean, jack bean and sunn hemp on the farm of Jaime Lopez, Las Marias, July-November 2008.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days	N content Kg/ha
			6 weeks	9 weeks	12 weeks		
Velvet Bean	70.4	52.5	77.5	97.5	100.0	2417	71.0
Jack Bean	18.4	100.0	27.5	45.0	57.5	2877	70.0
Sunn Hemp	121.8	91.0	37.5	50.0	75.0	2008	28.5
$LSD_{0.05}$	NS	13.1	NS	12.5	15.1	NS	NS
CV (%)	49.1	6.6	33.0	10.3	10.1	24.5	34.6

Table 33: Results from the soil test from the farm of Jaime Lopez, Las Marias, Puerto Rico, July 2008

Fertility factor	pH	OM	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_c kg^{-1}$--				%
Mean	4.4	4.6	10.0	6.9	2.3	1.1	0.3	3.9	23.0
Level in soil*	L	H	M	L	L	L	M	H	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

FARM 13

Farm # 13 is located in Bo. Buena Vista, sector Lomas de los Millonarios, Las Marías. The elevation is 495 m and the coordinates are Lat, 18°.23", N; Long, 66°.97", NW. The owner of this two ha farm is Mr. Roberto Quíles. The farm produces tangerines and oranges that are 3 years and older. The use of herbicide is the only weed control used for this farm due to the steep landscape. Soils are generally Ultisols, series Consumo (CoF2) with an average slope of 40%. Results from the soil test indicated high levels of organic matter and exchangeable Al and low levels of, P, Ca, Mg, NO_3^-N, K and pH (Table 35). Mr. Qulies expressed concern about the potential value of the legumes on his farm due to the extremely steep slopes. However, we had little difficulty planting the trial on this farm and all of the legumes performed well.

Jack bean produced the highest yield of biomass (5,385 kg/ha) and accumulated the greatest amount of nitrogen (164 kg/ha). At 6, 9, and 12 weeks after planting, the % canopy cover for velvet bean was superior to jack bean and sunn hemp. Jack bean flowered 108 days and sunn hemp flowered 99 days after planting whereas velvet bean flowered at 59 days after planting (Table 34).

Table 34: Means of plant population, flowering date, canopy cover, biomass and nitrogen content for velvet bean, jack bean and sunn hemp on the farm of Roberto Quiles, Las Marias, July-November 2008.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days	N content Kg/ha
			6 weeks	9 weeks	12 weeks		
Velvet Bean	75.1	59.0	85.0	100.0	100.0	2721	79.0
Jack Bean	19.7	108.0	37.5	42.5	60.0	5385	164.3
Sunn Hemp	140.4	99.0	35.0	52.5	75.0	2016	42.5
$LSD_{0.05}$	NS	13.1	NS	12.5	15.1	NS	NS
CV (%)	49.1	6.6	33.0	10.3	10.1	24.5	34.6

Table 35: Results from the soil test from the farm of Roberto Quiles, Las Marias, Puerto Rico July 2008

Fertility factor	pH	OM	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_c kg^{-1}$--				%
Mean	4.7	6.0	5.9	2.3	2.4	0.2	0.1	2.1	26.0
Level in soil*	L	H	L	L	L	L	L	H	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

FARM 14

Mr. Mingo Martel is the owner of farm number 14, located in Bo. Buena Vista, Sector la Perrera, Las Marías. The elevation is 365 m and the coordinates are Lat, 18°.14" N; Long, 66°.58",NW. The main crop produced on this 32 hectare farm is "Valencia" oranges. The trees were 3-4 years old and intercropped with coffee and bananas. Most weeds are shaded out with the intercropping or are controlled with the use of herbicide. Soils are Ultisol, series Humatas (HmE2) with a 40% slope. Results from the soil test reported high levels of organic matter, P and exchangeable Al; intermediate levels of NO_3^-N; and low levels of Ca, Mg, K and pH (Table 37).

This trial had more shade than other trials. As a consequence, the jack bean had a tendency to produce long vines and climb. On the other hand, sun hemp had poor germination in both repetitions. The growth and development of the velvet bean did not appear to be affected by the shade of the coffee and bananas trees.

The jack bean produced the highest yields of biomass (2,753 kg/ha) and accumulated the most nitrogen in the biomass (61 kg/ha). At 6, 9, and 12 weeks after planting, the % canopy cover for velvet bean was superior to jack bean and sunn hemp. The jack bean flowered at 99 days and sunn hemp flowered 90 days and the velvet bean flowered 55 days after flowering (Table 36).

Table 36: Means of plant population, flowering date, canopy cover, biomass and nitrogen content for velvet bean, jack bean and sunn hemp on the farm of Mingo Martel, Las Marias, July-November 2008.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days	N content Kg/ha
			6 weeks	9 weeks	12 weeks		
Velvet Bean	27.7	55.0	37.5	55.0	55.0	1913	51.5
Jack Bean	19.0	99.0	7.5	22.5	27.5	2753	60.5
Sunn Hemp	25.7	90.0	7.5	22.5	35.0	821	22.5
$LSD_{0.05}$	NS	13.1	NS	12.5	15.1	NS	NS
CV (%)	49.1	6.6	33.0	10.3	10.1	24.5	34.6

Table 37: Results from the soil test from the farm of Mingo Martel, Las Marias, Puerto Rico July 2008.

Fertility factor	pH	OM	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_c kg^{-1}$--				%
Mean	4.2	4.8	10.4	23.8	0.8	0.2	0.2	7.1	39.0
Level in soil*	L	H	M	H	L	L	L	H	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

FARM 15

Another trial was planted on a farm owned by Mr. Francisco Guillotis in Barrio Buena Vista, Las Marias. The elevation is 292 m and the coordinates are Lat, 18°.24”, N; Long, 66°.97”, NW. The farm has 15 hectares of tangerines and oranges. The 3 year old trees are planted as a monoculture. The use of herbicide is the only weed control used for this farm due to the steep landscape. Soils are on this farm are Ultisoles, series Humatas (HmE2) with an average slope of 28%. Results from the soil tests indicated high levels of organic matter and exchangeable Al and low levels of P, Ca, Mg, NO_3^-N, K and pH (Table 39). Mr. Gulliotis was concerned about the adverse effect on the citrus trees caused by climbing vines of jack bean. Therefore, we decided to prune the jack bean and demonstrate that with proper management the jack bean could be an excellent crop for cover.

The jack bean produced the highest yield of biomass (2,703 kg/ha). However, the three legumes accumulated similar amounts nitrogen in the biomass. At 6, 9, and 12 weeks after planting, the % cover ,of the legumes were similar. Jack bean flowered at 126-days, sunn hemp at 109-days and velvet bean flowered at 71-days after planting (Table 38).

Table 38: Means of plant population, flowering date, canopy cover, biomass and nitrogen content for velvet bean, jack bean and sunn hemp on the farm of Francisco Guillotis, Las Marias, July-November 2008.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days	N content Kg/ha
			6 weeks	9 weeks	12 weeks		
Velvet Bean	50.7	71.0	35.0	50.0	60.0	1807	58.0
Jack Bean	22.7	126.0	35.0	37.5	57.5	2703	58.0
Sunn Hemp	105.1	109.0	37.5	45.0	60.0	2077	46.5
$LSD_{0.05}$	NS	13.1	NS	12.5	15.1	NS	NS
CV (%)	49.1	6.6	33.0	10.3	10.1	24.5	34.6

Table 39: Results from the soil test from the farm of Francisco Guillotis, Las Marias, Puerto Rico July 2008.

Fertility factor	pH	MO	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--cmol$_c$kg^{-1}--				%
Mean	4.5	5.0	9.4	9.1	2.2	0.9	0.2	4.2	27.0
Level in soil*	L	H	L	L	L	L	L	H	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

The jack bean produced the largest average amount of biomass (3,579 kg/ha) and accumulated more nitrogen in the biomass (95 kg/ha) during this growing season. The velvet bean produced an average of 2,314 kg/ha of biomass and accumulated 65 kg/ha of nitrogen. Houngnandan (2000) reported greater yields of biomass of velvet bean in Benin. However, this velvet bean was harvested at 20 weeks after planting. The sunn hemp yielded an average of 1,886 kg/ha of biomass and accumulated 36 kg/ha of nitrogen. Schomberg et al. (2007) reported sunn hemp biomass yields of 9,600 kg/ha in Tifton, Georgia and 9,000 kg/ha in Watkinsville, Florida. Bhardwaj et al. (2005) reported a sunn hemp biomass yield of 8,800 kg/ha at 108 DAP in Virginia. It should be noted that some sunn hemp varieties do not flower in temperate regions that have longer photoperiods. This favors biomass production. At weeks 6, 9 and 12 weeks after planting, the velvet bean had the most % canopy cover.

Fourth growing season August-December 2008

Additional field trials were conducted in Maricao, which is known for coffee production. Due to the recent arrival of the coffee berry borer (*Hypothenemus hampei*), some coffee producers are considering alternatives crops. Four of the five farms used for trials in Maricao are part of the same family business. More than 81 ha of crops are produced by siblings. The cropping systems in Maricao are similar to Las Marias where citrus is intercropped with coffee and bananas. Average temperatures range from 20 to 29° C and average precipitation ranges from 114 to 127 mm for this growing season.

In the combined ANOVA, farm x species interaction was significant for nitrogen accumulation, plant population flowering date, and % canopy cover at 6, 9 and 12 weeks after planting. There were significant differences among legume species for population, flowering date, nitrogen accumulation and % canopy cover at 6 and 12 weeks after planting (Table 40).

Table 40: Analysis of Variance for biomass, days to first flower, % canopy cover at flowering and plant population for on-farm trials planted northwestern Puerto Rico from August-December 2008.

Source of variation	df	Mean square						
		Plant population	Flowering	% canopy cover			Biomass	N accumulation in the biomass
				Week 6	Week 9	Week 12		
Farm	3	89	36*	645**	803**	540**	2295975**	1480*
Rep (Farm)	4	321	5	12	5	14	263971	182
Species	2	26911**	1773**	1153**	472	183**	429501	1888*
Farm*species	6	359*	27*	629**	672**	572**	349791	1041*
Error	8	107	7	111	125	14	336103	295
CV (%)		13.9	3.4	19.6	15.6	8.0	28.6	26.1

*Significant at 5%, **Significant

FARM 16

The farm of Mr. Wilfredo Vargas is located in Bo. Indiera Fria, Rd. 366 in Maricao. The elevation is elevation 692 m and the coordinates are Lat, 18°.15" N, Long, 66°.94",S. Mr. Ruiz owns and operates a 67 hectare farm that produces mainly oranges and coffee. Most weeds are shaded out by the citrus and coffee plants or are controlled with the use of herbicide. Soils are generally Oxisols, series Los Guinea? (LuF2) with a 35% slope. Results from soil tests showed high levels of organic matter, P and exchangeable Al and low levels of Ca, Mg, NO_3^-N, K and pH (Table 42). The velvet bean in this trial was severely attacked by insects that were not identified. This may have reduced canopy cover and biomass production.

Jack bean (1,378 kg/ha) and sunn hemp (1,557 kg/ha) produced the highest biomass yields and the jack bean accumulated the greatest amount of nitrogen in the biomass (102 kg/ha). At 6, and 9 weeks after planting, the % canopy covers of the legume species were similar. Jack bean and sunn hemp flowered approximately 79 days after planting whereas the velvet bean flowered at 61 days after flowering (Table 41).

Table 41: Means of plant population, flowering date, canopy cover, biomass and nitrogen content for velvet bean, jack bean and sunn hemp on the farm of Wilfredo Vargas, Maricao, August-December 2008.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days	N content Kg/ha
			6 weeks	9 weeks	12 weeks		
Velvet Bean	88.4	61.0	42.5	55.0	67.5	852	35
Jack Bean	21.0	79.0	35.0	47.5	57.5	1378	102
Sunn Hemp	121.1	79.0	52.5	72.5	75.0	1557	58
$LSD_{0.05}$	65.9	13.1	23.4	24.9	14.2	NS	49.6
CV (%)	13.9	3.4	19.6	15.6	8.0	28.6	26.1

Table 42: Results from the soil test from the farm of Wilfredo Vargas, Maricao, Puerto Rico August 2008

Fertility factor	pH	OM	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_c kg^{-1}$--				%
Mean	4.2	5.7	9.4	31.7	2.0	0.3	0.2	4.3	30.0
Level in soil*	L	H	L	H	L	L	L	H	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

FARM 17

Mr. Miguel Vargas, son of Mr. Wilfredo Vargas is owner of a 20.2 hectare farm that produces mainly coffee and oranges. This farm is located in Bo. Indiera

Fria, Rd. 366, Maricao. The elevation is 866 m and the coordinates are Lat, 18°.15", N, Long, 66°89", S. The use of herbicide is the only weed control used for this farm due to the steep landscape. Soils are generally Oxisols, series Los Guine (LuF2) with an average slope of 43%. Results from the soil test reported high levels of organic matter, P, Mg, K and exchangeable Al; intermediate levels of NO_3^-N and Ca; and a low pH (Table 44). Sunn hemp was the farmer's favorite legume because the flowers of the sunn hemp appeared to increase the population of bees that could benefit coffee and citrus production.

Biomass production and accumulation of nitrogen in the biomass was similar for the legumes. At 6 weeks after planting, the % canopy covers of the legumes were similar. At 9 and 12 weeks after planting, sunn hemp produced the greatest amount of canopy cover followed by jack bean and velvet bean. Jack bean and sunn hemp flowered at 88-days after planting, while Velvet bean flowered at 60-days after planting (Table 43).

Table 43: Means of plant population, flowering date, canopy cover, biomass and nitrogen content for velvet bean, jack bean and sunn hemp on the farm of Miguel Vargas, Maricao, August to December 2008.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days	N content Kg/ha
			6 weeks	9 weeks	12 weeks		
Velvet Bean	50.1	60.0	35.0	47.5	52.5	2367	60
Jack Bean	17.0	88.0	50.0	65.0	80.0	2673	72
Sunn Hemp	136.4	88.0	57.5	80.0	97.5	2075	93
$LSD_{0.05}$	65.9	13.1	23.4	24.9	14.2	NS	49.6
CV (%)	13.9	3.4	19.6	15.6	8.0	28.6	26.1

Table 44: Results from the soil test from the farm of Miguel Vargas, Maricao, Puerto Rico, August 2008

Fertility factor	pH	OM	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--cmol$_c$kg^{-1}--				%
Mean	4.6	5.6	12.1	47.2	5.7	2.7	0.7	2.9	15.0
Level in soil*	L	H	M	H	M	H	H	H	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

FARM 18

Mr. Wilfredo Vargas Jr, is the owner of a 38.9 hectare farm that produces mainly coffee and oranges. His farm is located in Barrio Indiera fria, Rd. 365 in Maricao. The elevation is 888 m and the coordinates are Lat, 18°.15” N; Long, 66°90” NW. The use of herbicide is the only weed control method for this farm due to the steep landscape. Soils are generally Oxisols, series Los Guine (LuF2) with a 30% slope. Results from soil tests indicated high levels of organic matter, P, K and exchangeable Al; intermediate levels of NO_3^-N and Ca; and low levels of Mg and pH (Table 46). Growth and development of the legumes in this trial was poor. This environment was more shaded than the other trials which may have influenced the growth of the legumes.

Jack bean produced the highest biomass yield (3,076 kg/ha) and accumulated the most nitrogen in the biomass (115 kg/ha). At 6, 9, and 12 weeks after planting the % canopy cover of velvet bean was superior to jack bean and sun hemp. Jack bean flowered at 88 days, sunn hemp at 78-days, while velvet bean at 60-days after planting (Table 45).

Table 45: Means of plant population, flowering date, canopy cover, biomass and nitrogen content for velvet bean, jack bean and sunn hemp on the farm of Wilfredo Vargas Jr., Maricao, August-December 2008.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days	N content Kg/ha
			6 weeks	9 weeks	12 weeks		
Velvet Bean	85.7	60.0	72.5	94.5	100.0	2069	69
Jack Bean	26.7	78.0	35.0	55.0	67.5	3076	115
Sunn Hemp	115.4	88.0	37.5	57.5	70.0	1596	44
$LSD_{0.05}$	65.9	13.1	23.4	24.9	14.2	NS	49.6
CV (%)	13.9	3.4	19.6	15.6	8.0	28.6	26.1

Table 46: Results from the soil test from the farm of Wilfredo Vargas Jr., Maricao, Puerto Rico, August 2008

Fertility factor	pH	MO	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_c kg^{-1}$--				%
Mean	4.2	5.6	19.3	78.3	3.0	0.6	0.5	6.5	40.0
Level in soil*	L	H	M	H	M	L	H	H	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

FARM 19

Another trial was planted on a second farm owned by Mr. Wilfred Vargas Jr, on Rd. 120 in the Maricao area. The elevation is 561 m and the coordinates are Lat, 18°.15” N; Long, 66°89” W. Avocados, papayas, bananas, tangerines and oranges are produced on this 18.2 ha farm. Mr. Wilfredo Jr. intercropped bananas and papaya with young tangerine and orange trees. We established the trial among citrus trees that were at least two years old. Weeds were controlled with the use of herbicide. The intercropping of multiple crops makes the mechanical control of the weeds more difficult. Soils are generally composed of Oxisols, series Los Guine (LuF2) with an average slope of 18%. The soil was found to have high levels of organic matter, K and exchangeable Al; an intermediate level of Ca; and low levels of Mg, NO_3^-N, P and pH (Table 48).

In this field experiment, the sun hemp grew taller than the citrus trees which caused the farmer some concern that this might affect citrus development. All three species of legumes produced similar biomass yields and accumulated comparable amounts of nitrogen in the biomass. At 6, 9, and 12 weeks after planting the % canopy cover for velvet bean was superior to jack bean and sun hemp. Jack bean flowered at 77 days, sunn hemp flowered 82 days and velvet bean flowered 59 days after planting (Table 47).

Table 47: Means of plant population, flowering date, canopy cover, biomass and nitrogen content for velvet bean, jack bean and sunn hemp on the farm of Wilfredo Vargas Jr., Maricao, August-December 2008.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days	N content Kg/ha
			6 weeks	9 weeks	12 weeks		
Velvet Bean	93.8	59.0	87.5	100.0	100.0	1642	50
Jack Bean	11.7	77.0	57.5	70.0	75.0	1295	29
Sunn Hemp	123.4	82.0	50.0	70.0	82.5	1595	38
$LSD_{0.05}$	65.9	13.1	23.4	24.9	14.2	NS	49.6
CV (%)	13.9	3.4	19.6	15.6	8.0	28.6	26.1

Table 48: Results from the soil test from the farm of Wilfredo Vargas Jr., Maricao, Puerto Rico, August 2008.

Fertility factor	pH	OM	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_c kg^{-1}$--				%
Mean	4.6	5.8	6.8	9.2	3.6	0.8	0.5	5.6	40.0
Level in soil*	L	H	L	L	M	L	H	H	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

FARM 20

The farm of Mr. Luis A Ramirez farm is located in Bo. Indiera Fria, Rd. 366, Maricao. The elevation was 707 m and the coordinates are Lat, 18°.15", N; Long, 66°93", W. This 33 hectare farm produces oranges and coffee that are intercropped. Most weeds are shaded out or are controlled with the use of herbicide. Soils are generally Oxisols, series Los Guine (LuF2) with an average slope of 20%. Reports from the soil test indicated high levels of organic matter, K, P, Ca, Mg and pH; intermediate levels of NO_3^-N; and a low level of exchangeable Al (Table 50). All of the legumes developed well in this trial. The jack bean had better performance than other trials during this growing season. No climbing was observed for the jack bean on this farm.

All three species of legumes produced similar biomass yields and accumulated comparable amounts of nitrogen in the biomass. At 6 weeks after planting, the velvet bean produced the most % canopy cover followed by jack bean and sun hemp. At 9 and 12 weeks after planting, the velvet bean and jack bean had almost complete canopy cover. Jack bean flowered at 87 days, sunn hemp flowered 82 days and velvet bean flowered 59 days after planting (Table 49).

Table 49: Means of plant population, flowering date, canopy cover, biomass and nitrogen content for velvet bean, jack bean and sunn hemp on the farm of Luis Ramirez, Maricao, August-December 2008.

Species	Plant pop (1000 pl/ha)	Flowering date	% Cover at flowering			Biomass (kg/ha) at 120 days	N content Kg/ha
			6 weeks	9 weeks	12 weeks		
Velvet Bean	86.4	59.0	92.5	100.0	100.0	2965	61
Jack Bean	23.7	87.0	65.0	95.0	97.5	2848	89
Sunn Hemp	119.7	82.0	37.5	65.0	77.5	2416	75
$LSD_{0.05}$	65.9	13.1	23.4	24.9	14.2	NS	49.6
CV (%)	13.9	3.4	19.6	15.6	8.0	28.6	26.1

Table 50: Results from the soil test from the farm of Luis A Ramirez, Maricao, Puerto Rico, August 2008

Fertility factor	pH	MO	NO_3^-N	P	Ca	Mg	K	Exch Al	Al sat
			---mg kg^{-1}---		--$cmol_c kg^{-1}$--				%
Mean	7.1	5.0	12.5	55.6	8.0	21.4	1.6	0.2	1.0
Level in soil*	H	H	M	H	H	H	H	L	---

*Level in soil according to Sotomayor-Ramírez, 2006: L=low, M=medium, H= high.

There was an average amount of rainfall during this growing season. Most of the legumes had fair performance considering the amount of shade and steep land on some of the farms. Farmers may benefit from planting sunn hemp to attract pollinators for coffee and citrus production. Due to the rapid growth of the sun hemp, farmers expressed concern that the shading caused by this legume might affect the citrus trees development. Jack bean did not express a climbing habit in any of the on-farm trials.

In general, jack bean produced the greatest amount of biomass and accumulated the most nitrogen in the biomass. During this growing season, the velvet bean and sunn hemp produced similar amounts of biomass. At 12 weeks after planting all three species of legumes had produced a significant amount of canopy cover.

During this growing season, the mean biomass production and nitrogen accumulation for velvet bean for the five farms (1,979 kg/ha, 55 kg/ha respectively) are less than values (6,107 kg/ha, 100kg/ha) reported by Anthofer and Kroschel (2005). The mean biomass production of sunn hemp in this season was 1,848 kg/ha. Mansoer et al. (1997) reported much greater values of biomass of 7,300 kg/ha. However, this sunn hemp was harvested 84 DAP in Virginia. Higher levels of exchangeable Al and lower soil pH were associated with lower biomass production at this farm.

Summary

We asked farmers if they had ever used cover crops on their farm. One farmer answered yes and nineteen answered no. The one farmer that chose yes was Mr. Jimenez which has a permanent grass land cover in his cropping systems. Farmers were asked if the use of cover crops on their farm could help control weeds. Seventeen answered yes and three farmers were not sure. Most farmers were not clear of the function of the cover crop and its benefits. Farmers were asked which of the legumes planted in their farms was of greatest interest to them. Two farmers voted for cowpea, 11 voted for velvet bean, six voted for sunn hemp and 2 voted for jack bean. These results suggest that seed of several legumes should be available to farmers and so that they can identify the cover crop best suited to their environment and cropping system. Which of the cover crops planted in their farms generated the least interest? Five farmers voted for cowpea, 1 voted for velvet bean, 2 voted for sunn hemp, 9 voted for jack bean and 2 voted for none of the above. We asked if the farmers were interested in using cover crops in the future for their cropping systems. All of the farmers answered that they are interested in using cover crops. The farmers were asked which legume they would most likely integrate into their cropping system. Two farmers voted for cowpea, 7 voted for velvet bean, 6 voted for sunn hemp, 1 voted for jack bean and 4 voted all of the above.

Evaluations of more than 15 species of legumes were conducted at the Isabela Substation. Eleven species were not considered for further evaluation due to poor adaptation, low seed yield, insufficient weed control, unsatisfactory ground cover and other factors such as susceptibility to disease or pests and nutrient deficiencies. Velvet bean, sword bean, sunn hemp and cowpea were chosen to be evaluated as potential cover crops for citrus producers in Puerto Rico.

Cowpea proved to be the least desirable cover crop due to a short life cycle, low biomass production and susceptibility to insects. The timely application of insecticide and fertilization would be needed to use cowpeas as a cover crop or for seed production.

Farmers favored the rapid germination, fast growth and ability of sunn hemp to suppress weeds. There was some concern about the potential of sunn hemp to become a weed in the citrus orchards.

The jack bean was generally free of disease. It also has a longer life cycle than the other legumes and can tolerate shade. The farmer noted that the jack bean took a longer time to generate canopy cover. On some farms the jack bean produced vines that interfered with the growth of the citrus trees.

The determinate velvet bean was preferred by the greatest number of farmers because of its ability to produce canopy cover in a short period of time, productive biomass and no competition with the citrus trees. The indeterminate velvet bean cultivar was not a favored by the farmers due to aggressive growth and pods that can be mistaken with pica pica. In general, there was a negative relationship biomass production and exchangeable Al ($r= - 0.34$, $p= 0.01$).

Farmers in this study varied in their preference for a legume to use as a cover crop. In addition, it is advisable to rotate cover crops to avoid the build-up of disease and pests. Therefore, the University of Puerto Rico, Agricultural Experiment Station seed program should offer for sale seed several different legumes. All of the legumes provided good levels of ground cover that should increase the retention of water and reduce erosion. The legumes accumulated a significant amount of N which should increase the availability of this nutrient.

The legumes in this study may be used as cover crops, green manures or as forage crops. The use of these tropical legumes as cover crops can generally be applied to citrus and other farming systems in Puerto Rico. Results from this research will help the University of Puerto Rico Agricultural Experiment Station to produce legume seed more efficiently and provide farmers with access to seed of cover crops that are adapted to a range of climate conditions. The research results should also allow farmers to reduce operating costs and environmental risk.

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Appendix 1: Cover Crop Survey

Instrucciones: Esta encuesta es única y exclusivamente con el propósito de realizar un estudio sobre el uso de plantas coberteras en sistemas de producción en Puerto Rico. Contestar el cuestionario, es completamente voluntario, favor ennegrecer las burbujas con la alternativa que usted seleccione. Gracias por su aportación a esta investigación.

1. ¿Piensas que añadiendo plantas cobertoras en su sistema de producción es benéfica para el manejo de su operación?

   O. Si O. No se O. No

2. ¿Crees que la utilización de plantas cobertoras controlan las malezas?

   O. Si O. No sé O. No

3. ¿Crees que al incorporar plantas cobertoras mejora la estructura (condición física) de sus suelos?

   O. Si O. No sé O. No

4. ¿Haz utilizado anteriormente plantas cobertoras en su sistema de producción?

   O. Si O. No

5. ¿De las muestras de plantas cobertoras sembrada en su predio, cual es de su mayor interés?

   O. Mucuna O. Canavalia O. Frijol O. Crotolaria

   O. Ambas O. Ninguna

6. ¿Haz observado un cambio en el área de experimentación de su finca?

   O. Si O. No O. No se

7. ¿Cuál es la plantas cobertoras de menor interés?

   O. Mucuna O. Canavalia O. Frijol O. Crotolaria

   O. Ambas O. Ninguna

8. ¿Le interesaría incorporar plantas cobertoras en su sistema de producción?

   O. Si O. No

9. ¿Cuál de las plantas le interesa incorporar?

   O. Mucuna O. Canavalia O. Frijol O. Crotolaria

   O. Ambas O. Ninguna