Norwegian University of Life Sciences

Abstract:

Biodiversity is an important aspect of the agroecosystem and provides ecosystem services which can reduce reliance on phytosanitary chemicals. Increased knowledge of the role of biodiversity is needed for alternative production techniques, particularly of challenging crops. Peaches are one of the most difficult fruits to grow, and usually rely on several fungicide and pesticide applications each year. With a national goal to lower inputs, peach orchards in the Drôme, France are part of a long-term project comparing three agricultural production methods: Conventional, Low-Input, and Organic. This study is a gathering of baseline information on biodiversity in the three orchards to determine the best host for abundant and diverse fauna. Measurements were taken throughout spring and early summer to determine soil quaility and ground-dwelling arthropod abundance and diversity. A modified Beerkan test and number of earthworms in extracted soil volumes were used to measure soil quality. Pitfall traps collected ground beetles and spiders to analyze system dynamics. The three orchards were similar regarding soil quality. Arthropod results showed interesting differences between them, indicating that the surrounding environment greatly influences fauna in the orchard system. Several expected differences were not found, which is attributed to young age of the trees.

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1. Introduction

Fruit production in France faces several challenges today to meet a demand for environmentally conscious production methods. Control of pests and diseases is difficult when aiming to decrease the use of insecticides, herbicides and fungicides, and the maintenance of predatory arthropods is important to provide ecosystem services. Although many farmers recognize the environmental damage caused by these chemicals, evidence, knowledge and skills of alternative production methods and the benefits of biodiversity are needed to support a wish to change. To address this knowledge gap this study poses a question of what elements of different production methods impact abundance and diversity of arthropod and soil fauna? and how do they contribute to orchard resilience and pest control? This report documents and reflects upon differences observed in two year old peach orchards in south-eastern France.

The study addressed in this paper is one aspect of a larger project: CASDAR Faibles-Intrants, which in turn is part of a national project with a goal to lower agricultural inputs by 2018 (Ecophyto2018). The CASDAR, Compte d'Affectation Spéciale pour le Développement Agricole et Rural (Funds specifically dedicated to agricultural and rural development) project in question gives funds for a comparison of Conventional, Low-Input, and Organic fruit production. The project is a long term study that will be carried out over the next 15 years. The SEFRA (Station d' Expérimentation Fruits Rhône-Alpes) is participating in this project as one of three sites for experimentation on Peach trees. (Bussi, 2012)

Around 40% of France's surface area is dedicated to agriculture (Agreste, 2011). The country is heavily dependent on agriculture economically and accounts for 18% of European agricultural production (Agreste, 2012b). However, a relatively low percentage of this is dedicated to organic agriculture, only 3.5% (Agreste, 2012a). Arboriculture accounts for only a small portion of agricultural production in France, with only around 9% of fruit production organic (including non-tree fruits) according to the 2010 agricultural census (Chiron, 2013). Several stone fruits are mainly grown in southern France, since climate conditions limit the possible area of production, and there are even Product of Origin labels for regional fruits. In the case of peaches, no specific label exists, though there are several associations that group producers throughout different regions (Chiron, 2013). Current production levels leave peaches the second fruit most cultivated in France, after apples (Hilaire & Giauque, 2003). Despite being the fourth European producer of peaches, this does not account for much of what is consumed nationally (Chiron, 2013).

While the summer months account for a large portion of the national demand, France also imports a significant percentage of what the country consumes. Despite a decrease in the surface area under peach cultivation, total harvest levels have been relatively stable over the past two decades due in part to the concentration of production zones in climates that are favourable to high yields. (Hilaire & Giauque, 2003) One of these zones is the Drôme department, the area in which the project described in this paper is located.

Peach production is known to be one of the most difficult tree fruit crops to grow. It requires technical knowledge beyond that of other fruits and demands numerous interventions throughout the year, generally including several rounds of biocide applications. It was chosen for the CASDAR study because of its importance in the region, and because it is known to be particularly difficult to grow peaches organically, given the high number of pests and diseases that cause yield losses on a regular basis even for conventional growers. It is assumed that with organic production methods, peach trees will be under greater threat of pest and disease infestation, since several curative products that are allowed in conventional agriculture do not have organic equivalents. This assumption stems from a conventional grower mindset, that focuses solely on the problem and does not see the orchard as an agroecosystem and integrated in the landscape. Several factors contribute to the vulnerability of a crop plant, and an organic system could prove more resilient because of better adaptation and connection with its surroundings. Given the numerous challenges of growing peaches and the low earnings, it is no wonder producers are hesitant to change their practices if it could lead to yield losses.

The study described in this paper is an initial state examination of biodiversity for the comparison of three systems of peach orchards over the next 15 years. The comparison of the three systems at this stage sets a base for future comparison and the differences that may be observed along the course and at the end of the study. In light of this, measurements were carried out to determine the presence of predatory arthropods, earthworm activity, water infiltration rate, and canopy insect presence in the Conventional, Low-Input, and Organic peach orchards of the CASDAR Faibles-Intrants project.

1.1 Why Biodiversity?

Biodiversity is an important element of the agroecosystem. This is true at several levels, diversity of crops within a field or farm, diversity of landscape (cropped areas, semi-natural areas such as hedges, abandoned areas, canal systems, ponds, and natural areas including rivers, forests, open fields), and diversity of fauna both above and below ground, between and within species. Often when discussing biodiversity in terms of agriculture, the focus is on the role of certain fauna to perform a specific service for cultivated areas. It has been recognized globally that biodiversity is important to consider out of respect for the planet and its ecosystems, not only for its role in agriculture. The past 20 years in particular have seen the development of several organisations, associations, and policies from the global scale to local village interest groups. International reports call for the recognition of the need to maintain biodiversity and to sustain its well-being, instead of continuing to destroy species of plants and animals in our push to turn the face of the earth into cultivated land. (Herzog et al., 2012; Lepart, Marty, & Terraube, 2007; Le Roux et al., 2008; Peeters, Maljean, Biala, & Brouckaert, 2004)

Numerous studies discuss the benefits of increased biodiversity in agricultural systems and of the potential for natural biological control when predator habitat is provided (Garcin, Demarle, & Soldati, 2004; Peeters et al., 2004; Ricard, Garcin, Jay, & Mandrin, 2012). Though it has also been shown that enhancing biodiversity alone was not necessarily enough to provide adequate control of pest or disease infestation (Schmidt, Roschewitz, Thies, & Tscharntke, 2005). In the context of the study described in this paper, interest in arthropod diversity and abundance focused on the role of arthropods as predators of agricultural insect pests, and the potential to control disease by preventing transmission through insect vectors. Earthworm presence was used as an indicator of soil health in correlation with water infiltration rates. Additionally, a more general understanding of biodiversity present in each of the three agricultural systems was sought through observation and notation of all creatures seen during regular scouting activity in the orchards.

1.2 Biodiversity and phytosanitary chemicals

Interest from agricultural workers as well as the general population in re-installing and maintaining biodiversity in the agricultural landscape has increased in recent years. (Herzog et al., 2012) This is due to several factors but the underlying cause is the growing awareness of the decline and even extinction of several plant and animal species due in large part to modern agricultural practices. It is now well known that the use of chemical fertilizers and excessive applications of pesticides have led to the decline of many natural elements of agroecosystems , particularly species loss.(Lepart et al., 2007; Peeters et al., 2004) Despite providing plants with nutrients that are vital to growth, synthetic fertilizers do not compensate for the beneficial relationships between microorganisms and organic matter content in the soil. (Le Roux et al., 2008) Herbicides destroy important habitat for many insects, most of which do not impact crop yields negatively, and may even serve to benefit them. Weeds can help temper infestations of an insect pest by providing habitat and prey for predator species as well as providing alternate food source for the pest and thereby diminishing the attack on the crop plant. (Purtauf et al., 2005; Ricard et al., 2012; Wildlife Conservation Research Unit Oxford & Centre for Ecology & Hydrology, Lancaster, 2005) Additionally, by eliminating weeds before emergence or at an early stage, less plant material is available for reincorporation into the ground through decomposition. Insecticides and herbicides are also highly toxic to soils. Moreover, insecticides disrupt the natural cycles of several species, not only those targeted by the phytosanitary products, but numerous innocent bystanders as well. Though progress has been made in manufacturing chemicals that are specifically intended to kill a certain pest for a particular crop, it has been shown that nevertheless many other animals are affected. Even for predatory species that are not eliminated by the applied pesticide, with diminishing food source, their population will decrease, and those who can, will likely migrate to more inviting and sustaining habitats.(Ricard et al., 2012) There is still a large debate, however, as to the necessity in using such chemical products in order to grow the crops that contemporary human life depends on so heavily. The ecological costs are not seen in the marketplace, where the damage induced by using these chemicals is not represented in the price of agricultural crop products.

At the global level, there remains a question of how to increase yields for the growing population, as well as a question of how to change the unequal distribution patterns of what is produced today. Those who argue that the main global issue is primarily that of quantity often also support the continued use of phytochemicals in order to produce higher yields. They do not necessarily recognize, or are not willing to recognize, the tolls that such conduct takes on the well-being of the planet's ecosystems. The pesticides not only induce harm to the environment, being extremely dangerous for fish and other creatures in waterways, and contributing to colony collapse in bees, but they are also to humans, having carcinogenic effects and being endocrine blockers. Many products are taken off the market yearly, only to be slightly transformed and put back with a new name. Despite explicit labeling and courses on protection from pesticides, many agricultural workers do not protect themselves properly or almost not at all, wearing only a tee-shirt while spraying. In addition to those using biocides, the machines used to apply them send enormous clouds of mist into the air, and anything or anyone who is nearby is showered. This includes anyone passing by on a nearby road, or other workers in neighboring fields, and precautions are not necessarily carried out to warn potential victims. Though it is generally assumed that when fruit arrives in a shop a pesticide has had the time to break down chemically and no longer poses a threat to human health, this is not always the case. Often residues are found on fresh fruit, particularly on the skin where chemical remnants are easily traced. Even very small doses of some of the products used can cause illness and even be lethal. The continued use of these products poses a serious dilemma for those who are conscious of their effects, though in growing peaches lowering treatment rates is a challenge when high yields want to be assured.

Despite the continued research and the repeated conclusions that chemical fertilizers and biocides lead to overall decline of the agroecosystem (Lepart et al., 2007; Le Roux et al., 2008; Peeters et al., 2004), agricultural legislation concerning these products is slow to limit them. Such legislation in Europe continues to be controlled by those who favour the continued use of these products, and politicians consider that much is at stake if they go against the wishes of the phytochemical industry. In the case of France, the Common Agricultural Policy (CAP) is the main body of legislation for agriculture. There have been positive changes over the course of the different revisions of the CAP, including Agro-Environmental Measures (MAE) that require certain actions to maintain a continued presence of wildlife, such as leaving cut tree branches on the ground for supporting the enhancement of soil biodiversity and decomposition processes. Though the majority of the revised CAP in 2014 will still be heavily influenced by large-scale industrial agriculture, there will be continued and further consideration for alternative methods of cultivation, with greater support for organic agriculture as well as agroforestry (L. Castel, personal communication, March 12, 2013).

1.3 Context of study

Peaches are a main agricultural crop of the area in which the SEFRA is located, the Drôme department of the Rhône-Alpes region in South-Eastern France. Located along the valley of the Rhône, the SEFRA is an important reference for fruit growers of the area, particularly peach and apricot growers, which have long been a major part of the region’s economy. The SEFRA mainly experiments with new varieties, phytochemicals, and different growing techniques, including assessing different tree forms, and thinning and pruning practices. The Low-Input comparison study is a new undertaking for the SEFRA, particularly the concept of examining biodiversity. Up until now, this has not been an aspect that the experimental farm was concerned with. Despite being a leader and a center of research in fruit production, the SEFRA has remained focused on conventional methods of growing fruit when it comes to the use of inputs. Since the research is to a large extent driven by producer demands and the chemical and nursery industries, there has not been a push to know about insect life beyond the usual concerns for pest infestations. Unfortunately, even within the structure of the SEFRA it takes a certain effort to convince those outside of this particular study of the necessity and interest of the biodiversity aspect of the CASDAR project.

This paper intends to define the initial state of biodiversity in the three orchards under study and to examine what causes contribute to the differences observed, including, though not limited to, the choice of inputs. The same protocols will be carried out every 3-5 years over the course of 15 years total, in order to evaluate the development of the orchards and the potential emergence of differences between them, particularly in relation to the production method, i.e. Conventional, Low-Input, or Organic.

Two subjects are at the heart of the study presented in this paper, first, the influence of different row cultivation techniques on soil biodiversity and water infiltration, and second, the potential of arthropods, particularly ground-dwellers, to provide ecosystem services for the crop. Both of these contribute to the main question: which agricultural system (Conventional, Low-Input, Organic) provides the best habitat for abundant and diverse arthropod and soil fauna and supports and sustains their activity for providing ecosystem services.

2. Materials and Methods

2.1 Experimental sites

The three CASDAR orchards at the SEFRA were planted in March of 2012 with bud grafts of Nectardream, a variety of semi-late-ripening white-fleshed nectarine. The orchards each consist of 5 rows of peach trees with 6 meters between rows. An aerial photograph of the site is provided in Appendix 1, while Appendix 2 graphically depicts the orchards and layout of the measurement and trapping sites. In the row the orchards differ; in the Conventional orchard trees are spaced at 3.5 meters, while in the Low-Input and Organic plots the trees are closer together, at 3 meters, to account for the expectation of less tree vigor and lower yields. The number of trees per row also differs, with the Low-Input and Organic orchards having 28 trees per row and the Conventional 30. This is due to the set up of the main SEFRA orchards in which the Conventional plot is situated, where the rows are longer and were therefore filled. The orchards are each planted with a mix of rye-grass and fescue in the inter-row, while the planted row is either treated with herbicide (Conventional and Low-Input) or mechanically weeded (Organic). Additionally, in the Organic and Low-Input plots, other trees and shrubs are planted here and there between peach trees, with the intention of providing habitat for beneficial insects. The three systems also differ in their irrigation methods; the Conventional and Organic plots are irrigated with microjet aspersion sprinklers, whereas the Low-Input plot has an underground drip irrigation system at 45cm depth. For a complete description and calendar of the different interventions (pruning, thinning, phytosanitary treatments, etc.) see the table in Appendix 4, main differences are compared in the table below (Table 1).

The three orchards are not treated in exactly the same manner, the aim of the project being to duplicate the mindset of a grower using each of the agricultural methods. Thus, at any given point the same action might not be taken in all three orchards. For example, based on pest pressure the Conventional orchard might be sprayed as a local conventional grower might do, while the Low-Input orchard would not be sprayed in the logic of a low-input grower who might have a higher threshold for infestation damage. However, the numerous physical and chemical interventions in the three orchards have been quite similar in the time of the study, reflecting the fact that peaches are an intensively managed crop. From the time of planting in March 2012, the Conventional orchard received 17 doses of fungicide, 12 of insecticide, 16 of herbicide, while the Low-Input orchard had 19 doses of fungicide, 13 of insecticide, and 12 of herbicide, and the Organic orchard had 18 doses of fungicide, and 17 of insecticide. Additionally, the trees are frequently checked for rootstock sprouts at this stage of their growth, which are important to remove, and the branches are cut multiple times throughout the year to form them into the desired shape. In just the first two growing seasons branches are shortened and removed at 7 times, in addition to removing any flowers, forcing the trees to concentrate growth in the desired areas.

Table 1: Main differences in management between orchard systems

	Conventional	Low-Input	Organic
Row management	Herbicide	Herbicide	Mechanical weeding
Hedges	3 sides, 20 yrs old	1 side 20 yrs, 2 sides 2 yrs	2 sides, 20 yrs
Shrubs in the row	No	Yes	Yes
Irrigation	Microjet aspersion	Subterranean	Suspended Microjet
Fertilizer, biocides	Synthetic compounds	Synthetic compounds	Natural compounds

However, the immediate surroundings of each orchard differentiate them from one another. The Conventional orchard, placed within the SEFRA plots is on land that has long been used in a rotation of 5-10 years with peaches, followed by several years of an arable crop. Prior to planting the Conventional orchard, the ground had a 5-8 year 'rest' period from fruit production, while soy and alfalfa were alternately grown. The arable crop is harvested and not returned to the agricultural system, so the land still undergoes nutrient losses during this time. The hedges that surround this orchard on three sides are around 20 years old. The North and South hedges have a main function as windbreaks and are mostly characterized by Italian Alder (*Alnus cordata*) with several wild cherry and blackberry in between. The Eastern hedge is ornamental, with several lilac and redbud trees. To the west of the orchard in 2013, during the time the experiments that this paper describes, there was a cereal crop in place.

The Low-Input and Organic orchards are situated on land that was recently acquired by the SEFRA and formerly belonged to a private fruit grower. The peach trees that were standing at the time of purchase were removed in 2010 and burned, and the land was planted with wheat followed by alfalfa each for one growing season prior to planting the peach trees of this study. The Low-Input orchard has a Northern hedge similar to that of the Conventional orchard, however the Southern and Eastern hedges are only 2 years old, having been planted along with the peach trees. These two hedges are made up of a variety of species, with a certain consideration for the necessity of a windbreak for the South. The Western side of the orchard had a crop of rapeseed during the time of the study presented here. The Organic orchard had yet another setting, bordered on the North and East by 20 year old Italian Alder-dominant hedges, while to the South was a field of alfalfa and to the West a field of soybean.

Due to the limited space in each of the orchards, repetitions of the trapping and measurement set-up were not possible. Multiple sets of pitfall traps would have led to the de-fauning of the entire site. Moreover, the protocol stipulates 10 meters between traps, which made it impossible to have several repetitions, particularly if they were to be centrally located. This holds for the earthworm and infiltration set-ups as well, each of which demanded considerable space in a relatively small site.

The climate of the lower Drôme is characterized by mild winters, average temperatures around 8-10°C, rare frosts, and precipitation around 400mm, and one of the hottest summers in France, temperatures often around 30°C with low precipitation (150 mm) ("Meteo-France Climat: Montelimar," n.d.). The valley of the Rhône is large and flat, though to the east gentle hills lead to the mountain ranges of the Vercors and the Barronies, which eventually lead to the Alps. The Rhône valley is also known for the strong winds that blow year-round, particularly the wind from the north, the Mistral. This last has perhaps the greatest influence on the agricultural landscape, which includes several windbreak hedges that help to create micro-climates that are gentler on crops.

2.2 Soil quality measurements

Porosity and earth worm activity were the two measures of soil quality followed in this long term study. Chemical properties of the soil were not tested.

2.2.1 Earthworm protocol

On three dates in each orchard treatment six sites were randomly chosen for sampling. The days were chosen weather permitting, while keeping in mind the biological cycle of earthworms and their declining presence as temperatures increase at the end of spring. The first sampling date in March was when the soil was not frozen and moist though not saturated, March 22, 2013. The two following dates were at three week intervals, April 17 and May 6, 2013. Each was measurement site was situated in the row of peach trees to compare the effect of herbicide vs mechanical weeding between the different systems. Earthworm extraction was done in the morning on each date to avoid high temperatures and increased dryness of soil, which could cause lower numbers of individuals in the 40cm depth. At each site hole was dug 40x40x40cm with a garden fork and the soil placed in a large plastic container. Immediately following the removal of the soil those earthworms in the sides and at the bottom of the hole were removed and placed in a smaller bin or container. The soil in the large bin was then hand sifted, translocating all earthworms to the same smaller container. Identification of ecological category was carried out with the aide of a recording sheet provided by the Observatoire Agricole de la Biodiversité (OAB, Observatory of Agricultural Biodiversity). Identification was not done beyond this level, genera and species are therefore not taken into account in this study.

2.2.2 Porosity

Soil porosity was measured using a modified Beerkan test (Parveaud, n.d.). Once a month, starting at the earliest date when the soil was not saturated (ressuié), 6 sites in each agricultural system were randomly selected to compare the impact of soil management practices on porosity. Due to the rainy spring of 2013, the first test was carried out on June 25, when the soil was dry enough, followed by July 24, and August 12, 2013. Each test site was in the planted rows and in the zone of influence of the irrigation apparatus. Since the first date of testing was after the first irrigation, measurement dates were chosen between two irrigation times, so that the soil was dry. All measurements were done in the tree row, between trees, similar to the earthworm protocol. For each sampling, a 30cm diameter PVC cylinder 15cm in height was fixed at the soil surface by gently tapping it into the ground. Previously measured volumes of 0.75 liters of water were poured one at a time, covering the surface of the cylinder with approximately 1 cm of water. The time for the water to fully infiltrate was recorded with a stopwatch, and the next volume was poured on the surface until a steady state of infiltration was observed. A plastic sheet to cover the surface was used in order not to create indentations from the impact of pouring which could make puddle zones.

The time for infiltration of each volume of water poured was noted down in a table, and transferred to an Excel file where all time measured was converted into seconds between iterations. With this file, average rates for each 0.75l were calculated and then graphed using a scatter plot in Excel. Of the average rates, only the linear section was taken into account for comparison between orchards. These sections were extracted in order for the program to be able to graph each of them with a general trend line, the slope of which was used to calculate the infiltration rate.

2.3 Inter-row and Canopy fauna

2.3.1 Pitfall trapping

The experimental set up for these traps was decided with the assistance of Jean Michel Ricard and Alain Garcin, arboricultural entomology experts at the CTIFL (Centre Technique Interprofessionnel des Fruits et Legumes), and Sylvaine Simon at the INRA-Gotheron (Institut National de la Recherche Agronomique). In each of the three systems, pitfall traps were put in place for sampling ground-dwelling arthropods for 5 day periods. One week prior to capture, holes were dug and sleeves placed for five containers to be placed in the inter-row. The five traps were set in two lines parallel to the trees (see Appendix 2 for layout). The sleeves and covered traps were set in place one week prior to the start of the trapping period in order to let soil life regenerate after disturbance. Once set in place, the tops of the containers were flush with the soil surface or slightly below to ensure that creatures would not perceive them prior to falling in. The five traps were centrally placed in each of the orchards so as not to be influenced by outside factors such as hedges and other borders. Thus, three containers at 10 meter intervals were placed between rows 2 and 3 in the middle of the inter-row; and two containers between rows 3 and 4. Traps were uncovered on May 7, June 7, and July 5, 2013.

In the afternoon of measurement day 0, the containers were uncovered and filled with a solution of alcohol (~10%), water (~90%), and a few drops of dish soap to trap and drown any insect that fell in. The traps were left in place for 5 full days. On the morning of day 6 the traps were collected, replacing them with empty covered traps. Immediately after retrieval the traps were cleaned, pouring out the alcohol solution and rinsing the collected bugs and transferring them to a 70% alcohol solution to preserve them prior to sorting and identification. Each container was carefully labeled with number (1 through 5) and the orchard system (Conventional, Low-Input, Organic). The collected bugs, after cleaning and transfer, were sorted into three categories: ground beetles (Carabidae), spiders (Araneae), and other. The category 'other' was stored for potential future use, but was not further used in this study. The ground beetles were identified to species using a key guide (Coulon, Pupier, Queinnec, Ollivier, & Richoux, 2011a, 2011b; Jeannel, 1941, 1942) and with the help of experts at the CTIFL. Questionable identification and unidentified samples were sent to Alain Garcin at the CTIFL for confirmation and identification. Similarly, spiders were identified to the family level using a key guide (Roberts & Leraut, 2010); this level of identification being recognized as giving significant information as to their role in arboriculture food-web dynamics. The collected data was entered into a calculation table for analysis. Total abundance and richness over the course of the spring and early summer were sought in order to give a sound picture of the initial state of arthropod biodiversity.

Using the total number of individuals and species richness, the Shannon index was calculated for both ground spiders and Carabid beetles in each orchard. The Shannon index is recognized among ecologists as a good indicator of relative biodiversity, allowing for the comparison of one orchard with another, hence the calculation for this study. The index was calculated according to the following formula: $H' = \sum p_i * LN(p_i)$; where H' is the Shannon index, i is a species or family of the studied environment, p_i is the ratio of the individuals of a certain species to the total number of species found, which is calculated by: $p(i)= n_i /N$; where n_i is the number of individuals for a given species or family, and N is the total number of individuals for all species. This index is widely recognized as a way of representing the heterogeneity of biodiversity in a given area. It varies between 0 and the natural Log of the total number of species (S), with 0 representing few species being dominant in a certain area, and LN(S) a more balanced distribution of individuals among the different species. (Deraison, 2010; Peeters et al., 2004) Equitability (E) was calculated using the following formula: $E= H'/LN(S)$.

In addition to simply stating the presence of such species, it is important to know if they are constant, secondary, or accidental inhabitants of the field under study (Garcin et al., 2004). Presence of each Carabid species was calculated by giving a value of 1 or 0 for each of the 5 traps on each date. The sum of these was divided by the total number of traps set (15 in each agricultural system, 5 for each collection date) for a percentage of overall presence throughout the trapping months. A constant species is defined as having a presence of at least 25%, secondary between 10% and 25%, and accidental as less than 10%.

2.3.2 Pest/Disease observations

In addition to the more intensive identification of ground beetles and spiders, bi-weekly observations of pests, diseases, and canopy life were carried out in each of the orchards. The observations were done according to a simple method developed by the Chamber of Agriculture for producers to quickly evaluate the health of their orchards. Their standard form was used which provides a calendar with the weeks that major pests and diseases are generally present. With assistance from Yannick Montrognon, the peach technician at the SEFRA, the calendar was adapted for the specific challenges of the site. The modified calendar was then used during the observations to note down the presence or absence of each of the pests or diseases, and, when present, the percentage of attack. Observations were carried out by walking at a slow pace through the orchards, zigzagging between the rows in order to take the entire plot into account. Trees were carefully studied, and other canopy life was noted down as well, to give an idea of the abundance and diversity in each of the orchards. This protocol was used eight times throughout the study, on May 23, June 12, July 1, 16, 26, and August 2, 9, 16, 2013.

2.4 Statistical analysis

Because of the limited data sets and the non-normal distribution, a non-parametric test was used to analyze the data collected on earthworms, beetles and spiders. A Kruskal-Wallis test was performed using R for each date of collection, with the agricultural system set as the groups (Conventional, Low-Input, Organic) and the total number of individuals in each hole or trap as the response variable. When this test proved significant ($p<0.05$), a post-hoc test of paired comparisons was run, also in R with the pgirmess package, to see between which systems the significant differences occurred. For statistical purposes, in treating the beetle and spider data, only those species present in at least two plots and with a minimum of three individuals were compared. This choice was made based on a similar study that was carried out on Carabids (Mille, 2011).

3. Results

3.1 Porosity

There was great variability in water infiltration rates between repetitions at each date in all three orchards. However, average rates showed that fastest infiltration was in the Low-Input plot, which had an average of 0.05mm/s across the three dates, while the Conventional and Organic orchards averaged at 0.03mm/s. Looking at monthly averages (Figures 1a, 1b), the Conventional and Low-Input orchards had higher infiltration rates in June (0.03 and 0.07mm/s, respectively), while July (0.02 and 0.04mm/s) and August (0.03 and 0.04mm/s) were lower and almost at the same rate. The Organic orchard, on the other hand, showed a similar though inversed pattern, with an increased yet steady infiltration rate in July (0.04mm/s) and August (0.04mm/s) as compared to June (0.02mm/s).

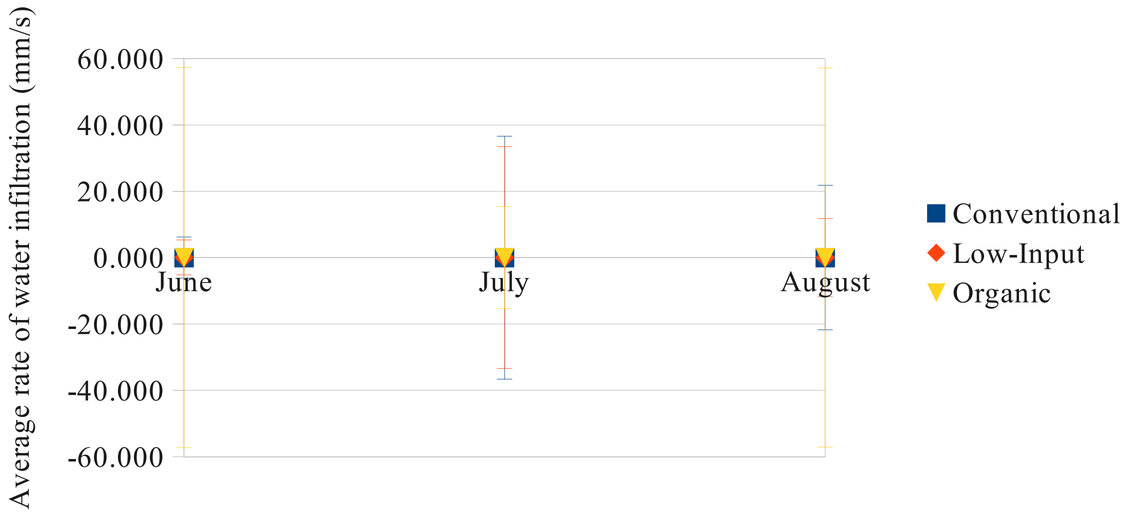

Figure 1a: Water infiltration averages per month for each production method (mean ± standard error)

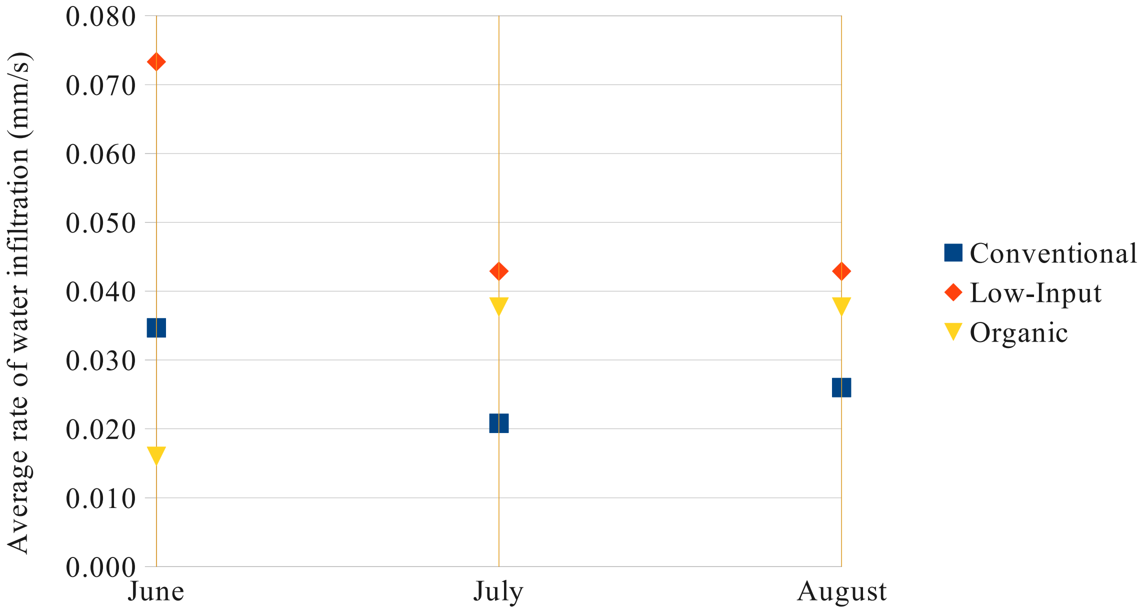

Figure 1b: Water infiltration averages per month for each production method (mean ± standard error)

3.2 Earthworms

Earthworm populations were not not significantly different across the three cultural systems ($p > 0.05$). The Kruskal-Wallis test made evident that there were no significant differences between systems at any of the dates of collection (March: W= 0.57, df = 2, p-value = 0.752, April: W = 2.56, df = 2, p-value = 0.278, and May: W = 5.41, df = 2, p-value = 0.067). At each of the three collection dates a different orchard had the highest average number of earthworms per hole dug (Figure 2), and the number of individuals fluctuated between dates. While the Conventional and Low-Input orchards had the highest average number of individuals in May, there was a constant decrease in the Organic orchard. Total number of earthworms amassed over the three collection dates was highest in the Conventional orchard (Figure 3). No epigeic earthworms were present in any system, while both juvenile and adult endogeics and anecics were present in each. Only juvenile endogeics were more present in the Organic plot, the other three ecological groups had highest numbers of individuals in the Conventional orchard.

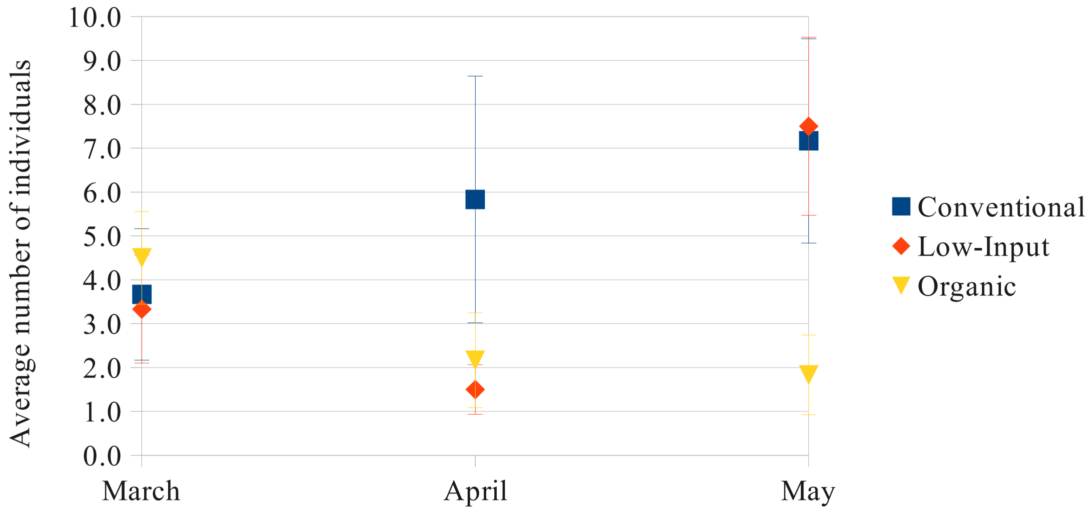

Figure 2: Earthworm averages per month at each site of extraction and for each production system (mean ± standard error)

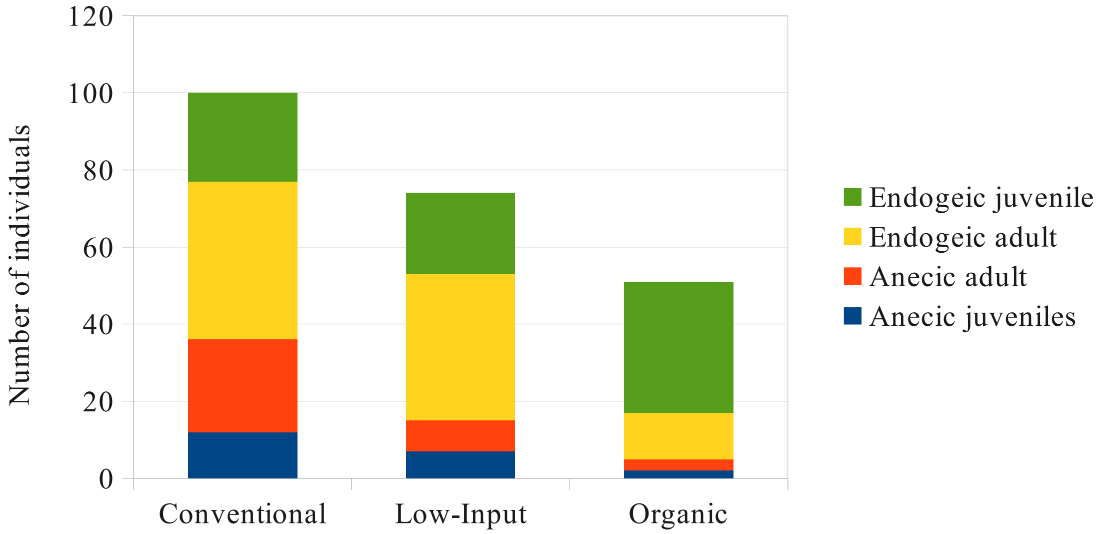

Figure 3: Total earthworms collected and their ecological groups for each production system

3.3 Pitfall traps

3.3.1 Carabids

Carabid beetles were found in greatest numbers in the Conventional orchard (561 individuals) (Figure 4) followed by the Organic (401) and Low-Input (302) plots. These data combine the three collection dates, to give a full picture of Carabid presence over the course of the spring and early summer. The Kruskal-Wallis test made evident that there were no significant differences between systems in May (W = 5.33, df = 2, p-value = 0.069). However, in June and July, differences were significant, (June: W = 9.38, df = 2, p-value = 0.009, and July: W = 6.06, df = 2, p-value = 0.048). The post-hoc test performed for the June results shows that the Conventional and Low-Input orchards, as well as the Low-Input and Organic orchards differed significantly in their beetle populations ($p<0.05$). The same test on the July results indicates significant differences between the Conventional and Organic orchards ($p<0.05$).

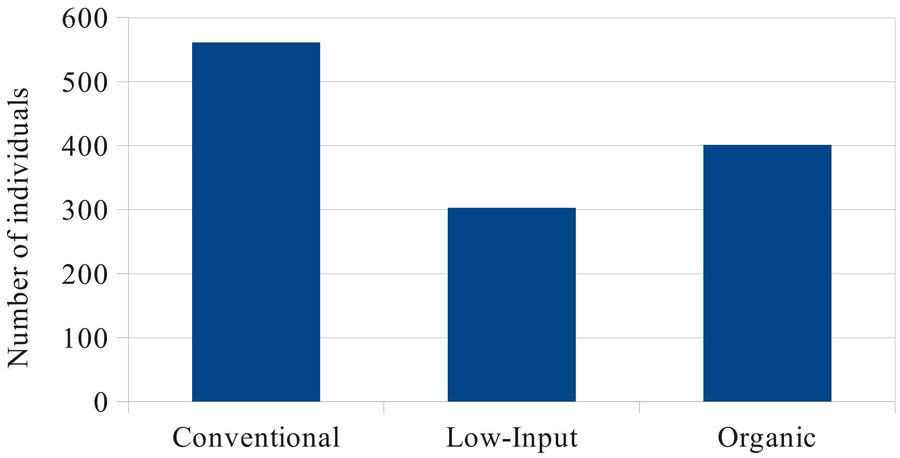

Figure 4: Total number of beetles across dates in each orchard system

The Shannon index, calculated for each orchard, shows that the Low-Input orchard has the highest level of biodiversity as well as this diversity being the most evenly distributed between species found (Conventional: H'=2.23, E= 0.073; Low-Input: H'= 2.41, E=0.78; Organic: H'=2.09, E=0.72). The calculated average number of individuals (Figure 5) found in a trap per month and per system shows that in May and July, the Conventional orchard had the highest average individuals in a pitfall trap (32, 14). However, in June, the Organic orchard has the highest average (64), this month corresponding with highest monthly averages in all systems.

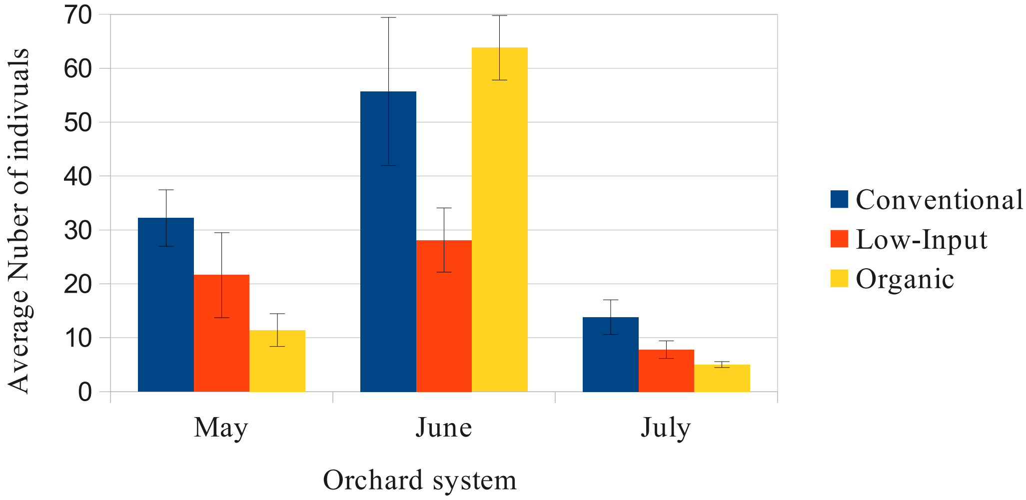

Figure 5: Average beetles in a pitfall trap per month for each production system (mean ± standard error)

In addition to comparing abundance and species richness, the difference in community make-up was also examined in relation to diet. The Organic orchard showed a large difference in predator-omnivore species, with 61% of individuals being predatory species, while only 33% was omnivorous. The Conventional orchard showed a smaller difference in percentage between the two groups, but also had a larger number of predators than omnivores (57% vs. 33%), and similarly for the Low-Input orchard (55% vs. 36%).

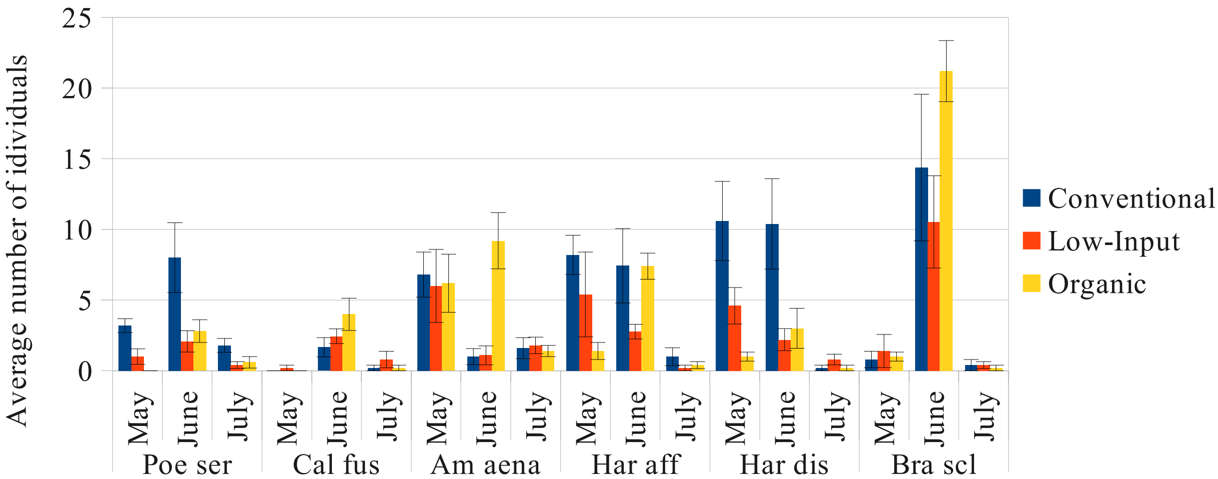

Figure 6: Monthly averages in each system of those species with the highest total individuals (mean ± standard error) Poe ser: Poecilus sericeus, *Cal fus:* Calathus fuscipes, *Am aena:* Amara aena, *Har aff:* Harpalus affinis, *Har dis:* Harpalus distinguendus, *Bra scl:* Brachinus sclopeta

When combining the three dates of capture, the six species that were commonly among the greatest in number of individuals in all orchards were the following (Figure 6): *Poecilus sericeus*, *Calathus fuscipes*, *Amara aena*, *Harpalus affinis*, *Harpalus distinguendus*, and *Brachinus sclopeta*. These species show a clear difference in their peak in population, three species having high numbers of individuals both in May and June (*A. aena*, *H. affinis*, and *H. distinguendus*) and three having the greatest number of individuals clearly in June (*P. sericeus*, *C. fuscipes*, and *B. sclopeta*). It is interesting to note that the three species that occur earlier in the year are omnivorous, while the other three are predatory (Table 2). The distribution of these species among the orchards over the three captures varied considerably, with only two species (*P. sericeus* and *H. affinis*) having consistently the highest number of individuals in the Conventional orchard.

Table 2: Main Carabid species presence in each orchard and their diet

Genus	species	Conventional	Low-Input	Organic	Diet
Anchomenus	dorsalis	constant	constant	constant	Predator
Brachinus	sclopeta	constant	constant	constant	Predator
Calathus	fuscipes	constant	constant	constant	Predator
Poecilus	sericeus	constant	constant	constant	Predator
Amara	aena	constant	constant	constant	Omnivore
Harpalus	affinis	constant	constant	constant	Omnivore
Harpalus	distinguendus	constant	constant	constant	Omnivore
Brachinus	crepitans	secondary	constant	constant	Predator
Metallina	properans	constant	constant	accidental	Predator
Poecilus	cupreus	secondary	constant	constant	Predator
Harpalus	pygmaeus	secondary	constant	constant	Omnivore
Pseudoophonus	rufipes	constant	secondary	constant	Omnivore
Pterostichus	niger	constant	secondary	secondary	Predator
Microlestes		accidental	constant	accidental	Predator
Poecilus	lepidus	constant	secondary	accidental	Predator
Harpalus	smaragdinus	secondary	secondary	not present	Omnivore

3.3.2 Spiders

Ground spiders were most predominant in the Organic orchard, with almost twice as many individuals as in the Conventional orchard (875 and 451, respectively) (Figure 7). The number of families represented was 9 in both the Conventional and Low-Input plots, and 11 in the Organic. The results show that the general make up of spider diversity remains relatively similar in each of the orchards, with Lycosidae and Linyphiidae accounting for over 90% of the total number of individuals. The calculated average number of individuals found in a trap per month and per system (Figure 8) shows that the Organic orchard had by far the highest average in July (113), while in May and June, the Low-Input orchard was very close to the Organic orchard, slightly higher in May and slightly lower in June.

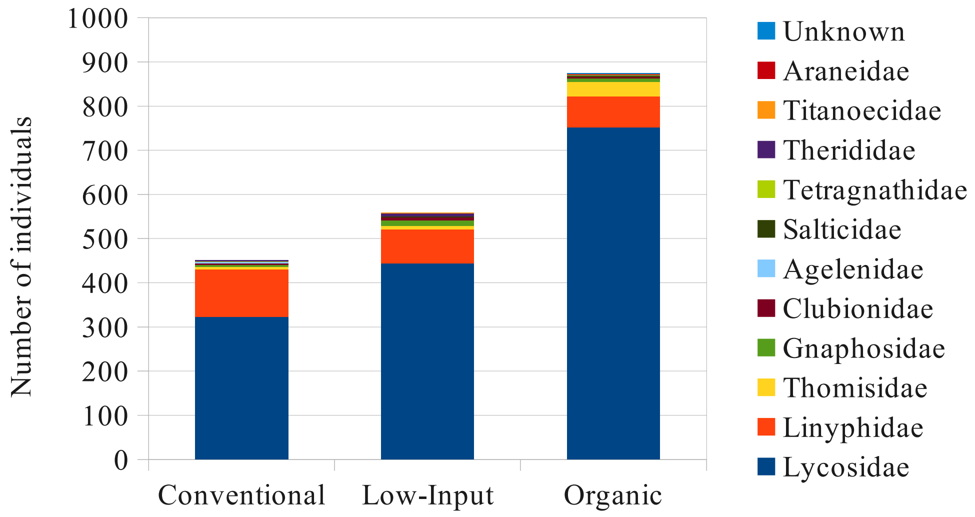

Figure 7: Total spiders collected in each orchard, family determined

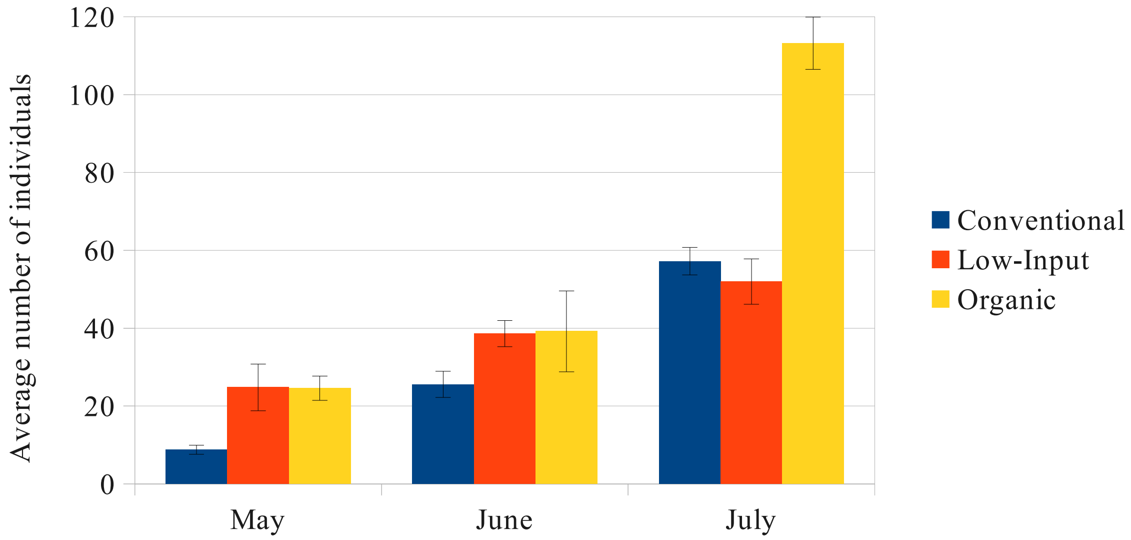

Figure 8: Average spiders in a trap per month for each production system (mean ± standard error)

The Kruskal-Wallis test made evident that there were significant differences in numbers of spiders between systems in May and July, though not June (May: W = 6.92, df = 2, p-value = 0.031, June: W = 3.30, df = 2, p-value = 0.192, July: W = 10.01, df = 2, p-value = 0.007). The post-hoc test shows that in May the the Conventional and Organic orchards differed significantly ($p < 0.05$), whereas in July, significant differences were between the Low-Input and Organic orchards ($p < 0.05$).

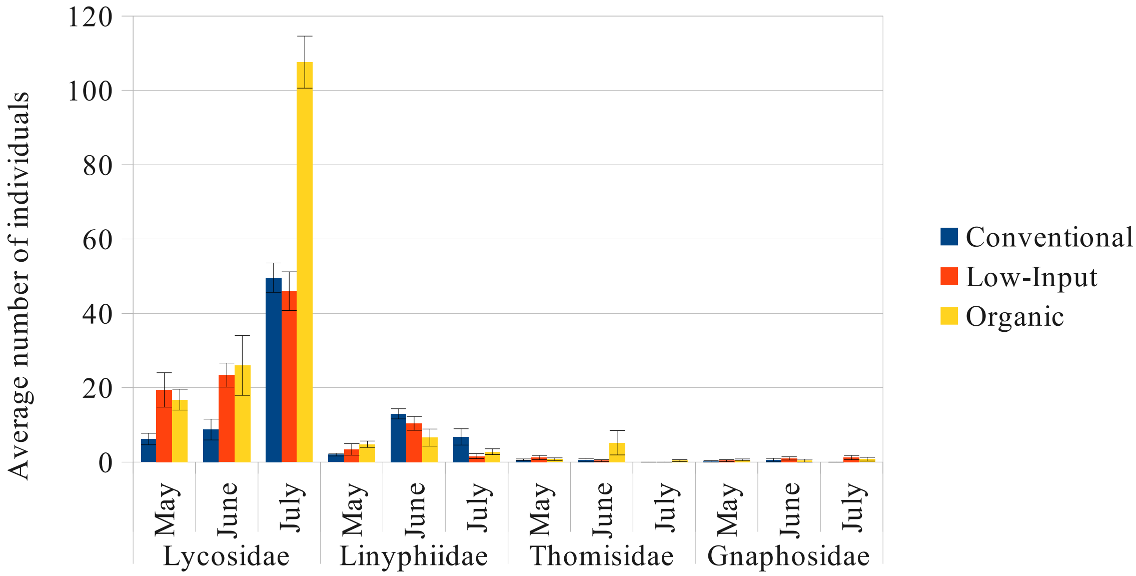

Figure 9: Monthly averages in each system of those families with the highest total individuals (mean ± standard error)

The average number of spiders in each trap varied over the months according to family. The Organic orchard consistently had more Lycosidae individuals than the Conventional orchard (Figure 9), and in July there was also a large difference with the Low-Input orchard. The Linyphiidae show smaller differences between orchard systems, but while in May the Organic orchard had the greatest average number of individuals found in the traps, the Conventional orchard had the highest averages for June and July.

3.4 Pest/Disease observations

The bi-weekly observations of biodiversity showed interesting differences between the orchard systems as well, the data collected being qualitatively descriptive. Simple presence/absence of the main pests and diseases showed slightly greater pressure of Peach Leaf Curl (*Taphrina* *deformans*) in the Organic orchard than in the other two plots, as well as a slightly higher presence of brown aphids in early summer. However, green aphids, which are a vector for Sharka, were seen slightly more in the Conventional orchard, and one tree was even removed due to Sharka leaf symptoms. Oïdium was seen only in the Low-Input orchard at one date.

It was interesting to notice that western flower thrips (*Frankliniella occidentalis*) were present in great numbers in all three orchards during their peak in population. The general threshold for spraying is 25 thrips per 10 trees, and in all three CASDAR orchards the numbers were well over this threshold. The trees were not sprayed despite the elevated populations found since their presence was not considered to be a problem due to the lack of fruit this year.

Canopy arthropod observations indicated the greatest presence in fauna activity in the Organic orchard, both in number of individuals and the variety of species observed. Additionally, within each orchard there appeared to be a positive influence of the northern hedgerow on communities. Each walk was started at the north edge of the orchard and as the distance from the hedge increased, fewer individuals were found. There was also a stark difference in observations after certain operations were performed on the peach trees or on the row vegetation. Just four days after a biocide was applied to the conventional orchard, a small number of individuals were found, and very few types of fauna, mostly large flies. Similarly, an observation carried out immediately after summer pruning showed very little biodiversity in the Low-Input orchard.

4. Discussion

The varied measurements taken over the course of the spring and summer in each of the three agricultural systems showed few overall differences between Conventional, Low-Input, and Organic peach orchards in terms of soil quality. Though the data collected on beetle and spider populations suggest divergence between systems. However, the initial state of the three orchards is generally quite similar. Few differences were expected between the Conventional and Low-Input systems since the two orchards have been conducted similarly for the past two years. It is only from this point onwards that they are expected to evolve separately to a greater extent and to host differing fauna.

The differences explained in this document show that the orchards do not start out with the same arthropod communities. This baseline gathering of information is important to have when future comparisons are made, keeping in mind that eventual differences may have already been present at the outset. However, this information is also important in order to see the evolution of differences between orchards over time. Though some differences are already clear, several factors do not become differentiable until after a certain number of years, especially if they are slow processes, such as the build-up of organic matter. It is also important to keep in mind that, though measured and described as separate aspects of orchard systems, the studied components do not act completely independently of each other. They are part of biological systems with many layers of interaction and representing them without connections is a false image of the complexity that determines abundance and richness of biodiversity.

Higher expectations both for numbers of insects and for species diversity were held for the Organic orchard, where it was thought that the surrounding environment would be supportive habitat for diverse fauna. However, this proved not to be true in every case, particularly since it has fewer hedges and at least one neighboring field likely acts as an insect sink. Moreover, since the orchards have few differences in production practice at this point, the insignificant variation between them was expected. Recolonization after disturbance may take several years; earthworm populations are representative of an orchard after approximately 3 years (Y. Capowiez, personal communication, March 6, 2013), and arthropod populations as well (Parmenter & Macmahon, 1987). It is important to note that the orchards start from a common base for determining possible reasons for divergence at the end of the study.

As stated above, in the first two years, the three systems have each been treated quite similarly. The most apparent difference is in the chemical make-up of the products used, where Conventional and Low-Input orchards are sprayed with synthetic compounds that include harmful adjuvants and the Organic products are made from naturally occurring minerals, though also containing hazardous agents which make them effective. Fertilization and herbicide application is carried out regularly according to a calendar which does not vary greatly from year to year, though is adaptable due to the year's weather and growing conditions. Fungicides and insecticides are applied in two ways. Firstly as part of preventative care, to avoid installation of disease or infestation of a pest, prior to observation in the orchards though at times of probable vulnerability, such as with Peach Leaf Curl. Secondly application is used curatively when deemed necessary after observing pest and disease presence in the orchards. Since the time of planting, in the spring of 2012, the Conventional and Low-Input orchards have been conducted almost exactly the same, with small differences in day of application of a biocide due to time and weather constraints. The Organic orchard is also conducted similarly in terms of the number of applications of biocide other than herbicide. Additionally, in terms of soil compaction due to tractor passages, all three systems are quite similar, since almost all interventions are done with a tractor, including the mechanical weeding.

Despite their classification into three agricultural production methods, technical operations on the trees are performed from the same frame of mind, in part due to the fact that one person is at the head of all three systems. The orchards are not treated as holistic systems, nor are they defined by a philosophy of production system. The main differences in production method stem from treatment products used and the expected growth rates and yields. This is reflected in the calendar of interventions, from which it can be seen that as many applications of insecticide and fungicide were used in the Organic orchard as in the Conventional and Low-Input orchards. Physical operations are also the same in each, and are expected to continue to be so, in terms of pruning, thinning, supporting branches, etc.

The fungicides and insecticides used do differ between the Organic orchard on the one hand, and the Low-Input and Conventional orchards on the other. All three orchards use a combination of mineral, pyrimidine, and triazole fungicides, which vary from no hazardous classification to irritant and dangerous for the environment. However the Conventional and Low-Input orchards also use carbamate, dicarboximide, guanidine, and pyrrole compounds, which are noxious and dangerous to the environment, and even highly toxic in the case of carbamates. The situation is quite similar for insecticides, where all three systems use petroleum based oil, pyridine, and avermectine, which have no toxic rating, though the second two are rated dangerous for the environment. The Organic orchard also uses kaolin clay, Bt, and pyrethrin, which also have no hazard rating, though pyrethrin is labeled toxic to the environment as well. In the Conventional and Low-Input orchards, additional products are pyrethrinoid and neonicotinoid, the first of which is noxious and both of which are dangerous for the environment. Several of these products are harmful for bees and for fish, and many are known or suspected carcinogens and endocrine blockers.

Though the products used in the Conventional and Low-Input orchards tend to be at least slightly more dangerous for human and environment, the Organic orchard is also sprayed with compounds that are harmful. To make up for the less efficient or the lower durability of the products allowed for organic agriculture, some of them are used more frequently than the conventional products. The difference in direct effect on the fauna of the orchards, could therefore be just as harmful in the Organic orchard as in the Conventional or Low-Input orchards.

The length of time that the chemical products are effective is an important difference between the Conventional and Low-Input orchards on the one hand, and the Organic system on the other. Biocides that are labeled for organic arboriculture generally have a shorter period of no-reentry for humans, and have shorter-lasting effects on the targeted pest or disease. It is therefore likely that their effect on other life is also of shorter duration, which implies a faster recolonization after spraying when compared to the products used in conventional agriculture. This difference could account for observing different or more numerous individuals in the Organic orchard when compared with the Conventional and Low-Input plots. However it is not what was seen for this study. The other main difference between systems is the presence of shrubs between trees in the Low-Input and Organic orchards, as described for the experimental site, and the un-mowed strip parallel to the trees in the Organic orchard. These environment factors seem to have played a small role in differentiating one orchard from another, though at this point do not appear to have great effects on the soil properties explored nor on the beetle and spider populations. Each of these is described in greater detail in the following sections.

4.1 Soil properties

There was very little difference in water infiltration rate or in earthworm community between the three systems. This is not surprising, as the soil conditions in the three orchards are quite similar (sandy loam). The past two years have not built up the soil organic matter content enough to show a difference between the Organic orchard and the two others, which might prove to play a role later on in the study. However it is more likely that a difference in plant residues on the surface play a larger role than those that may be incorporated into the soil from the mechanical weeding (Jossi, Zihlmann, Anken, Dorn, & Van der Heijden, 2011). It was not surprising that no epigeic species were found in the tree row. These species tend to spend their life in a plant litter layer (Capowiez, n.d.), which is almost non-existent in the three orchard systems studied. Therefore conclusions as to differences between the systems were drawn only from differences in the two other ecological groups, the endogeic, who live their lives mostly beneath the soil surface, and the anecic, who travel vertically, making the large galleries generally associated with earthworms, and who bring organic material from the soil surface below ground (Capowiez, n.d.). Earthworms were less abundant in the Organic orchard, which may be due to the mechanical weeding in the row that disturbs their habitat. Though it was thought that herbicide would make an unfavorable setting for earthworms, the data showed that, at this point, herbicide is not any more disruptive than the mechanical weeding.

Earthworms were likely disturbed by the mechanical weeding machine, which not only disrupts their habitat but may also physically harm them, cutting them in two. The data from this study show a drop in the number of earthworms in the Organic orchard between March and April (Figure 2), and it was thought that perhaps this could be due to mechanical weeding or another similar operation. But based on the intervention calendar, this appears not to be the case. However, whereas it would be likely to see a direct effect of the mechanical weeding on the earthworm population after a passage by this machine, in 2013 passages were after the earthworm collection, thus the low number of individuals observed is not a direct effect of the disturbed habitat. It is widely known that tillage has a negative effect on earthworm populations, shown in several studies (Jossi et al., 2011; Paoletti et al., 1998; Parveaud, Gomez, Bussi, & Capowiez, 2010b; Reeleder, Miller, Ball Coelho, & Roy, 2006), and the mechanical weeding machine disturbs the soil in a similar way, and therefore likely to have the same effect.

Fungicide and insecticide were applied in all three orchards a few days before collection in almost all cases, and though this may have had a negative effect on earthworm population, also does not account for the drop in numbers between dates. Paoletti et al. (1998) show that copper, in particular has a negative effect on earthworms, and this is a major component of peach fungus control agents. Fertilizer was applied one day prior as well as on the same day as the first earthworm collection in all three orchards, but this does not appear to have a great effect on them, and is not applied with heavy machinery, thus would not contribute to a compaction effect. The higher number of tractor passages in the Organic orchard may influence the earthworm population, as has been discussed in Jossi et al. (2011), though in the case of this project the difference between the orchards is not very great (42 Conventional, 41 Low-Input, 46 Organic). It is possible that weather conditions had an effect on the earthworm populations, but this should be represented equally across all orchards, and the weather remained relatively cool with regular precipitation throughout the experiment months.

The role of earthworms is important twofold, firstly for transforming organic matter, and hence making nutrients available to plants through translocation and decomposition, and secondly for creating macro pores for oxygen and water circulation. The galleries left by earthworms are linked to water infiltration rates, since they provide a path for water to flow, thus higher earthworm activity is associated with better infiltration rates and the both of which indicate better soil conditions, (Jossi et al., 2011; Parveaud, Gomez, Bussi, & Capowiez, 2010a) However, though the Conventional orchard had the most total earthworms, its average water infiltration rate was the lowest of the three orchards. Thus, in the case of these orchards at this point in time, earthworm activity is not an indication of the water infiltration rate. Nevertheless, if earthworm activity can positively affect the infiltration rate, there is potential for the latter to improve in the Organic orchard if the former increases.

The compaction level of the soil could lead to differences in water infiltration rates in the three orchards. Though as described for the earthworms, the similar number of tractor passes in each is not likely to have caused the differences observed. Nevertheless, there may be outstanding compaction of the soil due to the history of each field. The soils do not differ in their structure or texture very greatly, either, though the slight variance in them could contribute to differences observed. The Low-Input orchard is slightly more rocky than either the Organic or Conventional orchards. Though recently acquired by the SEFRA, it is likely that treatments, and therefore tractor passes, occurred at a similar frequency in the Low-Input and Organic orchards, since they were also previously peach orchards.

The initial plan was to associate the earthworm and infiltration rate measurements as has been done in other studies (Parveaud et al., 2010a) since earthworm burrows are passageways for water infiltration (Jossi et al., 2011; Parveaud et al., 2010a). However, due to the weather, it was not possible to run the infiltration experiment as early in the year as the earthworm collection. It was suggested to collect the earthworms starting as early as possible, hence the collection in March, and that May was certainly the latest month in which it was useful. However, had it been possible, in terms of time demand, to continue earthworm collection in the summer months, a comparison with the porosity may have showed greater correlation.

There was great variation between repetitions of the water infiltration test on each date, which could have led to differences in the calculated averages that are shown on the graph. This may account for the opposite trend that is seen in the Organic orchard when compared with the Low-Input and Conventional orchards. This may also be the reason for the faster rate seen in June in the Low-Input Orchard, which is a larger difference between months than in either of the other two orchards. The variation in time between the six repetitions could be due to a number of factors. The most evident being due to human error, in this case defined by the fact that several people were involved and no two have exactly the same application of the protocol despite prior agreement as to implementation of the actions involved. This includes numerous points at which a difference in procedure could skew the data, since the differences are only a matter of seconds, and when to start and stop the timers, or the rate of pouring, all impact the time between iterations. Additionally, the initial set up of the cylinders seemed to be important as well, though flat areas were targeted, they were not always as even as they appeared, and whether the surface was disturbed in order to flatten it or not seemed to make a difference, though this was not done at each repetition or by each person involved. Setting the cylinders firmly in the soil was also not always carried out thoroughly, and at times water would seep out from underneath, necessitating reinforcement of the cylinder after there was water in it. This too may have created a situation that differed from the other repetitions as well as perhaps falsely representing the soil of the orchard.

4.2 Pitfall Trapping

The young age of the orchards is the main reason that the three agricultural systems are quite similar at this point. Deeply ploughing the field and tilling to prepare for planting greatly disturbs the soil as well as ground-dwelling arthropods. The ground cover that was habitat for spiders and ground beetles does not remain a hospitable place after such action. The complete destruction of the prior vegetation leaves a field open to recolonization once the disturbance is over. The species that first come back to an area may be characterized by numerous factors. One main influence is the immediate surrounding, which, since adjacent to the field, provides a source of species. Species that are the primary recolonizers must be able to find food and shelter in the destabilized area, and able to take advantage of the disturbed environment. Species that are more sensitive to change are not likely to be found in a field that has recently been ploughed. (Gobbi & Fontaneto, 2005)

Another change that could lead to differences in the fauna trapped, particularly if directly before placement, is the use of biocides. However, the calendar (Appendix 4) shows that there were no chemical treatments in any of the orchards immediately prior to setting the pitfall traps, though fungicide and insecticide were sprayed in the Conventional and Low-Input orchards during the time the traps were in place for the May collection, and similarly for herbicide during the July collection. However, this does not seem to have effected these orchards negatively, as they still show higher numbers of beetles than the Organic orchard.

4.2.1 Carabids

Carabid beetles provide another insight into the composition of the different orchards. It was expected that more individuals and different species would be found in the Organic orchard compared to the two other plots. However, the Conventional orchard had the highest number of individuals overall, and the highest average for 2 out of 3 collection dates. The paired comparison test supported what was observed, showing a significant difference in June between the Low-Input orchard and the two others, which is reflected in the month's averages (Figure 5) where this orchard's average is quite low. Similarly the same test on July's data reflects the large difference in averages between the Conventional and Organic orchards, while the Low-Input average lies between them. The Shannon index could be an interesting point of departure for discussing differences among the orchards; however the differences between orchards are too small to be meaningful.

Several factors influence the presence of different species and their ability to reproduce. Since beetles are quite mobile insects, the conclusions that can be drawn from the pitfall traps are not specific to tree row management, but to the system as a whole. Even deciding where to delimit the system boundaries becomes complicated when considering these populations. In general, Carabids are considered to travel within a 450m radius (Millan Pena, 2001 in Aviron, Burel, Baudry, & Collet, 2003), thus the surrounding area is quite important to consider when analyzing their presence and behavior. (Garcin, Picault, & Ricard, 2011; Gongalsky & Cividanes, 2008; Ricard et al., 2012)

Species distribution with respect to recolonization and the differences between those who are more or less sensitive to change can be seen in studies that compare Carabid species of agricultural fields compared to field margins, hedges, or natural areas. (Gobbi & Fontaneto, 2005) Species that are more sensitive to disruption are generally found in fewer numbers or not at all in agricultural systems that use herbicides. Aviron et al. (2003) and Gobbi & Fontaneto (2005) showed that communities in different agricultural systems are made up of different species groups. The main division is along trophic lines, between species that are largely omnivorous and those that are more specifically predacious species. They also explain that species who mostly dwell in climacic environments tend to be larger, are generally wingless and less mobile, more predacious, and more sensitive to change in their environment. Often called forest species, they are not generally seen in agricultural fields, though they can be found in hedges. These are not the first to recolonize an area, and were not found in any of the pitfall traps of this paper's study.

The high number of individuals found in the Conventional orchard may be due to the older hedges that form 3 of the field edges, whereas the Organic field is only bordered on 2 sides by a similar hedge. Similarly, the Low-Input field has 2 out of 3 hedges that are only 2 years old, thus providing less shelter and food source for a potential beetle population to overwinter in. As the orchards progress, the species make-up of each may change, particularly if the addition of shrubs to the tree rows contributes to a more forest-like environment. This could attract larger predatory species to the Organic orchard, while the repeated herbicide treatments in the Conventional orchard may repel the same species and prevent them from recolonizing. On the other hand, there could have been some expectation that the Conventional orchard would more likely be re-colonized by larger species before the other two orchards due to the older hedge surroundings on three sides. If these species can be found in the older hedges, they would be more likely to migrate into the closest orchards. The low number of individuals and of species diversity in the Organic orchard may also be attributed to the neighboring alfalfa field which is very attractive to Carabids. It was stated by A. Garcin (personal communication, July 2013) that this most likely acted as a sink for the beetles that might otherwise have been found in the Organic orchard.

The surroundings, including hedges, field margins and row edges, all were likely influences on the beetle population that was captured for this study. This is in addition to the potential differences due to cultivation methods, both of which have been shown to impact beetle population composition (Purtauf et al., 2005). Similar to what was found in the studies by Gobbi & Fontaneto (2005) and Aviron et al. (2003), the main species that were found in each of the orchards are small, omnivorous, and winged, who take advantage of the disturbed environment. The genera *Harpalus* and *Amara*, fit this category, and were among those most represented in the pitfall traps in each of the orchards and in each of the traps. These omnivores account for 3 of the 6 species most present in the three orchards (Figure 6), while the other 3 species (*Poecilus sericeus*, *Calathus fuscipes*, and *Brachinus sclopeta*) are considered predators, potentially playing a more significant role in biological control. Additionally, A. Garcin (personal communication, July 2013) reported that *Brachinus sclopeta* is thought to prey on *Amara aena*, two of the species most found in the traps of this study. He stated that they are often found in high numbers together, which is in line with the data reported here, though the peak in *A. aena* appears to be in May while the *B. sclopeta* population is highest in June. However, this may be due to their respective reproduction cycles. The difference in diet is the main reason for which it was deemed of necessary import to identify the beetles found to the species level.

It is known that Carabids play a large role in control of pests both in orchard systems and in arable cropping, particularly as predators of gastropods (not a large concern for the orchards under study) and of aphids (Garcin et al., 2011). Their role in aphid control is of particular interest, as it is one of the major pests of peach trees affecting their growth and is also a vector for diseases. Though the exact diet of most species is not known, or at which period of life Carabids are more carnivorous or phytophagus, several are known to feed on aphids, lepidoptera, diptera, and hymenoptera.(Garcin et al., 2011; Ricard et al., 2012) Of particular interest for peach trees are those that feed on lepidoptera larvae, such as *Calathus fuscipes*, another one of the six most represented species (Figure 6), which can help to control infestation pressure from the oriental peach moth (*Grapholita molesta*). This, with aphids, is a major cause of disturbance in peach production. Most species also feed on aphids, certainly those that fall on the ground, though some species, such as *Anchomenus dorsalis* is attracted to the aphid's miellat and can climb trees in order to reach their prey. (Garcin et al., 2011) Though the number of individuals varied in each of the three orchards, it is interesting to note that these species were present in all cultivation systems, and were constant species in each (Table 2). In none of the orchard systems were they the only constant species, nor were they represented in greatest number. However, it is difficult to extract precise knowledge on the role of each species in predator-prey dynamics for each orchard system. Their presence in the orchards and their potential role in pest suppression are supported in literature (Garcin et al., 2004, 2011; Ricard et al., 2012).

An interesting difference to explore is the percentage of predatory versus omnivorous species found in the three orchards. The higher ratio of predatory to omnivorous beetles in the Organic orchard shows that the environment provides a good source of prey, despite the attraction of the nearby alfalfa field. The presence of predator species suggests that biological control is active in the Organic orchard. The slightly lower ratio of predatory/omnivorous Carabids in the Conventional orchard where chemical phytosanitary products account for elimination of potential prey indicates a limited attraction of predatory beetles who might otherwise feed on peach tree pests.

Another factor influencing the ground beetle population, and explaining the low findings in the Low-Input orchard is the underground irrigation system in this field. The Conventional and Organic orchards have above ground micro-jet aspersion irrigation, which creates a nicely humid micro-climate that suits Carabids. The underground irrigation leaves the surface of the soil dry especially in combination with the lack of vegetation cover due to chemical weeding, the both of which make for a less inviting condition for beetle life (Ricard et al., 2012).

4.2.2 Spiders

It is interesting to note that the Organic orchard, while low in numbers and species of beetles, hosts a larger number and variety of spiders. This is the opposite case for the Conventional orchard, where beetles were more abundant and spiders less so. The paired comparison test on total numbers of spiders in each trap on a given date showed significant differences in May between the Organic and Conventional orchard, which is also what is seen in the average (Figure 8). This holds true for July, where the test showed that the Organic and Low-Input orchards differed significantly, reflected in the averages as well. Ground spiders, similar to Carabid beetles play an important role as predators of other arthropods in an orchard system. Often habitats that favor spiders are not those that are best suited for Carabids and vice versa (Ricard et al., 2012). However, they can and do inhabit the same orchard systems, which is not surprising given the diversity of micro-climates present even in a small space. The diversity of spider families found was in line with what literature suggests for similar orchard systems (Schmidt et al., 2005). The two most represented in number of individuals are the Lycosidae, or Wolf spiders, and Linyphiidae, ballooning or sheetweb spiders (Figure 7). These two groups are important predators in agroecosystems, are often among the most found in orchard systems, and are common in the Rhône-Alpes region (S. Simon, personal communication, April 11, 2013). All spiders play a role in pest suppression since they are predators, and certain elements of their diet are pests of peach trees.

Ground spiders vary in their methods of hunting prey and in their living spaces. The Lycosidae do not make webs but hunt their prey on the ground, and being larger in size, tend to feed on larger prey. (Roberts & Leraut, 2010) They prefer to have plant detritus for overwintering, and prefer having perennial plant cover for habitat, rather than annual cropping systems that disturb available prey. Since they do not make webs, they are quite mobile, needing to move to chase and capture their prey. However, they are not necessarily among the first species to recolonize an area after disturbance because of their preference for cover. (Schmidt-Entling & Döbeli, 2009) Linyphiidae, on the other hand, are small species, who feed primarily on Collembola, though they are considered to be generalist predators. However, several studies show that they contribute considerably to aphid control (Chapman, Schmidt, Welch, & Harwood, 2013; Opatovsky, Chapman, Weintraub, Lubin, & Harwood, 2012; Schmidt-Entling & Döbeli, 2009) and are of particular interest early in the season, feeding on aphids when they first appear, which is the best way of minimizing population outbreaks in agricultural systems (Chapman et al., 2013). Thus, these two families are of significant importance for agroecosystem services, and their presence in all three orchard systems speaks to a good balance in predator-prey dynamics. The Organic orchard consistently had more Lycosidae individuals than the Conventional orchard (Figure 9), and in July there was also a large difference with the Low-Input orchard. This suggests that they find the Organic orchard a hospitable place, perhaps thanks to the additional cover provided by the un-mowed and un-weeded strip along the tree row, similar to the habitat provided by flower strips in the study by Schmidt-Entling & Döbeli (2009). The Linyphiidae were more present in the Organic orchard in May, but in June and July the Conventional Orchard had the highest number of individuals. Perhaps this is linked to the presence of Collembola, though these were not counted in the present study, having been put in the 'other' container at the time of initial trap sorting. On the other hand, aphid presence became noticeable at the beginning of May during the observation walks, particularly in the Conventional and Low-Input orchards, whereas their presence was not particularly noticed in the Organic orchard. A higher presence of Linyphiidae in the Organic orchard at this point may have helped to avoid an infestation which would have otherwise been more pronounced.

It was interesting to notice that Lycosidae eggs must have hatched a short time before the second collection date, since numerous very young Lycosidae were found in several of the traps. This coincided with an increase in the aphid populations that were found in the orchard systems as well. Though this does not necessarily imply that the spider life cycle is in synchrony with that of aphids, it does suggest that their cycle follows probable food sources, of which aphids are one.

The difficulty in identifying spider genera limits the information that can be gleaned from the data collected. Identification only at the family level allows for only very general knowledge, much less detailed than the Carabid species identification permits. The Shannon indices calculated for the spider families in each orchard evidently show a low level of diversity, but again, this is to be expected at the family level given the limited number of families in general. The Equitability index showed a rather large difference between the Organic orchard and the two others. The spider families in the Organic orchard being very disproportionately represented, even more so than in the Conventional and Low-Input orchards, though all of them had many more individuals of the Lycosidae than other families.

4.4 Canopy fauna

The differences in canopy findings described in the results were noticeably different across dates. The decreased sighting of canopy fauna after spraying for aphids and after herbicide application were a serious indication that these chemicals do affect insect life, even those that are not targeted by the specific product, particularly in the case of herbicides. However, it is logical that even if not directly harmed by the chemical product, if vegetation is lacking for an individual to rest in or where it might find a food source, it will most likely migrate elsewhere (Ricard et al., 2012). It has been seen in other studies that orchards that maintain a diversity of plant life in and near the tree rows have more insect activity than in those without, whether or not they are conventionally or organically cultivated (Garcin et al., 2004).

Additionally, tree row maintenance may play a significant role in arthropod life. As seen with the earthworm data, mechanical weeding can be disruptive just as much as herbicides. However, a positive aspect of the mechanical weeding is that, due to the tool used, the area disturbed (50cm strip) is less than the area covered by the herbicide (1m strip). This means that there is a 50cm strip parallel to the tree row that is neither turned over nor mowed in the Organic orchard, whereas the entire 1m strip is weeded chemically in both the Conventional and Low-Input orchards. This flower strip appeared to be an important space for general arthropod life, particularly since several species were observed in this area during the zigzag walks through the orchards. Flowering plants attracted numerous wild bees, complementing the attraction provided by the lavender planted in between certain peach trees. The flower strip was also visited by several butterflies of different species, which were not found in the Conventional or Low-Input orchards. This suggests that, though the mechanical weeding may negatively affect soil life, it is only in a reduced area, while the remaining surface has a positive effect on above ground biodiversity.

Moreover, physical operations performed on the trees also have a direct influence on wildlife found amongst the branches. This was evident during summer pruning, when observations were carried out both just before and immediately following. The removal of a large number of branches in each tree left the orchard with a low diversity of canopy inhabitants. The direct and sudden decline in leaf coverage resulted in fauna moving elsewhere, not in a concentration of them on the remaining branches. This operation, however, does not distinguish the three orchard systems from each other. It is common practice for producers to perform summer pruning under any cultivation method, be it conventional, low-input, or organic. That said, it would be interesting to see if there is a different effect of such action, related to the resilience of each system to react to a drastic removal of habitat for insect life. An orchard system having other areas that provide refuge, such as flower strips, well-developed hedges or other shrubs, may see a quicker re-installation or a smaller decrease in biodiversity than one without alternative spaces for such life to take shelter in (Diekotter, Wamser, Wolters, & Birkhofer, 2010; Le Roux et al., 2008; Ricard et al., 2012). As stated above, it was clear that the addition of shrubs in between peach trees led to an increase in the overall findings of fauna in the Low-Input and Organic orchards, where many insects were found visiting them. It is assumed that this has an impact on the potential for these fields to maintain a higher level of functional as well as general biodiversity.

4.5 Pest and Disease Challenges

None of the orchards had severe attacks of any pest or disease this year, so differences in the observations of the major pests and diseases of peach trees were minimal. The interventions regularly performed likely played a role in preventing and controlling outbreaks of those that were observed, such as Peach Leaf Curl, aphids, and Oïdium. This is true for each of the orchards, though the chemical composition of the products used is evidently not the same for the Organic orchard as the Conventional and Low-Input orchards. Nevertheless, it would be misleading to assume that the Organic orchard had fewer interventions than the others (see Appendix 3 & 4), or that these products have no negative effects on biodiversity. That said, it is difficult to control fungal attacks through increased wildlife, no link between Peach Leaf Curl and biodiversity was found in literature. There was some concern from the peach referent (Y. Montrognon, personal communication, May 2013) that aphid pressure would be higher in the Organic orchard even with the possibility to use certified organic chemical control. However, there were no more aphid colonies found in the Organic orchard than in the Conventional or Low-Input, which suggests that there is some assistance in control from beneficial insects or other environmental factors.

Due to the history of disease problems in the Rhône valley, producers are certainly concerned with outbreaks of Sharka or bacterial canker. Sharka is a serious concern for fruit growers due to a devastating epidemic around 20 years ago that decimated peach orchards, and was the cause of a program to eliminate the virus that forced the removal of vast numbers of trees. There was a 15 year ban on replanting in orchards that had been contaminated, and only recently have people in the hardest hit area begun to replant. The virus is an ongoing problem and there is continued surveillance of a maximum of all stone fruit orchards to remove any diseased trees. Sharka is a virus that does not kill the affected tree but leaves the fruit in an unsellable condition. The control agency in the Drôme and more generally in the Rhône-Alpes, the FREDON (Fédération REgionale de Défense contre les Organismes Nuisibles), sees to prospection in orchards and requires removal of diseased trees and even the entire orchard if there are more than 5% of trees contaminated. There is no treatment against the disease, so all producers are equally concerned, be they conventional, organic, or other. Thus, if green aphids are the main vector for the disease, any additional method to lower their populations could be beneficial for all producers, including hosting predatory fauna by providing habitat.(FREDON-RA, 2011)

4.6 Future recommendations

4.6.1 Insect measurement considerations

At the project scale, several points that were brought up during this study should be kept in mind over the course of the long term project. It will be interesting to see whether changes in biodiversity are seen across all orchards, or will be specific to each growing environment. This holds true for the orchard systems as a whole, as well as for what is found at a particular trapping site on a specific day. Since what was expected to be found in several of the measurements made was not what was seen, several questions remain. For one, it will be interesting to see if the earthworm population increases in the Organic orchard despite the mechanical weeding, or if this is too disruptive to their habitat to support their reproduction and survival. Similarly, particularly with respect to the Carabid population, it would be desirable to start trapping earlier in the year and to collect continuously each week, following through until mid-September, to account for both main reproduction cycles of Carabids.

For a fuller picture of biodiversity in the orchards and how different arthropod groups interact, traps set in the tree canopy would be useful, such as corrugated cardboard band traps around branches. Traps in the tree branches are a particularly good method for catching canopy spiders, though it was mentioned that they also become easily infested with earwigs (C. E. Parveaud, personal communication, March 6, 2013). A more detailed study of the canopy, though, would perhaps provide a clearer link between beneficial insects and pest populations, especially as the trees age and come into fruit production. Another method for trapping a greater range of life forms found in the canopy is using beating sheets or funnels in combination with jars. These allow for a similar harvest of biodiversity from the canopy as the pitfall traps placed in the ground. As with the pitfall traps, it may be necessary to limit identification to a selected set of arthropods, as the number of individuals collected can be exponential, and therefore quite time consuming (S. Simon, personal communication, April 11, 2013).

4.6.2 Communication and outreach

Stepping back from study measurements, questions arise as to how this project fits into a larger scale picture of peach production and even the global agricultural matrix. It is important that this project can position itself among present day agricultural research and its import for promoting agroecological cultivation. This includes communicating with other bodies that are involved in similar projects and fostering communication efforts at a local level, as well as connecting internationally. The knowledge gained for this specific region and culture can be applied to other situations, and help to promote alternative practices in fruit growing worldwide. Change in cultivation techniques can stem from consumer demand as well as from growers interest, and ideally from collaboration between different groups.

The vast majority of fruit growers in the Rhône-Alpes use conventional methods, particularly in peaches, which demand a lot of care and pose several challenges even for conventional growers (Y. Montrognon, personal communication, February 2013). Though the Drôme department is one of the leaders in organic production within France, organic fruit production remains behind the average. The department is showing interest at a political level to support the further development of organic production, and the CASDAR project is a part of this, along with the Agricultural Chamber who has recently become involved in a large collaborative project covering 20 hectares, the TAB (Techniques Alternatives et Biologiques) platform. Two of the three orchards, the Low-Input and Organic, of the CASDAR project are part of this area, which are for experimentation of numerous crops through organic and other alternative cultivation techniques. Supporting studies that can compare and test alternative practices are an important way of promoting change and reaching national goals to limit agricultural inputs and increase organic production.

Though the SEFRA remains an experimental farm that is somewhat isolated, it has an important role in communication to local producers. The main focus of their research is as much for phytochemical companies and hybridizer nurseries, as it is for the much larger group of fruit growers in the region. It is necessary that the studies carried out on all aspects of arboriculture be communicated to this public, particularly about production methods that may not have been previously explored. Producers are able to come to the SEFRA for weekly visits through the orchards led by the technicians to discuss the varietal trials that are carried out. During these walks there could be time to view and elaborate on the CASDAR project, of which the alternative growing methods could interest producers who might not otherwise seriously consider organic or low-input systems. This could spark their interest in observing and sustaining biodiversity in their own orchards and may foster awareness that could lead to changing certain elements of their current production methods. Given the current attitude of peach growers in the region, it is important for the SEFRA to be a source of information on the possibility of changing habits, and to communicate its research findings. As an organization that does not depend solely on selling fruit for economic survival, the SEFRA is able to take certain risks in experimentation and allocate funds in ways that private producers cannot permit themselves.

Despite an overriding interest in yield levels and economic survival, most fruit growers know and agree that the use of phytosanitary chemicals is not ideal, and mention wanting to decrease their use, though fearful of losing production.(Herzog et al., 2012) Regardless of the potential costs of such a study, the time demand makes it unlikely that a fruit grower would take measurements of arthropod life, though simple observations such as the zigzag walks or one earthworm collection is a possibility. Carabid and spider trapping are much too time consuming for a producer who is only marginally interested, as the identification process not only requires significant training but also the necessary materials. However, if interest can be sparked through captivating information channels, this is already a step in a positive direction. Workshops could be held to share what was found in this or similar studies, including a closer look at arthropods for those who are interested, or involvement through collection of samples at different sites. Other options for enhanced communication and learning could be to organize visits to orchards that use organic and alternate methods, both in the Drôme and in other peach growing regions. This could be done in cooperation with the SEFRA and with producer association groups, for example through AOP-Pêches et Nectarines (Association of Producer Organizations- Peaches and Nectarines).

4.7 Limitations

It is important to emphasize that the work of this study is exploratory, the aim was to have an understanding of the current state of biodiversity in each of the three orchards, particularly with respect to its influence on soil dynamics and pest predation. There were few expectations at the beginning of the work as to what would be found in the different systems. It was also unclear as to whether the methods chosen were the best for demonstrating the potential differences due to cultural techniques. With this in mind, considerable time was spent deliberating which methods to use and discussions with experts led to the choices made, along with the decision to cooperate with another study on the same site. Since the work commenced with a considerable limit in prior knowledge about arthropod communities, much was learned throughout the course of the study. However, this also results in an interpretation that may be limited as well. Additionally, therefore, the data do not lead to conclusions that can been seen in similar types of studies due to the continued development of understanding and amelioration of the proceedings over the course of this study. In hindsight, certain aspects of the protocol would perhaps have been changed, and will be in the future, in order to better cull information about the arthropod communities in the three orchards, allowing for meaningful comparison between them. The expectations at the start of this year's project were not to show large differences between systems, but rather to see if differences existed already and to describe the current state. Though the people at the head of the study at the SEFRA have a very solid base in knowledge about peach trees, general ecology is a new interest, and the development of this project is the starting point for exploring biodiversity of peach orchards and the many actors involved.

Other limits to the study carried out this year include the unusual weather patterns, though this is likely to be true at future points as well, since climate patterns are changing, and generally no one year is the same as the next. However, the spring had significantly higher precipitation than is usual for the region, and temperatures were lower during April and May, in particular. This led to delays in the development of fruit trees throughout the area, and therefore limited growth. In general, compared to production norms, there was a ten day to two-week lag in development at each stage. The weather affects the stages of insect cycles as well as plants, delaying emergence dates and reproduction. Thus, it is possible that some of the low numbers in individuals that were observed were also due to these climatic factors. A small change in weather patterns can have a large effect on insect populations, shifting the plants and animals they also depend on for survival, and potentially limiting food and shelter resources (Ricard et al., 2012). In addition to the increased precipitation, a large hail storm took a toll on parts of the SEFRA, though the orchards in this study were minimally damaged, having no fruit on the branches made the trees less vulnerable to breaking. However, the increased incidence of hail storms in the summer leads to concern for future years and adds another challenge to the already complex matrix of interactions. Damage from hail leads to increased likelihood of disease at the entry points left from the hailstones, as well as the simple markings leaving the fruit in an unsellable condition aesthetically. Additionally, affected fruit does not keep as long in cold storage, so the fruit must be sold immediately, if it passes inspection, or it will begin to rot.

Despite the limitations of the study described, the data collected are of certain value for the SEFRA and for the CASDAR project. Another round of measurement using the same protocols in 3-5 years will show different results and it will be interesting to see what emerges through comparison of the three orchard systems. However, though considering the lack of prior experience of those involved in this study, the protocols were followed without mishap and small adjustments were made over the three months. One drawback was not having continuous data throughout the growing season, thus limiting the extensiveness of the survey.

5. Conclusions

Which agricultural methods sustain biodiversity the best remains a complex question. The implications of this study are only a small piece of the Low-Input CASDAR project which will continue for the next 13 years. The data collected serve as a basis for comparing initial state biodiversity with what will be found at different points along the 15 year study. The experiments performed this year are to be repeated every 3-5 years to evaluate the evolution of biodiversity and its correlation with pests and diseases in each orchard as they grow on separate paths. The diversity of wildlife that was found in the orchards of the SEFRA appears to be typical of orchard systems in the Rhône-Alpes region of France, and is similar to other European orchards as well. The young age of the orchards makes comparison between the cultivation techniques difficult to extract from other confounding factors, but it is important to identify them at this point for consideration at future moments of observation. At two years into the study, differences in biodiversity findings between agricultural systems cannot be attributed to the cultural techniques alone, though what was observed is likely to be influenced by them. The divergence in cultivation methods over the next years will show if the differences in biodiversity populations found this year are increased.

Fruit growers may be interested by aspects of this study that could easily be instated in existing orchards as well as in new plantings, such as the addition of shrubs or other flowering plants in the tree rows. Maintaining low-growing shrubs does not add hours of extra work, and will not interfere with production needs of the peach trees, such as sunlight or water. This diversifying of the landscape could help to avoid pest problems if they continue to prove to be hosts of beneficial insects and therefore of use in biological control. The need for more proof that such simple actions can benefit farmers' needs along with the environment calls for studies such as this one. Interest at several levels is important to support such work, from the growers themselves to the policy makers writing up the Agro-Environmental Measures of the CAP.

The contemporary overriding method for fruit production remains highly dependent on several phytosanitary chemicals that components of which remain in the soil long after the desired effects have faded, or that percolate into waterways polluting natural areas and contaminating drinking water. There is a great need to change the direction of a large portion of agricultural systems, certainly including fruit production and peaches in particular, which have a high intervention rating. The societal demand for high yielding varieties that produce large fruit with high sugar levels and that can last long in storage (Buffat, personal communication, August 1, 2013) push the production methods that cause the most environmental damage.

The CASDAR Faibles-Intrants project is a small but important step in changing this trend and making agriculture more conscious of the environmental and human health costs it induces. The findings must be communicated to the practitioners along the course of the study, for it is the fruit growers who are most directly linked to the effects on biodiversity seen in their fields and the natural areas surrounding them.

This long term study fits into a greater scheme of attempting to move agriculture in a more ecological direction. It is a model that will be able to show what alternative practices can achieve, an important concrete example for producers, and should include their input as well. It follows similar studies that have been carried out in other parts of the world, and on other cultivated crops. Peaches are only a very small part of the world's agricultural production, but they are emblematic of the challenges that contemporary farmers face. They also are a good example of conflicting demands from consumers to have healthier products without necessarily understanding the issues at stake. Though the phytochemicals used are of serious threat to human health, particularly those who use them on a regular basis, there is a general ignorance of their considerable carcinogenic and hormonally disruptive effects. Many consumers are not currently willing to pay for today's hidden costs of production, which include the health-care needs of those affected, and the incredible environmental destruction from manufacturing and applying them. There is a real need to foster awareness of agricultural practices and their impacts on humans and the environment. This kind of study helps to reinforce that other options for cultivation exist which are socially and economically viable, on top of being less ecologically destructive.

The study described here is one of many that compare agricultural production methods, with an outcome that ideally provides options other than conventional methods and that shows the benefits of exploring possibilities. There is much to be learned from observing interactions between crops and their environment which could potentially lead to better solutions for current cultivation challenges. Only through long term studies is this possible, since emergent properties of orchard systems are not immediately visible. Multiple complex interactions lead to the eventual outcomes that determine the health of the numerous system components. The long term nature of this study also allows for communication with other similar projects, leaving time for exchange and therefore adaptation based on knowledge from other people and places.

Making informed choices is an integral part of improving the world's agriculture. All parties involved need to be aware of the impacts farming has not only on farmers but the entire biosphere. Agriculture is deeply embedded in contemporary human life, depending on what has become a global marketplace that is often an unequal meeting of parties. Economic viability is hard to achieve for farmers, who are often outside of the social networks in which their crops circulate. Many consumers lack a connection to what they find on their plate though their health and well-being are concerned, and their physical surroundings impacted by agricultural inputs upstream. Governments and institutions along with private individuals and public interest groups all must be involved in working to make agriculture, and for the case of this study, peach orchards, more integrated with the environment and all its components.

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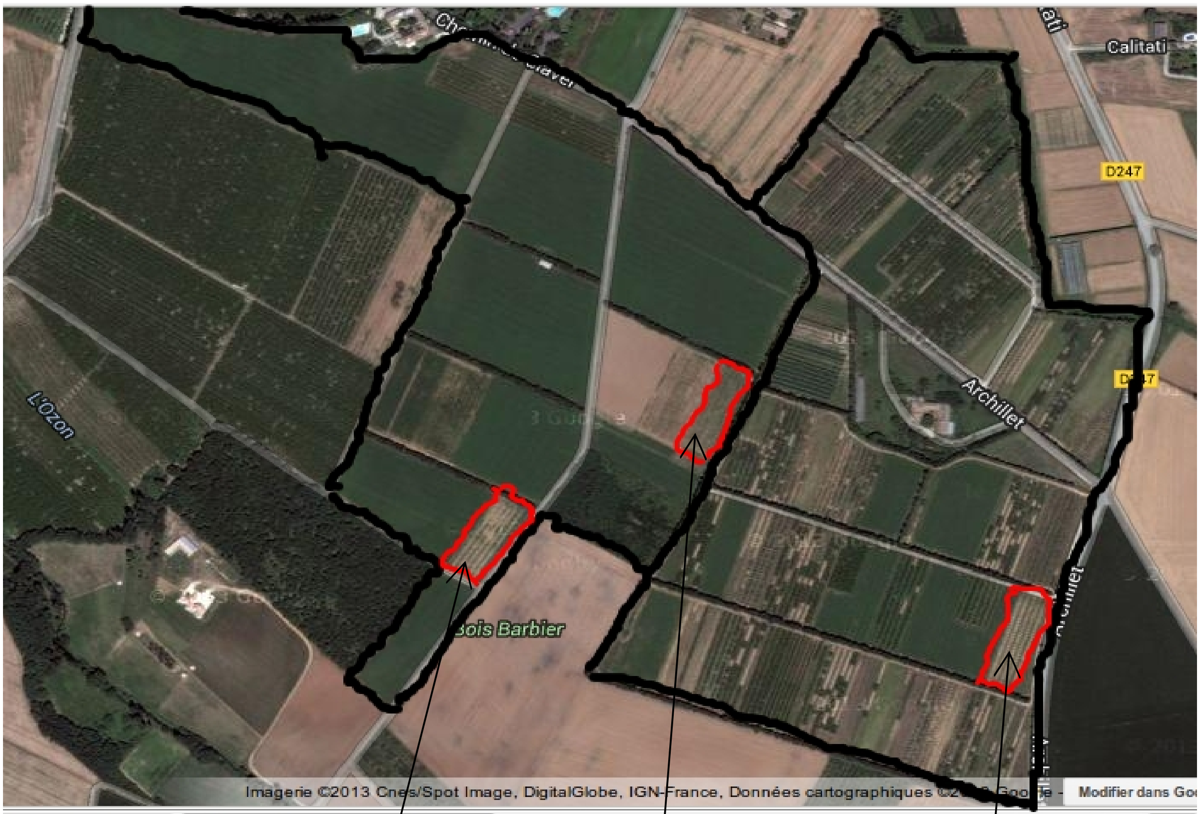
Appendix 1: View of orchards



(Google Maps Etoile-sur-Rhone [Web Map]. Retrieved from https://maps.google.fr/maps?hl=fr&tab=wl)

Low-Input

Organic

Conventional

Appendix 2: Orchard layout

Orchard layout Nectardream Conventional **North** **20 yr Hedge**

6m between rows, 3.5m between trees

	Row 5	Row 4		Row 3		Row 2	Row 1	
	Peach 1	Peach 1		Peach 1		Peach 1	Peach 1	
	Peach 2	Peach 2		Peach 2		Peach 2	Peach 2	
	Peach 3	Peach 3		Peach 3		Peach 3	Peach 3	
		Infiltration 1		Earthworms 1				
	Peach 4	Peach 4		Peach 4		Peach 4	Peach 4	
				Earthworms 2				
	Peach 5	Peach 5		Peach 5		Peach 5	Peach 5	
		Infiltration 2		earthworms3	Infiltration 1			
	Peach 6	Peach 6		Peach 6		Peach 6	Peach 6	
		Infiltration 3		Earthworms 1				
	Peach 7	Peach 7		Peach 7		Peach 7	Peach 7	
				Earthworms 2	Infiltration 2			20 yr Hedge
	Peach 8	Peach 8		Peach 8		Peach 8	Peach 8	
		Infiltration 1		Earthworms 3	Infiltration 3			
	Peach 9	Peach 9		Peach 9		Peach 9	Peach 9	
Barley				Earthworms 1				
	Peach 10	Peach 10		Peach 10		Peach 10	Peach 10	
		Infiltration 2		Earthworms 2				
	Peach 11	Peach 11		Peach 11		Peach 11	Peach 11	
		Infiltration 3		Earthworms 3	Pitfall Trap 1			
	Peach 12	Peach 12		Peach 12		Peach 12	Peach 12	
		Infiltration 1		Earthworms 1				
	Peach 13	Peach 13		Peach 13		Peach 13	Peach 13	
			Pitfall Trap 5	Earthworms 2	Infiltration 1			
	Peach 14	Peach 14		Peach 14		Peach 14	Peach 14	
		Infiltration 2		Earthworms 3				
	Peach 15	Peach 15		Peach 15		Peach 15	Peach 15	
		Infiltration 3			Pitfall Trap 2			
	Peach 16	Peach 16		Peach 16		Peach 16	Peach 16	
				Earthworms 1	Infiltration 2			
	Peach 17	Peach 17		Peach 17		Peach 17	Peach 17	
			Pitfall Trap 4	Earthworms 2				
	Peach 18	Peach 18		Peach 18		Peach 18	Peach 18	
		Infiltration 1		Earthworms 3	Infiltration 3			
	Peach 19	Peach 19		Peach 19		Peach 19	Peach 19	
		Infiltration 2		Earthworms 1	Pitfall Trap 3			
	Peach 20	Peach 20		Peach 20		Peach 20	Peach 20	
		Infiltration 3		Earthworms 2				
	Peach 21	Peach 21		Peach 21		Peach 21	Peach 21	
				Earthworms 3				
	Peach 22	Peach 22		Peach 22		Peach 22	Peach 22	
	Peach 23	Peach 23		Peach 23		Peach 23	Peach 23	
	Peach 24	Peach 24		Peach 24		Peach 24	Peach 24	
	Peach 25	Peach 25		Peach 25		Peach 25	Peach 25	
	Peach 26	Peach 26		Peach 26		Peach 26	Peach 26	
	Peach 27	Peach 27		Peach 27		Peach 27	Peach 27	
	Peach 28	Peach 28		Peach 28		Peach 28	Peach 28	
	Peach 29	Peach 29		Peach 29		Peach 29	Peach 29	
	Peach 30	Peach 30		Peach 30		Peach 30	Peach 30	

South **20 yr Hedge**

Orchard layout Nectardream TAB – Low-Input

North **20 yr Hedge**

6m between rows, 3m between trees

	Row 5	Row 4		Row 3		Row 2	Row 1	
	Peach 1	Peach 1		Peach 1		Peach 1	Peach 1	
				Spirea X Vanhouttei				
	Peach 2	Peach 2		Peach 2		Peach 2	Peach 2	
	Taxus bacata						Eleagnus ebbengei	
	Peach 3	Peach 3		Peach 3		Peach 3	Peach 3	
		Infiltration 1		Infiltration 1		Rhus Cotinus		
	Peach 4	Peach 4		Peach 4		Peach 4	Peach 4	
		Infiltration 2		Infiltration 2				
	Peach 5	Peach 5		Peach 5		Peach 5	Peach 5	
		Kerria japonica		Earthworms 1		Earthworms 1		
	Peach 6	Peach 6		Peach 6		Peach 6	Peach 6	
				Earthworms 2/ infiltration 3		Lavendula x intermedia		
	Peach 7	Peach 7		Peach 7		Peach 7	Peach 7	
		Infiltration 3		Earthworms 3		Earthworms 2		**2 yr Hedge**
	Peach 8	Peach 8		Peach 8		Peach 8	Peach 8	**Road**
Rape Seed		Infiltration 1		Earthworms 1/ infiltration 1		Earthworms 3		
	Peach 9	Peach 9		Peach 9		Peach 9	Peach 9	
				Earthworms 2		Earthworms 1		
	Peach 10	Peach 10		Peach 10		Peach 10	Peach 10	
		Infiltration 2		Eleagnus ebbengei		Earthworms 2		
	Peach 11	Peach 11		Peach 11		Peach 11	Peach 11	
		Infiltration 3		Infiltration 2	Pitfall Trap 1	Earthworms 3		
	Peach 12	Peach 12		Peach 12		Peach 12	Peach 12	
				earthworms 3/ infiltration 3		Punica grnatum		
	Peach 13	Peach 13		Peach 13		Peach 13	Peach 13	
	Lavendula x intermedia	Infiltration 1	Pitfall Trap 5	Earthworms 1		Earthworms 1	Taxus bacata	
	Peach 14	Peach 14		Peach 14		Peach 14	Peach 14	
				earthworms 2/ infiltration 1		Earthworms 2		
	Peach 15	Peach 15		Peach 15		Peach 15	Peach 15	
		Rosmarinus officinalis		Earthworms 3	Pitfall Trap 2	Earthworms 3		
	Peach 16	Peach 16		Peach 16		Peach 16	Peach 16	
	Peach 17	Peach 17		Peach 17		Peach 17	Peach 17	
		Infiltration 2	Pitfall Trap 4	Punica grnatum				
	Peach 18	Peach 18		Peach 18		Peach 18	Peach 18	
		Infiltration 3		Infiltration 2				
	Peach 19	Peach 19		Peach 19		Peach 19	Peach 19	
		Infiltration 3			Pitfall Trap 3			
	Peach 20	Peach 20		Peach 20		Peach 20	Peach 20	
	Peach 21	Peach 21		Peach 21		Peach 21	Peach 21	
				Lonicera arborea				
	Peach 22	Peach 22		Peach 22		Peach 22	Peach 22	
	Eleagnus ebbengei					Rosmarinus officinalis	Spirea X Vanhouttei	
	Peach 23	Peach 23		Peach 23		Peach 23	Peach 23	
	Peach 24	Peach 24		Peach 24		Peach 24	Peach 24	
	Peach 25	Peach 25		Peach 25		Peach 25	Peach 25	
		Cornus alba						
	Peach 26	Peach 26		Peach 26		Peach 26	Peach 26	
	Peach 27	Peach 27		Peach 27		Peach 27	Peach 27	
				Taxus bacata				
	Peach 28	Peach 28		Peach 28		Peach 28	Peach 28	

South **2 yr Hedge**

Orchard layout Nectardream TAB – Organic

North **20 yr Hedge**

6m between rows, 3m between trees

	Row 5	Row 4		Row 3		Row 2	Row 1	
	Peach 1	Peach 1		Peach 1		Peach 1	Peach 1	
				Lonicera arborea				
	Peach 2	Peach 2		Peach 2		Peach 2	Peach 2	
	Taxus bacata			Earthworms 1		Earthworms 1	Eleagnus ebbengei	
	Peach 3	Peach 3		Peach 3		Peach 3	Peach 3	
				Earthworms 2		Viburnum lantana		
	Peach 4	Peach 4		Peach 4		Peach 4	Peach 4	
		Infiltration 1		Earthworms 3/ infiltration1		Earthworms 2		
	Peach 5	Peach 5		Peach 5		Peach 5	Peach 5	
		Jasminum nudiflorum		Infiltration 2		Earthworms 3		
	Peach 6	Peach 6		Peach 6		Peach 6	Peach 6	
		Infiltration 2		Earthworms 1				
	Peach 7	Peach 7		Peach 7		Peach 7	Peach 7	
		Infiltration 3		Earthworms 2/ infiltration 3		Lavandula x intermedia		
	Peach 8	Peach 8		Peach 8		Peach 8	Peach 8	
				Earthworms 3				
	Peach 9	Peach 9		Peach 9		Peach 9	Peach 9	
Soy		Infiltration 1		Infiltration 1		Earthworms 1		**20 yr Hedge**
	Peach 10	Peach 10		Peach 10		Peach 10	Peach 10	
	Taxus bacata			Eleagnus ebbengei		Earthworms 2		
	Peach 11	Peach 11		Peach 11		Peach 11	Peach 11	
		Infiltration 2		Infiltration 2	**Pitfall Trap 1**	Earthworms 3		
	Peach 12	Peach 12		Peach 12		Peach 12	Peach 12	
		Infiltration 3						
	Peach 13	Peach 13		Peach 13		Peach 13	Peach 13	
	Ribes sanguineum		**Pitfall Trap 5**	Infiltration 3		Punica grnatum	Taxus bacata	
	Peach 14	Peach 14		Peach 14		Peach 14	Peach 14	
		Infiltration 1		Earthworms 1		Earthworms 1		
	Peach 15	Peach 15		Peach 15		Peach 15	Peach 15	
		Phlomis fruticosa		Earthworms 2	**Pitfall Trap 2**	Earthworms 2		
	Peach 16	Peach 16		Peach 16		Peach 16	Peach 16	
				Earthworms 3		Earthworms 3		
	Peach 17	Peach 17		Peach 17		Peach 17	Peach 17	
		Infiltration 2	**Pitfall Trap 4**	Lavandula x intermedia				
	Peach 18	Peach 18		Peach 18		Peach 18	Peach 18	
				Infiltration 1				
	Peach 19	Peach 19		Peach 19		Peach 19	Peach 19	
		Infiltration 3			**Pitfall Trap 3**			
	Peach 20	Peach 20		Peach 20		Peach 20	Peach 20	
		Infiltration 3		Infiltration 2				
	Peach 21	Peach 21		Peach 21		Peach 21	Peach 21	
				Lonicera arborea				
	Peach 22	Peach 22		Peach 22		Peach 22	Peach 22	
	Eleagnus ebbengei						Spirea X Vanhouttei	
	Peach 23	Peach 23		Peach 23		Peach 23	Peach 23	
						Rosmarinus officinalis		
	Peach 24	Peach 24		Peach 24		Peach 24	Peach 24	
	Peach 25	Peach 25		Peach 25		Peach 25	Peach 25	
		Viburnum opulus						
	Peach 26	Peach 26		Peach 26		Peach 26	Peach 26	
	Peach 27	Peach 27		Peach 27		Peach 27	Peach 27	
				Taxus bacata				
	Peach 28	Peach 28		Peach 28		Peach 28	Peach 28	

South **Alfalfa**

Appendix 3: Treatment calendar diagrams

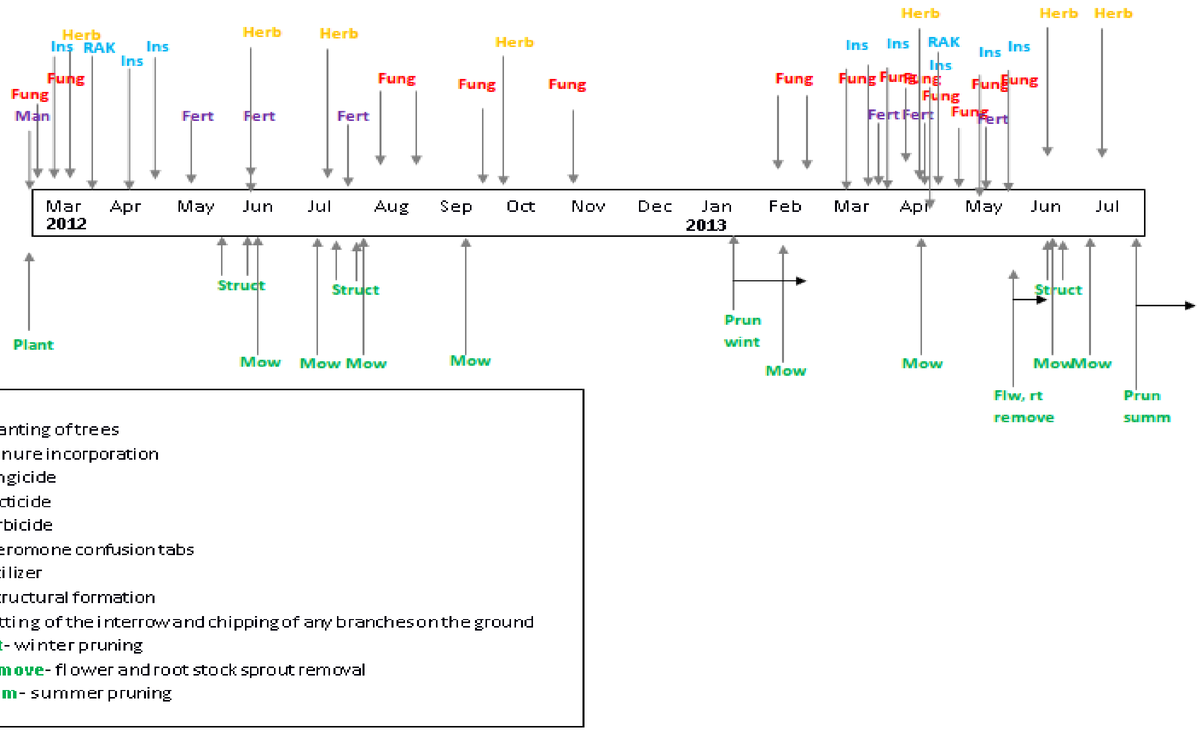


Figure 10: Technical intervention calendar for the Conventional orchard

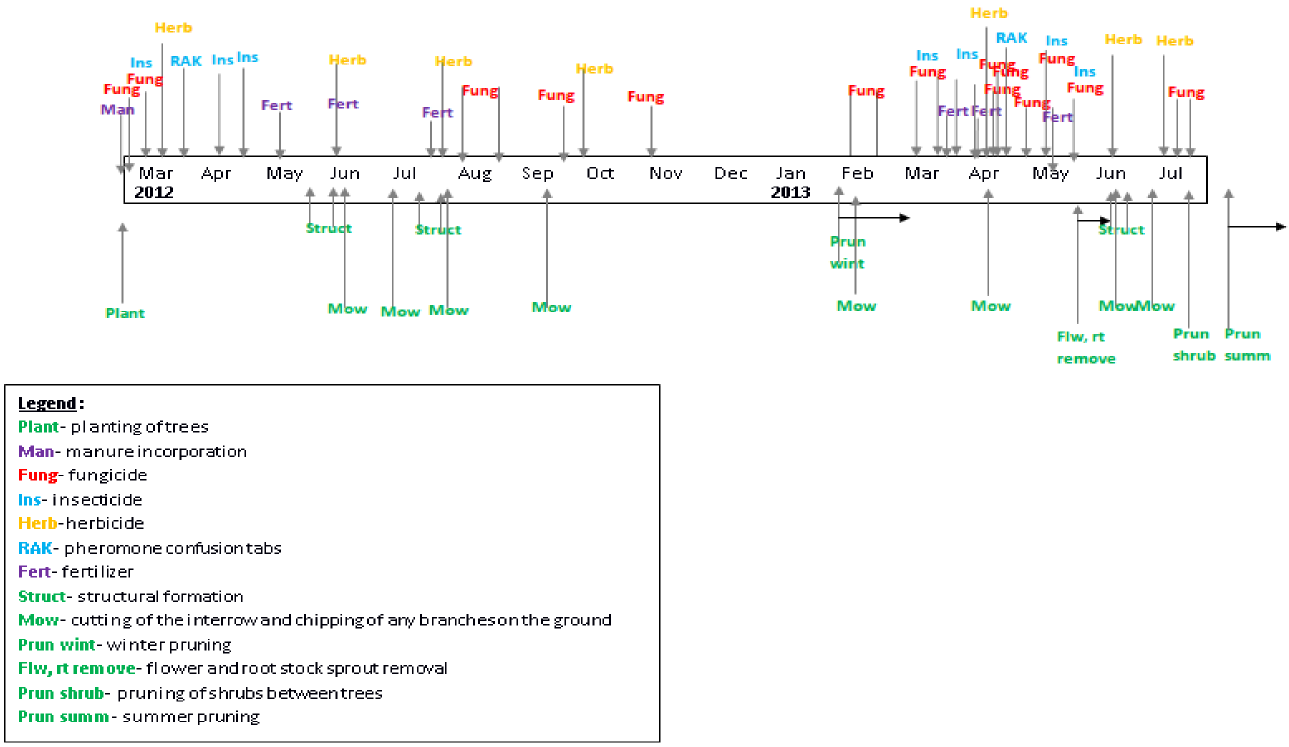


Figure 11: Technical intervention calendar for the Low-Input orchard

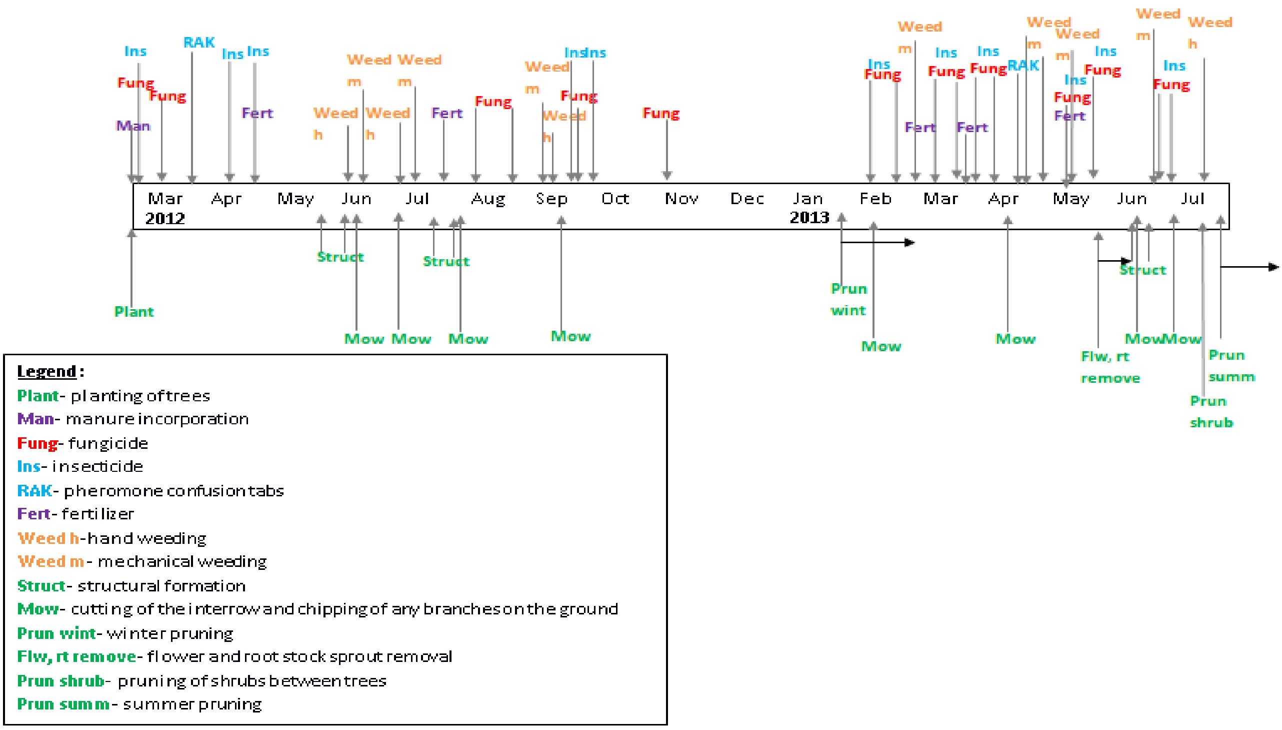


Figure 12: Technical intervention calendar for the Organic orchard

Appendix 4: Treatment calendar table

		Conventional	Low-Input	Organic
2012				
March 3		planting	planting	planting
	8	manure	composted manure	composted manure
	12	fungicide	fungicide	
	13			insecticide, fungicide
	20	insecticide and fungicide	insecticide and fungicide	fungicide
	22	herbicide	herbicide	
	30	RAK	RAK	RAK
April 12		insecticide	insecticide	insecticide
	26	insecticide	insecticide	insecticide, fertilizer
May 4		fertilizer	fertilizer	
	14	clearing inner branches (manual)	clearing inner branches (manual)	clearing inner branches (manual)
June 1		structure formation	structure formation	structure formation
	5			hand weeding
	6	herbicide, fertilizer	herbicide, fertilizer	
	7	cutting interrow	cutting interrow	cutting interrow
	14			mechanical weeding
	29		cutting interrow	cutting interrow
July 4		cutting interrow		hand weeding
	10	herbicide		
	13	structure formation		
	16	fertilizer	fertilizer	mechanical weeding
	20	structure formation	structure formation	structure formation
	23	cutting interrow	cutting interrow	cutting interrow
	29		herbicide	
August 2		fungicide	fungicide	fungicide
	31	fungicide	fungicide	fungicide
Sept 11				mechanical weeding
	13	cutting interrow	cutting interrow	cutting interrow
	18			hand weeding
	20			insecticide
	21	fungicide	fungicide	fungicide
	27			insecticide
October 1		herbicide		
November 6		fungicide	fungicide	fungicide
2013				
Jananuary 23		winter pruning		
	31			winter pruning
February 1			winter pruning	
	11	cutting interrow	cutting interrow	cutting interrow
	12	fungicide	fungicide	fungicide, insecticide
	27			fungicide, insecticide
	28	fungicide	fungicide	
March 4				fertilizer, mechanical weeding
	11	fungicide, insecticide		fungicide, insecticide
	19	fungicide, insecticide	fungicide, insecticide	fungicide, insecticide
	21	fertilizer	fertilizer	
	22	fertilizer	fertilizer	fertilizer
	23	earthworm collection	earthworm collection	earthworm collection
	27	fungicide, insecticide	fungicide, insecticide	fungicide, insecticide
April 3		fungicide	fungicide	fungicide, insecticide
	4	herbicide	herbicide	

6	cutting interrow	cutting interrow	cutting interrow
8	herbicide	herbicide	
9	fertilizer	fertilizer	
12	fungicide, insecticide	fungicide, insecticide	fungicide, insecticide
15	RAK	RAK	RAK
17	earthworm collection	earthworm collection	earthworm collection
23			mechanical weeding
24	fungicide	fungicide	
May 6	earthworm collection	earthworm collection	earthworm collection
7	Pitfall trap set	Pitfall trap set	Pitfall trap set
10	fungicide, insecticide	fungicide, insecticide	
13			fungicide, insecticide, fertilizer
14	fertilizer	fertilizer	mechanical weeding
20	fungicide, insecticide	fungicide, insecticide	fungicide, insecticide
22	Flower & rootstock growth removal	Flower & rootstock growth removal	Flower & rootstock growth removal
23	Pest/Disease observation	Pest/Disease observation	Pest/Disease observation
June 7	Pitfall trap set	Pitfall trap set	Pitfall trap set
12	Pest/disease observation, structure formation	Pest/disease observation, structure formation	Pest/disease observation, structure formation
13	herbicide, cutting interrow	herbicide, cutting interrow	cutting interrow
19	pruning lower branches	pruning lower branches	pruning lower branches
25	infiltration test	infiltration test	mechanical weeding, infiltration test
July 1	Pest/Disease observation	Pest/Disease observation	Pest/Disease observation
3	cutting interrow		
5	Pitfall trap set	Pitfall trap set	Pitfall trap set
12	herbicide	herbicide	
16	Pest/Disease observation	Pest/Disease observation	Pest/Disease observation
17	summer pruning	shrub pruning	shrub pruning and hand weeding
19		fungicide	fungicide
23		fungicide, insecticide	fungicide, insecticide
24	infiltration test	infiltration test	summer pruning, infiltration test
26	Pest/Disease observation		Pest/Disease observation
August 2	Pest/Disease observation	Pest/Disease observation,summer pruning	Pest/Disease observation
9	Pest/Disease observation	Pest/Disease observation	Pest/Disease observation
12	infiltration test	infiltration test	infiltration test
16	Pest/Disease observation	Pest/Disease observation	Pest/Disease observation