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Basis for agroecological management of aphids (Aphis craccivora Koch) on cowpea (Vigna unguiculata L.) in Cuban agroecosystems

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BASIS FOR AGROECOLOGICAL MANAGEMENT OF APHIDS (*APHIS CRACCIVORA* KOCH) ON COWPEA (*VIGNA UNGUICULATA L.*) IN CUBAN AGROECOSYSTEMS

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Promotion 2009

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	AUTHOR'S SUMMARY
INDICATIVE PLAN	A. Introduction B. Materials and methods C. Results D. Discussion E. Conclusion
GOALS OF THE STUDY	Knowledge acquisition and establishment of relationships between elements that will serve to design agroecological management of aphids on cowpea.
MATERIALS & METHODS	Aphid fluctuation in a cowpea crop was observed by weekly counting in a control treatment. Precipitation and temperature were recorded to explain this fluctuation. Three fertilization regimes were applied to cowpea plots and related with their aphid population. Environment and aphid population of two plots were correlated. Finally, three farms were compared in terms of biodiversity, of presence of hosting or repelling aphid plants, of crop management, of yield and of aphid population in a cowpea crop. 12 Cuban farmers were interviewed about their farming practices, how they decide it and their opinion on agroecological practices.
RESULTS	Farmers seemed to prefer biopesticides application to the use of vegetal barriers, of repelling plants and of colored traps. A lack of knowledge was observed. Good practices and good results were however observed in the region. Aphids attack cowpea crop at the beginning of the cropping season and during flowering-pod formation. Factors explaining presence and variation of aphids can be local biodiversity, crop stage and precipitation. Fertilization does not seem to have an effect.
CONCLUSION	It is suggested to create a structure for farmers to exchange their practices and to continue research on okra-cowpea association and the presence of neem three.

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LIST OF ABBREVIATIONS AND ACRONYMS

°C	Celcius degree
€	euro
APM	Agroecological Pest Management
cm	centimeter
CPA	*Cooperativa de Producción Agropecuaria* - Farming productive cooperative
day-°C	degree day
G	gram
h	hour
ha	hectare
IITA	International Institute of Tropical Agriculture
IPM	Integrated Pest Management
kg/m^2	kilogram per square meter
km	kilometer
L	liter
m	meter
m^2	square meter
mm	millimeter
n.s.	non specified
PIAL	Program for Local Agrarian Innovation
t/ha	ton per hectare
UBPC	*Unidad Básica de Producción Cooperativa* - Basic Unit of Cooperative Production

A. INTRODUCTION

A.I. Agriculture in Cuba

When the Soviet Union collapsed (1991), Cuba lost his main trade partner. Petroleum, fertilizers, pesticides and food imports drastically decreased (Gonzalez, 2003). Therefore, Cuba had to face an important decrease in food production. The government decided to make significant changes in agricultural production and to promote organic farming techniques (Gonzalez, 2003).

There are now four types of agricultural land ownership: State farms (representing 33% of land area), Basic Unit of Cooperative Production (UBPC, 42% of land area), production cooperative (CPA) and private farmers (the last two representing 25% of land area) (Gonzalez, 2003). The agricultural area, with 6 408 000 ha, represents 58% of the land (FAO Stat, 2011). A large portion of this area is dedicated to permanent meadows and pastures (cf. figure 1). 12.4% of Cubans works in agriculture (FAO, 2014).

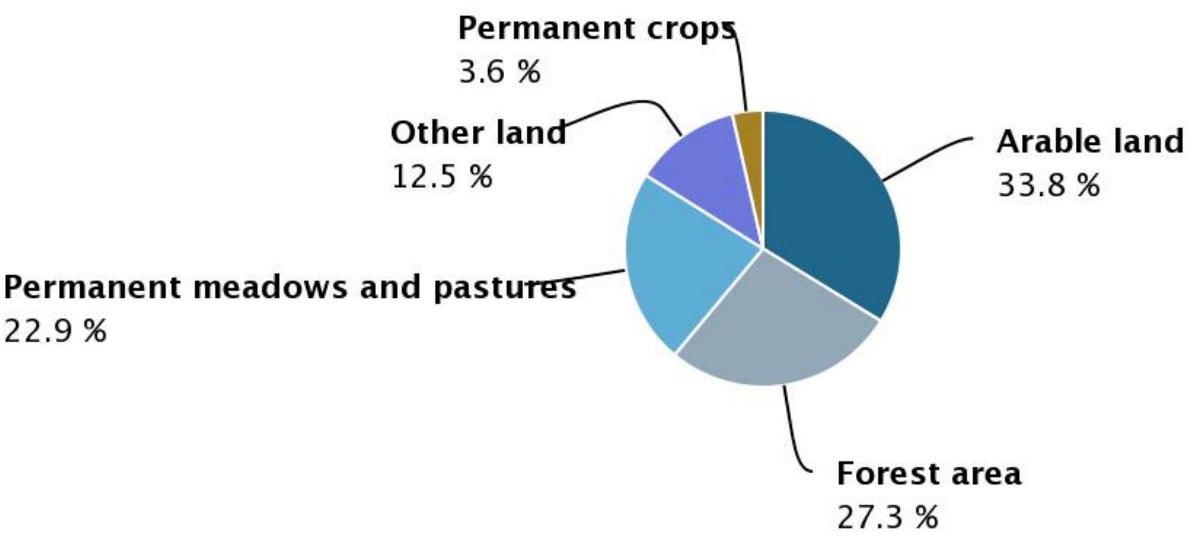

Figure 1 – Land use in Cuba (FAO Stat, 2011)

Sugar cane, like before 1959 Revolution and during the period of trade with the Soviet Union, remains one of the most important production in Cuba (FAO Stat, 2011) and is one of the most exported product (Gonzalez, 2003). Other important vegetal productions in Cuba are tubercles (mainly sweet potato) and plantain, vegetables, cereals (rice and maize), beans, citrus and other fruits (like mango, guava and papaya) and cocoa (Oficina nacional de estadísticas e información, 2013).

Cuban agriculture has to face several constraints: natural disasters (like hurricanes), difficulties to acquire inputs (fertilizers for example), insufficient or aged equipments and machineries (tractors for example) (González Corzo, 2011), poor soil quality (Altieri *et al.* 1999).

To overcome food crisis after the fall of the Soviet Union, urban gardens spring up in urban Cuba (Altieri *et al.*, 1999). Now, urban gardens in Cuba include "organopónicos" (raised bed gardens filled with soil and organic matter), intensive gardens (where the soil is highly fertilized), hydroponics (where the crops are grown indoors in a nutrient rich solution) and suburban farms (at the periphery of the cities) (Gonzalez, 2003). In 1996, it was estimated that there were 1 613 organopónicos in Cuba, yielding in average 16 kg/m^2 of produce (Altieri *et al.*, 1999). Urban gardens produce mainly vegetables and fruits, sometimes spices and medicinal plants. Besides increasing food security, urban gardens have allowed to empower and strengthen communities. The majority of those urban gardens are managed in an agroecological way, use integrated pest management and organic soil management (Altieri *et al.*, 1999). Agroecology has a wide range of definitions. In Latin America, it is viewed as an alternative to intensive farming that is a basis for sustainable development, food sovereignty and promotes agrobiodiversity (Wezel *et al.*, 2009). An agroecological practice is defined as a practice that do not harm environment. In Latin America practices are based on the conservation of natural resources and of agrobiodiversity, as well as a soil fertility management coherent with the needs (Wezel *et al.*, 2009).

A.II. Agroecological pest management

Insects in fields are considered as pests when they damage the crop in such important way that economic losses are threatening the system viability (the loses exceed the economic threshold). When natural communities are intensely modified, the equilibrium is lost and the pests become abundant and serious (Altieri and Nicholls, 2005). Such a modification occurs in large-scale monoculture because of landscape and on-farm plant diversity suppression, vegetation simplification, pesticides and fertilizers induced outbreaks (Altieri and Nicholls, 2005).

The concept of Integrated Pest Management was created by entomologists at the University of California in the 1950s in order to answer to two main problems: insecticides resistance increase and their destruction effect on natural enemies (Peshin *et al.*, 2009). IPM creators believed that to best suppress pests, one should have practices that preserve natural enemies and use insecticides only to supplement natural regulation when needed (Peshin *et al.*, 2009). However, nowadays, in many IPM programs, the major strategy is the use of pesticides (Peshin *et al.*, 2009). In the case of organic agriculture, some farmers practice "inputs substitution" strategy, which masks and does not face the problem at its roots. Limiting factors (such as pest infestations) have to be understood as part of an agroecosystem. Their appearance reveals its underlying illness (Rosset and Altieri, 1997). So, there is a need to view farming systems as agroecosystems and to find long-term solutions to pest problems. Focusing on the system offers ways to manage the reasons why insects arrive to the fields, establish and develop (Vázquez Moreno, 2006b). Agricultural systems have to be re-designed, minimizing therapeutic tactics and favoring preventive strengths, as long-term solutions (Altieri and Nicholls, 2005).

The Agroecological Pest Management (MAP) concept is developed in that direction. The focus is on the system, integrating social, economical, environmental and technological components (Vázquez Moreno, 2006b). In diverse agroecosystems and in the absence of pesticides, crop diversity, the presence of a ground cover, of weeds and natural vegetation adjacent to crop lead to parasitoid diversity (Altieri and Nicholls, 2005) and therefore leading to a natural insects regulation.

« *The agroecological pest management does not consist in applying biocontrol agents or other control alternative as an unique and principal option, but, at first place, sustain the biophysical management of the agricultural system and the biodiversity of the farm*. »

(Vázquez Moreno and Matienzo Brito, 2010)

In such systems, pests are regulated by:

- An increase in parasitoid and predators;
- A decrease of pests colonization and reproduction;
- The prevention of movement and emigration;
- A synchrony between pests and natural enemies;
- The presence of alternative prey and hosts for natural enemies;
- Feeding inhibition or chemical repellence from non-host plants.

(Altieri and Nicholls, 2005)

A.III. Status of pest management in Cuban agricultural systems

Because of the collapse of trading relations with soviet block, Cuba had to face important decrease in fertilizers and pesticides imports (80%) as well as petroleum imports (50%) in 1990 (Rosset, 1997). The country has transformed its agriculture from a modern conventional agriculture to semi-organic agriculture at a large scale (Rosset, 1997). Vegetal sanitation has been developed with an agroecological tendency (Vázquez Moreno, 2010). In the 1980, researchers had started to reorient their research, mainly toward insect pests biological control. Current used techniques include biopesticides, biofertilizers, biological control, resistant varieties and crop rotations. Since the 1990s, Integrated Pest Management (IPM) programs are developed as an alternative to pesticide use problems (Vázquez Moreno, 2010).

One of the most used pest control method is biocontrol. Cuba has a great experience in rearing and using natural antagonists for insect pests management (Oppenheim, 2001). Those biological control agents are mass reared in decentralized Entomophagous and Entomopathogens Reproductive Centers (*Centros de Reproducción de Entomofagos y Entomopatogenos* - CREEs), spread throughout the country (Rosset, 1997) and sustained by the Plant Health Research Institute and the network of Plant Health Provincial Laboratories (Vázquez Moreno *et al.*, 2010). Biopesticides are also in use and are produced in Cuba thanks to four production plants in the country. Thus, the evolution from conventional intensive farming to sustainable agriculture in Cuba has mainly resulted in the transition from pesticides or fertilizers use to environmentally benign and locally available technologies (Nicholls *et al.*, 2002). Mainstream current farming approach in Cuba is similar to the "input substitution" described by Rosset and Altieri (1997), while Vázquez Moreno and Matienzo Brito (2010) advocate for the use of biodiversity and biophysical management to re-design the agroecosystem and to fight pests.

However, Cuban urban farming show a different trend, with the generalization of agroecological pest management (Vázquez Moreno, 2006a). An effort is made towards floristic diversity. The most used methods (cf. figure 2) are crops associations, living barriers (mostly maize, sorghum and sunflower) and repelling plants (mainly marigold). Vegetal diversity in urban agriculture is considered as one of the main component of pest management (Vázquez Moreno and Fernández Gonzálvez, 2007). In terms of pest management, those systems are subject to special conditions, since plots are isolated from an ecological point of view. As a result, predators' activity is low in urban agriculture. At the contrary, suburban agriculture is close to rural agriculture and then is more affected by pests that come from nearby fields (Vázquez Moreno *et al.*, 2005).

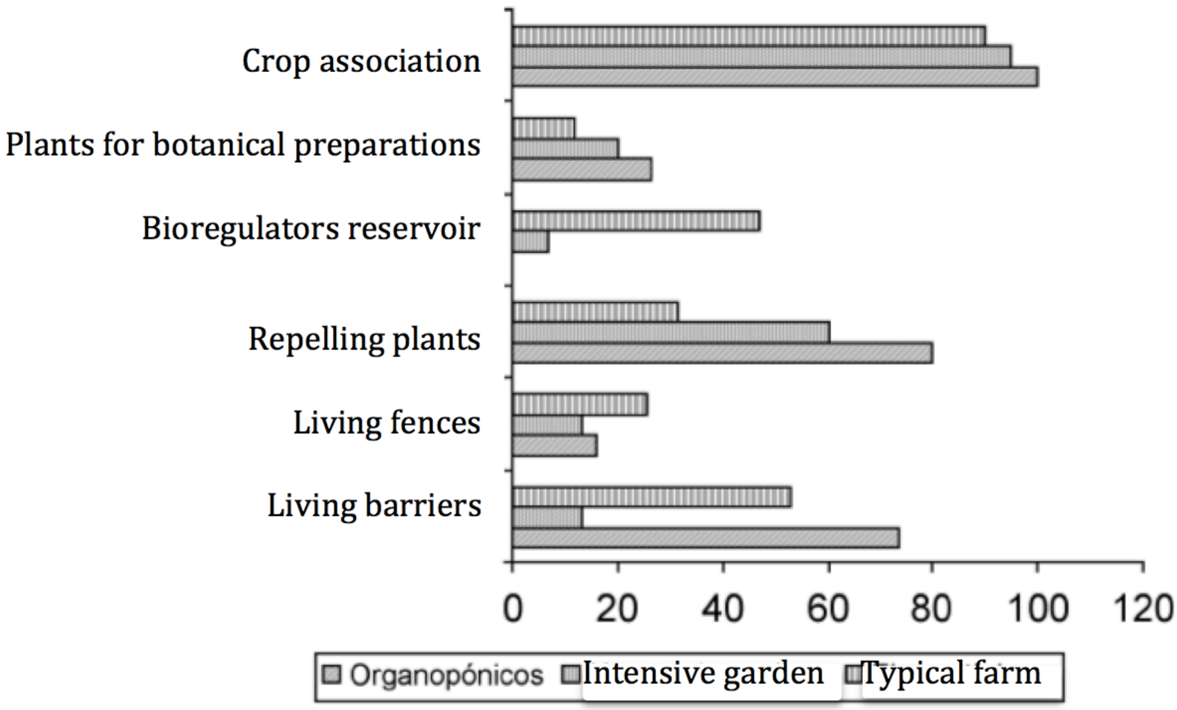

Figure 2 – Adoption of floristic diversity management practices in urban agriculture in La Havana, Cuba (Vázquez Moreno and Fernández Gonzálvez, 2007)

As a result, in Cuba nowadays, different agroecosystems coexist and there are two forms of pest management:

- Integrated Pest Management (IPM), for intensive productions in fields or "casa de cultivo", where pesticides are still in use on potatoes, tomatoes and other vegetables or legume crops;
- Agroecological Pest Management (APM), which is used by smallholders or in urban agricultural programs, where pesticides are not used or only occasionally (Vázquez Moreno, 2010).

A.IV. Presentation of system components

A.IV.1. Cowpea (*Vigna unguiculata* L. Walp)

Cowpea (cf. figure 3) is one of the most important legume crops in the world. It originated in Africa (Davis, *et al.*, 1991) and is now grown mainly in sub-Saharan Africa, but also in South America, Asia and the southeastern and southwestern part of North America (Ehlers and Hall, 1997). Cowpea is particularly important in West Africa, Nigeria producing 70% of the world's cowpea production (Blade *et al*., 1997).

Figure 3 – Cowpea plant

Cowpea is interesting for several reasons. It has a large spectrum of uses: dried grains for human consumption (main use) but also leaves, fresh beans, fresh bean pods, cowpea is as well used as green manure and fodder (Ehlers and Hall, 1997). Cowpea grain has a short cooking time (Blade *et al*., 1997). In Cuba, bean pods are consumed fresh by the population and are used by the food industry (Huerres Pérez and Caraballo Llosas, 1996). In terms of nutrition, protein content is high, with 24.8% of protein in mature ripen seeds (Davis *et al.*, 1991). Cowpea is well adapted to drought, high temperature and other kind of abiotic stress, as well as to favorable growing conditions (Ehlers and Hall, 1997). Due to its resistance to warm conditions, cowpea is one of the few crops in Cuba that are well adapted to spring and summer growing conditions (Arias Aroche *et al.*, n.s.).

Cowpea is grown in all Cuban provinces, in cooperative farms and by smallholders (Huerres Pérez and Caraballo Llosas, 1996). It is an annual herbaceous crop, with a short vegetative period. Plant height and ramification status depend on the variety: some are 25 to 60cm high and have few ramifications, while others are 100 to 150 cm high and have more ramifications (Huerres Pérez and Caraballo Llosas, 1996). Seeds color and shape widely differ. Plant optimal temperature for germination, growth, pods formation and filling is comprised between 19 and 22.5°C (Huerres Pérez and Caraballo Llosas, 1996; Ehlers and Hall, 1997). Temperature above 30°C with low humidity provokes the fall of a large number of flowers and pollination cannot be complete (Huerres Pérez and Caraballo Llosas, 1996).

In Cuba, cowpea is grown during the coldest period of the year, which also coincides with the driest season, to allow reducing illness incidence produced by different pathogens (Huerres Pérez and Caraballo Llosas, 1996). Another source says that in Cuba, the most favorable growing period is from September to December, but cowpea can grow in Cuba all the year round (Guenkov, 1969).

This plant does not have high light requirements and can be sown in intercropping (Huerres Pérez and Caraballo Llosas, 1996). In Africa, cowpea is traditionally grown as intercrop with maize, millet, cassava, cotton or sorghum (Blade *et al.,* 1997). In terms of humidity requirements, cowpea is sensible to high soil moisture content and can suffer low humidity during the first phases of its development. Nevertheless, flowering and fructification are critical phases during which the plant needs a certain level of humidity (Guenkov, 1969). Cowpea requires neutral to lightly alkaline soils, and is sensible to soil acidity (Huerres Pérez and Caraballo Llosas, 1996). Another source states that cowpea can grow on a variety of soils, but performs better on well-drained sandy loams or sandy soils, where soils are neutral to acidic (Davis *et al.*, 1991).

Cowpea vegetative cycle is short, about 60 days (Huerres Pérez and Caraballo Llosas, 1996). In Cuba, the green pods are harvested about 45 to 50 days after sowing (Arias Aroche *et al.*, n.s.).

Cowpea is a leguminous specie that fixes nitrogen. But, it seems that nodules are formed late in the cropping period and thus have little importance for the plant nitrogen nutrition (Guenkov, 1969). In Cuba, yields are considered as sufficient if they reach 4-5 t/ha, the targeted yield should be 10 t/ha (Huerres Pérez and Caraballo Llosas, 1996).

A.IV.2. The aphid *Aphis craccivora* (Koch) (Hemiptera: Aphididae)

The major constraint for cowpea grain production is insect damage (Ehlers et Hall, 1997). *Aphis craccivora* (Koch) is one of the key pests of cowpea (Karungi *et al*, 2000), affecting 90% of plants according to a field study, that took place in Cuba (Gómez Souza *et al.*, 2007). Cuban farmers of different municipalities identified aphids as a pest of major importance (Vázquez Moreno *et al.*, 2005). *Aphis craccivora* is polyphagous (Kataria and Kumar, 2013) affecting more than 15 different crops in Cuba, mostly pertaining to the family Leguminosae (Gómez Souza *et al.*, 2007), and therefore have an important spreading potential from one crop to another. Experiments in semi-protected areas in Cuba revealed that amongst all plants, this insect likes cowpea the most (Gómez Souza *et al.*, 2007).

Figure 4 – Alate aphids and apterous aphids (adults and different nymphs steps) on a cowpea leave

Aphis craccivora are small dark brown insects (cf. figure 4) that feed together in small groups on young shoots of plants (Pettersson *et al.*, 1998). The insect completes 4 nymph steps before becoming an adult (Obopile and Ositile, 2010). The time to adult depends upon temperature and diet and determines the rate of turnover of generations (Campbell *et al*., 1974).

The temperature threshold for development and the rate of insect development vary according to species. In the case of *A. craccivora*, Campbell *et al.* (1974) measured that in New South Wales the minimum temperature for its development was 8.3°C. Berg (1984) found similar results, with a threshold temperature development of 8.1°C. Developmental and reproduction rate increase with temperature, up to a threshold of 30°C (Berg, 1984). This insect develops rapidly, with a development thermal constant of 80 days-°C (Campbell *et al.*, 1974). Similar results were obtained by Gutierrez *et al.* (1974) in South East Australia, with a low development period of immatures and a low pre-reproductive period (16-18 h after becoming an adult). Cowpea aphid females can produce up to 98 progeny (Gutierrez *et al*., 1974). If there are too many aphids on the same plant (overcrowding), if there is a food shortage or if there is important temperature changes, alatea form is produced (Obopile and Ositile, 2010).

Aphids are feeding on plant sap, after piercing their tissues, sometimes therefore transmitting phytopathogen viruses. Fewer nutrients are available for plant development. Consequences on crops are stunting, delay in the initiation of flowering and viruses infestations (Davis *et al*., 1991 ; Obopile and Ositile, 2010). As the crop grows, the population of the aphids also does (Kataria and Kumar, 2013).

Aphids on plants form a mutual interaction with ants. Aphids produce an excretion rich in nitrogen and carbohydrates, called honeydew, which is collected by ants, providing in turn protection (Kataria and Kumar, 2013). In India, ants commonly associated with *A. craccivora* were found to be *Camponotus compressus* (Fabr.), *Pheidole* sp., *Monomorium* sp. and *Solenopsis* sp. (Kataria and Kumar, 2013).

Population dynamics studies show that aphids attack cowpea early in the season, increase in number rapidly and a population peak (up to 137 aphids/plant) can be observed, 13 days after inoculation (Gómez Souza, 2007). Similar results were obtained on alfalfa in Spain, with *A. craccivora* number staying non-significant until an exponential increase, leading to the population peak (Pons y Llovera, 1999).

As said earlier, *A. craccivora* affects number of crops. In India, it has been found to attack cotton (*Gossypium arboreum* L.), cowpea (*Vigna unguiculata*), potato (*Solanum tuberosum* L.) and eggplant (*Solanum melongena* L.), as well as the ornamentals *Hibiscus mutabilis* (L.), *Hibiscus rosa-sinensis* (L.), *Nerium indicum* (Mill), *Chrysanthemum* sp. and weeds like *Calotropis procera* (Ait.) in and around agricultural fields (Kataria and Kumar, 2013). In Cuba, one of the major problems that can be encountered by farmers is that they use the tree *Gliciridia sepium* (Jacq.) as a living barrier, which is a host of *A. craccivora* (Gómez Souza *et al*., 2007).

A.IV.3. Natural enemies

Authors identified several natural enemies that are likely to reduce *A. craccivora* infestations: *Cheilomenes sexmaculata* (F.) (in laboratory, Pervez and Omkar, 2005), *Coleomegilla cubensis* (Casey) (Milán Vargas *et al*., 2005), *Cycloneda sanguinea* (L.) (Milán Vargas *et al*., 2005), *Lysiphlebus testaceipes* (Cresson) (Costa and Stary, 1988) and *Cheilomenes vicina* (Fabricius) (Ofuya, 1986). *Colemegilla cubensis* and *Cycloneda sanguinea* were found to be the most numerous coccinellid species in Villa Clara province (52.8% and 37.9% of total coccinellid found respectively) and were associated on cowpea in this province as well as in other provinces of Cuba (Milán Vargas *et al*., 2005).

The functional response of predators determines the efficiency to regulate prey populations by representing its rate to kill preys at different prey densities. The proportion of *A. craccivora* consumed by coccinellid predators decrease with the number of preys, reaching at some point a threshold (Pervez and Omkar, 2005), while the total number of preys consumed increases with their number, up to the threshold (Aguilar *et al*., 2005). The functional response of coccinellid predators represents a decelerating curve (type II of Holling) when they are confronted to aphids (Ofuya, 1986; Pervez and Omkar, 2005; Aguilar *et al*., 2005). Therefore, aphid density is a key factor in the number of aphids killed by natural enemies. Temperature is another one (Isikber, 2005).

Cardinale *et al*. (2003) found that pests (pea aphids in this case) are better suppressed when there is a multi-enemy assemblage (better than the summed impact of each enemy taken individually). Adult aphids defend better themselves than young aphids when they are attacked by coccinellid (Ofuya, 1986).

Predators need additional aminoacids and carbohydrates than those they found in their prey. Those nutrients are to be encountered in plants, which provide them with pollen, nectar, leaves and plant sap (Beltrame and Saltago, 2005 in Milán Vargas *et al*., 2008). Thus, there is the need to provide them with such nutrients thanks to relay plants.

This report will mainly focus on the three natural enemies *Colemegilla cubensis* and *Cycloneda sanguinea* since the two fists were found in the specific studied region.

A.V. Aphid management by farmers: State of the art

Considering the above-mentioned facts, there are needs to study agroecological pest management methods that have been developed in practice, so as to possibly apply them in Cuban agroecosystems.

Some factors, such as insecticide application and nitrogen fertilization are involved in the increase of aphid infestation.

Insecticide applications are effective in reducing punctually the amount of aphids in fields but not on the long run. A re-colonization by aphids (insect pest resurgence) is observed few days after insecticides treatment (Hasken and Poehling, 1995). Moreover, insecticides applications are linked with the death of natural enemies. For example, spider mites (*Tetranychus urticae* Koch) number has been found to increase because of the dead of their natural predators caused by the application of pesticides on bean plants (James and Price, 2002).

Nitrogen fertilization has also been identified as an explanation of aphids' invasion. Indeed, soil chemical (but also physical and biological) proprieties are linked to plant ability to resist or to tolerate insect pests (Altieri and Nicholls, 2005). Plant attracted aphids when they have a high amino-acid content and when vegetation period is extended resulting from nitrogen fertilization (Hanish, 1980, Hansen 1986 in Hasken and Poehling, 1995). Non-fertilized and non-chemically treated fields show a reduced aphid infestation in winter wheat fields (Hasken and Poehling, 1995). Similar results were achieved by Altieri *et al*. (1998, in Altieri and Nicholls, 2005): cabbage aphid (*Brevicoryne brassicae* L.) was significantly reduced in organically managed broccoli. This reduction was attributed to a lower content of free nitrogen in plant foliage.

Other techniques, such as plant traps, application of biopesticides, mulching and the use of resistant varieties have been found to be effective alternative techniques in the fight against cowpea aphids.

Mixed cropping showed its efficiency to face *A. craccivora* infestations. In soybean fields, Abdallah (2012) showed that the presence of a mixture of maize, mung bean and sunflower surrounding the crop decreased the amount of aphids. El-Khouly *et al*. (1994) found in different systems that intercropping maize and cowpea allowed reducing aphids' infestation. Hassan (2013) found a similar result with an intercrop of sorghum with cowpea. Farmers appreciate the intercropping of cowpea and sorghum for its effect on aphid reduction, but also potential marginal return (farmer participatory evaluation, Nabiryea *et al*., 2003). Nevertheless, Bottenberg *et al*. (1998) found a limited effect of intercropping cowpea with millet in terms of percentage of infested plants.

Plant extracts are effective in reducing aphids' densities (Ofuya and Okuku, 1994) but can also be toxic to their coccinellid predators (Ofuya, 1997). This result was obtained with essential oil vapors of pennyroyal, peppermint, basil and orange fruits by Kimbaris *et al.* (2010). In Cuba, maceration of marigold (*Tagetes erecta* L.) and mottled spurge (*Euphorbia lactea* L.) showed their efficiency on *A. craccivora* without affecting cowpea growth and yield (Pascual, 2007 ; González Ochoa *et al*., 2010).

In Cuba, some farmers are using rice husk as a much. It reflects the sun under the plant leaves and therefore impedes aphids to hide (Cuadra Molina, n.s.). Nevertheless, there can be a concern of the effect of this technique on natural enemies. Does mulching also bother them?

Researchers of the International Institute of Tropical Agriculture (IITA) in Nigeria have developed varieties that are resistant to several diseases and pests, amongst which *A. craccivora* (Ehlers and Hall, 1997). They found a beneficial interaction between plant resistance and biocontrol by coccinellid predators (Ofuya, 1995). Nevertheless, adaptations to crop resistance have been observed, so Ofuya (1995) suggests the use of both partial resistance and natural enemies.

In Cuba, one of the strategy used to fight cowpea aphid is the conservation of natural enemies, by growing maize as living barriers or intercropping, by taking care of the plants hosting natural enemies (based on observation), by moving natural enemies from some plants where they are observed to the crop or by rearing and releasing them. Against cowpea aphids, *Lysiphlebus testaceipes, Cycloneda sanguinea* and other Coccinellid species are used (Vázquez Moreno *et al.*, 2007).

A.VI. Problematic situation

Aphis craccivora is a major cowpea crop pest in Cuba. Pesticides being a costly external input for farmers and being involved in ecosystem degradation, there is a need to find alternative techniques to fight cowpea aphids. Several methods are used by farmers, but there is no evaluation so far of their combined effectiveness on aphid population fluctuation in Cuban agroecosystems. Moreover, aphid infestation reveals a weakness of the system and therefore the factors involved in the system equilibrium disruption have to be looked for. Besides that, there is a need to know what are farmers' practices in the region and how they choose them in order to know how to possibly have an influence on it.

This thesis is an attempt to establish the basis of agroecological aphid management on cowpea crops in different Cuban agroecosystems. This is only the basis since the experiments were conducted only in one area of Cuba and on a reduced amount of farms. To have more significant results, a large-scale experiment would have been needed. Agroecology here has been reduced to its technical aspect, as most Cubans perceive it. Social, economic and environmental factors will nevertheless be discussed. The agroecosystem studied here is considered at the plot level, so interactions between the crop, its environment and its management are examined.

A.VI.1. Research question:

How to regulate *Aphis craccivora* on cowpea crop (*Vigna unguiculata*) in specific Cuban agroecosystems?

Sub-questions:

- How does Cuban farmers manage cowpea crop, specifically regarding aphids?
- How does aphid population varies in cowpea fields during cropping time?
- What factors can explain aphid population on cowpea?

A.VI.2. Hypothesis

Farmers are using different techniques to crop cowpea and fight pests, amongst which aphids is an important one, that is not well controlled. These techniques include the use of biopesticides, colored tramps, vegetal barriers and repelling plants.

Winged aphids arrive early in the cropping season on the plants, when cowpea plants are small. They start to establish colonies of aphids, population peak is reached later in the cropping season.

Pest problems solutions have to be found in ecosystem design. At some point, aphids establish themselves there and form unsustainable number of colonies in the field due to disequilibrium in the system (lack of biodiversity, pesticides application, inappropriate fertilization) or an error in its design (nearby presence of aphids host plants), causing important crop damages. Crop diversification, attraction of natural enemies, and repellence of aphids are techniques that provide a sufficiently good control. So, the factors causing aphid infestation on cowpea are believed to be the use of insecticides or the misuse of fertilization, the lack of biodiversity on the farm and the nearby presence of host plants. The weather (precipitation and temperature) is also considered as possible explanations of aphid infestation.

B. MATERIALS AND METHODS

This study is divided into two parts. The first one aim at answering to the first research question and the second part to the second and third research questions.

B.I. Where farmer's practices are explored

The first part aims at knowing what are the farmers' practices in the region and how they decide their practices. Interviews with ten farmers growing cowpea in the province of Santa Clara were realized. They were randomly chosen: during several transect walks, when a cowpea field was found, the farmer was asked for an interview. Questions focused on general information about the farm and crops grown; on the farmer practices on cowpea and specifically on the use of biopesticides, repelling plants, vegetal barriers, colored tramps and release of natural enemies; and on the factors and organization influencing on their practices. Those interview aimed at determining what are cowpea farmers doing in the region and why. Interview guide can be found in appendix I. Interviews lasts about half an hour to an hour each, and the farm was observed so as to have a visual idea of farm diversity and the use of repelling plants and vegetal barriers.

In total, 12 interviews were realized. It would have been interesting to interview more farmers and in different locations, but there was no time and no possibility for this.

B.II. Where aphid population is observed and explained

This second part of the study was conducted in three farms next to Santa Clara, in the province of Villa Clara, Cuba. The three farms were: an agroecological farm and two "organopónico", where vegetables and legumes are grown on raised-beds (cf. figure 5). It would have been interesting to also carry out this experiment on a more industrial state farm as well but there was no possibility for this.

Figure 5 – The organopónico “Patria” en Santa Clara

The agroecological farm is located in Antón Díaz, a village next to Santa Clara and managed by Rubén Torres. On the 17 ha of the farm, various crops are grown and cattle raised: rice, bean, tomato, avocado, cassava, maize, seasoning pepper, peanut, cucumber, coffee, eucalyptus, coconut, chicken, cow and goat. All the crops are managed in an agroecological way since 1997. Rubén Torres was at that time aware of agricultural problems and the misuse of chemicals. That is the reason why the persons in charge of the project of the United Nations “Pan para el mundo”, contacted him and helped him to convert his farm to an agroecological management. He later participated to other projects and is now a member of the “Campesino a Campesino” network (a Cuban project, coming from the national syndicate - ANAP - aiming at creating a network of farmers exchanging practices). Rubén Torres is also member of an international project named Program for Local Agrarian Innovation (PIAL – Programa de Innovacion Agropecuaria Local). This program is run by the Central University “Marta Abreu” de Las Villas, Santa Clara and financed by a Swiss organization, called COSUDE (Swiss Agency for Development and Cooperation). This project helps the farmer to find products and innovations to implement agroecological practices on his farm. No chemical pesticides or fertilizers are used on his farm. The farmer is producing its own vermicompost to enrich its soil. The soil is therefore rich in organic matter and contains about 3,5% of organic matter. It is a family farm, on which some family members work.

The organopónico, called “Las Marianas”, is located in the city of Santa Clara and is surrounded by other fields. The farm is separated into two organopónicos, one mainly dedicated to vegetables crop (hereafter called organopónico 1) and the other one to fruits production (hereafter called organopónico 2). The two organopónicos are the same juridical entity but are managed in a different way.

On the 0,5 ha of the organopónico 1, several crops are grown during the year: cowpea, tomato, cucumber, onion, chard, lettuce, carrot, beetroot, eggplant, radish, chives and okra. Vegetables are grown on raised beds, which soil is made out of ground, vermicompost, compost, manure and “*cachaz*a”, a residue from sugar cane production. There are about 20 workers on the farm. Those workers are Cuban soldiers in formation completing a civic service.

On the 2,5 ha of the organopónico 2, several crops and trees are cultivated: cowpea, maize, plantain, mamey sapote, red pepper, avocado, guava and flowers. Vegetables are grown on raised beds, which soil is made out of ground and compost (manure and *cachaza*). Soil fertilization is done chemically. There are 4 workers on the farm. From time to time, soldiers from organopónico 1 help on this farm as well.

B.II.1. Experimental design

In this study, we aim at observing aphid population fluctuation without interference and under different management systems in field and at trying to find what factors are influencing on population fluctuation. We aim at observing systems that are feasible for farmers so the experimental design is intended to be close to what farmers are currently doing.

In all the experiments, the cowpea variety used was Cantón, which is one of the most used in the area. It is a susceptible variety, which will allow seeing population fluctuation without interference.

Three experiments were conducted, each one with its own treatments:

i. Effect of fertilization on aphid population fluctuation

The plants were grown on raised beds, next to the farmer’s crop, in the organopónico 1. Seeds were sown on May 11th. Supposedly, no pesticide was used on the crop. Weeding was done from time to time. Harvest started on June 11th and the plants were removed on June 20th.

Every week, aphid population was evaluated (see method in B.II.2.a.) on twenty plants for each treatment (two replicates of ten randomly chosen plants, in two different raised beds, cf. figure 6). Presence of insects and fungus, crop stage (thanks to BBCH scale, cf. appendix II) and height as well as weather was recorded.

In order to observe the effect of fertilization, three fertilization treatment were realized:

- Control without pesticide or fertilization
- Fertilization with organic mater (produced on the farm) on June 2nd.
- Fertilization with a synthetic product containing 9% of nitrogen, 13% of phosphorous and 17% of potassium, at about 4 T/ha at the beginning of the culture.

Mean number of aphids per sampling date will be compared per treatment using the statistical analysis software R.

This control treatment was also used to determine aphid population fluctuation without interference and to determine the influence of the weather (see B.II.2.e for data collection method for the weather).

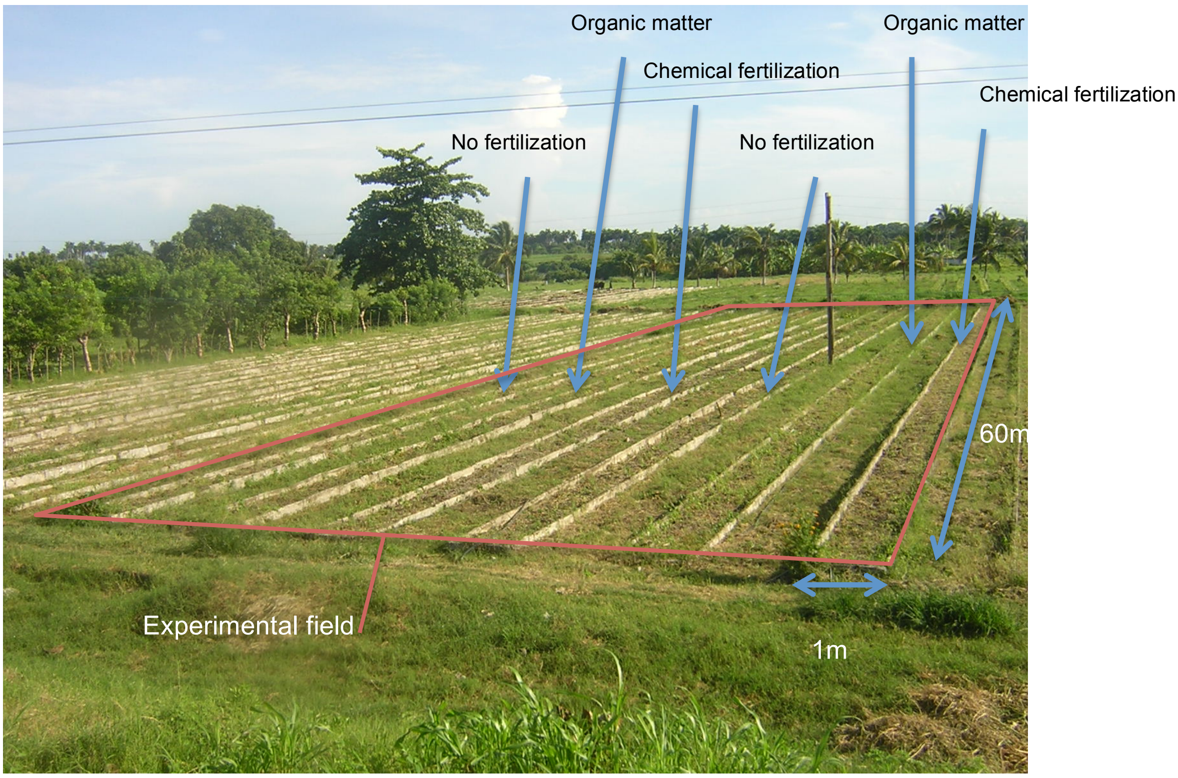

Figure 6 – Design of the experimental field

ii. Comparison of three agroecosystems management

Three agroecosystems will be compared, in the sense that, at the crop level, the interactions between the crop, its environment and its management will be studied. In the three farms, the cowpea crop will be studied in its environment, with the usual management of the farmer. The three agroecosystems will be compared in terms of biodiversity on the farm to which they pertain (see method below in the part B.II.2.b.), of presence of aphid host or repelling plant (see method in the part B.II.2.c.), of crop management, of yield (see method in B.II.2. d.) and of aphid population (see B.II.2.a.). In this experiment, aphid population was evaluated on 50 plants (randomly chosen) every week. Hereafter is quickly described how was managed the studied cowpea field in the three different farms.

In the organopónico 1, seeds inoculated with *Rhizobium* were sown in raised beds on May 11th. Fertilization with 60 kg/ha of a synthetic product (9% of nitrogen, 13% of phosphorous and 17% of potassium) was realized on May 17th. About 2kg/ha of copper was sprayed on the plants on May 25th and on June 5th. Weeding was done from time to time. Harvest started on June 11th and the plants were dug up on June 20th. The crop was irrigated when necessary. Cowpea was grown in a field where cucumbers were previously grown.

In the organopónico 2, seeds were sown on February 21st in raised beds, where cucumbers were previously grown. Seedlings were fertilized with 50 kg/ha of a synthetic product (9% of nitrogen, 13% of phosphorous and 17% of potassium) on March 8th. B-58 (an insecticide), Mancozeb (a fungicide, 1.5L/ha) and Cuproflow 38% concentrated solution (a fungicide, 1L/ha) were applied on April 13th, at the beginning of flowering period. P-50 (against ants, also known as carbaryl) and methylparathion (an insecticide) were applied on April 20th. A combination of Pyrethrum Daisy (insecticide) and Ridomil (a fungicide) was applied on the 27th of April and on the 4th of May (1L/ha each time). Harvest started on April 24th and the crop was dug up on May 15th.

In the agroecological farm, soil was ploughed with a mechanical ploughing machine carried by oxen mid-March. This area was not cultivated the past two years. A week later ploughing, seeds inoculated by mycorrhiza (Ecomic) and *Trichoderma sp*. were manually sown on the 28th of March, after irrigating the field and fertilizing with vermicompost. This crop failed, probably due to the lack of seed quality. So, seeds were sown again on April 29th. Plants were regularly irrigated. On May 21st, a leaf stimulant, called Fitomás and the bacteria *Bacillus thuringiensis* (Br.) were sprayed. On May 29th, vermicompost was distributed on plant rows and then recovered by soil. Harvest started on June 20th. Sulfur was sprayed on June 25th (100 g in 20 L of water for the 171 m^2 of the field). The farmer stopped harvesting on July 30th because there were almost no pods left.

iii. Comparison of aphid population on cowpea in two different environments

During a walk through the organopónico 1, it was observed that in two fields, separated by about 50m, the number of aphids on cowpea plants was different in the two fields. At those two locations, plants were of the same variety (Cantón), were sown at the same date, had received the same treatment, were managed by the same persons and were at the same stage (beginning of the flowering period) at the date of the observation. The only difference was the environment of the field. In the rest of this report, the two different location will be named A and B.

It was therefore decided to determine aphid population (see method in B.II.2.a.) on 40 randomly chosen plants at each location. Mean number of aphids at each location will be statistically compared using the software R. Plants present in the environment of the two fields were recorded, focusing on aphid host or repelling plants (see method in B.II.2.c.).

B.II.2. Evaluated factors

B.II.2.a. Aphid infestation grade and presence of other insects

No difference was done between aphid stages (larval and different adult stages).

Aphids were evaluated on the whole plant. For all the experiments, aphid amount was evaluated on every plot once a week (same day, same time, except for the experiment iii. Evaluation was done only one time), thanks to a scale. Indeed, it was not possible to count the exact number of aphids on each plant. The following scale was designed after the ones used by Bottenberg *et al*. (1998) and Nabiyre *et al.* (2003), taking into account aphids population fluctuation in Cuban fields described by Gómez Souza *et al.* (2007):

0 : 0 aphids/plant

1 : 1-4 aphids/plant

2 : 5-20 aphids/plant

3 : 21-50 aphids/plant

4 : 51-100 aphids/plant

5 : 101-200 aphids/plant

6 : > 200 aphids/plant

For each date and plot, other insects present in the fields were recorded. A special attention was given to natural enemies. Their presence was checked (on the same plants), focusing on *Colemegilla cubensis* and *Cycloneda sanguinea* since those species have been specifically identified in Cuban farming systems and in the region for their efficiency on cowpea aphids.

This was done for the three experiments.

B.II.2.b. Biodiversity characterization

The floristic biological diversity of the three farms was evaluated, as described in the method of Vázquez Moreno and Matienzo Brito (2010). This characterization is done at the farm level. This method considers that biodiversity is composed out of five components: productive biodiversity, auxiliary biodiversity, functional biodiversity, introduced functional biodiversity and noxious biodiversity. For each component, several indicators, like the number of crops or the diversity of pollinators, are evaluated (cf. appendix IIIa). Then, the result for each indicator is converted into a grade thanks to a converter (cf. appendix IIIb). The grade is comprised between 0 and 4. A mean grade is attributed to each component and globally to the farm.

This was done for the three farms of the experiment ii.

B.II.2.c. Local environment

The environment of the cowpea field was appreciated in the three farms. A mapping of the field design and its environment was done, focusing on potential aphids host plants. Bruner *et al*. (1975) recorded a list of cultivated plants attacked by *Aphis craccivora* in Cuba (cf. appendix IV). The presence of the tree *Gliciridia sepium*, which is known in Cuba to be an aphid host, was also looked for. This information served as a possible explanation of aphid population infestation.

This was done for the three fields of the experiment ii and the two fields of the experiment iii.

B.II.2.d. Crop management and yield

Farmer's practices on their cowpea field were asked for during every visit. Those practices were recorded and compared for the three farms.

At the end of the experiment, yield per square meter (kg/m^2) was evaluated for every treatment by weighting the total pods harvested as done by González Ochoa (2010). Crop stage was recorded on every aphid counting date. Several indicators of crop proceeding were calculated: duration of cropping cycle, number of days between sowing and harvest and duration of harvesting period (in days).

This information served to compare the three farms of the experience iii.

B.II.2.e. Weather

Daily temperature and precipitation were obtained from the meteorological station of an agronomical experimentation center in the Central University "Marta Abreu" of Las Villas, Santa Clara, Villa Clara province. This experimental center was situated 4.5 km far from the organopónicos 1 and 2 and 23 km far from the agroecological farm.

This was used to explain aphid infestation, using the experience i and aphid population in the agroecological farm of the experience ii. Aphid population in the organopónico 2 cannot be used because pesticides use could false the results.

C. RESULTS

The result section is divided in two parts. In a first part, the results of farmer interviews, corresponding to the first sub-research question are commented. The second part is dedicated to the result of the field experiments, corresponding to the second and third sub-research question.

C.I. Agroecological management of cowpea in Cuba

Cowpea was found to be grown in urban farming. Amongst the twelve farmers interviewed, six pertain to an organopónico (one of them being part of an agroecological farm), five to an urban garden and one to a UBPC. In average, those farmers were cropping for 15 years. Those farms differ in size; minimum was 0.046 ha and maximum 3.16 ha. Average size was 1.16 ha. Mean number of workers on those farms was three; one of them was usually dedicated to sales. In general, those farms had a small shop where they directly sell their productions to neighbors. Besides providing essential fresh vegetables, fruits and tubercles to the population, in some cases, the local urban garden is a central place in the neighborhood, where people meet and socialize. Schools sometimes visit and work in urban gardens.

Crops grown in those urban gardens were diverse, with in average 21 different crops grown. Most common crops grown were salad, chard, cowpea, cucumber, tomato, sweet green pepper, okra, eggplant, spinach, beetroot, carrot, pumpkin, coriander and chives. Raised-beds are made out of a mix of soil and organic mater. This organic mater was made out of compost or vermicompost in all the cases (homemade with, amongst others, crop residues), sugarcane processing residue in five farms and manure in five farms as well. In four farms, they used zeolite, which is a mineral capable of retaining water; it is therefore used to maintain soil moisture content in raised-beds.

Cowpea was found to be cropped during the whole year in six farms and from March or April to September in six farms. Farmers who cropped cowpea from March or April to September are doing so because cowpea can support the high temperatures and rains of this season, unlike other crops. The variety Cantón was used in ten farms, some of those farms also grow another variety, like “Enana” or “Taiwanesa”. Farmers used the variety Cantón because this variety is quicker to produce pods than others, it is easy to harvest and because consumers like it. One farmer used the variety Lina and the other one the varieties Cuba-22 and Cuba-92.

Those two last varieties start to produce after three months, compared to two months for the variety Cantón, but give a better yield in the end. The election of those varieties is the result of an experiment with several varieties in his organopónico. This farmer is the only one interviewed to produce his own seeds.

Cowpea association with another crop was sometimes done in seven farms and always done in three farms. When association was done in those seven farms, it was done with chives, chard, lettuce or okra so as to better use available space. One farmer mentioned okra repulsive effect on pests. Farmers who always associated cowpea with another crop did it with chives as a barrier to protect the crop and to better use available space; with chard, radish or salad for productive and economical reasons (to maximize crop production on the available space and to prevent weed growth with a soil cover); with maize (cowpea is climbing up on maize), okra and sunflower (to mitigate heat).

Aphids were recognized as to be important pests in nine farms. One farmer said that there were more aphids during flowering. Another said that there were no aphids during the rainy period when he cannot weed and his field was full of weeds. Farmers mentioned whitefly (in four cases), slug (in three cases), cricket (in three cases), snail (in two cases), and ant (in two cases) as being important pests.

In terms of bioproducts, farmers used a diversity of products on cowpea crop. Seven farmers used neem oil as an insecticide, three used fitomás as a leaf stimulant, four were using tobacco residues, four were using lime as an insecticide, five were inoculating seeds with *Trichoderma* sp. against soil diseases and three farmers were sometimes using *Beauveria bassiana* and *Bacillus thuringiensis*. Two farmers were making their own preparations. One of them was rearing a mix of microorganisms with syrup and spraying it as an insecticide on crops. The other one is mixing neem oil, mottled spurge and bitter melon (*Momordica charantia* L.) and let this mix fermenting during 72 hours. It is a general insecticide, used when there is a population peak of some insects. This same farmer stated that *Bacillus thuringiensis* 24 was recently made available in Cuba and was very efficient against aphids. All farmers were convinced of the efficiency of those products that they used. Nevertheless, three of them regret to not be able to use chemical pesticides that are available on the black market. They were very probably already using them. Two of them admit that they were using cypermethrin, a synthetic pyrethroid, as an insecticide.

Most farmers were also convinced of the efficiency of vegetal barriers (nine farmers), while two did not really understand the interest and one said that it was not useful. Nevertheless, they were all using them. Most used vegetal barriers were sorghum (eight farms), maize (seven farms), millet (two farms), sunflower (two farms), moringa (one farm), okra (one farm), achiote (*Bixa orellana* L., one farm). Two farmers mentioned that some of those vegetal barriers were useful in the sense that they protect the crops and are also productive (in the case of maize for example). In almost half of the farms, vegetal barriers were present but those plants were not numerous.

The same trend was observed for repelling plants. They were present in all the farms, but in half of them, they were very few. Four farmers were not really convinced by the use of repelling plants and were thinking that they do not work well. Repelling plants used were marigold (in all the farms), oregano (in height farms), basil (in three farms), neem tree (in three farms) and pretty sneezeweed (*Helenium elegans* Gray, in one farm). One farmer considers other plants that he crops as repelling plants: carrots, chives and parsley.

All the farmers were using colored traps, of different colors but they were not convinced of their efficiency. They think that it is a tool to see, know and count insects present into the fields but do not serve to trap them. It is useful to see when insect number is increasing but it is not a good pest control method. There were no farmers using release of natural enemies to fight against pests. Some did not even understand the question. Others not very interested, mentioned the high cost of this method or its low efficiency.

Overall, the knowledge of the interviewed farmer was in general poor for seven of them. They were applying the methods that they were told to. The other five farmers had intermediate or high knowledge level about the plants and farming practices, because of their education, their own experience or their own interest.

Interviewed farmers received technical advices from one main organization, called *Empresa horticola* (horticultural company). It is a State agency, organized at the municipality level. This organization rent the land to farmers who also pay to this company social security and taxes. In exchange, the company sells seeds and means of production, gives technical advices (what product to use and when, what are the rules, etc.) and a technician regularly visits the farm. Farmers are not employees of this organization, they earn the money they make when selling their products, but they have to justify the use of their techniques and to prove that they are really employing recommended techniques (like the use of repelling plants or vegetal barriers). Farms are regularly inspected. Three farmers complained about this organization, two because help provided was not sufficient because of a lack of resource, organopónicos receive more help than gardens and one because of the insufficient knowledge of the technician and the lack of quality of the help. Three farmers mentioned the Cuban association of agricultural and forest technicians (*Asociación Cubana de Técnicos Agrícolas y Forestales* – ACTAF), providing pamphlets to provide farmers with cropping advices. One farmer mentioned the help of the Entomophagous and Entomopathogens Reproductive Center (*Centro de Reproducción de Entomofagos y Entomopatogenos* – CREE) where she can buy biological agents to spray on her crops. Two farmers were identified to have a special network allowing them to have more information. One of them was member of the ANAP, tried to enter in the *Campesino-a-Campesino* network and was looking for a lot of information by her own. Sometimes, professors from the local university came to visit her and gave her advices. A farmer has a really good connection with this same university, with professors coming regularly to his farm and students going there to realize experiments. Like this, he was kept updated and regularly implements new techniques. He also received advices from an instructor from the Institute of fundamental investigation in tropical agriculture (*Instituto de Investigaciones Fundamentales en Agricultura Tropical* – INIFAT), who has a PhD and provides good advices.

None of the farms received economical help.

Several problems came up when talking with the farmers. Two of them complained that seed price was too high and was a very important charge. Two farmers also said that the foliar stimulant called Fitomás was promoted at a national scale. It has very good results. But, it is difficult to find. There are regular shortages of this product.

One farmer explained that pesticides products on the black market cost less than bioproducts. For example, *Verticillium* sp., is a fungi used for biocontrol. It costs nine pesos per kilogram (about 0,27€) and can be used for 80L of preparation. 1L of chemical insecticide costs about 5 pesos (about 0,15€) and can be diluted so as to make about 100-120L of preparation. Some farmers are therefore tempted to buy chemical pesticides besides the interdiction.

Another farmer explained that there is a problem of workforce. Most of the organopónicos (90%) are governed by one single person and the others are salaries who earn little money. The responsible pays salaries and takes for himself all the money left. There is no motivation of the worker. As a result, every worker stays little time on an organopónico.

C.II. Study of aphid population

C.II.1. Population fluctuation through time

Aphids were observed in general on cowpea stems, under the leaves or on flower buds.

On the untreated plot in the organopónico 1, aphid infestation started early in the season, since they were present in the crop at the first counting, which occurs when the plants had three real leaves (cf. figures 7 and 8). Nevertheless, there were few aphids in the crop throughout the experiment, since the maximum was reached for apterous aphids with 1.2 (mean for all the plants on June 12th). This value corresponds to less than 20 aphids per plant. This is a mean number, hiding the fact that aphids heavily infected some plants (cf. figure 8), a plant was found to have an infestation grade of 7 on June 16th for example, while there were no aphids at all on the majority of plants on this same day.

Alate aphids were present only the first day of the experiment (cf. figure 7). This day, the mean number of winged aphids per plant was 0.1, which corresponds to less than 5 aphids per plant. This number is low. In general, on all the experiments, alate aphids were observed alone on plants.

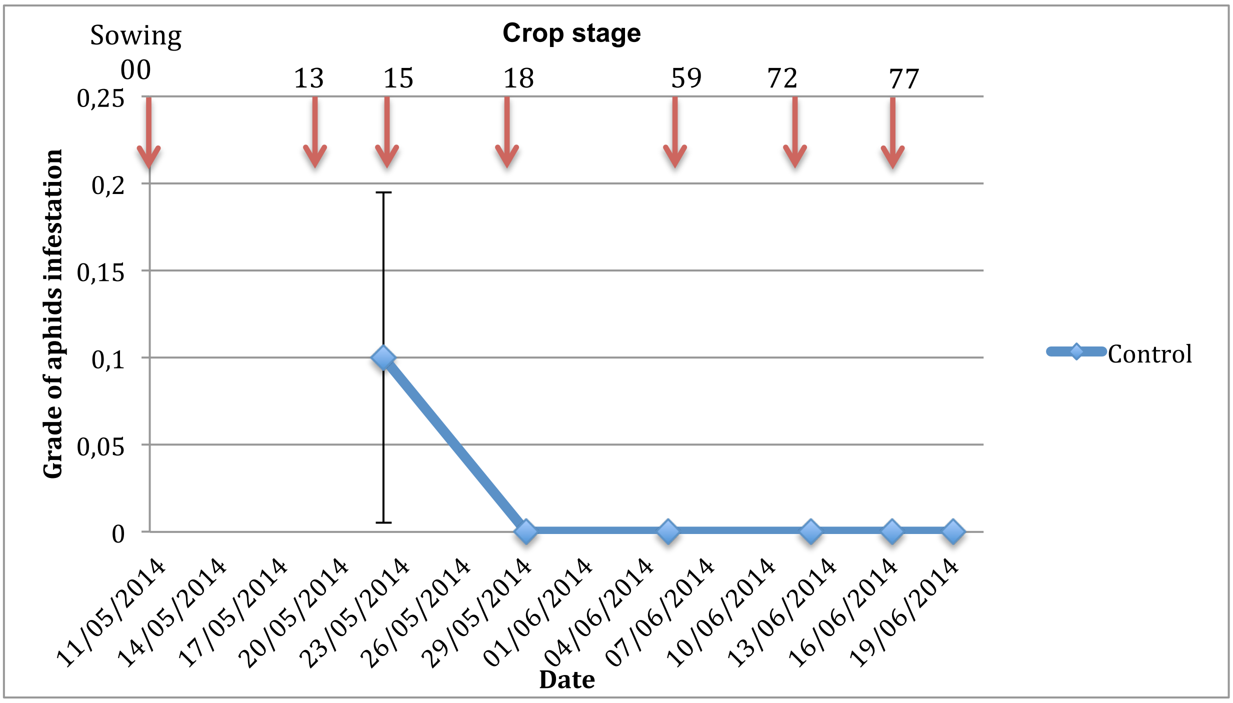

Figure 7 - Grade of infestation through time of alate aphids in a non-treated cowpea plot, in relation with crop stage according to BBCH scale

Apterous aphids were present until the lasts stages of the crop, when there were no more flowers and the last pods were growing (cf. figure 8). The maximum grade of infestation was reached on June 12th, which corresponds to the beginning of pod formation. Another peak is visible on the first day of counting, on May 22nd, which corresponds to the vegetative period.

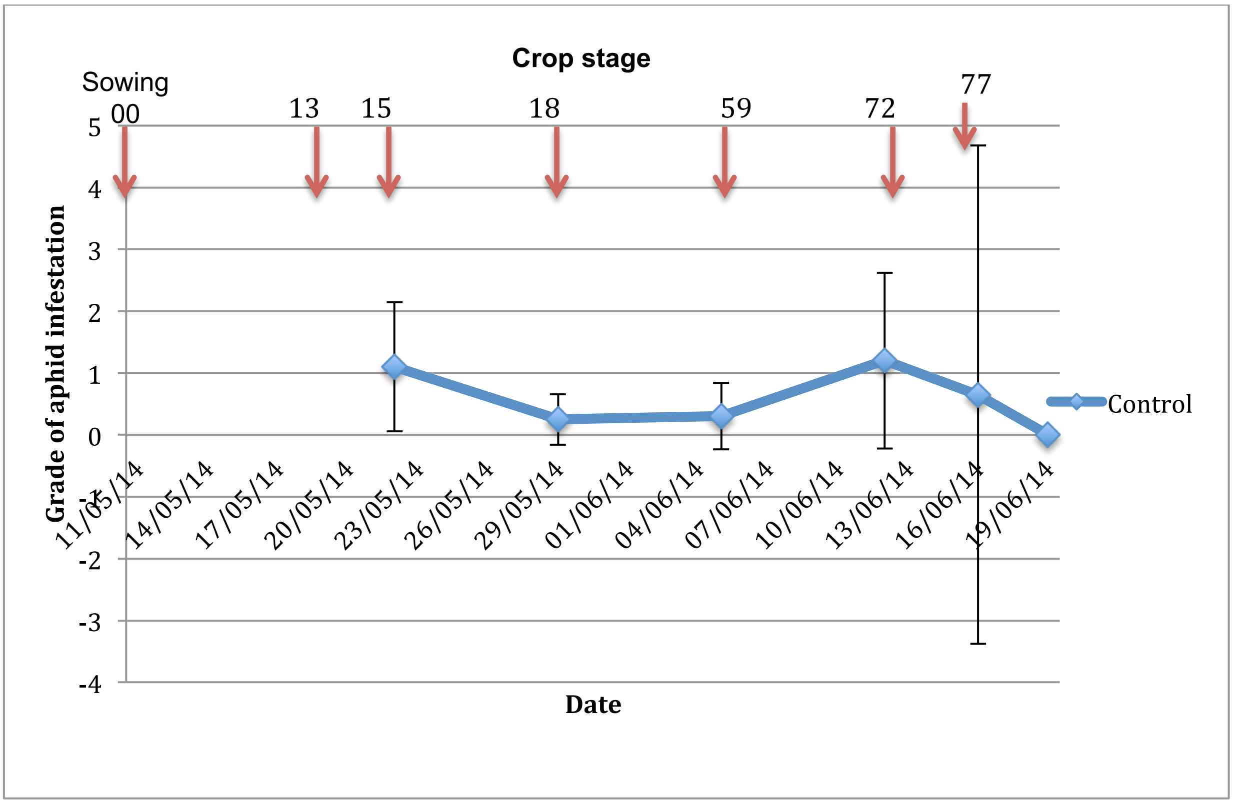

Figure 8 – Grade of infestation through time of apterous aphids in a non-treated cowpea plot, in relation with crop stage according to BBCH scale

C.II.2. Factors influencing aphid infestation

C.II.2.a. Local environment

This section concerns the experiment called iii in Materials and methods.

The environment surrounding two locations containing cowpea in the same organopónico was registered. Around location A, there were plantain, cucumber, grass, guava, pine tree but above all, neem tree, which is a repelling insect. Around location B, cucumber, onion, maize, coconut tree, marigold and salad were grown. Marigold is known to attract aphids natural enemies but very few of them were present. Maize was used as a vegetal barrier but few plants were present and they were very small.

Visually, there was a difference in aphid numbers between the two locations. Location B was containing much more aphids than location A. Aphid infestation grade was evaluated. Mean grade for location A was 1.175 and was 2.81 for location B. This difference was confirmed statistically, aphid infestation grade differs at the two locations at the 5% level (p-value = 0.01137) and was statistically greater at location B than at location A (p-value = 0.9943).

Cycloneda sanguinea was present at the two locations, but was visually more numerous at location B, on the plants that contain most aphids.

C.II.2.b. Fertilization

The three sub-plots, which were fertilized with organic matter, synthetic fertilizer or without fertilization visually do not differ in terms of aphid number in the cowpea crop. Mean grade of aphid infestation was low during all the cropping season on this plot for all the different treatments, reaching a maximum of 1.2 in the case of the control treatment on June 12th (cf. figure 9). Nevertheless, this hides the fact that some plants were attacked by more than 500 aphids (on June 5th for the organic matter treatment for example). This fact can be observed thanks to the variance (cf. figure 9). On June 5th and June 16th, variance was high.

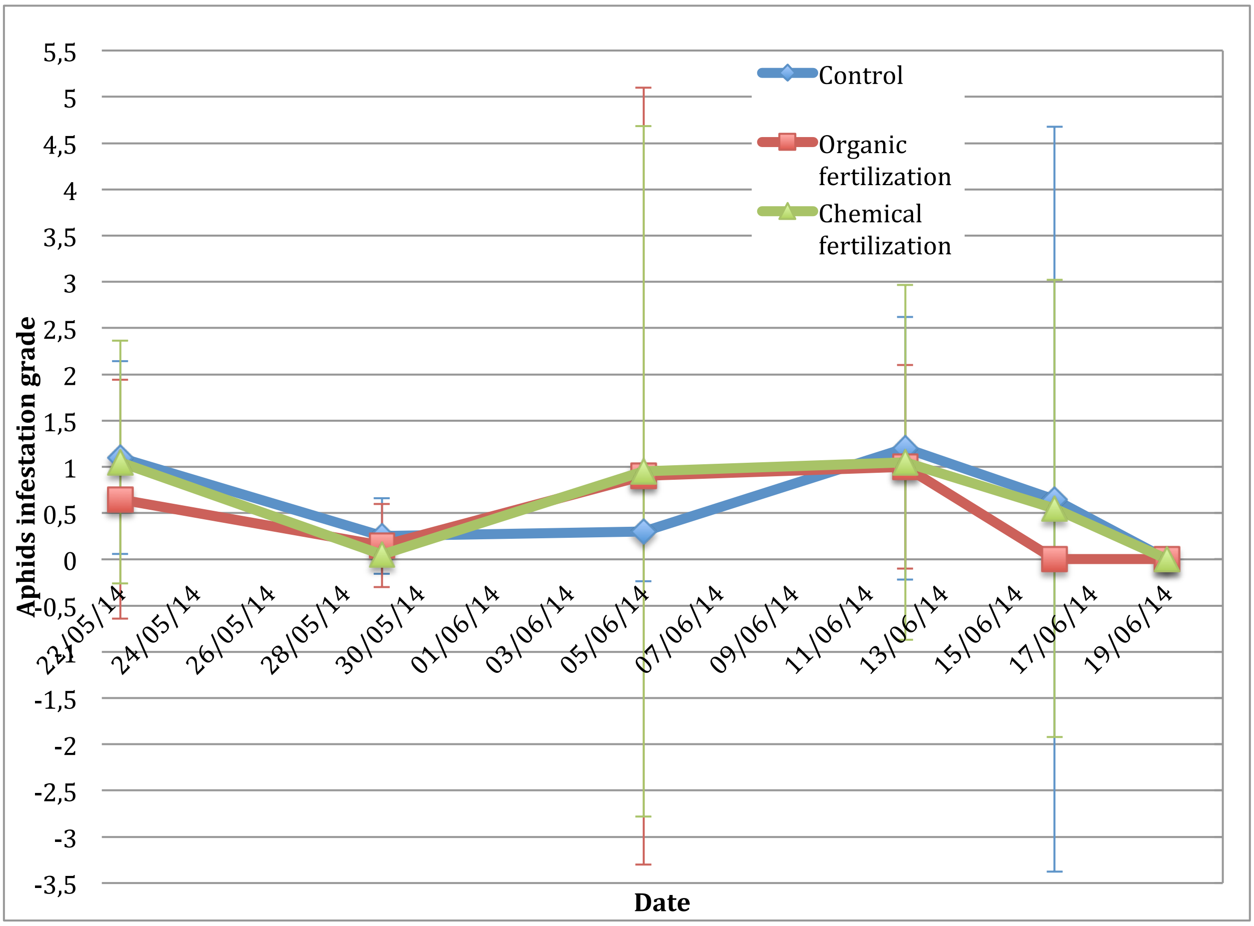

Figure 9 – Effect of fertilization on aphid infestation grade on cowpea through time

Graphically, mean grade of aphid infestation in time showed a similar trend for all the treatments. This mean grade was high on May 22nd, when plants have about three leaves, then decreased on May 29th, increased on the three following dates, during flowering and pods formation and decreased just before crop destruction, when the plants did not produce new pods anymore. There is no statistical difference between the mean grades of infestation for the tree fertilization treatments at the 5% level (mean comparison two by two, p-value = 0.6627, p-value = 0.8415 and p-value = 0.547).

On May 29th, there was a general decrease of aphid infestation, combined with a little variance. The reason for this should be looked for (see other paragraphs). On June 5th, more aphids were found on both fertilized plot, be that organically or chemically.

C.II.2.c. Weather: temperature and precipitation

Temperature was almost stable during the experiment (cf. figure 10). One can observe a slight increase of temperature through time. Minimum was 20.7°C (on March 11th) and maximum 27.6°C (on June 15th). Mean temperature between the 21st of Febuary, date of the beginning of the first experiment and the 4th of July (about the end of the last experiment) was 24.6°C. This temperature is above cowpea optimum temperature for development, as found by Huerres Pérez and Caraballo Llosas (1996) and Ehlers and Hall (1997). Nevertheless, maximum temperature is under 30°C, the maximum temperature development for cowpea but also for aphids.

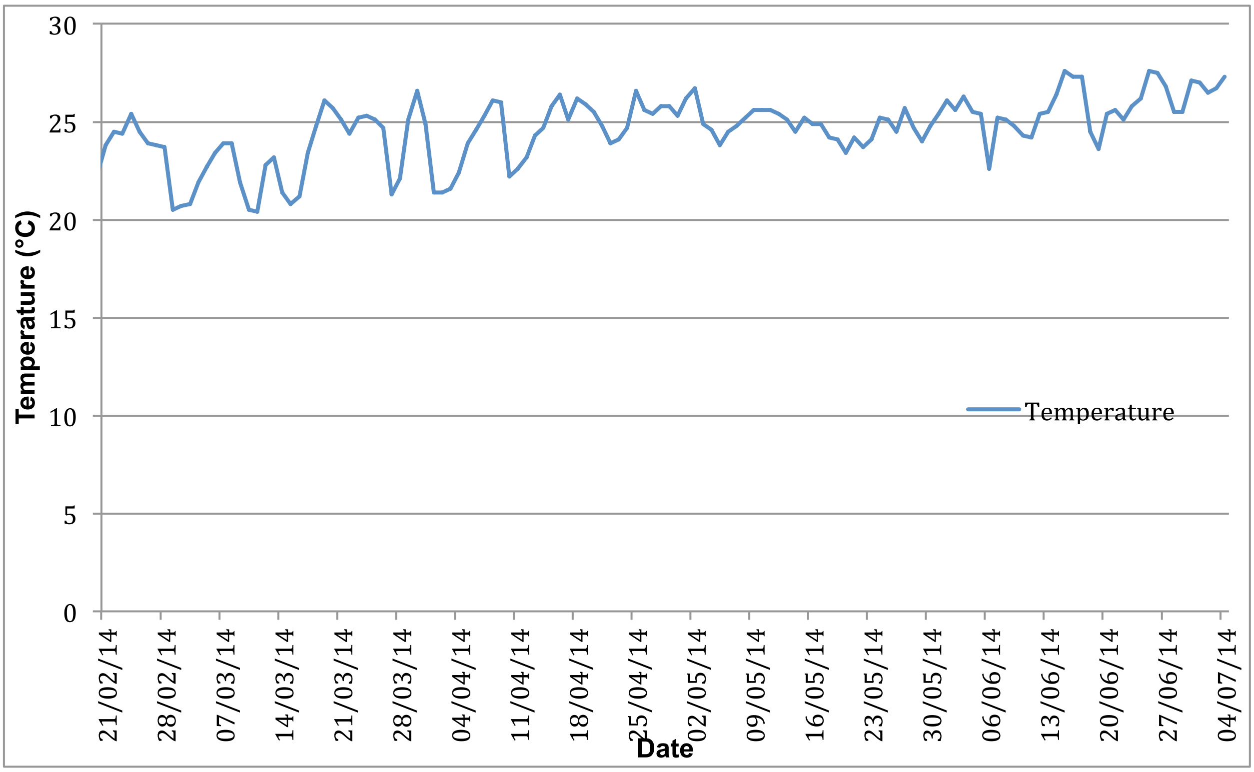

Figure 10 – Temperature each day during the study in Santa Clara, Cuba

Rainfall was not constant through all the studied period (cf. figure 11). Until the end of April, the period was dry, with only 136.8 mm of rainfall (until April 29th), then went the rainy season, with 492.8 mm from April 29th to June 13th and then again a period with less rainfall: 54.4 mm from June 14th to July 9th. Cowpea in the organopónico 2 was cropped during a dry period (cf. figure 11) and ended during the rainy period. This corresponds to cowpea moisture requirements as described in the introduction (see A.IV.1.). In the agroecological farm, the crop started during the rainy period and ended when heavy rain ended. In the organopónico 2 (where the control treatment was realized), the crop was grown during the rainy season, while it was found in the literature that cowpea is sensible to high soil moisture content (see A.IV.1.).

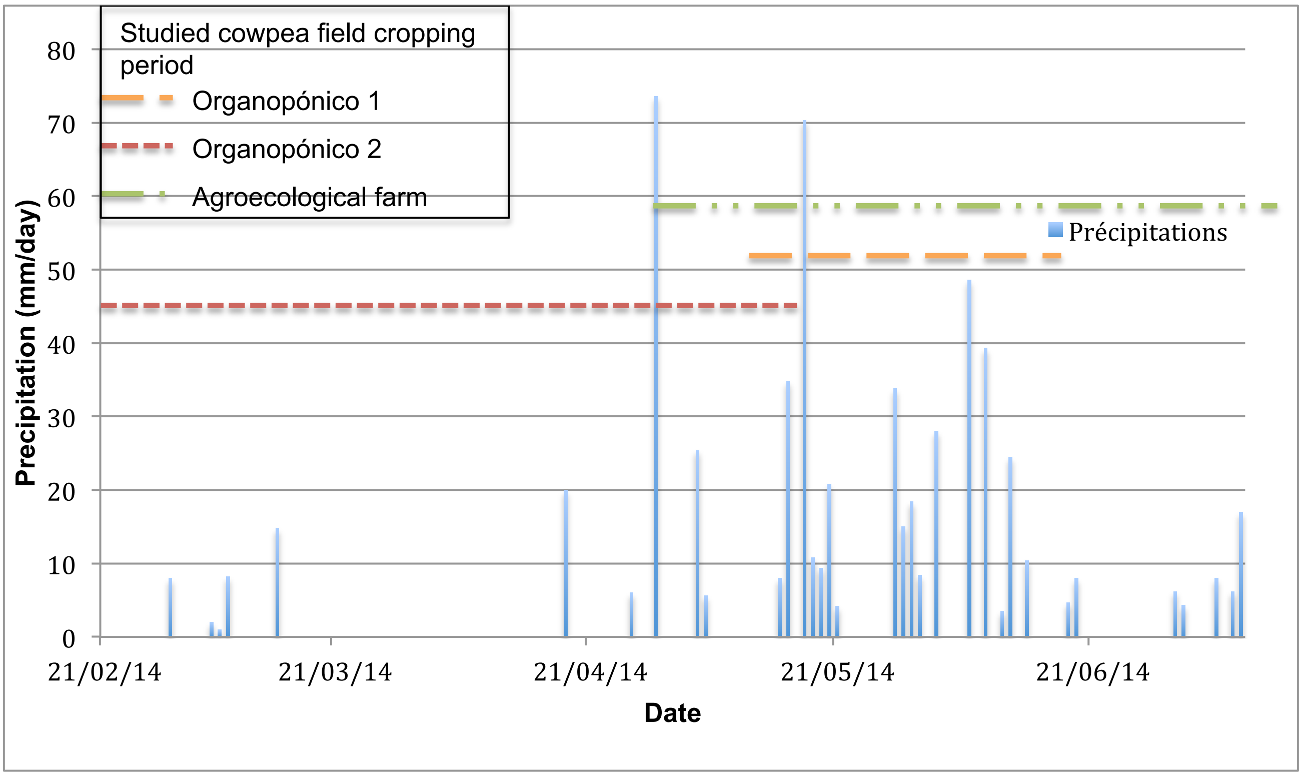

Figure 11 – Precipitation per day during the study in Santa Clara, Cuba and cowpea cropping period of the three studied farms

If we try to link fluctuation of aphid population through time in the control treatment (cf. figure 12) and on the agroecological farm (cf. figure 13) with the precipitation, one can see that on May 23rd and 24th, there are more aphids than on the other days. Moreover, on May 24th in the agroecological farm, variance of aphid number was high, which means that some plants had a high number of aphids. Few days before this observation, there was a rainy period, with 115.5 mm in five days. This period also corresponds to the beginning of the crop, when new tissues are formed and when aphids are supposed to attack easier.

On the 12th and 13th of June, on both farms, a resurgence of aphids was observed on both farms, although it was slight in the agroecological farm. Moreover, on June 17th in the organopónico 1, variance was high. This observation was preceded by several rainy days (115.9 mm in 6 days). This period corresponds to pods formation in the organopónico 1 and to the beginning of flowering period in the agroecological farm.

Nevertheless, from May 28th to June 2nd, there was another rainy period and this was not linked to a higher number of aphids on both farms. In the cowpea crop of the organopónico 1 (the regular crop, not the control treatment), a peak of aphid number was observed on June 5th, just after this rainy period (cf. figure 17 in the section C.II.3.d. below).

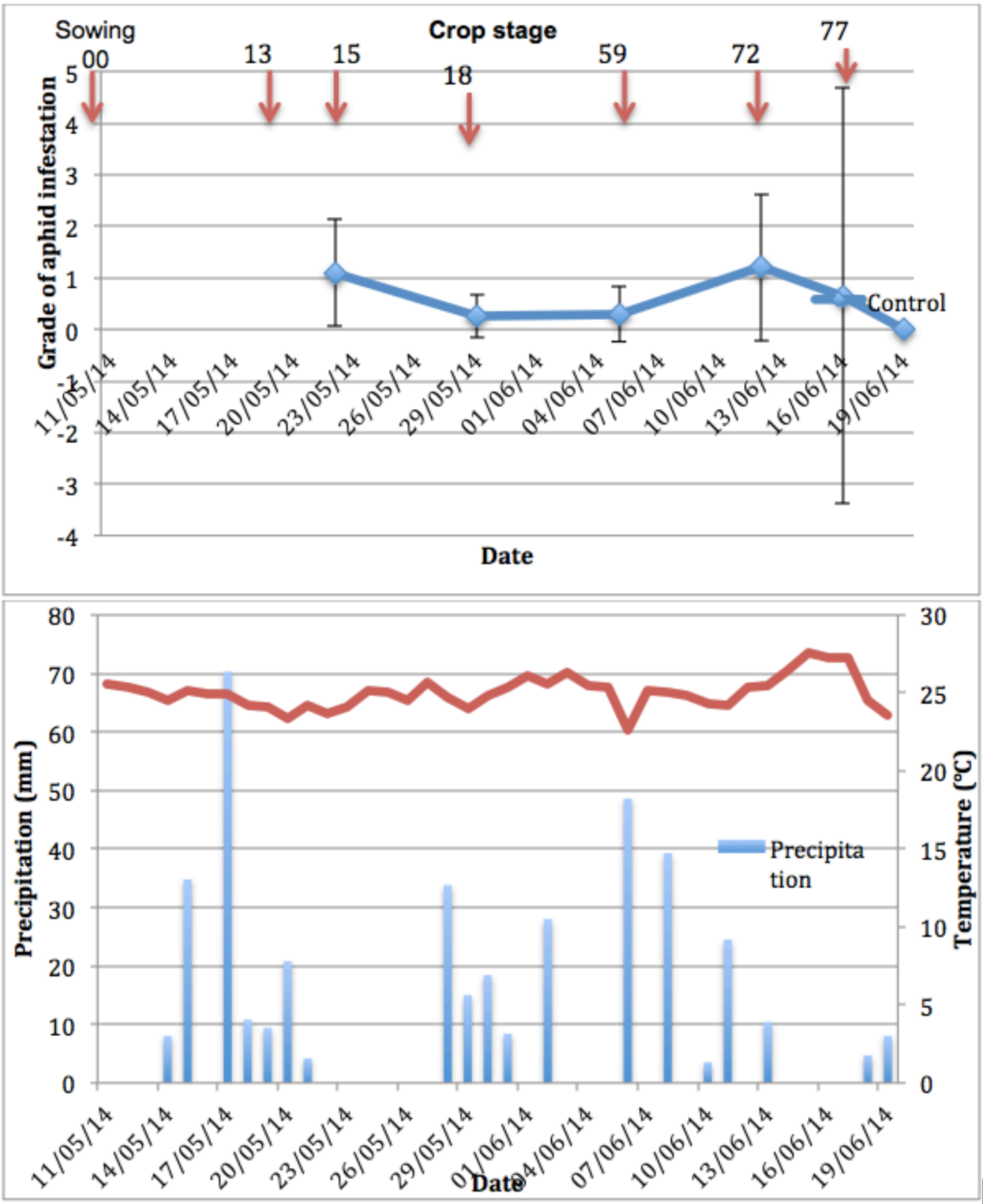

Figure 12 – Aphid population fluctuation, cowpea crop stage in the organopónico 1, precipitations and temperature in Santa Clara

From June 20th to June 30th, there is a non-rainy period. This observation is not accompanied by an increase in aphid number, although crop stage is the same than in the organopónico 1 on June 12th (peak of aphid number), that is to say, about 60 to 70% of pods formed. This can be explained by the difference of biodiversity in both farms, as will be explained after.

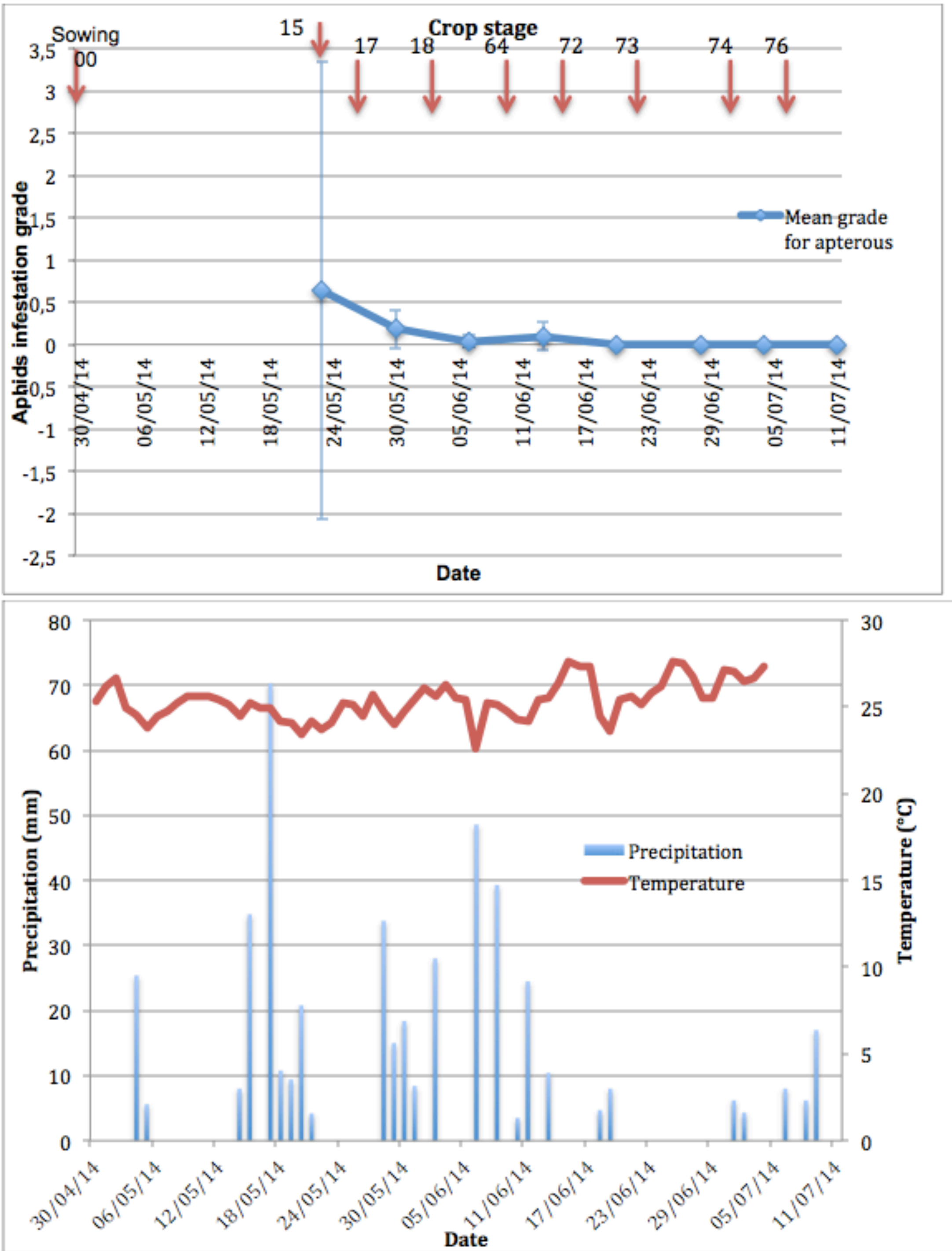

Figure 13 – Aphid population fluctuation, cowpea crop stage in the agroecological farm and rainy periods in Santa Clara

After a heavy rain like May rains, counting dates occurring just after the rain, it was visually observed that the water somehow mechanically washed aphids away.

C.II.2.d. Other possible factor: the presence of weeds

Another possible factor that could not be evaluated because it is a personal field observation is the presence of weeds. It seemed that the presence of weeds in high amounts do not allow aphids to find the plant in between the weeds. Indeed, in the organopónico 1, at the end of the crop, when weeds started to attack the plants, on the 9th and the 16th of June, plants that had aphids were those without weeds around. Indeed, the field was partially weeded. On the last date, the 19th of June, the entire field was invaded by weeds and there were no more aphids (cf. figure 14).

Figure 14 – Cowpea field full of weeds in the organopónico 1 on the 16th of June

C.II.3. Farm and crop management

In this section, three farms will be compared in terms of biodiversity, presence of repelling aphid plants or aphid host plants, crop management and yield. This will be related to aphid population fluctuation in time in a cowpea field on each farm.

C.II.3.a. Biodiversity characterization

According to the result of Vázquez and Matienzo Brito (2010) biological diversity characterization, biodiversity grade differed in the three studied farms (cf. figure 15).

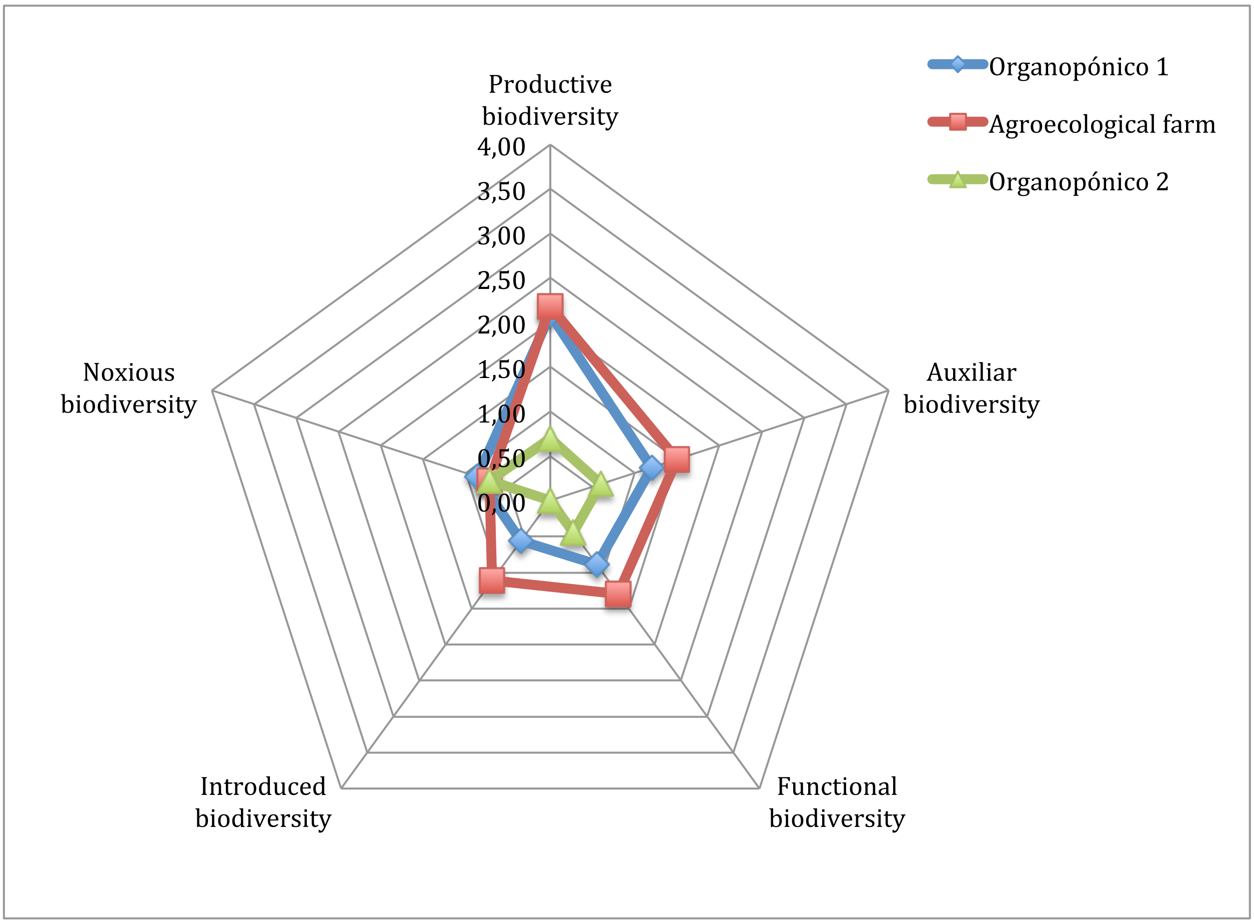

Figure 15 – Comparison of biodiversity components on the three studied farms

Biodiversity in the organopónico 2 was very low. Introduced biodiversity grade was even zero. This farmer was relying more on the use of chemical products than on biodiversity because of personal believes and interest. Mean biodiversity grade for this farm was 0.49 (maximum on the scale is 4).

Biodiversity in the organopónico 1 was higher with a mean biodiversity grade of 1.12. Productive biodiversity was especially high, reaching a maximum grade of 2.09 for this farm. This result was mainly due to the fact that this farm is cultivating 12 different crops, selecting varieties for phytosanitary reasons and cropping them several times per year. Auxiliar biodiversity grade was the second most important component of biodiversity on this farm, reaching 1.20. This was due to the use of repelling plants on the totality of the crops and the number of different repelling plants used (4).

Biodiversity on the agroecological farm was higher than on the two other farms. Mean biodiversity grade was 1.36. The component that reached the highest grade was the productive biodiversity, with 2.18. This was due to the high number of crops grown on the farm (14), to the use of special varieties for phytosanitary reasons and the use of living barriers on all the crops. Auxiliar biodiversity was the second most important component.

Nevertheless, mean grade and grade of every components are similar for the agroecological farm and the organopónico 1. Management on those two farms is different but the result of biodiversity characterization was similar. Those two farms were subject to different cropping conditions and regulations. Indeed, on organopónicos, farmers are forced to use vegetal barriers and repelling plants. Moreover, they have to produce a certain amount of crops per year, which forces them to crop a variety of plants, but mainly crops with a short cropping cycle and to rotate crops on seedbeds. This results in a relatively high biodiversity grade.

Noxious biodiversity grade is similar on the three farms: 0.86 on the organopónico 1, 0.71 on the organopónico 2 and 0.71 on the agroecological farm.

C.II.3.b. Local environment

Concerning the presence of aphid host plants, it was not possible to check the presence of all aphid host plants of the list presented in appendix IV and V. Only cultivated host plants were looked for.

On the organopónico 1, cowpea was the only aphid host plant culture present (from the list presented in appendix IV). Nevertheless, the crop was located next to a mango field, which is an aphid host plant. Moreover, some field fences were made out of living 'bienvestido' tree, wich is known to be an aphid host plant. Several neem trees (repelling insects) were present on the farm and in the farm edges. Marigold (*Tagete erecta* L.) is a plant attracting aphid natural enemies (cf. appendix VI) and is grown on this farm.

On the organopónico 2, cowpea was the only cultivated crop hosting aphids. There were no repelling plants used on this farm, neem tree were not present but there were several 'bienvestido' trees in the farm edges.

On the agroecological farm, crops hosting aphids were grown: common bean, peanut and mango. There were no neem trees present on the farm. Some 'bienvestido' trees were present. There were apparently no aphids repelling plants.

Those three farms did not seem to show many differences in the presence of aphid attracting or repelling plants.

C.II.3.c. Crop management and yield

Table 1 – Comparison of cropping cycle and yield of cowpea in the three studied farms

	Organopónico 1	Organopónico 2	Agroecological farm
Duration of cropping cycle (in days)	40	84	93
Number of days between sowing and first harvest	31	63	53
Duration of harvesting period (in days)	9	21	40
Yield (in t/ha)	4.8	7.5	8.3

As can be seen in the table 1, the organopónico 1 was the farm where the shortest crop cycle, the shortest period between sowing and harvest, the shortest harvesting time and the lowest yield were observed. For the organopónico 2, those results were intermediate and for the agroecological farm, those results were the highest, except for the time between sowing and harvesting. It is notable that the highest yield was reached in the agroecological farm, with 8.3t/ha.

In Cuba, cowpea pods are sold fresh (cf. figure 16) and should then be sold quickly. In the agroecological farm, bunches of cowpea pods were sold directly to the consumers at 3 pesos (about 0.09 €) per bunch. They therefore won 852 pesos for the whole harvest, equivalent to 4.98 pesos/m^2. In the organopónicos 1 and 2, they sold their harvest to schools and kindergarten because they have to: it is a State farm, where militaries work. They sold cowpea pods at 3 pesos per bunch, wining a total of 1 740 pesos for the organopónico 1 and 2 700 pesos for the organopónico 2, equivalent to 2.9 pesos/m^2 and 4.5 pesos/m^2 respectively.

Figure 16 – Cowpea (*Vigna unguiculata*) as it is harvested in Cuba

(source : http://www.mybestcv2.co.il/TextPage_EN.aspx?ID=11563520)

C.II.3.d. Aphid population fluctuation through time in three different farms

In the organopónico 1, aphids were present from the beginning of the culture (cf. figure 17). Mean grade was low on this date (0.7 for apterous aphids and 0.2 for alate aphids), but variability of apterous aphid number on plants was high. Then mean aphid number was almost stable, around 0.5, until the 16th of June when no aphid was found. This date corresponds to the period of harvest. Alate aphids were found only on the first date.

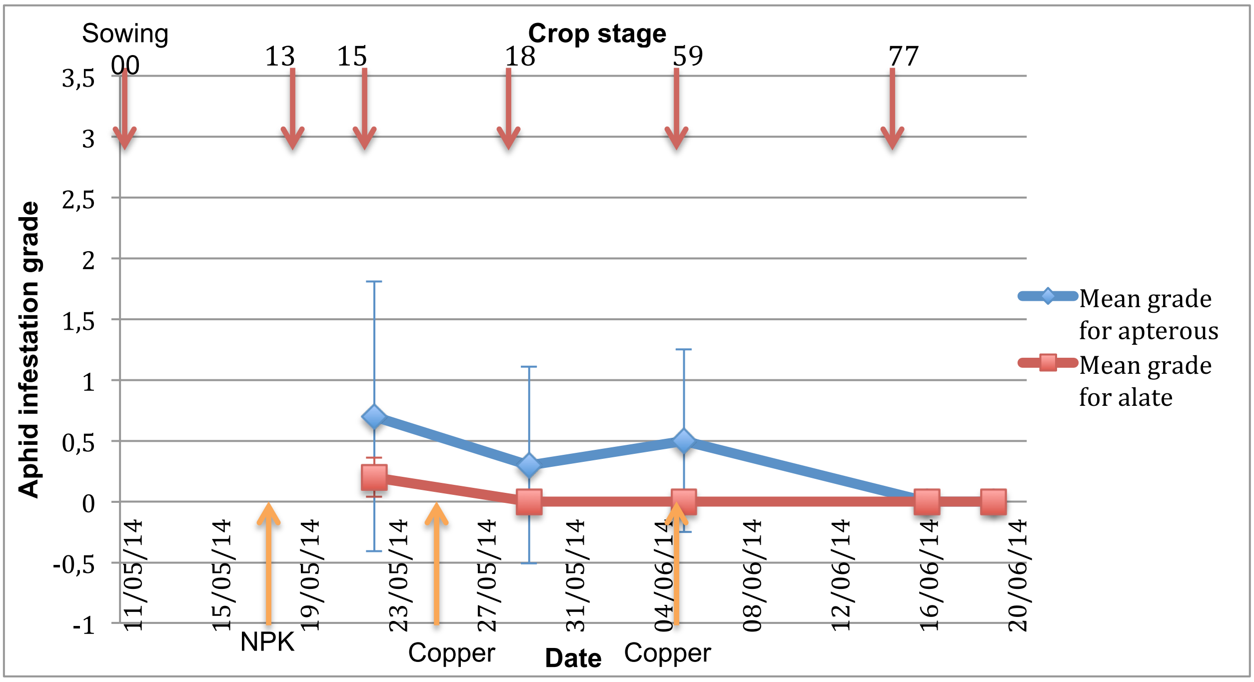

Figure 17 - Mean grade of aphid infestation through time for apterous and alate aphids on cowpea crop in the organopónico 1

Main pests present during the crop were aphids (*Aphis craccivora* Koch), leafhoppers (*Empoasca kraemeri* Ross and Moore) and ants (*Atta insularis* Fabricius). It was observed that ants were present even in the absence of aphids. In that case, they were present on flower buds and it seemed that they were feeding on plant sap there (cf. figure 18). Rust (*Uromyces phaseoli* Reben) starts appearing on May 25th. From June 5th, plants were almost left to abandon and started to be invaded by weeds (cf. figure 19), some plants stayed very small with few leaves.

Figure 18 (left) – Ant on cowpea flower bud

Figure 19 (right) – Weeds in the cowpea field on May 16th in the organopónico 1

In the organopónico 2, aphids were not present at the beginning and start appearing on the 20th of March, for alate aphids (cf. figure 20).

On the three following dates, apterous aphids were present. The maximum number of aphids was reached on April 3rd. On this date, the variance was high. Alate aphids were also present on this date. On this day, aphids were in a vegetative period; flowering started later, on 14th of April. After 14th of April, during the flowering, pods formation and harvesting period, no more aphids were observed.

Mean aphid infestation grade was low during the whole cropping period. Main pests during the crop were leafhoppers (*Empoasca kraemeri*), ants (*Atta insularis*) and aphids (*Aphis craccivora*). On the 8th of May, plants were almost not producing cowpea pods and a lot of weeds were present in the crop.

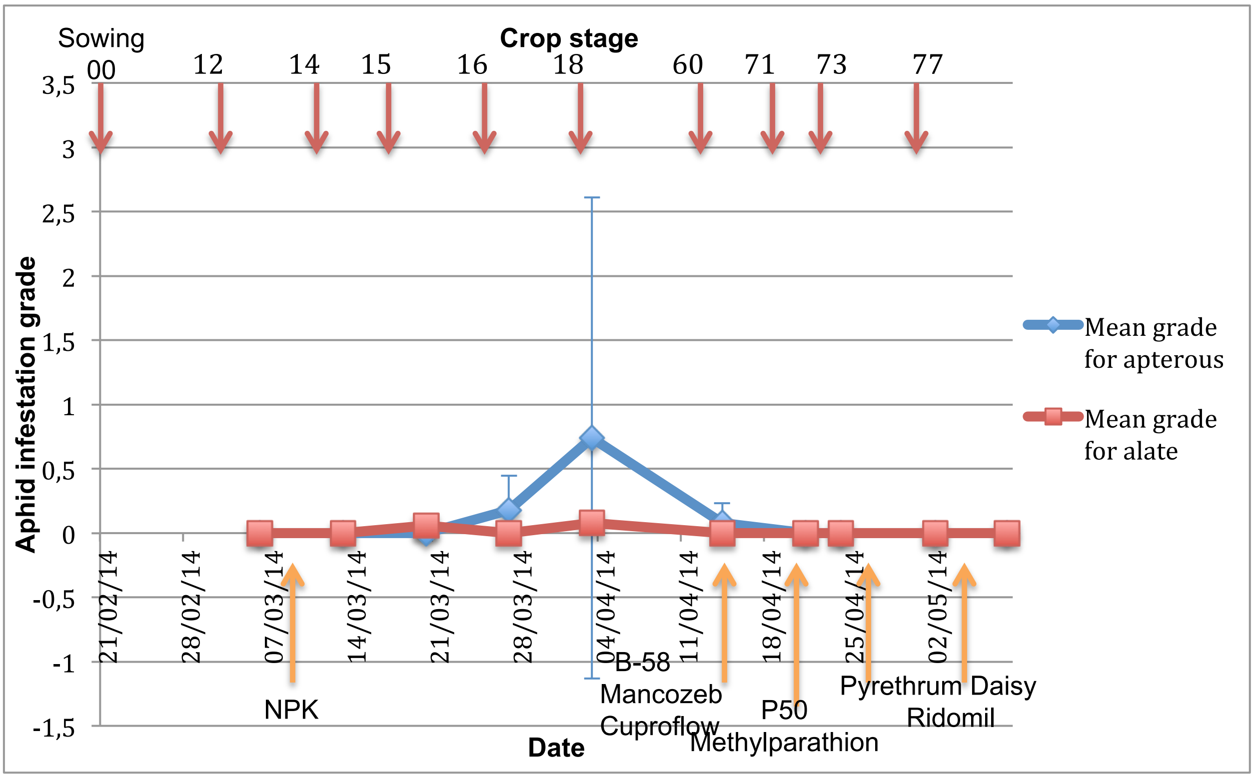

Figure 20 - Mean grade of aphid infestation through time for apterous and alate aphids on cowpea crop in the organopónico 2

In the agroecological farm, aphids were present from the beginning of the study (cf. figure 21). On the 23rd of May, aphid infestation grade reaches its maximum with 0.64 for apterous aphids and 0.12 for alate aphids. On this date, some plants were hosting a lot of aphids while others did not host any, as indicated by the high variance. Alate aphids were also present on the next date but not later. During the whole cropping cycle, there were few aphids present in the crop. They were present only at the beginning, up to 13th of June. The main pest present during the crop was ant (*Attas insularis*). Like in the organopónico 1, ants were observed including in the absence of aphids and were probably feeding on sap that they found on flower buds. A diversity of other insects was punctually present in the crop, like leafhoppers (*Empoasca kraemeri*), coffee leaf miner (*Perileucoptera coffeella* Guérin-Mèneville) and different spiders.

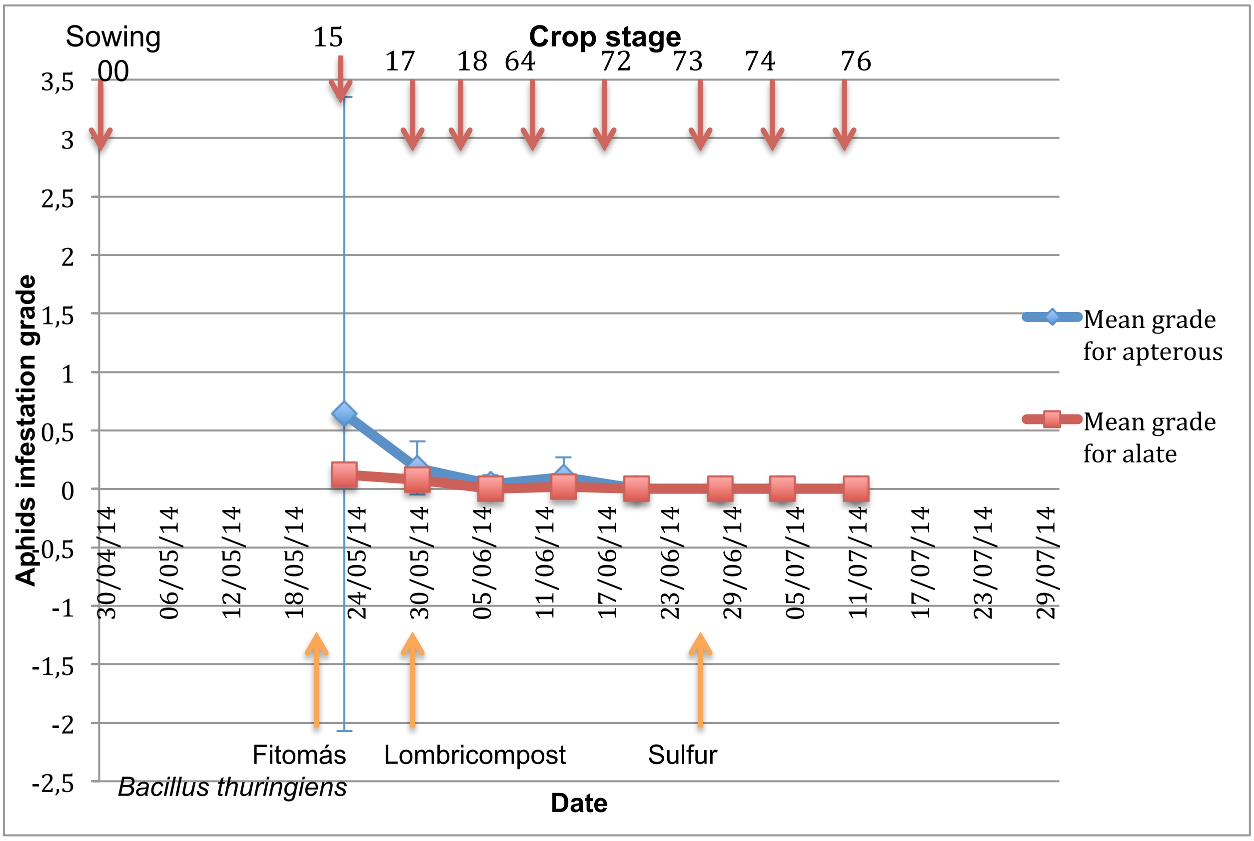

Figure 21 – Mean grade of aphid infestation through time for apterous and alate aphids on cowpea crop in the agroecological farm

If the three farms are compared, in the organopónico 1, aphids where present during the majority of the crop cycle, while in the organopónico 2 and the agroecological farm, they were present only during a part of the cropping cycle, respectively the vegetative and flowering period and the vegetative period. The aphid enemy *Cycloneda sanguinea* was observed on plants in the organopónico 1 and in the agroecological farm only when aphids were numerous on plants. Few *Coleogemilla cubensis* were observed on the agroecological farm.

D. DISCUSSION

The results can have been biased by the unwillingness of some farmers to participate and/or by fear of telling the truth. For example, pesticides are forbidden to use in urban farming in Cuba. Farmers can sometimes hide their practices because of the risk. Moreover, some farmers can be tempted to glorify their work or to orient their responses in order to satisfy their audience.

Hereafter will be discussed the results of the experiences, following the same structure of the results section.

D.I. Agroecological management of cowpea in Cuba

Farms growing cowpea were all found very close to the city center. This can be explained by the necessity to sell it fresh to the population. But, in the literature, it was found that cowpea is grown in cooperative farms (Huerres Pérez and Caraballo Llosas, 1996), which are in general outside the cities. It is possible that farms outside city borders were growing cowpea but were not interviewed because of the method to select farms.

Cowpea was found to be cropped in farms where there is high crop diversity. This comes from the fact that it aimed first at providing food to urban populations. Those urban farms are now fostering social cohesion, communication within the neighborhood, children and adults education about farming and the diversity of vegetables. Moreover, having a diversity of crops is almost an obligation to grow all the year round and maximize available space so as to produce a sufficient quantity to reach the quota. Crop rotation is important for pest and disease control.

Input substitution theory in Cuba is not completely true because they also, in the case of organopónicos, try to increase biodiversity, thanks to the use of repelling plants, living barriers and the fact that they crop a diversity of plants.

In the literature, it was found that cowpea is mainly grown in the coldest season, so as to reduce illness incidence, but it was found thanks to those interviews that cowpea is grown throughout the year and more preferably from April to September, while the coldest season is from November to February-March. They will probably continue to do it because of the adaptability of cowpea to heat, which makes it one of the few vegetables growing during the hotter days.

Some farmers were found to be using crop associations but only for space reasons. A crop should also be selected for its sanitary effect, be that to attract natural enemies or repel pests. Moreover, attention should focus on whether those associations have a negative effect on crops involved. One of the crop associated with cowpea in several farms was okra. In a study where cowpea and okra were intercropped, land equivalent ratio was significantly different from one and was up to 2.69 (John and Mini, 2005). Besides the fact that aggressivity was favorable to cowpea, meaning that cowpea was dominant on okra, the best yield and net return (for okra crop) amongst several associations was found to be okra-cowpea (John and Mini, 2005). This choice of crop association might therefore be an interesting one. Reasons explaining this positive intercropping would be interesting to investigate.

Although aphids were considered as being the most important pest, they were not the only insect attacking cowpea crop. Therefore, future intents of agroecological pest management in cowpea should consider several insects and not only cowpea.

Farmers seem to favor the use of bioproducts and in some cases chemical pesticides to manage their crops. They are sometimes not really convinced by the methods that they are told to use. Education should be provided to farmers so as to show them the utility of those techniques. This should be done in practice, with workshops on one thematic on a farm that performs well in that sense. For example, farmers complained about seed prices. One farmer of the organopónico interviewed was producing all of his seeds (except radish). He is knowledgeable and could explain it to other farmers so as to reduce their inputs and increase profitability of their crop.

In the literature, it was found that to fight cowpea aphids, farmers in Cuba are translating natural enemies from nearby host plant used as reservoir to the cowpea crop and that *Lysiphlebus testaceipes*, *Cycloneda sanguinea* and other coccinellid species are used (Vázquez Moreno *et al.*, 2007). Such practices were not observed. It was also found that rice husk are used as mulch and are effective to repel aphids (Cuadra Molina, n.s.). This practice was neither observed. The reason for this might be that those practices are used in urban farms in La Havana, where they might receive better advices. Weed presence was a constraint in the organopónicos where experiments were realized. Much would therefore be an interesting alternative to fight weed pressure.

A lot of farms had very similar practices. This comes from the fact that there is one main company giving advices to farmers. Farmers are really dependent upon this company, are forced to use their practices. This is a good opportunity for rapidly changing practices. But, some farmers were found to be skeptical to practices advised by this company. This can comes from the fact that mandatory measures are not well understood. Farmer’s knowledge should be enhanced.

The three farms that had a higher crop diversity, that used uncommon or innovative practices and that choose resistant varieties were the ones that had knowledge and/or had external support. This calls for the creation of a network of exchanges between farmers because all farmers cannot have a privileged relationship with the local university for example. The case of those three farmers also shows that organopónicos can obtain better results when they are willing to. Some farmers need a force to push them. Creating a network of farmers exchanging on practices during organized workshops could be a good opportunity to give the willingness to farmers to improve their system. It would allow them to exchange experience, knowledge and ideas with peers, while complementing it with practice. For example, they could focus at a first place on the use of vegetal barriers and repelling plants. Cuba has an experience in this kind of farmer field schools. Indeed, the social movement *Campesino-a-Campesino*, organized by the association of small farmers (ANAP), is a network in which farmers exchange practices. It has allowed spraying agroecology in the island while increasing production (Rosset *et al.*, 2011). This network is not available to urban farmers that are pertaining to the horticulture company and not to the ANAP, but they could mimic their actions and benefit from their experience in this regard.

Moreover, farmers could be mobilized to realize future research on cowpea so as to implicate them and prove them the efficiency of used methods, in particular the use of repelling plants or living barriers. This research could be done directly with a group of farmers, who would identify topics to work on, set up the experiment by their own and evaluate the results in groups. It would bring farmers and researchers closer, while allowing to find new cropping techniques, enhancing farmers' knowledge and comprehension and therefore the efficiency of promoted methods.

Finally, a socio-economical study of the relationship between farms structure and workers assiduity to work should be realized in Cuban farms. If the statement of the farmer saying that workers are working better when they are sharing the fruit of their work, farm managers should find a way to give economic interest to the worker or creating cooperative in urban farming should be promoted.

D.II. Study of aphid population

D.II.1. Population fluctuation through time

Alate aphids were present only at the beginning of the culture and one can suppose that they were at the origin of the infestation in the field, as described in the literature (Gómez Sousa, 2007). Alate aphids were present in very low number. So, this type of aphids might allow establishing the further aphid population in the field.

A peak of infestation was reached during the first stage of the experiment, when the plant produces rapidly new leaves. In this case, aphids could be attracted because of the presence of young fresh leaves, which tissues are easy to penetrate so as to suck plants salvia. The second peak of infestation was during the pods producing period, when there where some flowers. At this date, aphids were observed on plants where there were flowers, new leaves and the future pods. In this case as well, new tissues attracted aphids, probably because of the easiness to pierce them. The richness in nutrients of new tissues could also be a reason for this attraction. This observation is in accordance with the results of Hanish (1980 - in Hasken and Poehling, 1995) and Hansen (1986 - in Hasken and Poehling, 1995). Nevertheless, this control treatment was not fertilized so this supposition is questionable.

The observations should have started earlier, because aphids were present since the first observation. It was not possible to start earlier: a first experiment was realized but failed because of low seed quality and low attention to the crop by the farmer (fertilization, weeding, irrigation), resulting in low seedling emergence. Another field was looked for and found when the crop was already advanced.

The spray of copper at two repetitions could bias the results of this experiment: 2kg/ha of copper were sprayed on the plants on May 25th and on June 5th. This application should not have been done on the control treatment. But there is a doubt since leaves with a blue powder trace were found on the following observation dates (cf. figure 22). The workers do not pay a lot of attention to their work in general because they are not interested in and will receive the same very low salary (about 8 € a month), since they are State employees, forced to be there because of their civic service. This could be the reason for copper application although there should not be. Another possible explanation could be the fear of the farm manager to see his field full of aphids like his preceding crop, resulting in two applications of copper besides my specific request to don’t do it on the experimental part.

Figure 22 – A blue trace on cowpea leave of the control treatment

Moreover, at the end of the experiment, the field was full of weeds (cf. figure 14 in C.II.3.d.), cowpea plants were even difficult to distinguish. This could have influence the crop duration, since weeds compete with the plants for nutrients, water and light, but also on aphid infestation, as explained in the point C.II.3.d. of the results section.

If all the graphics of aphid population fluctuation in time are considered, it can be observed that every peak of aphid number was short in time. This result is in line with the information found in the literature: aphids have a short living cycle. Annan *et al.* (1995) found that time-based action threshold for aphids on cowpea was three to seven days for economic yields. In this experience, peaks of aphid number lasted about seven days or less. Aphids damage on yield is therefore questionable. But aphids were present during the whole cropping period for the control treatment. In that case, yield was probably affected by the presence of aphids.

There were no aphid at the end of the crop. An explanation for this could be the presence of weeds, impeding aphids to find its host (except in the case of the agroecological farm, where the crop was clean during the whole cropping season). Another explanation could be that the plant is not attractive anymore because tissues are older and therefore harder to pierce for aphids. A different odor secreted by fresh or old tissue could be involved in the attraction of aphids or not.

In all the experiments (except the experiment comparing aphids in two different environments, C.II.3.a.), mean aphid number was low during the whole experiment. But some isolated plants presented a high number of aphids (more than 500, cf. figure 23). There were sometimes several highly infested plants; while the majority of the plants did not have any aphid. Those aphids never sprayed to the whole field. Moreover, illnesses that could be transmitted by aphids were not observed on plants. Therefore, the importance of aphids for cowpea crop can be questioned. Is it really an important pest in Cuba? Farmers might think that aphid is an important pest when they see a plant like the one of the figure 23 below and might be afraid by such plants.

Figure 23 – A cowpea plant carrying numerous aphids

Finally, aphid-counting dates were maybe not enough numerous to see a real evolution, since aphid development is quick. Two counting per week might have been necessary.

D.II.2. Factors affecting aphid infestation

D.II.2.a. Local environment

This experiment underlines the importance of the environment surrounding a cowpea field. The presence of neem tree potentially acts as an effective aphid repellent and could be implemented in other farms. The presence of few maize plants as living barrier and marigold to attract natural enemies was in that case not sufficient as the only fighting method against aphids. Nevertheless, this experiment was done only one time and it is not enough to confirm the results. It should be repeated several times, and in different environments.

D.II.2.b. Fertilization

Contrary to what was found in the literature (Hanish, 1980, Hansen 1986 in Hasken and Poehling, 1995, Altieri *et al*. 1999 in Altieri and Nicholls, 2005), it seems here that fertilization regime had no effect on the number of aphids on plants.

Several factors could have influenced this lack of difference. First, the control treatment cannot be considered as a non-fertilized plot because raised-beds contain organic matter: soil is made out of compost, manure and sugar cane processing residue. Then, copper applications were probably done on all the plants, as explained in the paragraph D.II.1. of this section. This could have influence aphid presence on the plots, thus hiding possible effects of fertilization on the number of aphids. This hypothesis can be supported by the fact that on May 29th, four days after an application, aphid population was greatly reduced. In an experiment, Bonde and Snyder (1946) found that copper spray could increase or decrease aphid number on potatoes, depending on the type of copper used. So, this hypothesis is possible. Moreover, the presence of weeds (as described in the paragraph D.II.1. of this section) could have an effect on aphid population. Weeds were present indifferently in all fertilization regime plots. Another explanation could be the little distance between the plots (about a meter, sometimes full of weeds), so aphids could go from one plot to another. Finally, there is a doubt that compost was applied to the plots that should have received organic mater. Anyway, the application of organic fertilization was delayed compared to the chemical one (June 2nd compared to May 17th), so plants could not benefit from fertilization the same way.

D.II.2.c. Weather

Temperature during the study was more appropriated for the development of aphids than for the growth of cowpea. Nevertheless, huge amounts of aphids were not observed as could have been expected.

With the weather data, it was shown that aphid number was higher few days after several rainy days. But the rain was not the only possible explanation of such aphid fluctuation. Crop growth stage could also be a reason. The combination of good weather conditions and appropriate growth stage for aphid is the most probable explanation.

The reason why aphids were more numerous few days after the rain can be discussed. During the rain, aphids could be washed away by the rain and come back just after. Jones (1979) found that after heavy rains aphids were washed away to the ground. This experiment was done with cereal aphids but the effect of rain could be the same on *Aphis craccivora.* Walker *et al.* (1984) found another explanation: the combination of rainfall and wind caused potato aphid (*Macrosiphum euphorbiae* Thomas) death.

Conditions could also be appropriate for aphids just after a rain: plant tissues could be softer and thus easier to pierce for aphids. Rains are sometimes combined with wind in Cuba. Therefore, the wind could carry aphids that establish themselves into the crop after the rain. It would have been interesting to record wind during the study.

Nevertheless, the results of this section can be nuanced because the meteorological station was not situated very close to the two farms. It was even 23km far from the agroecological farm. Sometimes, storm and rainfall are local and it could have rain at the experimental station and not on the farm or conversely. Moreover, temperature were found to be not overpassing 30°C (maximum for cowpea development) but mean temperature per day can hide temperature peak higher than 30°C during the day.

D.II.2.d. Other possible factors

The presence of weeds seemed to impede the presence of aphids. This is in line with the observation of an interviewed farmer: during the rainy season, he did not have the time to weed, so cowpea crop was full of weeds. During this period, there are almost no aphids.

Weed presence observation was not a scientific experience. It might be interesting to carry out an experience. But in practice letting weeds grow so as to fight aphids is not conceivable. It could be a basis for crop protection: to find a plant that could be cropped in association with cowpea and hide a little the plants or make them more difficult to access. This solution would nevertheless constrain cowpea harvest.

D.II.3. Farm and crop management

D.II.3.a. Biodiversity characterization

Biodiversity was low on the three farms, including the agroecological farm. There is not a high difference between each farm, except maybe between the organopónico 2 on one side and the organopónico 1 and the agroecological farm on the other. However, the questionnaire answers were maybe not complete since it is difficult to see all the natural enemies present in the crops of the farm for example.

The results from the biodiversity characterization form can be discussed. Indeed, for several factors, it would be difficult to obtain a high value, including for a very diverse farm. For example, to obtain more than the grade 1 to the factor “animal for labor”, a farmer should have more than three different animal species for labor. Similarly, to obtain the maximum grade (4) to the factor “soil organic mater”, soil organic mater should be superior to 75%! A lot of practices in the functional biodiversity criteria can hardly be done on a lot of crops by the farmers when his farm is diversified (translation or rearing of natural enemies, etc) because they are time consuming. Therefore, farms will hardly get a good grade to this characterization, even if they are diverse.

Nevertheless, this is a way to classify farms according to their practices. The analysis of the results from this questionnaire allows differentiating and characterizing farms. From this, we can differentiate three farmers’ strategy.

D.II.3.b. Three farms, three management systems

Hereafter will be discussed the results of the three farms comparison. Farm by farm, will be discussed the results of biodiversity, local environment, crop management and yield evaluation. There is an attempt to link those results with aphid population.

D.II.3.b.i Agroecological by default: the organopónico 1

Biodiversity in the organopónico 1 was found to be intermediate. This farm is employing some techniques like the liberation of antagonists, the use of vegetal barriers and repelling plants because they are encouraged by the local state urban gardening agency (*Empresa horticola* – Horticultural company). This organization is advising practices to farmers, renting them the land and verifying every year the use of agroecological techniques. Then a grade is given to each organopónico, according to their use of such techniques and the productivity of the farm. They have to reach a certain productivity level. This is the reason why the number of crops is high, why they crop several times a year the same crop and why they have to rotate crops. The use of chemical pesticides is prohibited in urban farming.

Therefore, the use of agroecological techniques is pushed by external forces and does not come from the own willingness of the farmer, and even less of the employees working there.

As a consequence, it was observed that the use of this technique was relatively rare and not well done. For example, repelling plants are present but in low number. Next to the studied cowpea field, the only repelling plant present was marigold and there were only two, for 20 raised-beds measuring 60 m x 1 m (cf. figure 24). Moreover, plants cropped are only short cycle plants, which could influence the presence of certain insects or weeds hosting aphids.

Figure 24 – Only two Marigold were surrounding 20 cowpea raised-beds

In this farm, aphids were present during the whole crop. They could come from the near field of mango trees or from the near *Gliciridia sepium* tree. The presence of few marigold and neem trees on the farm might have somehow limited aphid infestation. Aphid host trees might have constituted a reservoir of aphids that were not well fight by predators (although very few *Cycloneda sanguinea* were observed) and not well repelled by distant neem trees. The farmer did not make any other management against aphids.

The crop had a short cycle. This was maybe because the crop took place during the rainy season so that the crop has sufficient water to grow (compared to the crop in the organopónico 1). It could have grown quicker than in the agroecological farm because there, the fertilization was delayed. Nevertheless, the pods formation and harvest period was very short. This is evidently due to the lack of weeding.

Management in this farm is probably due to the fact that the workers are not the owners of the land and of their work, so they are not benefiting from it. They are pushed by external forces to crop that way and might not understand the benefits of it, when "modern" practices could be applied and make their work easier. The majority of workers is not very interested by their work and earns little money (as explained before), even if they work more. Working conditions are not optimal: some tools are not very appropriated and they have to work under a burning sun. The responsible of the organopónico was conscious of the need to crop in an agroecological way but most of the workers were not.

Yield was low in this farm, but conform to what Huerres Pérez and Caraballo Llosas, (1996) consider as a sufficient yield (4 to 5t/ha). This can be the result of the lack of care and pest attack: aphids but mostly ants were present during almost the whole cropping cycle. It was first thought that ants were present because of the presence of aphids, but they were there even when aphids were no present (flower buds were split up to check for aphid presence). Buckley (1987), wrote that ants do not feed on sap directly, probably because of plant chemical defense and not because sap is not suited to feed ants. There is therefore a possibility for ants to feed on sap found on future flower buds. Yield could have suffered from insufficient fertilization.

Investment for cowpea crop was probably low on this farm (except cost for workers), but this very low yield did not allow the farmer to get a lot of money from this crop. There is a doubt that this crop was profitable for the farmer.

D.II.3.b.ii Conventional agriculture: the organopónico 2

In the organopónico 2, the farmer has chosen another strategy. He was not relying on biodiversity, which was found to be very low on his farm. Introduced biodiversity was even zero. In the local environment, the tree *Gliciridia sepium* was present and can explain the arrival of cowpea in this field. Few days after the maximum aphid number found, the farmer sprayed an insecticide. This explains the decrease of aphid number. Some insecticides could have been sprayed before, without informing. During the counting that occurs one day after insecticide spray (on April 14th), aphid number was low. Local biodiversity cannot explain the low number of aphids, because repelling plants were absent. Other insecticide sprays were realized on April 20th, April 27th and May 4th. However, pest resurgence was not observed after insecticide spray, as expected with what was found in the literature (Hasken and Poehling, 1995). The reason for this could be the continuous spray of insecticides during the study.

Yield in this farm was higher than in the organopónico 2 and sufficient regarding to average in the country, but still lower than yield in the agroecological farm. It might be possible to increase them with a better irrigation. With the surface dedicated to this crop, such yield provided revenue better than what get the other two farmers. However, investments needed by his crop management are relatively high and revenue per square meter was lower to the one of the agroecological farm.

The strategy of this farmer to fight pests is to use chemicals. But some products that were used are very dangerous for health and the environment. For example, mancozeb is highly fish toxic, is dangerous for human skin if there is a contact. One of its main active metabolite for humans is toxic for the thyroid (INRS, 2000). Methylparathion is an endocrine disrupting chemical toxic for mamals (Rengaraj *et al.*, 2006). It is highly toxic by inhalation, ingestion, toxic by skin contact and is a possible teratogen for humans (Cooperative Extension Offices of Cornell University, 1994). Those pesticides were sprayed without protections and workers were working in the field the day after.

D.II.3.b.iii An agroecological farm

On this farm, the result of biodiversity characterization was higher than on the other farm. Aphid regulation by biodiversity can explain the fact that aphids were present at the beginning of the crop but not after. Biodiversity evaluation of this farm was higher than on the other two farms. Moreover, the two natural enemies *Cycloneda sanguinea* and *Coleomegilla cubensis* were observed in the fields. Other natural enemies could have played a role in this regulation. The farmer applied agroecological practices for 17 years now and he observed very little pests in his crops. Natural enemies are well established and allow regulating pests. Nevertheless, this farmer considers that some pests can be present in his crops, if they are few. The spray of Fitomás, a plant stimulant and of vermicompost could also have played a role and help the plant to be stronger and defend itself against aphids.

Cropping cycle was long. It was probably delayed because of late fertilization. The fertilization could not be realized before because of rainy weather, soil was wet and it was difficult to access to the crop. Just after, visually, the plant develops rapidly. The long harvested period allowed having a good yield. It almost reached the target of 10 t/ha as described by Huerres Pérez and Caraballo Llosas (1996). This is the result of a good management: regular irrigation and weeding. The very nearby presence of a lake makes irrigation easier for this farmer. The fact that workers on his farm are his relatives, that his model of farming had proven to be effective (his farm is regularly taken as an example of agroecological success) and that workers are convinced by his way of farming plays an important role in the fact that his crops are well managed. Yield could have been improved by fertilization. Indeed, cowpea plot soil was not very fertile. The farmer got this land recently and was before intensely farmed. Moreover, ants were present during the whole cropping cycle and could have affected yield.

Revenue was low for this crop but revenue per square meter was the highest of the three farms. The farmer judged this crop as a complement of income. This crop did not require a lot of investment for him (neither financial nor in time). So, he considers it as a success and will crop cowpea again next year (it was the first time for him).

To conclude by a comparison of the three farm management, it can be said that in the organopónico 1, the crop was attacked by aphids during the whole cropping season and the yield was the lowest, crop management in the organopónico 2 allowed to fight aphids but resulted dangerous for environment and health. Crop management in the agroecological farm allowed fighting aphids while providing a better yield, better revenue per square meter and was environmentally safe.

E. CONCLUSION

The aim of this thesis was to establish the basis for agroecological aphid management in Cuban agroecosystems.

Aphids were found to be present in the crops at the beginning of the crop cycle and during the flowering and pod formation period. Possible explanations are the formation of new tissues and precipitation. Fertilization seemed to have no effect on aphid population. The presence of nearby aphid host crops or the tree *Gliricidia sepium* seemed to be a source of aphids for a nearby cowpea crop. Few repelling plants were not found to be sufficient to reduce aphid incidence. Nevertheless, the neem tree showed to have an interesting potential to fight aphids. Okra was also identified as having a good potential, when it is intercropped with cowpea. Ants were identified as another a possible important cowpea pest.

Farmers growing cowpea were found to be urban farmers, having a diversity of crops and already using agroecological techniques. Nevertheless, some of them did not apply well those techniques. Some farmers were even using chemical pesticides. The majority of farmers had a low knowledge about best practices. They were following the guidance of the unique company advising them, guidance that are in reality obligations that farmers sometimes do not understand and therefore do not follow properly.

Knowing that, it is possible to formulate some recommendations for agroecological pest management on cowpea crops in Cuba.

First, a complex of pests should be studied, integrating ants for example and not only aphids. Then, the potential of nearby presence of neem tree, of okra as an intercrop and of rice husk as mulch should be studied. The economical aspect should be deepened, integrating crop costs, so as to know how much a farmer can earn with his cowpea crop. Lastly, farmers' knowledge in the region should be used to benefit others. There is an opportunity to create a farmer network, as it is present in rural Cuba (*Campesino-a-Campesino* network). It would allow them to exchange experience, knowledge and ideas with peers, while complementing it with practice. Such a network is viewed as a way to foster communication, comprehension, knowledge exchange about good practices and to foster motivation. Research should be made more dynamic, involving farmers in the process so as to link research findings and practices as well as to convince them of future recommended techniques.

This study brought to evidence the fluctuation of aphids in field in cowpea crop, while investigating the reasons for this fluctuation. Some relationships were found. Others were identified as potentially interesting and to be studied. Farmer practices in the region were observed. A need for farmer education and knowledge exchange was identified. This report aimed at setting up the basis for agroecological management of cowpea crops, more research is necessary so as to further investigate identified potentials and action is needed to involve, interest and mobilize workers and farmers.

REFERENCES

Abdallah, Y., 2012. Effect of plant traps and sowing dates on population density of major soybean pests. The journal of basing & applied zoology, 65 (1), 37-46.

Aguilar, A., Emmen, D., Quiros, D., 2005. Respuesta funcional de Diomus sp. (Coleoptera: coccinellidae) sobre Aphis craccivora (Homoptera: Aphididae). Tecnociencia , 7(2), 109-122.

Altieri, M., Nicholls, C., 2005. Agroecology and the Search for a Truly Sustainable Agriculture. Berkeley, USA: United Nations Environment Programme.

Altieri, M., Companioni, N., Cañizares, K., Murphy, C., Rosset, P., Bourque, M., 1999. The greening of the "barrios": urban agriculture for food security in Cuba. Agriculture and human values , 16, 131-140.

Annan, I., Schaefers, G., Tingey, W., 1995. Influence of duration of infestation by cowpea aphid (Aphididae) on growth and yield of resistant and susceptible cowpea. Crop protection , 14 (7), 533-538.

Arias Aroche, A., Zamora Pérez, M., Velázquez Peria, R., 2014. Comportamiento agroproductivo de diez variedades de habichuela (Vigna unguiculata L. Walp) en condiciones semicontroladas, con método participativo. http://www.actaf.co.cu/biblioteca/granos/comportamiento-agroproductivo-de-diez-variedades-de-habichuela-vigna-unguiculata-l-walp-en-condiciones-semicontroladas-con-metodo-participativo.html (retrieved January 2014).

Berg, G., 1984. The effect of temperature and host species on the population growth potential of the cowpea aphid Aphis craccivora Koch (Homoptera : Aphididae). Australian Journal of Zoology, 32, 345-352.

Blade, S., Shetty, S., Terao, T., & Singh, B., 1997. Recent developments in cowpea cropping systems research, in: B. Singh, D. Mohan Raj, K. Dashiell, & L. Jackai (Eds), Advances in Cowpea Research. Copublication of International Institute of Tropical Agriculture and Japan International Reserach Center for Agricultural Sciences, Ibadan, Nigeria, pp. 114-128.

Bonde, R., Snyder, E., 1946. Comparison of different organic and copper fungicide and some combinations of fungicide with DDT for the control of potatoe diseases and insects. American potato journal, 23, 415-425.

Bottenberg, H., Tamo, M., Singh, B., 1998. Occurrence of phytophagous insects on wild Vigna sp. and cultivated cowpea: comparing the relative importance of host-plant resistance and millet intercropping. Agriculture, Ecosystems and Environment, 70, 217-229.

Brunner, S., Scaramuzza, L., Otero, A.1975. Catalogo de los insectos que atacan a las plantas economicas de Cuba (Second edition). Academia de ciencias de Cuba, La Habana, Cuba, 395 p.

Buckley, R., 1987. Interactions involving plants, Homoptera and ants. Annual review of ecology and systematics, 18, 111-135.

Campbell, A., Frazer, B., Gilbert, N., Gutierrez, A., & Mackauer, M., 1974. Temperature requirements of some aphids and their parasites. Journal of applied ecology, 11(2), 431-438.

Cardinale, B., Harvey, C., Gross, K., Ives, A., 2003. Biodiversity and biocontrol: emergent impacts of a multi-enemy assemblage on pest suppression and crop yield in an agroecosystem. Ecology letter, 6, 857-865.

Cooperative Extension Offices of Cornell University, 1994. Methyl Parathion. http://pmep.cce.cornell.edu/profiles/extoxnet/haloxyfop-methylparathion/methyl-parathion-ext.html#9 (retrived August 2014).

Costa, A., Stary, P., 1988. Lysiphlebus testaceipes, an introduced aphid parasitoïd in Portugal (Him: Aphidiidae). Entomofaga, 33(4), 403-412.

Cuadra Molina, R., 2014. Experiencias de productores. Manual sobre agricultura organica sostenible: http://www.rlc.fao.org/es/publicaciones/agricultura-organica/ (retrieved Febuary 2014).

Davis, D., Oelke, E., Oplinger, E., Doll, D., Hanson, C., Putnam, D., 1991. Cowpea alternative fields crop manual. University of Minnesota, Madison, USA.

El-Khouly, A.S., Ali, M.A., Ibrahim, L.I., Naga, S.A., 1994. Effect of intercropping maize and cowpea on their susceptibility to infestation with aphids. Bulletin of the Entomological Society of Egypt, 72, 229–235.

Ehlers, J., Hall, A., 1997. Cowpea (Vigna unguiculata L. Walp). Field crop research, 53, 187-204.

FAO., 2014. FAO Statistical Yearbook, Latin America and the Carribean, Food and Agriculture. FAO publication, Santiago, USA.

FAO Stat., 2011. Cuba. http://faostat3.fao.org/faostat-gateway/go/to/browse/area/49/E (retrived August 2014).

Federal biological research center for agriculture and forestry (BBCH), 2001. Growth stages of mono- and dicotyledonous plants. Uwe Meier.

González Corzo, M., 2011. Update on Cuba's non-sugar agricultural sector. Cuba in Transition, 21, 123-132.

González Ochoa, N., Pacheco Ferriol, H., Danger Hechavarría, L., Jiménez Arteaga, M., 2010. Respuesta agronómica de la habichuela variedad Cantón-1 a las aplicaciones de purines vegetales y bioestimulantes. Revista electrónica Granma sciencia, 14(2).

Gonzalez, C., 2003. Seasons of resistance: sustainable agriculture and food security in Cuba. Tulane environmental law journal, 16, 685-732.

Guenkov, G., 1969. Hortalizas de la subfamilia papilionaceae y de las familias marvaceae y gramineae. In: G. Guenkov (Eds), Fundamentos de la horticultura cubana. Instituto del libro, La Habana, Cuba, pp. 193-216.

Gómez Souza, J., Oliver Díaz, I., Espinosa Álvarez, L., González Pérez, M., 2007. Apuntes sobre Aphis craccivora Koch (Homoptera: Aphididae) . Centro Agrícola, 34 (4), 87-88.

Gutierrez, A., Havenstein, D., Nix, H., Moore, P., 1974. The ecology of Aphis craccivora Koch and subteranean clover stunt virus in South East Australia. Journal of Applied Ecology, 11(1), 1-20.

Hasken, K.-H., Poehling, H., 1995. Effects of different intensities of fertilisers and pesticides on aphids and aphid predators in winter wheat. Agriculture, Ecosystem & Environment, 52(1), 45-50.

Hassan, S., 2013. Effect of variety and intercropping on two major cowpea (Vigna unguiculata L. Walp) field pests in Mubi, Adamawa State, Nigeria. International Journal of Agricultural Reserach and Development, 1 (5), 108-109.

Huerres Pérez, C., Caraballo Llosas, N., 1996. Cultivo de zanahoria, remolacha, rabanito, lechuga y habichuela. In: Huerres Pérez, C., Caraballo Llosas, N., 1996. Horticultura. Editorial Pueblo y Educacción, México D.F., Mexico, pp. 96-140.

INRS, 2010. Fiche toxicologique FT 277 Mancozèbe. Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles, Paris, France.

Isikber, A., 2005. Functional Response of Two Coccinellid Predators, Scymnus levaillanti and Cycloneda sanguinea, to the Cotton Aphid, Aphis gossypii. Turkish journal of agriculture and forestry, 29, 347-355.

James, D., Price, T., 2002. Fecundity in Twospotted Spider Mite (Acari: Tetranychidae) is Increased by Direct and Systemic Exposure to Imidacloprid . Journal of Economic Entomology, 95 (4), 729-732.

John, S., Mini, C., 2005. Biological efficiency of intercropping in okra (Abelmoschus esculentus (L.) Moench) . Journal of tropical agriculture, 43 (1-2), 33-36.

Jones, M., 1979. Abundance of aphids on cereals from before 1973 to 1977. Journal of applied ecology, 16, 1-22.

Karungi, J., Adipala, E., Kyamangyawa, S., Ogenga-Latigo, M., Oyobo, N., Jackai, L., 2000. Pest management in cowpea. Part 2. Integrating planting time, plant density and insecticide application for management of cowpea field insect pest in Eastern Uganda. Crop protection, 19, 237-245.

Kataria, R., Kumar, D., 2013. On the Aphid-ant association and its relationship with various host plants in the Agroecosystems of Vadodara, Gujarat, India. Halteres, 4, 25-32.

Kimbaris, A., Papachristos, D., Michaelakis, A., Martinou, A., Polissiou, M., 2010. Toxicity of plant essential oil vapours to aphid pests and their coccinellid predators. Biocontrol science and technology, 20 (4), 411-422.

Milán Vargas, O., Cueto Zaldívar, N., Hernández Pérez, N., Ramos Torres, T., Pineda Duvergel, M., Granda Sánchez, R., 2008. Prospección de los coccinélidos benéficos asociados a plagas y cultivos en Cuba. Fitosanidad, 12, 71-78.

Nabirye, J., Nampalaa, P., Ogenga-Latigoa, M., Kyamanywaa, S., Wilsonb, H., Odekec, V., et al., 2003. Farmer-participatory evaluation of cowpea integrated pest management (IPM) technologies in Eastern Uganda. Crop protection, 22, 31-38.

Nicholls, C., Pérez, N., Vasquez, L., Altieri, M., 2002. The development and status of biologically based integrated pest management in Cuba. Integrated Pest Management Reviews, 7, 1-16.

Obopile, M., Ositile, B., 2010. Life table and population parameters of cowpea aphid, Aphis craccivora Koch (Homoptera: Aphididae) on five cowpea Vigna unguiculata (L. Walp.) varieties. Journal of Pest Science, 83, 9-14.

Oficina nacional de estadisticas e informacion, 2013. Capítulo 9. Agricultura, ganadería, silvicultura y pesca. In: Oficina nacional de estadisticas e informacion, Anuario estadístico de Cuba 2012. Oficina nacional de estadisticas e informacion, La Habana, Cuba, pp. 123-132.

Ofuya, T., 1995. Colonization and control of Aphis craccivora Koch (Homoptera: Aphididae) by coccinellid predators in some resistant and susceptible cowpea varieties in Nigeria. Crop protection, 14, 47-50.

Ofuya, T., 1997. Effect if some plant extracts on two coccinellid predators of the cowpea aphid, Aphis craccivora (Hom.: Aphididae). Entomophaga, 42(1/2), 277-282.

Ofuya, T., 1986. Predation by Cheilomenes vicina (Coleoptera: Coccinellidae) on the cowpea aphid, Aphis craccivora (Homoptera: Aphididae) : effect of prey stage and density. Entomofaga, 31-4, 331-335.

Ofuya, T., Okuku, I., 1994. Insecticidal effect of some plant extracts on the cowpea aphid Aphis craccivora Koch (Homoptera: Aphididae). Anz. Sch/idlingskde., Pflanzenschutz, Umweltschutz, 67, 127-129.

Oppenheim, S., 2001. Alternative agriculture in Cuba. American entomologist, Winter, 216-227.

Pascual, Y., Montero, A., Jimúnez, M., Púrez, Y., 2007. Efecto de sustancias de origen botánico sobre plagas y enfermedades de la habichuela. Centro Agrícola, 34(3), 87-90.

Pervez, A., Omkar, 2005. Functional responses of coccinellid predators: An illustration of a logistic approach. Journal of Insect Science, 5, 5-11.

Peshin, R., Bandral, R., Zhang, W., Wilson, L., Dhawan, A., 2009. Integrated pest management: a global overview of history, programs and adoption. In: Peshin, R., Dhawan, A. (Eds). Integrated Pest Management: innovation-development process. Springer, Jammu, India, Volume 1, pp. 1-50.

Pettersson, J., Karunaratne, S., Ahmed, E., Kumar, V., 1998. The cowpea aphid, Aphis craccivora, host plant odours and pheromones. Entomologia Experimentalis et Applicata, 88, 177-184.

Pons, X., Lloveras, J., 1999. Densidad poblacional de pulgones en cultivares de alfafa en los regadios de Lleida. Investigación agrícola: Producción y Protección de los Vegetales, 14(3), 405-413.

Rengaraj, S., Li, X., Tanner, P., Pan, Z., Pang, G., 2006. Photocatalytic degradation of methylparathion - an endocrine disruptor by Bi3+-doped TiO2. Journal of molecular catalysis, 247, 36-43.

Rosset, P., 1997. Cuba: ethics, biological control and crisis. Agriculture and human values, 14, 291-302.

Rosset, P., Altieri, M. (1997). Agroecology versus input substitution: a fundamental contradiction of sustainable agriculture. Society and Natural Resources, 19(3), 283-295.

Rosset, P., Machín Sosa, B., Roque Jaime, A., Ávila Lozano, D., 2011. The Campesino-to-Campesino agroecology movement of ANAP in Cuba: process methodology in the construction of sustainable peasant agriculture and food sovereignty. The journal of peasant studies, 38 (1), 161-191.

Vázquez Moreno, L., 2006a. La lucha contra las plagas agrícolas en Cuba. De las aplicaciones de plaguicidas químicos por calendario al manejo agroecológico de plagas. Fitosanidad, 10(3), 221-234.

Vázquez Moreno, L., 2006b. XV Congreso Cientifico del Instituto Nacional de Ciencias Agrícolas. Tendencias y percepciones acerca del manejo de plagas en la producción agraria sostenible. Instituto de Investigaciones de Sanidad Vegetal Ministerio de la Agricultura, La Habana, Cuba, pp. 1-27.

Vázquez Moreno, L., Caballero Figueroa, S., Carr Pérez, A., Gil Michelena, J., Armas García, J., Rodríguez Fernández, A., 2010. Diagnóstico de la utilización de entomófagos y entomopatógenos para el control biológico de insectos por los agricultores en Cuba. Fitosanidad, 14, 159-169.

Vázquez Moreno, L., Fernández Gonzálvez, E., 2007. Manejo agroecológico de plagas y enfermedades en la agricultura urbana. Estudio de caso ciudad de La Habana, Cuba. Agroecología, 2, 21-31.

Vázquez Moreno, L., Fernández Gozálvez, E., Alfonso Simonetti, J., 2007. Manejo de reservorios de entomofagos por agricultores urbanos en ciudad de La Habana. Fitosanidad, 11(2).

Vázquez Moreno, L., Fernández Gonzálvez, E., Lauzardo Rico, J., García Torriente, T., Alfonso Simonetti, J., Ramírez Ochoa, R., 2005. Manejo agroecologico de plagas en fincas de la agricultura urbana. Instituto de Investigaciones de Sanidad Vegetal Ministerio de la Agricultura, La Habana, Cuba.

Vázquez Moreno, L., Matienzo Brito, Y., 2010. Metodología para la caracterización rápida de la diversidad biológica en las fincas, como base para el manejo agroecológico de plagas. Instituto de Investigaciones de Sanidad Vegetal (INISAV), La Havana, Cuba.

Walker, G., Nault, L., Simonet, D., 1984. Natural mortality factors acting on Potato aphid (Macrosiphum euphorbiae) populations in processing-tomato fields in Ohio. Environmental entomology, 13(3), 724-732.

Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D., David, C., 2009. Agroecology as a science, a movement and a practice. A review. Agronomy for sustainable development, 29, 503-515.

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APPENDIX

Appendix I – Interview guide for cowpea growers

Note the name of the farm.

0. When was your farm funded?
1. How many hectares do you have?
2. How many people work on your farm?
3. What do you crop?
4. What is your management on cowpea crop? (sowing date, variety, fertilization, crop association)?
5. What are the most important pests on cowpea crop?
6. How do you decide what kind of product to apply against cowpea pests?
7. I have here a list of methods to fight against pests, could you tell me which one you use for cowpea crop? What do you think about those measures?
    - biopesticides
    - release of natural enemies
    - colored traps
    - vegetal barriers
    - repelling plants
8. Are there skilled people or organization that provides you advices for your crop management?
9. Do you receive technical or economical help from any organization, association or project?
10. How do you think that cowpea cropping could be improved?
11. Would it be possible, on your farm, to use more agroecological cropping techniques? If not why? What are the hindering forces?

Appendix II - BBCH scale for beans (Federal biological research center for agriculture and forestry, 2001)

Bean Feller et al., 1995 b

Phenological growth stages and BBCH-identification keys of Bean

(*Phaseolus vulgaris* var. *nanus* L.),

Code	Description
Principal growth stage 0: Germination	
00	Dry seed
01	Beginning of seed imbibition
03	Seed imbibition complete
05	Radicle emerged from seed
07	Hypocotyl with cotyledons breaking through seed coat
08	Hypocotyl reaches the soil surface; hypocotyl arch visible
09	Emergence: hypocotyl with cotyledons break through soil surface (“cracking stage”)
Principal growth stage 1: Leaf development	
10	Cotyledons completely unfolded
12	2 full leaves (first leaf pair unfolded)
13	3rd true leaf (first trifoliate leaf) unfolded
1 .	Stages continuous till . . .
19	9 or more leaves (2 full leaves, 7 or more trifoliate) unfolded
Principal growth stage 2: Formation of side shoots	
21	First side shoot visible
22	2nd side shoot visible
23	3rd side shoot visible
2 .	Stages continuous till . . .
29	9 or more side shoots visible
Principal growth stage 5: Inflorescence emergence	
51	First flower buds visible
55	First flower buds enlarged
59	First petals visible, flowers still closed

Bean Feller et al., 1995 b

Phenological growth stages and BBCH-identification keys of Bean

Code	Description
Principal growth stage 6: Flowering	
60	First flowers open (sporadically within the population)
61	Beginning of flowering: 10% of flowers open[1] Beginning of flowering[2]
62	20% of flowers open[1]
63	30% of flowers open[1]
64	40% of flowers open[1]
65	Full flowering: 50% of flowers open[1] Main flowering period[2]
67	Flowering finishing: majority of petals fallen or dry[1]
69	End of flowering: first pods visible[1]
Principal growth stage 7: Development of fruit	
71	10% of pods have reached typical length[1] Beginning of pot development[2]
72	20% of pods have reached typical length[1]
73	30% of pods have reached typical length[1]
74	40% of pods have reached typical length[1]
75	50% of pods have reached typical length, beans beginning to fill out[1] Main pod development period[2]
76	60% of pods have reached typical length[1]
77	70% of pods have reached typical length, pods still break cleanly[1]
78	80% of pods have reached typical length[1]
79	Pods: individual beans easily visible[1]
Principal growth stage 8: Ripening of fruit and seed	
81	10% of pods ripe (beans hard)[1] Seeds beginning to mature[2]
82	20% of pods ripe (beans hard)[1]
83	30% of pods ripe (beans hard)[1]
84	40% of pods ripe (beans hard)[1]
85	50% of pods ripe (beans hard)[1] Main period of ripening[2]
86	60% of pods ripe (beans hard)[1]
87	70% of pods ripe (beans hard)[1]
88	80% of pods ripe (beans hard)[1]
89	Fully ripe: pods ripe (beans hard)[1]

1 For varieties with limited flowering period
2 For varieties in which the flowering period is not limited

Bean Feller et al., 1995 b

Phenological growth stages and BBCH-identification keys of Bean

Code	Description
Principal growth stage 9: Senescence	
97	Plants dead
99	Harvested product

Appendix IIIa – Biodiversity characterization form (Vázquez Moreno, Matienzo Brito, 2010)

Rapid evaluation of biodiversity in production systems

Name of the farm:

Responsible of the farm:

Date of realization of the evaluation:

Components and indicators of biodiversity	**Indicator expression for each evaluation**	**Result**	**Obtained value (complexity grade *)**
PRODUCTIVE BIODIVERSITY			
Crop diversity	Number of crops		
Varieties of crops	Crops for which varieties are selected for a phytosanitary purpose (% of total)		
Sowing of crops	Number of sowing per year		
Associations and intercropping of crops	Crops associated or intercropped (% of total)		
Living barrier	Crops with living barrier (% of total)		
Species of living barrier	Number of species used		
Crop rotation	Field that were subject to crop rotation (% of total)		
Rotation with cover crops	Cover crops (% of crops)		
Association with living cover	Fields associated with living cover (% of crops)		
Temporal shade	Crops with a temporal shade (% of total)		
Animal diversity	Number of animal species reared on the farm		

AUXILIAR BIODIVERSITY			
Repelling plants	Crops with repelling plants (% of total)		
Species of repelling plants	Number of species		
Living fences	Farm borders with living fences		
Species in living fences	Number of species		
Permanent shade	Number of cultivated species providing a permanent shad		
Wood	Number of existing woods		
Diversity of species in the wood	Fruit and forest trees species present in the wood		
Semi-natural environment	Percent of farm surface where is growing wild vegetation		
Working animals	Number of animal species that are employ for farm labor		
FUNCTIONAL BIODIVERSITY			
Bioregulators reservoir	Number of reservoir that are managed		
Translation of natural enemies from reservoirs	Number of crop with realized translation		
Rustic breeding	Number of species of bioregulators that are reared on the farm		
Liberation of rustic breeding	Number of realized liberations		
Diversity of natural enemies	Number of natural enemies groups that are commonly observed in farm crops		
Diversity of pollinators	Number of species		

Soil organic mater	Estimated percent of organic mater, according to analysis		
Production of organic mater	Number of organic fertilizers that are produced and used on the farm		
Organic fertilization	Number of fields or plots with incorporation of organic fertilization before sowing		
Foliar organic fertilization	Number of foliar organic fertilization		
Efficient microorganism	Number of applications of foliar and to the soil		
INTRODUCED FUNTIONAL BIODIVERSITY			
Diversity of entomophagous released	Number of species of entomophagous that were released		
Release of entomophagous	Number of release per year		
Diversity of entomopathogens	Number of species and family		
Applications of entomopathogens o biopesticide	Number of applications per year		
Diversity of antagonists	Number of species and family		
Applications of antagonists	Number of applications that were realized during the year		
Soil biofertilizers	Number of used products		
Micorrhiza	Number of crops with application of micorrhiza		
NOXIOUS BIODIVERSITY			
Insect pests	Total pest species in the crops		

Mite pests	Total mite pest species in the crops		
Phytopathogenic fungi	Total of fungic illnesses in the crops		
Phytopathogenic bacterias	Total of phytopathogenic bacterias in the crops		
Viruses	Total of viral illnesses in the crops		
Animal parasites	Total of parasites of reared animals		
Animal illnesses	Total of reared animal illnesses		
EVALUATION OF THE PRODUCTION SYSTEM			
Total number of grades on the scale			5
Mean grade for productive biodiversity			
Mean grade for auxiliary biodiversity			
Mean grade for functional biodiversity			
Mean grade for introduced functional biodiversity			
Mean grade for noxious biodiversity			
Mean grade for the farm			

*** Appendix IIIb - Converter from absolute number or percentage to complexity grade**

Complexity grade	Absolute value result	Result in percentage	Denomination of the complexity grade
0	0	0 %	Simplified
1	1-3	1-25 %	Little complex
2	4-6	26-50 %	Moderately complex
3	7-10	51-75 %	Complex
4	> 10	> 75 %	Highly complex

Appendix IV – List of cultivated plants attacked by Aphis craccivora en Cuba

(after Bruner *et al*., 1975 ; Gómez Souza *et al*., 2007 ; Ramos González *et al*., 2010)

Latin name	Common name (English)	Common name (Spanish)
Asparagus officinalis	Asparagus	Espárrago
Arachis hypogaea	Peanut	Maní
Bauhinia variegata	Orchid tree	Casco de buey
Cassia alata	Ringworm senna	Guacamaya francesa
Crotalaria retusa L.		
Datura stramonium	Datura	Estramonio
Gliricidia sepium	Gliricidia	Piñon amoroso
Glycine max	Soybean	Soya
Gossypium hirsutum	Upland cotton	Algodón
Indigofera tinctoria	True indigo	Añil
Jasminum officinale grandiflorum	Common jasmine	Jazmin de cinco hojas
Mangifera indica	Common mango	Mango
Melicoccus bijugatus		Mamoncillo
Phaseolus aureus	Mung bean	Frijol mungo
Phaseolus vulgaris	Common bean	Frijol común
Stizolobium duringianum	Deering velvetbean	Frijol terciopelo
Vigna unguiculata	Cowpea	Habichuela

Appendix V – List of *Aphis craccivora* host plants in Cuba (after Bruner et al., 1975)

Abutilon americanum (L.) Sweet
Abutilon umelatum (L.) Sweet
Acacia farnesiana (L.) Willd
Achyranthes aspera L.
Agave legrellina Jacobi
Alternanthera polygonoides (L.) R.Br
Alternanthera sessilis (L.) R.Br
Amarantus sp.
Amarantus crassipes Schltr.
Amaranthus dubius Mart.
Amaranthus viridis L.
Annona squamosa L.
Antigon leptopus Hook and Arn.
Apium leptophylum (Pers.)
Arachis hypogaea L.
Asparagus myriocladus Baker
Bauhinia sp.
Bauhinia divaricata L.
Bidens sp.
Bidens pilosus L.
Boerhaavia diffusa L.
Boerhaavia erecta L.
Bougainvillea spectabilis Willd.
Bursera simaruba (L.)
Brasiletia violacea
Calliandra surinamensis Benth
Calophyllum antillarum Britt.
Calotropis procera (Ait.)
Canavalia cubensisi Griseb.
Canavalia gladiata (Jacq.) D.C.
Cassia fistula L.
Chamaesyce berteriana (Balbis) Millsp.
Chamaesyces hirta (L.)
Chamaesyce pilulifera (L.)
Citrus sp.
Coccoloba sp.
Coccoloba retusa Griseb.
Coccoloba uvifera L.
Commelina elegans HBK.
Cordia collococca L.
Cordyline terminalis
Cordia gerascanthus L.
Cordyline terminalis
Cordia gerascanthus L.
Crotalaria lanceolata L.
Croton lobatus L.
Delea domingensis D.C.
Distictis gnaphalantus (A. Rich.)
Dolichos lablab L.
Eyngium foetidum L.
Euphorbia heterophylla L.
Ficus laevigata Wahl.
Flaveria trinervia (Spreng.)
Forsteronia corymbosa (Jacq.)
Galactia rudolphioides (Griseb.)
Gliciridia sepium (Jacq.)
Gossypium arboreum L.
Gossypium hirsutum L.
Hibiscus cannabinus L.
Hibiscus rosa-sinensis L.
Indigofera suffisticosa Mill.
Ixora coccinea L.
Jatropha curcas L.
Kallstroemia maxima (L.)
Krugiodendron ferreum (Vahl.)
Kagerstroemia indica L.
Lasonia inermis L.
Lepidium virginicum L.
Macroptilium lathyroides L.
Malpighia sp.
Mangifera indica L.
Matricaria chamomilla L.

Melicocca bijuga L.
Mikania micrantha HBK.
Murraya paniculata L.
Pavonia fruticosa (Mill.)
Phaseolus lunatus L.
Phaseolus limensis Bailey
Phyla nodiflora (L.)
Pisonia eculeata L.
Pithecellobium hystrix (A. Rich.)
Pittosporum tobira L.
Plumbafo capensis Thunb.
Plumbago acandens L.
Poincianella pulcherrima L.
Poriulaca oleracea L.
Pothomorphe peltata (L.) Miq.
Pueraria phaseoloides Benth.
Rauwolfia nitida Jacq.
Rhynchosia minima (L.)
Ruellia paniculata L.
Sarcostema clausum (Jacq.)
Selenicereus grandiflorus (L.)
Serjania subdentata Juss.
Solanum nigrum L.
Stigmaphyllon sagraeanum A. Juss.
Talinum triangulare (Jacq.)
Tamarindus indica L.
Tephrosia cinerea (L.)
Tephrosia sena HBL.
Theobroma cacao L.
Tithonia sp.
Tournefortia hirsutissima L.
Tribulus cistoides L.
Urchites lutea L.
Vaudelia sp.
Vernonia cinerea (L.)
Vernonia hieracioides Griseb.
Vigna luteola (Jacq.)

Appendix VI - List of plants that attract beneficial insects in aphids fight (after Holman, 1974)

Plant common name	Plant latin name	Beneficial insect concerned
Anise		Aphid parasites (*Aphis matricariae*)
Alfalfa	*Medicago sativa*	Damsel bug (*Narbidae* family)
Angelica	*Angelica archangelica*	Ladybeetle (*Coccinellidae* family)
Baby-blues eyes	*Nemophila*	Syrphid fly, Damsel bug (*Narbidae* family)
Bishop' weed		Syrphid fly, Ladybeetle (*Coccinellidae* family)
Buckwheat		Syrphid fly, Braconid wasp (*Braconidae* family), Ladybeetle (*Coccinellidae* family)
Buckthorn	*Rhammus*	
Butterfly weed	*Asclepias*	Ladybeetle (*Coccinellidae* family)
Black locust	*Robinia pseudoaccacia*	Ladybeetle (*Coccinellidae* family)
California lilacs	*Ceanothus* spp.	Syrphid fly
Candytuft		Syrphid fly, Damsel bug (*Narbidae* family)
Caraway		Syrphid fly, Aphid parasites (*Aphis matricariae*)
California lilacs	*Ceanothus* spp.	Syrphid fly, Damsel bug (*Narbidae* family)
Coreopsis		Syrphid fly, Damsel bug (*Narbidae* family), Ladybeetle (*Coccinellidae* family)
Coriander	*Coriandrum sativum*	Syrphid fly

Cosmos	*Cosmos caudatus*	Syrphid fly, Damsel bug (*Narbidae* family), Ladybeetle (*Coccinellidae* family)
Cowpea	*Vigna unguiculata* L.	Braconid wasp (*Braconidae* family)
Coyote brush	*Baccharis pilularis*	Syrphid fly
Crocuses		Braconid wasp (*Braconidae family*)
Crimson clover		Ladybeetle (*Coccinellidae* family)
Dill		Syrphid fly, Aphid midge (*Aphidaletes aphidimyza*), Aphid parasites (*Aphis matricariae*), Ladybeetle (*Coccinellidae* family)
Fenel		Syrphid fly, Braconid wasp (*Braconidae family*), Ladybeetle (*Coccinellidae* family)
Gloriosa daisy		Syrphid fly, Damsel bug (*Narbidae* family)
Goldenrod		Ladybeetle (*Coccinellidae* family)
Hairy vetch		Braconid wasp (*Braconidae* family), Ladybeetle (*Coccinellidae* family)
Hemp sesbania	*Sesbania exaltata*	Ladybeetle (*Coccinellidae* family)
Holly-leaved cherry	*Prunnus ilicifolia*	Syrphid fly
Knotweed	*Polygonum aviculare*	Syrphid fly, Braconid wasp (*Braconidae* family)
Marigold	*Tagete erecta* L.	Syrphid fly, Damsel bug (*Narbidae* family)
Meadowfoam	*Linnanthes dougasil*	Syrphid fly, Damsel bug (*Narbidae* family)
Mustard		Aphid parasites (*Aphis matricariae*), Braconid wasp (*Braconidae* family)

Parsley	*Petroselinum crispum*	Syrphid fly, Braconid wasp (*Braconidae* family)
Queen Anne's lace		Syrphid fly, Aphid parasites (*Aphis matricariae*), Braconid wasp (*Braconidae* family), Ladybeetle (*Coccinellidae* family)
Rye		Ladybeetle (*Coccinellidae* family)
Scabiosa		Syrphid fly
Saltbush	*Atriplex* spp.	Ladybeetle (*Coccinellidae* family)
Soapbark tree		Syrphid fly, Damsel bug (*Narbidae* family), Ladybeetle (*Coccinellidae* family)
Spearmint	*Mentha spicata*	Syrphid fly, Braconid wasp (*Braconidae* family)
Sunflower		Syrphid fly, Aphid parasites (*Aphis matricariae*), Damsel bug (*Narbidae* family), Ladybeetle (*Coccinellidae* family)
Sweet alyssum		Syrphid fly, Damsel bug (*Narbidae* family)
Sweet clover		Aphid midge (*Aphidaletes aphidimyza*)
Tansy		Braconid wasp (*Braconidae* family), Ladybeetle (*Coccinellidae* family)
Thyme		Aphid midge (*Aphidaletes aphidimyza*)
Ustard		Aphid midge (*Aphidaletes aphidimyza*)
White clover		Braconid wasp (*Braconidae* family)
Yarrow		Syrphid fly, Aphid parasites (*Aphis matricariae*), Damsel bug (*Narbidae* family), Ladybeetle (*Coccinellidae* family)

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