# POLLINATORS BEHAVIOR ON FABA BEANS

HÄMEEN AMMATTIKORKEAKOULU
HÄME UNIVERSITY OF APPLIED SCIENCES

Bachelor's thesis

HAMK Forssa, Sustainable Development

Spring 2019

Apri Lönnqvist

Kestävä kehitys
HAMK Forssa

| | | |
|---|---|---|
| **Tekijä** | Apri Lönnqvist | **Vuosi** 2019 |
| **Työn nimi** | Pollinators Behavior on Faba Beans | |
| **Ohjaaja** | Harri Mattila | |

TIIVISTELMÄ

Opinnäytetyön tarkoituksena oli selvittää miten pölyttäjät käyttäytyvät tutkittavilla härkäpapupelloilla. Tutkimuskysymyksiä oli viisi, joihin kaikkiin saatiin vastaukset. Tutkittavana oli muun muassa kimalaisten ja mehiläisten härkäpapujen pölytys-, ryöstö- ja EFN-käyttäytyminen. Mehiläisten ja kimalaisten välisiä suhteita ja ympäröivän metsän vaikutukset lajeihin tarkasteltiin. Työssä tutkitaan myös torjunta-aineiden vaikutuksia pölyttäjiin tutkimuspelloilla.

Kenttätutkimus toteutettiin Skånen alueella Etelä-Ruotsissa kesällä 2017. Tutkittavat pellot olivat tavanomaisesti viljeltyjä. Opinnäytetyö toteutettiin Hämeen ammattikorkeakoululle ja sen tilaaja oli Ruotsin maatalousyliopisto. Työ toteutettiin osana tohtorinopintoja.

Tutkimustuloksista selvisi metsittyneisyyden lisäävän kimalaisten määrää ja puolestaan vähentävän mehiläisiä pelloilla. Torjunta-aineilla ei havaittu olevan selvää merkitystä pölyttäjien käyttäytymiseen. Selvitettyä saatiin vierailevia kimalaislajeja, niiden tyyppejä ja käyttäytymistä. Teoriosassa paneudutaan härkäpapujen historiaan, nykyisyyteen sekä tulevaisuuden kuviin. Läpi käydään mehiläisten ja kimalaisten käyttäytymistä sekä pölyttäjien vaikutusta ihmiselämälle. Työssä korostetaan kestävän kehityksen, ekosysteemipalveluiden sekä luonnonsuojelun tärkeyttä.

**Avainsanat** Pölyttäjät, härkäpavut, kestävä kehitys

**Sivut** 39 sivua

Degree Programme in Sustainable Development
Forssa

**Author** Apri Lönnqvist **Year** 2019

**Subject** Pollinators Behavior on Faba Beans

**Supervisor** Harri Mattila

ABSTRACT

The aim of the thesis is to find out the behavior of the pollinators in the faba bean fields. The basics of the study consisted of five research questions, i.e. the pollination, flower holing (robbing), EFN visiting behaviors, the intercourse of bees and the forestry cover impact on different species. Focus was also laid on pesticides impact on the behavior of the bees.

The field study was executed in the county of Scania located in southern Sweden, during the summer of 2017. The study fields were conventionally managed. The thesis was conducted for HAMK University of Applied Sciences, the commissioner being the Swedish University of Agricultural Sciences as a part of a doctoral study.

The research results indicated that a forested area increases the number of bumblebees and in turn decreases the number of honeybees in the fields. The pesticide treatment did not have any significant impact on the behavior of the pollinators. The caught bumblebee species, their types and behavior were categorized during the study. In addition, the theoretical part of the study discussed some history, the present state and future prospects of the faba beans as well as the behavior and impact of the pollinators on human lives. Finally, the importance of ecosystem services, sustainable development and nature protection were determined.

**Keywords** Pollinators, faba bean, sustainable development

**Pages** 39 pages

CONTENTS

# 1 INTRODUCTION

Pollinators are important for the Earth. Through pollination, they offer an important service to the ecosystem by letting many plants thrive and offering animals and human beings food. Pollinator species have decreased in the past few years due agricultural changes. Some of the species have learned to adapt to these changes better than others. These survivor species have come up with new habits after their natural habitats have been declared or destroyed during past decades.

Faba beans are a sustainable protein source all over the world, including Nordic countries. They are well cultivated in colder climates and their soil improving qualities makes them highly suitable for plant rotation. Local food is a sustainable trend; it has been found to be a good way to improve the economy, appreciation and safety of the country's food supply management. People tend to care more about their immediate environment and habitats than about something that has an impact on some other area far away. Making local food more approachable for consumers can have a huge impact on the wellness of the planet and on human lives.

The subject of this thesis is current since the sustainable future depends on protecting pollinators and the local protein source faba beans. The lack of pollinators is threatening many other species and all the ecosystems including humans as well. In the nature, everything is connected and if one highly important activity is missing, that can lead to catastrophic consequences.  This thesis discusses both subjects; pollinators and faba beans with the focus on Nordic countries and Sweden.

The idea for the thesis came from the Swedish University of Agricultural Sciences (SLU), where the author of the thesis had the second internship as an assistant. The utmost kindness, shared experience and knowledge of the co-workers in the faculty were indispensable, leaving an unforgettable memory and gratitude for the author.

First, the pollination on faba bean is discussed in the theory section of the thesis, where, among other things, faba beans profile, history, cultivation, health benefits and future prospects are taken into consideration. Second, the focus will be on some entomology related to the main faba bean pollinators like bumblebees and honeybees. Hence, some ideas about the species in general and why they are interesting, will be introduced.

The functional research included one month on site work for data collection. In the materials and methods, the implementation of the experiment is clarified. The results and discussion go through the achieved results. Finally, the author's own conclusions will be drawn about the subject and the results summarizing of what had been learned during the progress of this thesis making. In addition, future prospects for new information related to the subject will be suggested.

# 2 FABA BEAN

Faba beans (*Vicia faba*) belong to the large family of Fabaceae and family of vetches (Vicia). So, it is not actually a bean as the name misleadingly suggests. Faba beans are an annual plant and they are widely used as a vegetable and a fodder. Vicia faba have several subgroups such as minor, major and equina. (Oplinger, Putnam, Doll & Combs, 2017.) In Sweden, the refinements of vicia faba minor and vicia faba major are used. That is why in this study the vicia faba is named as faba bean instead of broad bean (major) or other different names of the same species. Differences within plants are the seed size, the taste and the usage. Minor is more used as a vegetable in southern Europe and major as fodder because of its rich protein content. (Elfström, 2014, p.10-11.) Cultivars used in Sweden are called Alexia, (Banquise), Boxer, Fuego, Gloria, Julia, Marcel, Taifun and Tiffany. (Jordbruksverket, 2016.) In this study fields, cultivars used were Boxer, Fuego, Gloria, Taifun and Tiffany. Only three fields had flowers with dots, others pure white flowers.

## 2.1 Profile

Vicia faba is an annual plant. It is planted in spring or in autumn. It has a strong erect stem with 0-5< basal branches coming from a basal leaf axis. (Link et al., 2008, p. 72). Faba beans stele can reach the height of over one meter. Steles are rough and angular. Flowers are in rare clusters and they are usually either white or white with a motley color (purple, white and black). Some cultivars are violet. (Anderberg, 2000.)

Racemes have 3-8 flowers. The youngest flowers arise from the apex. The flowers are in papilionoid shape (butterfly) with an erect standard petal (Figure 1.) There are two wing petals that usually have large dark dots in each of them. Nectar is held at the base of the corolla tube; nectar secretion rates are at their highest in the early mornings and late evenings. (Stoddard & Bond, 1987.)


Figure 1. Vicia faba flowers are in a papilionoid shape and in rare clusters. (Wikimedia commons, n.d.)

Bean pods are roundish, hairy and usually 100-200 mm long. Each flower cluster has 1-4 pods. (Muehlbauer & Tullu, 1997). Each pod has 4-8 beans inside. The bean size is 20-30 mm and is shaped as a kidney. Leaflets are 3-8 cm. Blades are oval shaped and greyish green and they are in one to three pairs without tendrils. (Stenberg,L, 2003, p.347.) The plant has extrafloral nectaries (EFN) on the base of the upper leaves. EFN contains sugar and it interests aphids, ants and pollinators as a source of feed. (Engel, Fischer, Wäckers & Völkl, 2001).

## 2.2 **History**

The demonstrable agricultural history of Vicia faba starts from a late Neolithic period. It was first cultivated in Near East, Iraq, Iran and later reached to Afghanistan and Ethiopia. By 1000 BCE faba beans had been settled in European agriculture. However, largely seeded Vicia faba types have a shorter history. Their origin goes to Eastern Iraq, from where they spread to Asia, northern Africa, Europe and America. Southern America got their faba beans from Spanish newcomers exploring the continent. (Link et al., 2008.)

In the northern part of Europe, the plant was first introduced by the Romans and Catholic monks. (Hietanen, 2010). However, in Sweden some archaeological evidence has been found of faba bean cultivation both in the Stone age and stretching back to the Bronze ages. (Anderberg, 1998).

## 2.3 Farming

Faba beans suit well for Nordic farming with its craving for quite low temperatures and high moisturized lands. They tolerate water loggings better than other grain legumes and even require a moisturized soil for growth. They are sensitive to heat and dry periods during podding. The flowering is interrupted in case the temperatures are over 27 degrees Celcius. (Robinson, 1994.)

Vicia faba needs space and light while farming. (Kasvi & Laine, 2008, p.64). The preferred sowing density is around 60-70 plants per square meter since, at bigger densities, risks are increasing for plant diseases. The seeding depth is 6-8 cm. The plant needs water over twice of the amount of its weight in case of germination. (Hietanen, 2010, p.14.) Sowing density depends upon the seed size varieties. In agriculture, the mathematical formula is used for getting the right densities for each seed type: Seeding rate (kg/ha) = Plant density (plants/m2) x 100 seed weight (g) x 10 ÷ Germination percentage. (Robinson, 1994.)

The gap between rows in the field needs to be around 60-100cm. The pH of the field should be around six to seven. Depending on the weather, growth place, nurturing and other circumstances, it takes around 100 days to get a yield from Vicia faba. (Kasvi & Laine, 2008, p.64-65.) Vicia faba optimal growth temperature is 15-20 Celsius. It can handle frost better than other grain legumes. (Robinson, 1994) Crop damages under -3 degrees, so the harvest should be collected before that. (Kasvi & Laine, 2008, p.64). In northern Europe, the seeds are planted during early spring and harvesting is done when pods have turned from green into a black color. In southern Sweden that usually happens during September. (Holmberg, 2013.)

The farming of faba beans improves the soil quality making it valuable for crop rotation. The plant mass that stays in the soil since harvesting increases the biomass and carbon content of the soil. (Manni, 2017.) Farming faba beans decreases the occurrence of a cereal cyst nematode which affects cereals. The same equipment used for cereals in many farming activities can be used for faba beans, too. (Robinson, 1994) Rhizobium bacteria or rhizobia live in the root nodules of the plant which help their host plant bind nitrogen. (Kasvi & Laine, 2008, p.64). Faba beans have wide and deep roots which make the soil lighter and more suitable for microorganisms. During early springs, faba bean can be given some nitrogen for the start of the growth, but otherwise it is self-sufficient with it. The plant can get 30-150 kg/ha nitrogen from the air and leaves 10- 70 kg/ha from it to the ground. Grounded nitrogen can be utilized with upcoming years farming of plants needing it. (Manni, 2017.) With all the benefits given to farming faba beans, farmers are able to decrease the use of fertilizers. This, on the other hand, saves farmers money and is beneficial for the environment.

## 2.4 Threats of Vicia faba

Vicia faba suffers from certain plant diseases and pests. Most common diseases are chocolate spot (Botrytis fabae) and gray mold (Botrytis cinerea). Chocolate spot is one of the most restrictive diseases in faba bean cultivation around the world. According to research results, it can cause over 50 percent losses of crops. (Hietanen, 2010, p.16-17.) Symptoms of chocolate spot are round chocolate brown spots on leaves and reddening of stems. They can spread easily and finally cause blighting of the plant. Logging water, wet weather and too dense planting increase the risk for chocolate spot.

Some other diseases found on faba beans are: ascochyta blight (Asco-chyta fabae), rust (Uromyces viciae-fabae), cercospora (Cercospora zo-nata) and alternaria (Alternaria alternata). (Robinson, 1994). Faba beans can also suffer from plant viruses such as Bean common mosaic virus, BeMV and Bean yellow mosaic virus, BYMV. Planting healthy seeds and preventing virus spreading aphids to enter plants are the most convenient ways for keeping faba beans healthy. (Hietanen, 2010, p.17.)

Faba beans have a similar pest strain as peas and some of the most common pests in northern Europe are pea leaf weevil (Sitona lineatus), pea aphid (Acyrthosiphon pisum) and pea moth (Cydia nigricana). (Hietanen, 2010, p.18-19). Aphids found in faba beans can cover the whole plant and conquer wide areas of the field, like in Figure 2. Several other pests have been found around the world. Some of these are: Black bean aphid (Aphis fabae), Ground nut aphid (Aphis cracivora), pea aphid (Acyrthosiphon pisum), pea thrip (Kakothripsrobustus), cowpea bean beetle (Callosobruchus macculatus), seed weevils (Apion spp.), bean weevil (Sitonia lineatus), and Egyptian leaf worm (Spodoptera littoralis). (Muehlbauer &Tullu, 1997.)

Figure 2. Faba bean plant covered with aphids.

At the beginning of the growing season weeds may take over the growing area from faba beans. In Uppland area in Sweden there has been a traditional way to overcome this problem by growing faba beans and early potatoes together since potatoes prevent spring weeds from growing in the field therefore giving more space to faba beans to grow. (Kasvi & Laine, 2008, p.65.) This habit is better when growing faba beans to ones own purpose on a small scale. There is no serious need for weed prevention later in the growing season since when faba beans get bigger they shade the ground enough and seize the growing space for them exclusively. (Hietanen, 2010, p.18-19).

## 2.5 **Economic value**

Faba beans are commonly used as human food and animal feed. They are common food in Mediterranean, Middle East, Latin America, China and Ethiopia. They are one of the most important winter crops for human consumption in the Middle East. (Link et al., 2008, p. 73.) That explains why the faba beans are cultivated in large scales.

The amount of faba beans in all cultivated land areas in 2005 were 41% in Asia, 33% in Africa, 12% in Europe, 7% in Oceania and 7% in America, showing that in Asia faba beans are grown the most. The largest individual grower country of faba beans was China with 39% of the agricultural area from the whole world. In Africa, cultivation was mostly concentrated in Ethiopia with 15% of the worldwide area. (Link et al., 2008, p. 72-73.) In 2016, faba beans were produced 4.569.493,00 tonnes worldwide of which 1.725.225,00 tonnes came from Asia, 1.252.574,00 tonnes from Africa, 961.545,00 tonnes from Europe, 423.527,00 tonnes from Oceania and 206.622,00 in America. (FAOstat, 2018.)

Faba beans can be exploited in various untraditional ways and farmers have already found ways to fully benefit from the plant. Especially in areas with poor food supplies, the usage might be more affluent. Based on literary sources, the stems of faba beans have even been used in making bricks and fuel. (Link et al., 2008, p. 73.)

## 2.6 Nutrition and health

Vicia faba has several health benefits for human and animals. It is an easy protein source containing many dietary minerals and starch. Generally, faba beans cultivated in the European Union are safer for consumers than legumes brought from areas with fewer regulations in their cultivation processes. Some livestock producers plant faba beans so as to make it homegrown and an easily processed protein source. Since they do not contain antinutritional enzymes they do not need to be roasted before used. Faba beans contain approximately 30% crude protein and around 15% soluble protein. (Heeg, 2016.)

Faba beans include a lot of starch, fiber, folic acid, potassium, iron and magnesium. (Rankila, 2013, p.23). They are also a good source of lysine, thiamin and phosphorus. The energy provided by faba beans is greater in comparison with soybean meal. (Heeg, 2016). When comparing dried faba beans with soybeans, faba beans have the energy of 1,383.5 kJ/100 g whereas the soybeans of 1,565.5 kJ/100 g. Faba beans consist of 42.2 g/100g carbohydrates but soybeans only 10.3 g/100 g. The fat content of soybeans is 17.7 g/100g whereas faba beans comprise only 1.9 g/ 100g. (Fineli, 2018.)

Purple and pink flowery faba beans have more tannin than cultivars with white flowers. Tannin gives beans more flavor, but monogastric animals cannot digest it easily. For this reason, the colorful cultivars are farmed for the feed of ruminants. (Heeg, 2016.) Tannin can also be found in the faba bean shell, so it is often eaten without it. In white cultivars, the shell is thinner than in others. (Rankila, 2013, p.23).

Besides the health benefits of faba beans already discussed, there has been research of L-dopa after it was found by Marcus Guggenheim in 1913. The whole faba bean plant is a source of L-dopa, although the amount of it can vary depending, for example, on climate and soil growing conditions. Pods and young beans contain more dopamine than older beans. Green faba beans comprise L-dopa around 50-100mg/100g. Nutritionally, faba beans have advisable qualities for combating against the effects of Parkinson's disease. Long before Guggenheim's findings, there was proof of the medicinal usage of the faba beans. Indian sacred texts from second millennium BCE had described a plant from the Fabaceae family for the treatment of “trembling” individuals. (Raminez-Moreno, Salguero Bodes, Romaskevych & Duran-Herrera, 2015.)

## 2.7 **Future of faba beans**

Worldwide, the current main feeds for meat and dairy products are soybean meal and fish meal. In addition, fish are increasingly fed with soy. Following the trend, soy is the primarily imported protein feed in Nordic and Baltic regions. There are some main concerns about the soy import to Europe, like the unsustainability of the soy production in southern America and dependency on import. This dependency of other countries leaves the EU livestock sector vulnerable to price volatility and trade distortion. Locally produced feed would benefit many sectors in case of preservation and creating different kinds of job opportunities. (Lindberg et al., 2016, p.13.)

Nordregio case studies about potential of local food initiatives in the Baltic Sea Region showed that local food initiatives are mostly appealing to environmentally and socially conscious customers; people who are concerned about nutrition, health issues, the origin of food and its environmental impact.  Local food appeals also to tourists, who want to gain the experience of a place through food tasting. Local food is said to be a wide-ranging issue as part of tourism and cultural heritage. Developing local food initiatives are a good way to increase the attractiveness of a place through branding traditional or innovative local foods. (Berlina, Tepecik & Jungsberg, 2017, p.45.)

The total EU protein crop production occupies only 3% of EU’s arable land 34 million tons of soybeans and soybean cakes were imported to EU in 2012. That means 15,5 million of tons of protein was imported mainly from Southern America to EU. The need for proteins is expected to increase globally due to the growth of population. This will put pressure on animal production, increase the food prizes and is hazarding the food security.
Some literature supports the idea for grain legumes, including faba beans replacing soy partially or completely in the diet of pigs. (Lindberg et al., 2016, p.14-15, 27.)

As far as the food and feed production of Sweden are concern, one third of the crops is imported. Ecological issues are then problems of the onsite country, like Brazil, where most of the soy is cultivated. Some of these ecological issues from soy farming are soil erosion, rainforest felling for the cultivation land and the usage of different kinds of chemicals in the area, that have negative impacts on the local nature, animals, insects and humans. Monoculture in soy cultivation increases the heavy usage of fertilizers that are polluting soil and waterways. Transportation in large volumes has its effects on climate, soils and waterways. Farm workers are in danger from the direct contact of pesticide use. There is also a hint of some traces of pesticides in the ready-made products. Heavy metals like cadmium are used for example in Southern America more widely than in Europe. Those metals remain in feed and food later transported to Sweden. GMO is allowed in many soy cultivations. (Heimer, 2010, p.12-14.)

Self-sufficiency gives many positive outcomes, such as potential to close nutrition cycles and potentially more jobs for locals. It gives more time to react in different crisis and scenarios like climate change, economic or energy crisis, conflicts, wars and sale restrictions. Moreover, self-sufficiency strengthens democracy when there is no dependency for transnational relations. When produced locally, the less transport is needed and relations between producers and consumers are improved. This closeness can improve the local food quality, taste and diversity. (Karlsson et al., 2017, p.60-61.) Self-sufficiency provides consumers better understanding about the food producing, the effort, plant protection usage and makes people appreciate their food and environment. Some companies have started making new meat-like products, there are also some projects for producing legumes domestically. (Karlsson et al., 2017, p.61.) Cultivating grain legumes like faba beans offers one solution for this trend in future. Guidelines for a new Nordic diet towards more plant-based food consumption include legumes. Plant-base diet has shown multiple health benefits and is environmentally friendly. With this plant base diet, could Nordic countries improve Nordic identity, sustainability, gastronomic potential and health. (Mithril et al., 2012.)

# 3 ENTOMOLOGY

The term entomology comes from Ancient Greek, where words ἔντομον and entomon mean “insect” while λόγος and logos mean “study”. Entomology stands for research focused on insects. This branch of science is part of zoology, the research of animals. Entomology has many different branches and interest approaches. The focus of this thesis is on specific insects: pollinators with focus on some Apoidea bees: honeybees and bumblebees. One of the reasons to take an extra look on them is their special connection with humans. Social bees have their own art-like communication styles and they are priceless for human life. Human actions have changed the world tremendously with taming nature to serve mostly human life and taking the living space from other species.

There are concerns that pollination ecosystem service provided by plant visiting insects, including social bees, is threatened. The species richness of different pollinators has declined during last decades. Pesticides used in agriculture since the 20th century may have been causing stress for pollinating insects and is one of the reasons that have caused the population to decrease in some species. (Bommarco, Lundin, Smith & Rundlöf, 2011.p.5.) Some other suspected threats to wild bumblebees are climate change, pollution, urbanization, habitat loss due to agricultural intensification and a pathogen spill over from managed bees. (Colla, Richardson & Williams, 2011.p.9). These threats can include other pollinators as well.

From the European wild bee species 9.2% are threatened with extinction and 5.2% more will likely be threatened with extinction soon. Still, over half of the wild bee species have not been classified and so their statuses are unknown. Bees are important for ecosystems and agriculture. Their crop pollination is worth around 153 billion euro globally and 22 billion euro in Europe yearly. From the main crops for human consumption in Europe, 84% requires insect pollination, showing the importance of every pollinator. (IUCN, 2015.)

## 3.1 Robbing behavior

Nectar robbing means that bees are not pollinating but sucking the nectar from a hole on top of the flower, as done in Figure 3. Nectar robbing has several hierarchical levels. A single bee level, some bees are pollinating flowers normally and some are robbing. An individual can execute both traits within a lifetime. There have been studies that show forages being able to remember at least two different types of foraging. Though, usually they stay in one habit, otherwise they might have to re-learn other habits again.  Within a colony both normal flower visits and nectar robbing can happen. Different types of foraging can happen between several plant species. Primary nectar robbers are making holes by chewing the flower. Secondary robbers are using the ready-made holes. The nectar robbing has both positive and negative effects on a plant. Primary robbers shake the plant and release some pollen. If there are several insect species in the field, the pollinators might avoid pollinating the plants what have been earlier robbed. Also, the robbing can cause heavy damage to the reproductive structures of a plant. (Bronstein, Barker, Lichtenberg, Richardson & Irwin, 2017, p.14-17.)

Figure 3. On the left a bumblebee robbing the flower. On the right a bumblebee pollinating. (Hesse, 2017.)

## 3.2 **Apis mellifera**

The western or European honeybee (Apis mellifera) has a natural habitat in Europe, the Middle East and Africa. Apis mellifera has spread all over the world with humans since the 17th century. The European honeybee has spread in almost every continent (except Antarctica) due to the economic benefits from pollination and honey production. (Mortensen, Schmel & Ellis, 2013.)

### 3.2.1 Habitat

Honeybees habitat areas are temperate, tropical or terrestrial. Honeybees prefer to live in meadows, gardens, open wood areas or fields since they get their food from flowering plants. They can also survive in grasslands, deserts or wetlands, if they are provided enough water food and shelter. They also need some cavities to nest in. (Hammond & Blankenship, 2009.)

### 3.2.2 Physical description

Honeybees are reddish brown with black bands and orange yellow rings on their abdomen. Legs are dark brown/black with pollen baskets on workers hind legs. Honeybees have a hairy thorax and a less hairy abdomen. There are over 20 recognized subspecies of the Apis mellifera. Subspecies have differences on their molecular characteristics as well as abilities to tolerate colder and warmer climates. Their outlooks can differ with wing or tongue length and coloration; some abnormalities can be shown as darker shades or as brighter banding patterns. (Hammond & Blankenship, 2009.)

### 3.2.3 Behavior

Honeybees are eusocial insects, i.e. they live in colonies with usually one reproductive female queen and her offspring. They normally stay at a maximum of three-kilometre distance from the hive, but they can even fly 10 kilometres to find food and water. If the temperature goes under 10 degrees, workers refuse to fly. They do not visit flowers when it is too windy or rainy. Signifying that most of the collecting happens during good sunny days. Honeybees are partially endothermic since they can warm up their bodies and hive with working on their flight muscles. (Hammond & Blankenship, 2009.)

### 3.2.4 Colonies

The main task of the colonies is to produce more colonies. Producing a new colony “swarming” happens usually during spring to early summer and often only once a summer. During this time, 10-20 daughter queens are produced. When they are in a pupal stage, the mother queen leaves the colony with most of the adult workers. They travel to a place where they can be in peace, while scout workers search for the new place to start a fresh colony. The daughter queens in the original colony fight with each other for their lives in case they become the new queen. The winner goes on a couple of weeks mating trip and mates with several drones. She storages sperm in her spermatheca and uses that for the rest of her life for reproduction. Meanwhile colonies gather pollen and nectar for autumn and winter. (Mortensen et al., 2013.)

Honeybees development has four stages; egg, pupa, larva and adult. All the individuals of the colony go through these stages. The feed will determine what job they will have later in their life. Queens are the most important individuals of the colonies. Female larvae fed with royal jelly, pollen and nectar develop as queens. In a hive, there is normally only one queen as a reproductive female. The queen can make up to 1500 eggs a day and even 200,000 eggs in her lifetime. The queen can control if she fertilizes her eggs or not. Fertilized eggs become females (either workers or queens) and unfertilized eggs develop into males. Her abdomen is longer than the one of the workers. Fertile queens are 18-20 mm long. Both workers and queens' abdomens are pointy at the end. Queen has a stinger, too, but without barbers, so she does not die in case of stinging. The queen lives the longest, her lifespan can reach for to 2-5 years. (Hammond & Blankenship, 2009; Mortensen et al., 2013.)

Workers are the ones who keep the community together. They have many kinds of jobs as a majority of the hive. Female larvae fed with normal feed; pollen, nectar and brood food develop as a worker. The workers are sterile females and reach the 10-15 mm length as adults. Their body is developed to collect pollen and nectar from flowers. Their hind legs have pollen baskets, corbicula's, what with they can carry great amounts of food to the colony. Worker bees' stingers are barbed with a poison sac and they can only use it once in once lifetime. Workers jobs are divided according to their age. The youngest ones are taking care of eggs and larvaes. Older ones are building the wax combs and the food storages. The Oldest workers are the ones outside the nest pollinating. Adult workers can live for to 11 months if they live through winter. (Hammond & Blankenship, 2009; Mortensen et al., 2013.)

Drones are male bees; they are 15-17 mm long at maturity. Male's head, a thorax and eyes are bigger than females. Big eyes help them locate mating queens during mating season. Male's abdomen is rounder than female's; bullet shape. Males develop from unfertilized eggs. Their only job is to mate with a virgin queen from another colony. Their lives last only for 4-8 weeks, so they do not live through the winter. (Hammond & Blankenship, 2009; Mortensen et al., 2013.)

### 3.2.5 Communication

Bees communicate mainly with pheromones. Members of each hive are chemically bonded so they can recognize each other and protect their hive from other bees. Different kind of pheromones are used to indicate the state of a colony. When a worker uses her stinger that only time, it will release pheromones as a warning and thread navigation for the colony. Honeybees use their vision to locate flowers and animals. They can see in ultraviolet wavelengths, which help them see marks on flowers. They use polarized light on navigation. Honeybees have their own communication style called dancing. Forages communicate with other bees when an abundant food selection has been found. From this complex dancing routine, they understand the location of flowers. (Hammond & Blankenship, 2009.)

### 3.2.6 Human and threats

Honeybee management is popular worldwide. They are used for the pollination of commercial agricultural crops and wild plants, but also for getting benefits for food-, beauty-, pharmacy-industries. Honeybee hives provide honey, wax, pollen, propolis and royal jelly for several usages. Honeybees venom interest researchers for the treatment of autoimmune disease or inflammation, so in the future we might get even more things to be thankful to bees. Honeybees have a warning color with yellow and dark stripes, as seen in Figure 4. Even other species are mimicking that in case of confusing their predators. (Hammond & Blankenship, 2009.)

Figure 4. Honeybee has yellow and dark stripes. A honeybee is pollinating a faba bean.

Bees have commonly protected the cavity in their hive since worker bees are guarding their hive tirelessly. They have a barbed stinger, what keeps some threats away from the hive. The Main veritable enemies are mammals like bears, who like to dig in the food storages of hives. Some bird species are specialized of eating bees and their hives. Insects enemies are for example hive beetles and wax moth larvae. Invertebrate enemies include some todds, spiders and wasps. (Hammond & Blankenship, 2009.)

### 3.3 Bumblebees

Social bumblebees belong to the family of Apidae, the subfamily of Apinae, the tribe Bombini and a Genus Bombus. There are over 255 bumblebee species worldwide. Bumblebee species are difficult to identify since they can be quite homogenous or monotonous. Colors and hair can vary locally. (The Natural History Museum London. n.d.) Bumblebees are easy to recognize as a group from other pollinators like honeybees. They are bigger and have fuzzy bodies with stubby wings, as seen in Figure 5. Bumblebees keep a fuzz-noise when they fly, so their unique pollination style is called buzz- pollination. (Bradford, 2017.)

Figure 5. A fuzzy bumblebee buzz-pollinating a faba bean.

In their singular style of pollination, they grab the anther cone so it shakes releasing pollen what would otherwise stay trapped inside the plant. Some plants, like tomatoes needs buzz pollination to pollinate. Good pollination produces large, well-shaped fruits. That is important for food industries, for maximizing the vendible products. Most other bees, including honeybees are not capable of doing buzz pollination. Bumblebees are commonly used in greenhouse pollination due this gesture. Some wild plants are dependent on bumblebees pollination. Without pollination, they cannot produce seeds and are forbidden to increase. (Evans, Burns & Spivak, 2007, p. 3.)

Bumblebees are intelligent insects. Researches have done some cognitive research from bumblebees learning capacities. Similar studies had been made before for birds and apes. Bumblebees needed to pull a string in order to get sugar water. First, they taught this task for some bumble- bees and the rest learned that by watching others doing that. Researchers found out that bumblebees learn by watching others and can pass the information from bee to bee spread in different colonies. The results show that regardless of their small size and brains the bumblebees have flexible behaviors and can pass the new information to others. (Pennisi, 2016.)

Bumblebees have the similar award system in their brains as human and many other species. Their dopamine levels increase when they are treated with sucrose solution and that makes them more optimistic. Emotions affect their decision making and behavior. When they were happy, they were faster reinitiating foraging after predator attack than the ones who had had some antagonist for dopamine or not given any sugar at all. (Perry, Baciadonna & Chittka, 2016.)

### 3.3.1 Habitat

Bumble- bees prefer flower rich areas with one cool winter period. These conditions are found on north temperate and subalpine meadows. (The Natural History Museum London. n.d.) Bumblebees nests are usually close to the ground, under some old leaves or even under the ground in the abandoned tunnels of other species. (Bradford, 2017.)

Bumblebees have rare ability among insects. They can use their muscles to generate heat. That ability gives them possibility to fly on colder temperate regions, since their internal temperature can be well above the ambient. (Colla et al., 2011.p.7.)

### 3.3.2 Development

Bumblebees have four development stages: egg, larva, pupae and adult. The queen starts a colony by laying around ten white sausage shaped eggs. The egg stage lasts about five days, after that the larvae hatch. The larvae stage continues around two weeks, depending on feed and temperatures. Finally, larvae start to develop a cocoon from special silk what they produce in the glands of their mouths. Development stages take place inside a wax cover, that is often removed after silk cocoon has made. In pupae stage many changes happens; bumblebee develops eyes, tongues, change color from white to specie coloration. After two weeks in this stage, the full-sized adult bumblebee emerges from the cocoon. The whole development from egg to adult takes typically five weeks. (Evans et al., 2007, p. 7-10.)

### 3.3.3 Feed

Bumblebees use flowering plants for food. Adults use mainly nectar for food, but they feed larvae with protein rich pollen. Bumblebees usually uses different kind of flowers as their feed, because of the length of colony cycles. Different bumblebee species have different type of habitat selections, colony cycles, timing emergence, foraging behaviors. Species tongue length determines their food-flower choices. Usually bumblebees prefers flowers with depth like their tongue length. (Colla et al., 2011.p.7.)

Bees probably learn by experience to visit flowers what suits best for their tongue length. Long tongued bees usually visit flowers with long-corolla and short tongued short-corolla. Their tongue is the main foraging tool. Tongue tip has hairs what takes by capillary action minor amounts of nectar. Long-tongued bees visits faster long-corolla flowers. (Heinrich, 2004 p.152.) Bees probably learn this by experience as some studies have shown. Being able to forage from different kind of flowers, enlarges species living area. Fabaceae plants such as Vicia faba are recorded to be a key nutrition source for bumblebees. (Bommarco et al., 2011.)

### 3.3.4 Colonies

Bumblebee colony consist of queen, workers and drones. Queens starts the colony and her main mission is to lay eggs. Unfertilized eggs develop male drones and fertilized become female workers or new queens in late season. Colonies are annual. Overwintering mated queens start to wake up from hibernation early on spring. They begin feeding and looking for nest sites to start colonies. Queen lays her eggs and grows only female workers first. These workers feeds broom and forages the colony. When the colony reaches its maximum worker potential it starts producing males and queens-to-be. These non-workers fly away from the nest and mates with virgin queens. New queens find their over-wintering places and diapauses for the winter. Males and the workers colony dies for the cold weather in autumn. (Colla et al., 2011.p.8.)

### 3.3.5 Human and threats

Bumblebees stinger is not barbed, so it can sting many times. They can also spray feces as a defensive function. Bombuses main enemies among human actions are todds, birds etc. They quite often learn not to touch any similar coloured insects. Queen bumblebees main enemies are other queens if they need to fight over a nest site. (Heinrich, 2004, p.18.)
Bumblebees provide ecosystem services with pollinating of variation crops in temperate regions and in greenhouses. Bumblebees can work in cold, cloudy and rainy temperatures unlike honeybees. (Colla et al., 2011.p.9) Their ability to work in colder climates helps agricultural practices done in places, where it would not be otherwise possible. For example, Icelandic agriculture has multiple berries, tomatoes and cucumbers; all of these could not be yielded in that cold atmosphere without greenhouses with bumblebee workers.

From European bumblebee species 46 % are decreasing, 29 % stable and 13 % increasing. Majority of the species have faced abatement. Climate change with warmer climate and long drought periods affects heavily for the northern species living habitat. (IUCN, 2014.) For bumblebees' downfall effects them for several other reasons stated before.

### 3.3.6 Bombus terrestris

Bombus lucorum and Bombus terrestris are both short tongued bumblebee species. Workers cannot be identified easily from each other's since their multiple similarities. Both have a white tail and two yellow stripes on back. Bombus terrestris is one of the earliest bumblebee species. They make their nests into the ground usually using old small mammals' nests. (Edwards & Jenner, 2009.)

Bombus terrestris have round short faces and short tongues, for that reason they usually visit short open flowers but can make holes to longer flowers. Other pollinators use these holes as secondary robbers. There has been speculations about robbing behavior affecting negatively or positively. If there are a lot of choices of different kind of flowers Bombus terrestris rarely makes an effort of robbing. Bombus terrestris colonies can contain even hundreds of workers making its colonies powerful. (Prys-Jones & Corbet, 1987.)

### 3.3.7 Bombus hortorum

Bombus hortorum and Bombus ruderatus have both long faces and long tongues. With their long tongues they have ability to pollinate long open flowers like faba beans. Bombus hortorum is one of the best pollinators of faba beans. They make only around 100 workers colonies with a short lifecycle. Because of the short life they have, there can rarely be two colonies in one summer. That is uncommon among bumblebees. Their nests are usually placed onto ground surface, a bit above or below. Nests can also be hidden under plant roots. (Free, 1970: Prys-Jones & Corbet, 1987.)

### 3.3.8 Cuckoo bumblebees

One genus of bumblebees (Psithyrus) specializes in taking over Bombus nests. They are social parasites or "cuckoos" of Bombus. They do not have their own workers and they do not have pollen carrying apparatus on hind legs. Psithyrus females enters Bombus colonies and kills the queen. They lay their own eggs, letting Bombus workers take care of them like they would take care of their queens. (Heinrich, 2004. p.20.)

# 4 STUDY AIMS

The following study was carried out in order to find out the behavior traits of different pollinators in faba bean fields. Interesting was to find out the pollination and robbing behaviors on different pollinators. The landscape surrounding the fields could have some effects on the insects and their behavior. The crop stages of plant assumingly impact how effectively the insect food collection was made. Each of the conventionally managed study field had a plot, that was not sprayed with pesticides. Conventionally managed fields are normally protected with different pesticides as they do not belong to organic farming. In the thesis two different terms are used to describe them: treated and non-treated or sprayed and unsprayed. Pesticides have had affects on pollinators and their usage worries many. For this reason, the study included the treated versus the non-treated comparison.

The following questions formed the basis of the study:
1. What could the differences be between robbing and pollination?
2. What types of bumblebee species pollinate and rob faba beans flowers?
3. Are there any differences between honeybee and bumblebee populations on the field? If yes, what are the factors behind that?
4. Does forestry have an impact related to the number of bumblebees and honeybees?
5. Are there some differences between treated and non-treated areas?

# 5 MATERIALS AND METHODS

The study was carried out in 2017 in 16 conventionally managed faba bean (Vicia faba) fields in the province of Scania, southernmost Sweden (Figure 6.)

Figure 6. Scania county in Sweden. (Wikimedia commons, n.d.)

The average size of the fields was around 17 ha. Within each field a plot was selected, 24 m wide and 50 m long, from the edge of each field what was excluded from insecticide treatment. Transect of 30 m long and 1 m wide was monitored within 10 minutes from unsprayed and sprayed areas. The monitoring required the full concentration, as seen in Figure 7. Transect was 10 meters away from the edges of each plot to minimize pollinator movement between unsprayed and sprayed plots.

Figure 7. Monitoring happened within 10 minutes on each section.

The experiment was carried out between June 13th to July 13th. The pollinator transects were executed when the temperature was above 15 Celsius and it was at least sunny or bright overcast without rain during the last hour. Wind speed was less than 28 km/ h what is equal to the Beaufort scale 4 (moderate breeze where small branches start to move). The temperature, wind and time were recorded every time.

Every pollinator seen visiting flowers or extra floral nectars and the behavior of each visitor was recorded. For the pollinator catching a net was used with diameter ca.40 cm. Bumblebees were caught for identification but other pollinators (such as honeybees and bumblebee queens) were excluded for minimizing the ecological disruption on site. The timing was not recorded during pollinator catching and switched on again after completing a 10 minute time limit. The captured bumblebees were placed immediately in jars with ethyl acetate for rapid fainting and for later species determination. The equipment used is seen in Figure 8.

Figure 8. Jars with ethyl acetate, a net, a stopwatch, a clicker and datasheets.

Flower and plant density were also measured from sites. Flower density was taken by picking one flower randomly and then observing the nearest one by repeating 10 times. This was repeated both sprayed and unsprayed areas. Notes were made of the fully open flowers and the total amount of the flowers. Holes of robbing were calculated as well from both fully opened flowers and total amount of flowers including pesticide sprayed and unsprayed areas.

## 5.1 Research methods

The thesis study was executed by using a scientific research method including research specific questions. Qualitative methods were used since there was need to get a deeper understanding about the subject. Great amount of practical job was done in the field, which supports the qualitative method with more complex subject what only collected data can give. (University of Jyväskylä, 2015.) Since the thesis was mostly based on on site experiments including the development aspects of the subject, it can be called a functional research. By using reflective touch, the goal is to understand why pollinators act the way they do. (KAMK n.d.) The study is repeatable and all the methods are clearly described. In the future, some findings may be different, since nature and the environment are continuously changing. That gives the researches new inspire for future research and data collection, perhaps showing some new trends in progress.

## 5.2 Identification

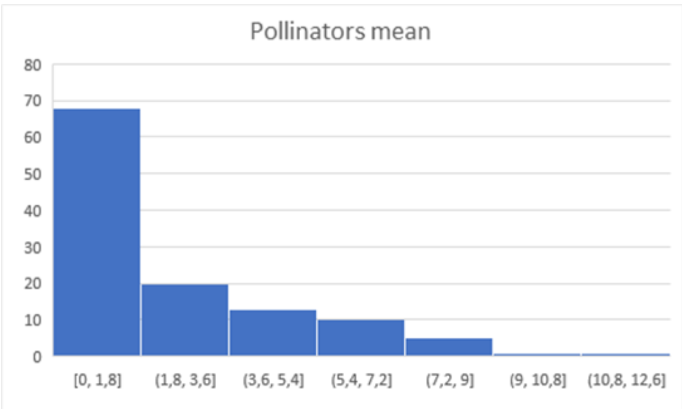
Different bumblebee species were determined by using different databases, literature and finally verified species with personnel from the Swedish University of Agricultural Sciences entomological department. Species were summed into common denominator groups because of their great similarities among functions and appearance. Bombus terrestris group contained Bombus terrestris, Bombus lucorum and Bombus soroeensis. The group of Bombus hortorum consisted of Bombus hortorum and Bombus ruderatus while the Bombus pascuorum group consisted of Bombus pascuorum, Bombus humilis and Bombus muscorum. The Bombus lapidarius group involved Bombus lapidarius and Bombus ruderarius species. Bombus sylvarum and Bombus pratorum were not grouped. Only social bees were analyzed because there were not any cuckoo species found during the experiment.

Once species and their functions were recognized, they were divided into short, medium and long tongued groups to clarify data. In total, 848 flower visiting insects were observed, with honeybees (565 individuals), bumblebees (232 individuals) and others (51 individuals.) Others were hoverflies etc.

## 5.3 Statistical analysis

Statistical analyses were performed with RStudio Version 1.0.153 – © 2009-2017 RStudio, Inc for Windows NT 6.2 and Microsoft Excel 2016. How the forestry was influencing the pollinator species were tested by using the "glmer" function of package "lme4" in R with Poisson distribution. From collected data were used different bees and forestry as interactions. The disadvantage was the number of visits in each field, because there was a slight variation. A total of 105 bumblebees were collected for species determination. The total behavior data consisted of 848 observed individuals, from which was done the mean of pollinators observed (Table 1). Flower density was an average of ten flowers from each treated and untreated site.

Table 1. Mean from all pollinators observed.




In the treated versus untreated areas the differences between pollinating and robbing behavior were tested by using glm with family Poisson. The results were confirmed by using the non-parametric statistical hypothesis test of the Wilcoxon signed- rank test. In addition, the Chi-squared test was used. According to the tests, there were no significant differences between treated and untreated areas. The species were not specified, only areas with different treatments were used as a baseline.

# 6 DISCUSSION AND RESULTS

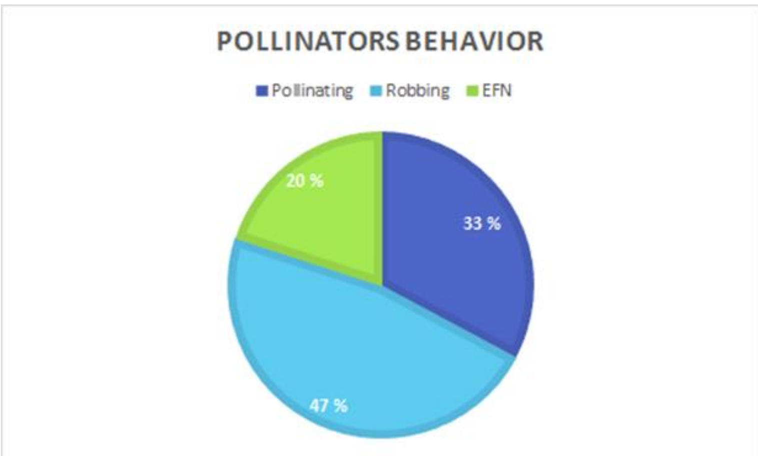
Pollination has several positive effects on Vicia faba. The bee-pollinated plants offer more pods compared to self-pollinated plants. Pollinated plants pod set lower helping pods not ripen so easily, providing them better drying and easier harvesting. (Stoddard & Bond, 1987, p.4.) Therefore, cultivars that bees find easier to pollinate could be an option for a farmer who wants to have a better yield. Some cultivars have so long flowers that bees cannot easily reach the pollen inside. Thus, different bumblebee species tongue length has been developed to reach pollen from variety of flowers.

Faba beans have extrafloral nectarines (EFN) on the marked dark spot of their leaves. Pollinators visit these spots to get nectar. EFN are popular among honeybees in faba bean flowering, but they might attain interests of bees during the whole growing season. (Stoddard F L, Bond D A. 1987, p.6.) According to the results, EFN visits were frequent. However, this activity was not so popular in comparison with pollinating or robbing, but honeybees were the ones most active in EFNs.

## 6.1 Pollinators behavior

From all observed pollinators, can be seen that robbing was the most popular behavior during the field period. Nearly half of the observed pollinators were robbing. The second most popular behavior was pollination with nearly third part of all the observations. The least popular act was EFN visiting, which is the least helpful in case of plant reproduction. Collected data from behavior was put into the Table 2 and presented as a pie chart.

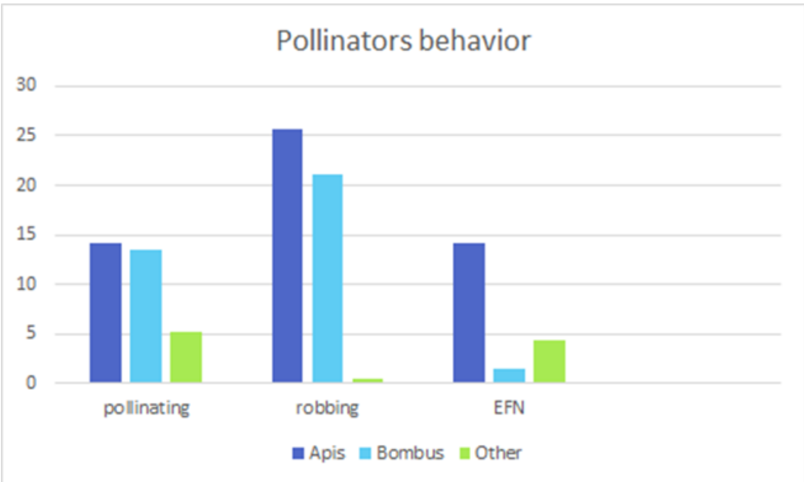
Table 2. Pollinators behavior from all observed data with percentages, indicating that robbing behavior was the most common behavior of pollinators.



When data was put into smaller pieces, it can be seen how each pollinator group was acting. The Table 3 shows the groups and their actions in a bar chart. The groups used were honeybees (Apis), bumblebees (Bombus) and others. The largest group on the faba bean field actions were honeybees (Apis). Over one quarter of all pollinators was robbing honeybees. Over one fifth of all robbers were bumblebees (Bombus). Other species did not rob like the previous described. Pollination was the second popular act with pollinators. Honeybees were the most active in pollination, secondly, and almost the same level as honeybees reached bumblebees. Few other species were seen pollinating. From EFN visits the most active ones were again honeybees, then others and the least active EFN visitors were bumblebees.

Honeybees were robbing tremendously using previously made holes. This finding favors Stoddard & Bond (1987) research. Bombus terrestris groups robbing behavior has been well-known so this thesis is not deviant in this field. According to literary sources, even Bombus terrestris would prefer pollination, if there were short corolla flowers close to them. In modern agriculture, bumblebees have lost some natural flower variations, and due to managing the loss, they get their feed from the flowers available.

Table 3. Model of pollinating, robbing and EFN visits as percentages from all visits observed. Showing that robbing was most common behavior and honeybees were percentually the main robbers



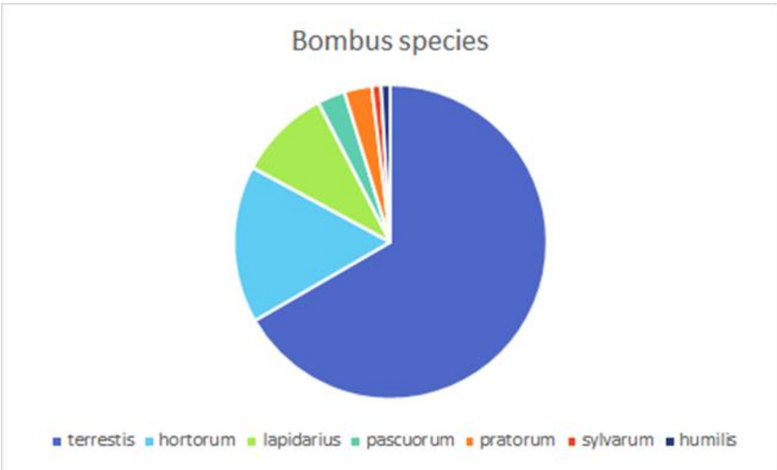

## 6.2 Bumblebees

The 18th century when the agricultural style transformed, there was a change also in bumblebee species. Earlier, bumblebees used to have their natural habitat places with flourishing ditches and field margins. Industrial agriculture, the increasing usage of pesticides and plain field surroundings changed the bee species. Bombus terrestris and Bombus lapidarius were more easily able to adapt to the changes in agriculture than other species.

Therefore, they are dominant species in Sweden also nowadays. (Bommarco et al., 2011.)

From the caught and identified bumblebees it can be concluded and observed that Bombus terrestris group was the biggest group of all, with over half of the collected bumblebees belonging to that group (Table 4.) Bombus hortorum was the second largest group followed by Bombus lapidarius. Others were Bombus pascuorum, Bombus pratorum, Bombus sylvarum and Bombus humilis.

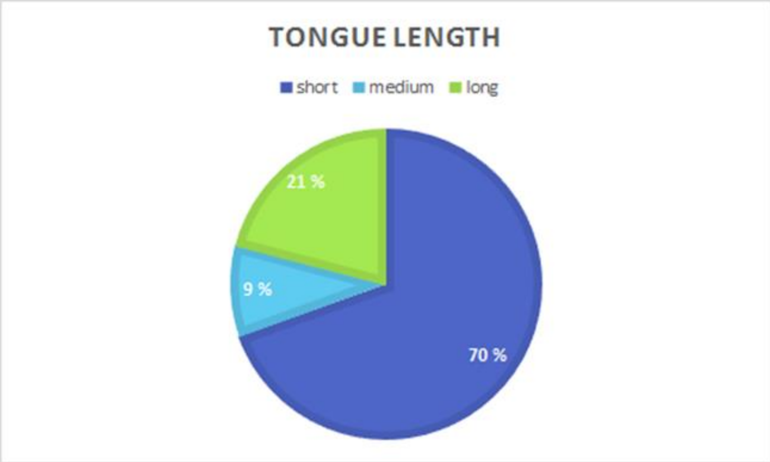
Table 4. Percentages from collected bumblebees. Showing that Bombus terrestris group was remarkably common visitor on faba bean fields. Second largest group was Bombus hortorum.




70 percent of the recognized species were short-tongued and 21 percent long tongued (Table 5.) Only nine percent had middle length sized tongues. The large occurrence of the group of short tongues could be explained by the fact that the Bombus terrestris group is largely spread compared to all other species.

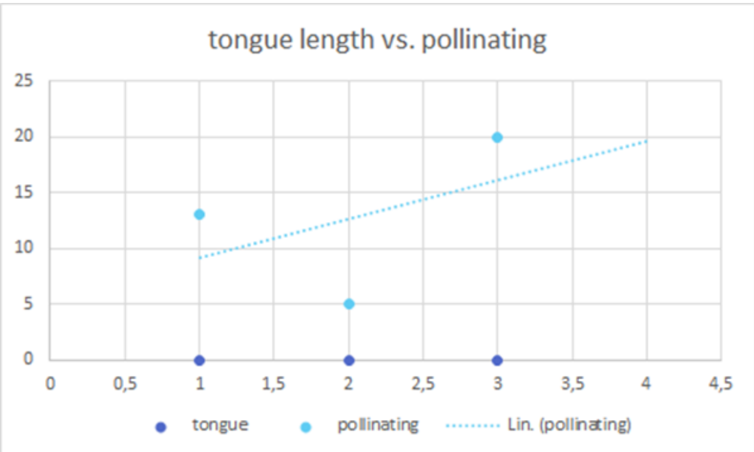
The short- tongued species are dominant in the fields, even though Vicia faba corollas are long. The reason for this is most likely linked to Bombus terrestris since similar findings have been found in Swedish studies in clover fields. Bombus terrestris dominance have been linked to their ability of being generalists in fields. Bombus terrestris have adopted agricultural landscapes better and therefore they are more common. (Bommarco et al., 2011.)

Table 5. Tongue length between collected species taken by percentages from recognized and behavior marked species. Indicating that short tongued species were major visitors




Vicia faba has flowers with long corolla therefore they are easier approachable for long tongued bumblebees. The previous result showed that the main bumblebee visitors had short tongues. Still, with short tongue it is difficult for the bumblebee to pollinate faba beans. The next interest was to find out if the tongue length really mattered in pollination action. As a result, the longer the tongue was, the more pollination happened (Table 6.) This result supports previous researches.

Table 6. Tongue length versus pollination. Bumblebees tongue length on horizontal: 1 short, 2 medium, 3 long. Indicating the longer the tongue the more pollination.

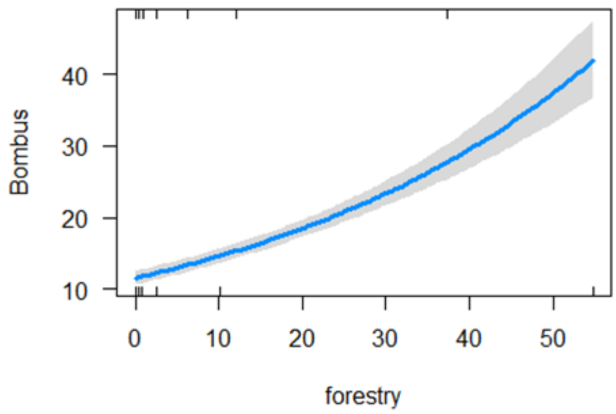



The article by Stoddard shows that bumblebees with longer tongues, like Bombus hortorum group, have been positive pollinating visitors in Vicia faba fields. These "Hortobombuses" tongues reach easily long corollas and they shake their fuzzy bodies on the way reaching the pollen. Again, Bombus terrestris group with short tongues has more likely been the robbing ones when getting nectar, but for collecting pollen they have been pollinating. (Stoddard & Bond, 1987, p.4.)

## 6.3 Forestry cover and pollinators

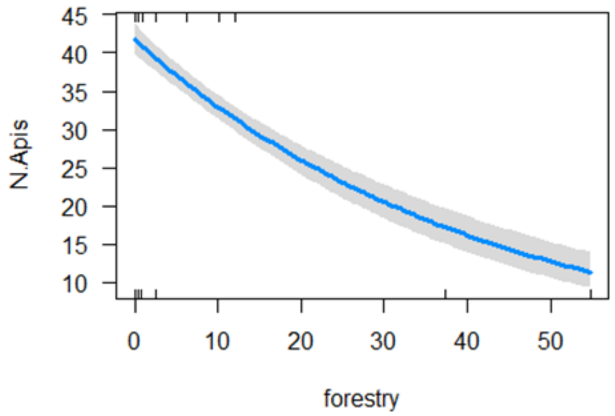
In Sweden, the nesting land like hay land has been turned into forests. Still forest land and its surroundings offer the bees more nesting places than a plain agricultural land can offer. (Bommarco et al., 2011). It is important to provide recent nesting zones for bumblebees since they are the main insect pollinators of Vicia faba (Muehlbauer & Tullu, 1997). If there is not forestry available close to agricultural lands, an option could be in the future to build “bee-hotels” or something similar next to the fields. In cities, these small man-made hotels have provided nesting places for bees, so why not in agricultural landscapes? The more forest was around the faba bean fields, the more bumblebees were observed. Showing that for the bumblebees the forestry cover had significant positive impact (Table 7.)

Table 7. Model of forestry cover with a significant positive impact (p-value < 0,002) for bumblebees. The error bar denotes 95%.



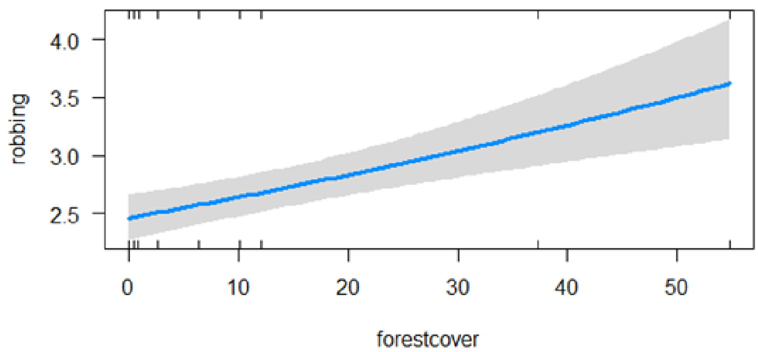

Honeybees have a positive pollination on Vicia faba when collecting pollen, but for the nectar hunting they prefer holes, chewed by other bees. That is a reason why honey makers do not profit so much when having honeybee farm next to a field, where the robbers have already been. Honeybee colonies can also be without pollinating male sterile plants, found in some commercial growed hybrid Vicia fabas. Additionally, they can cause cross pollinating when it is not wanted. (Stoddard & Bond, 1987, p.5.) The more forestry cover was close to the fields, the less honeybees were seen (Table 8.) The reason behind this phenomenon might be the competition of living space, leaving the more forest covered fields for bumblebees. Honeybee farmers might be aware of bumblebee hole chewing habits, and so on they have located their honey farms close to fields with plain surroundings.

Table 8. Model of forestry cover with a significant negative impact for Apis mellifera (p-value < 0,002). The error bar denotes 95%.



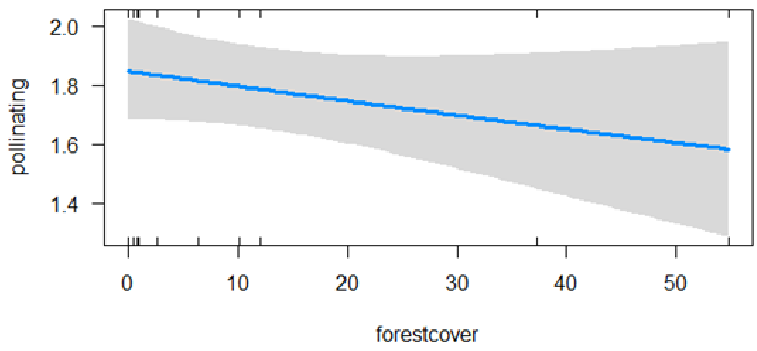

Bumblebees are the primary hole makers for flowers and the ratio of bumblebees increased with forestry cover. It is not a major surprise that the increasing forest cover increased the robbing behavior (Table 9.)

Table 9. Model how forest cover impacts robbing behavior. Increasing forest cover seems to have a significant positive impact for robbing. (P-value < 0,002). The error bar denotes 95%.




From the previous results of the thesis was seen that honeybees were the most active pollinators in the research fields and that honeybees increased with plainer agricultural land. Most pollination was done in the fields with less forest cover close by (Table 10.)

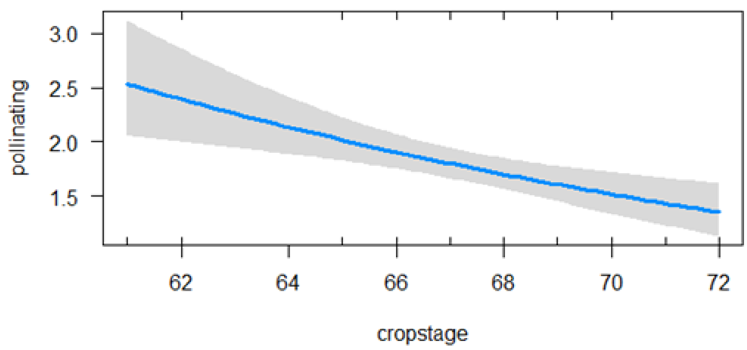
Table 10. Model how forest cover impacts to pollinating. Increasing forest cover seems to have a significant negative impact for pollinating. (P-value < 0,002). The error bar denotes 95%.




## 6.4 Crop stage and behavior

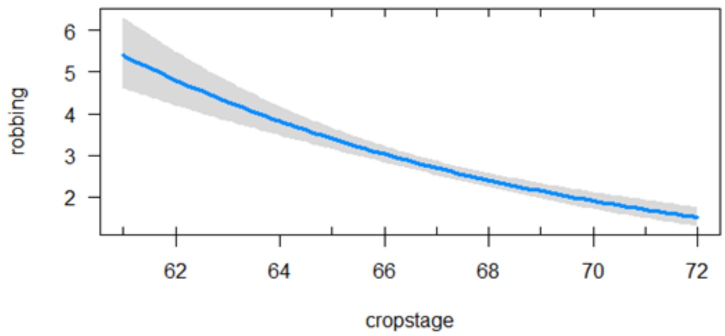
For pollination bees need blooming flowers. When crop stage goes over this blooming time, pollination decreases on fields (Table 11.) Within the robbing, the same phenomenon can be seen, since it is more difficult for the pollinators to get the nectar from the flowers as shown in the following table.

Table 11. Model how crop stage impacts on pollinating behavior. When crops are not fully flowering anymore also pollinating abates. Crop stage has a significant impact for pollinating giving a P- value < 0,005. The error bar denotes 95%.




Robbing behavior dropped also, when the crop stage reached the point where there were no fully open flowers left (Table 12.)

Table 12. Model how crop stage impacts for robbing behavior. That also seems abate when flowering is reaching its final point. Crop stage has a significant impact for robbing giving the P-value < 0,002. The error bar denotes 95%.



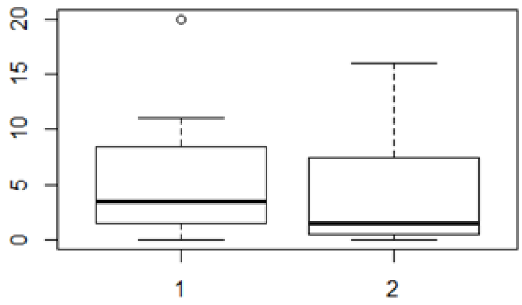

## 6.5 **Treated versus untreated areas**

Between untreated and treated areas, Pearson's Chi-squared test indicated the p-value of 0, 3655. Species were not specified. This indicates that there were no differences between the areas. In comparison of the pollinating, similar results were achieved the p-value being 0.8391. Within the comparison of only bumblebees and honeybees, the Chi-squared test p-value was 0.7715. Comparing robbing results in containing all species, the results showed a p-value of 0.9654. Finally, comparing the EFN differences of the areas, the gained p-value was 0.7102.

The results show no significant differences between untreated and treated areas. Null hypothesis was accepted by considering untreated and treated areas are independent samples. This result was the same by using both Wilcoxon and Chi-squared tests.

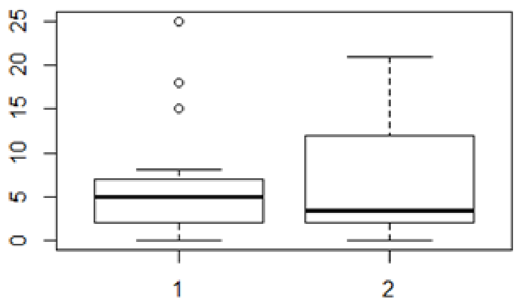
Pesticides can affect bees indirectly due to herbicides since they kill their food plants. Or directly as insecticides, that are meant for killing pests. There have been difficulties in separating the pesticide effect from the effects of landscape and other factors. Some local acute poisonings from insecticides have been reported. Bumblebees forage earlier in the morning, so their queens have a risk of poisoning during spring spraying. (Williams & Osborne, 2009. p. 373-374.) The pesticides used, did not have effect on bees behavior in this study. Pollination between unsprayed and pesticide sprayed sections of the field did not have any significant differences (Table 13.)

Table 13. 1. Unsprayed. 2. Sprayed. Pollination with boxplot. Showing that there were not any significant differences between unsprayed and sprayed areas of field.




During the research differences were not found in robbing behavior between the sections (Table 14.) The amounts of pesticides used can be one factor when analyzing the impact of pesticides on pollinators. The more they were pesticide treated, the more it could have impact on them even though this study did not notify any significant differences. Accumulation for pollinators might still happen. One hypothesis is that it takes more time for pesticides to have significant effect on pollinators. Those effects might accumulate on pollinators and have then far reaching consequences for pollinating, robbing and EFN behavior. Untreated area was 24m*50m and pollinators tend to spread in wider areas, so the result was not unexpected with flying insects.

Table 14. 1.unsprayed. 2 sprayed. Robbing with boxplot. Showing that there were not any significant differences between unsprayed and sprayed areas of the field.



# 7 CONCLUSION

The study in Scania was an amazing opportunity to learn more about bees. This was the first study that the author of the thesis had been part of, and it taught how research is made. Concerning the pollinator research, the weather conditions were quite wet and chilly nearly all the summer. Those abnormal weather conditions which might have had some effects on the behavior of pollinators. Hypothesis and results were in balance with each other.

Since pollination has such a positive effect on Vicia faba, it is important to focus on offering pollinators a versatile habitat, so they would increase as population but also have a chance to fulfil their pollination behavior with satiate flowers. Thus, robbing behavior has some positive effects on plants, it does not give them as much advantage as pollination.

Pollinators have a fascinating world. The more the author of the thesis was studying and getting into the topic, the more versatile the study seemed to get. Pollinator lives and significance for the life on the planet earth have many interesting aspects. This is something that researchers are documenting in numerous ways. The more knowledge gained about pollination and pollinators, the more the value of their existence is appreciated. Without them, life on Earth may not be extinct but at least it would be very different.

Multiple factors have impact on pollinators behavior. One important one is the change of agriculture, where the commercial crop fields are quite plain from other plants and even the surroundings of the fields might be cleaned. That does not offer any nesting places for wild bees such as bumblebees. The results showed that the more forestry there was close by, the more bumblebee activity was reported.

From the bumblebee species observed there was a significant preponderance of Bombus terrestris-group and the good second was the Bombus hortorum- group. That shows poorness in the faba bean species. The Bombus hortorum among other long tongued species was more common. Nevertheless, the Bombus terrestris group has become the generalists of the fields. There has been evidence of pathogen spillover from commercial greenhouses. Also new pests and diseases can form a threat to wild bumblebees. (Williams & Osborne, 2009, p. 373) It is suggested that one reason for that might be found in the growing commercial usage of the Bombus terrestris.

Ecosystem services provided by bees is economically essential. Due to economic profit it is also ethically important to protect bee ecosystems. There are still many species unknown and many of them have faced extinction without people knowing about them. Bees are valuable food for birds, too, so they have their own space in the ecosystem. If one link in the ecosystem is missing, that can have a huge impact on the whole system. Conserving as many species as possible can avert bigger ecological disasters. In case of reducing our carbon footprints as humans, less climate and environment consumptive options should be favored. Those options should go within both micro and macro scales. There is increasing interest in local food in the Nordic countries and hints for changing eating and consumption habits. Legumes have many health benefits for the positive impact on agricultural soils.

The thesis offers valuable information to farmers. Domestic grown faba bean is an easy plant to grow and the information of all the benefits plant gives is welcomed to the Nordic agriculture. The bee knowledge can be used when cultivating practices are done. Plant protection could be focusing on natural predators and the right farming practices. The thesis making process was challenging, but the learning process and information gained have been notable.

# 8 FUTURE PROSPECTS

For the future, it would be interesting to measure, to what extent neonicotinoids have affected the bees with different behavior. That study would need to use molecular research on pollen from bees. In addition, more research could be done to find out whether some bumblebee species absorb more toxins than others.

Even within this thesis study, more data about the same topic could be gathered; possibly starting the study earlier in spring before the flowering starts in addition to visiting all the fields for a couple of hours. Alternatively, field visits could be done every day at different times. That way it would be possible to make more comparison related to the behavior in times of the day. Earlier observation periods would help find species that use the extrafloral nectar of the plant and how that effects on the species that are going to pollinate.

In addition, it would be interesting to repeat this study in multiple countries and compare the results, and finding solutions for the questions like how much the climate will affect the behavior of pollinators? Or: Do some species rob more when it is colder? It would not be necessary to compare other countries, even repeating this study in different summer seasons could give us priceless information about climate effects on bees. Some summers (like the thesis field work summer of 2017) have been recorded cold and late growing season so it is different from the summer of 2016 for example, that proceeded more quickly. By repeating this study throughout the following years could give us more information on climate change and its effects and if the queen bee teaches this robbing skill for new generation and thus it being inherited from the latter colony.

Since multiple factors have effects on bees, the research field is flourishing as well. Finding out that bumblebees have such amazing abilities for learning, the author cannot avoid offering the idea that they also learned to escape during the author’s field visits - an interesting topic to think about.

## REFERENCES

Anderberg, A. (2000). Naturhistoriska riksmuseet. (In Swedish)
Retrieved from:
http://linnaeus.nrm.se/flora/di/faba/vicia/vicifab.html

Berlina, A., Tepecik Dis, A. & Jungsberg, L. (2017). Nordregio working paper 2017:7- Local Food Systems Formation. The potential of local food initiatives in the Baltic Sea Region.
Retrieved from:
https://www.norden.org/fi/node/7320

Bommarco, R., Lundin, O., Smith, H. G. & Rundlöf, M. (2011). Drastic historic shifts in bumble-bee community composition in Sweden.
Retrieved from:
https://www.researchgate.net/publication/51222741_Drastic_historic_shifts_in_bumble-bee_community_composition_in_Sweden

Bradford, A. (2017). Live Science: Facts About 00s.
Retrieved from:
https://www.livescience.com/57509-bumblebee-facts.html

Bronstein, J.L., Barker, J.L., Lichtenberg, E.M., Richardsson, L.L. & Irwin, R.E. (2017). The behavioral ecology of nectar robbing: why be tactic constant?
Retrieved from:
https://www.uvm.edu/rsenr/taylorricketts/documents/Bronstein%20et%20al.%20-%202017%20-%20The%20behavioral%20ecology%20of%20nectar%20robbing.pdf

Colla, S., Richardson, L. & Williams, P. (2011). Bumble bees of the Eastern United States.
Retrieved from:
https://www.fs.fed.us/wildflowers/pollinators/documents/BumbleBeeGuideEast2011.pdf

Edwards, M. & Jenner, M. Field guide to the bumblebees of Great Britain & Ireland.
ISBN 0954971302, Published by Ocelli Limited.

Elfström, C. (2014). Svenskodlade bondbönor som proteinkälla till köttsubstitut: Miljöpåverkan, odling, förädling och tillverkning. Bachelor thesis. Örebro university. (In Swedish)
Retrieved from:
http://www.diva-portal.org/smash/get/diva2:744512/FULLTEXT01.pdf

Engel, V., Fischer. M.K., Wäckers, F.L. & Völkl, W. (2001.) Interactions between extrafloral nectaries, aphids and ants: are there competition effects between plant and homopteran sugar sources?
Retrieved from:
//link.springer.com/article/10.1007%2Fs004420100765

Evans, E., Burns, I. & Spivak, M. (2007). Befriending Bumble Bees: A Practical Guide to Raising Local Bumble Bees. St. Paul, MN: University of Minnesota Extension Service. Retrieved from the University of Minnesota Digital Conservancy.
Retrieved from:
http://hdl.handle.net/11299/51331.

FAOSTAT. (2017). FAO Statistics World food and agriculture. Rom: Food and Agriculture Organization of the United nations.
Retrieved from:
http://www.fao.org/faostat/en/#home

Fineli. Finnish National Institute for Health and Welfare. (2018). (In Finnish)
Retrieved from:
https://fineli.fi/fineli/fi/elintarvikkeet/vertaile?c=2331&c=2034&c=2230&c=2157&c=2168&c=2217&sortByColumn=component&sortOrder=asc&component=2331

Hammond, G. & Blankenship, M. (2009). "Apis mellifera", Animal Diversity Web.
Retrieved from:
https://animaldiversity.org/accounts/Apis_mellifera/

Heeg, A. 10/2016. Update 2/2017. Factsheet: Faba Beans as Protein in Livestock Feed. Ontario Ministry of Agriculture, Food and Rural affairs.
Retrieved from:
http://www.omafra.gov.on.ca/english/livestock/dairy/facts/16-057.htm

Heinrich, B. (2004). Bumblebee Economics with a new preface. 1979f. 2004. Originally Published: Cambridge: Harvard University Press 1974.
Retrieved from:
https://books.google.fi/books?hl=fi&lr=&id=73yeOpls5qsC&oi=fnd&pg=PR11&dq=bumblebee&ots=-HFGNfq4b4&sig=ZnjIVl4k9xIO6F7PJpFzaHqYCF0&redir_esc=y#v=onepage&q=bumblebee&f=false

Heimer, A. (2010).Rapport: Soja som foder och livsmedel i Sverige – konsekvenser lokalt och globalt, Naturskyddsföreningen ISBN: 9789155801427. (In Swedish)
Retrieved from:
https://matochjordbruksnatverket.files.wordpress.com/2010/09/sojarapport_2010.pdf

Hietanen, V. (2010). [Verkkojulkaisu]. Härkäpavun (Vicia faba) viljely. Bachelor thesis. Degree programme: Agriculture and Rural Enterprises Specialisation: Crop Production. Seinäjoki University of Applied Sciences. (In Finnish)
Retrieved from:
https://www.theseus.fi/bitstream/handle/10024/10799/Hietanen_Vesa.pdf?sequence=1

Holmberg, I. (2013). Faba bean – in organic cropping systems. Swedish University of Agricultural Sciences. (In Swedish)
Retrieved from:
http://stud.epsilon.slu.se/6025/1/Holmberg_I_130906.pdf

IUCN article 4/2014. Bad news for Europe's bumblebees.
Retrieved from:
https://www.iucn.org/content/bad-news-europe%E2%80%99s-bumblebees

IUCN article 3/2015. Nearly one in 10 wild bee species face extinction in Europe while the status of more than half remains unknown - IUCN re-port.
Retrieved from:
https://www.iucn.org/content/nearly-one-10-wild-bee-species-face-extinction-europe-while-status-more-half-remains-unknown

Jordbruksverket. (2016). DATABASEN 2016 del 1, Lantbruksväxter. (In Swedish)
Retrieved from:
http://www.jordbruksverket.se/download/18.66a85ef415ac9fe2e0b40e05/1489504495363/Databasen+2016+lantbruksgr%C3%B6dor+2017-03-14.pdf

KAMK- University of Applied Sciences. n.d. Toimintatutkimus. (In Finnish)
Retrieved from:
https://www.kamk.fi/fi/opari/Opinnaytetyopakki/Teoreettinen-materiaali/Tukimateriaali/Toimintatutkimus

Karlsson, J., Röös, E., Sjunnestrand, T., Pira, K., Larsson, M., Hessellund Andersen, B., Sørensen, J., Veistola, T., Rantakokko, J., Manninen, S. & Brubæk, S. (2017) Future Nordic Diets: Exploring ways for sustainably feeding the Nordics. TemaNord 2017:566. Nordic Council of Ministers. ISBN 978-92-893-5257-4 (PDF)
Retrieved from:
https://www.norden.org/en/publication/future-nordic-diets-0

Kasvi, A. Laine, S. Kustannusosakeyhtiö Tammi. (2008) Arnon keittiökasvit.1 painos. Hämeenlinna. Kariston kirjapaino Oy. s.64-65. ISBN 9789513142568

Lindberg, J. E., Lindberg, G., Teräs, J., Poulsen, G., Øivind Solberg, S., Tybirk, K., Przedrzymirska, J.,Pazikowska Sapota, G., Lihme Olsen, M., Karlson, H., Jóhannsson, R., Örn Smárason, B., Gylling, M., Trydeman Knudsen, M., Dorca-Preda, T., Hermansen, J.E., Kruklite, Z. & Berzina, I. (2016) Nordic Alternative Protein Potentials; Mapping of regional bioeconomy opportunities. Norden 2016:527.
Retrieved from:
https://www.norden.org/fi/node/7091

Link, W. Hanafy, M. Malenica, N. Jacobsen, H-J. & Jelenic, S. (2008). Faba Bean.
Retrieved from:
https://www.uni-goettingen.de/en/2008-w-link-intro-to-v-faba/414461.html

Manni, K. (2017). Härkäpapu mukaan viljelykiertoon. HAMK Unlimited Professional 27.5.2017. (In Finnish)
Retrieved from:
https://unlimited.hamk.fi/biotalous/harkapapu-mukaan-viljelykiertoon/

Mithril, C. Dragsted, L. O. Meyer, C. Blauert, E. Krog Holt, M. & Astrup, A. (2012). Guidelines for the New Nordic Diet.
Retrieved from:
https://www.cambridge.org/core/journals/public-health-nutrition/article/guidelines-for-the-new-nordic-diet/B495738BC44965E3968004DCD5EDD294/core-reader

Mortensen, A.N, Schmel, D.R. & Ellis, J. (2013), reviewed 2017. Entomology and Nematology Department, University of Florida. Featured Creatures: European honey bee.
Retrieved from:
http://entnemdept.ufl.edu/creatures/MISC/BEES/euro_honey_bee.htm

Muehlbauer, F.J. & Tullu, A. (1997). Update 1998. New crop datasheet: Vicia Faba L.Purdue University.
Retrieved from:
https://hort.purdue.edu/newcrop/CropFactSheets/fababean.html

Oplinger, E.S. Putnam, D.H. Doll, J.D. & Combs, S.M. (2017 update!) Alternative Field Crops Manual: Fababean. University of Wisconsin- Extension, University of Minnesota.
Retrieved from:
https://hort.purdue.edu/newcrop/afcm/fababean.html

Pennisi, E. 10/2016. Science magazine article: Hints of tool use, culture seen in bumble bees.
Retrieved from:

https://www.sciencemag.org/news/2016/10/hints-tool-use-culture-seen-bumble-bees

Perry, C. J. Baciadonna, L. & Chittka, L. 9/2016. Unexpected rewards induce dopamine-dependent positive emotion–like state changes in bumblebees. Retrieved from:
https://science.sciencemag.org/content/353/6307/1529?sso=1&sso_redirect_count=2&oauth-code=67a0d990-a033-40eb-ba84-3be9669f54b4&oauth-code=372ae001-b547-4bc2-9d5d-a9df3119c212

Prys- Jones, O. & Corbert, S. Naturalists' Handbooks 6: Bumblebees.
ISBN 0855462574 Paper, Published by The Richmond Publishing Co. First published by Cambridge University Press 1987, Reprinted 2003.

Raminez-Moreno, J.M. Salguero Bodes, I. Romaskevych, O. & Duran-Herrera, M.C. (2015). Broad bean (Vicia faba) consumption and Parkinson's disease: a natural source of L-dopa to consider. Original-ly:
Consumo de habas (Vicia faba) y enfermedad de Parkinson: una fuente natural de L-dopa a tener en cuenta.
Retrieved from:
http://www.elsevier.es/en-revista-neurologia-english-edition--495-articulo-broad-bean-vicia-faba-consumption-S2173580815000887

Rankila, M. (2013). SeAMK, School of Food and Agriculture.
Degree programme: Degree Programme of Hospitality Management.
Title of thesis: Broad beans as a source of domestic vegetable protein: Product development of broad bean products. (In Finnish)
Retrieved from:
https://docplayer.fi/10449523-Marjo-rankila-harkapapu-kotimaisen-kasvivalkuaisen-lahteena.html#show_full_text

Robinson, B. (1994). Updated in 2008, 2009 & 2010 by Raynes,M. Growing Faba Bean. Agriculture Victoria: Department of Environment and Primary Industries. ISSN 1329-8062.
Retrieved from:
http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/crop-production/growing-faba-bean

Stenberg,L; Mossberg, B.(2003). Suuri Pohjolan kasvio. Suomenkielinen laitos Väre, V. Kustannus Oy Tammi 2005. 2.painos. ISBN 9513129241

Stoddard, F.L. & Bond, D.A. (1987). Bee World Article: THE POLLINATION REQUIREMENTS OF THE FABA BEAN.
Retrieved from:
https://www.researchgate.net/publication/236874685_The_Pollination_Requirements_of_the_Faba_Bean

University of Jyväskylä (2005). Koppa. Laadullinen analyysi. (In Finnish.)

Retrieved from:
https://koppa.jyu.fi/avoimet/hum/menetelmapolkuja/menetelmapolku/aineiston-analyysimenetelmat/laadullinen-analyysi

Williams, P.H. & Osborne, J.L. (2009). Bumblebee vulnerability and conservation world-wide.
Retrieved from:
https://www.researchgate.net/publication/257828654_Bumblebee_vulnerability_and_conservation_world-wide

For bumble-bee species identification:

ArtDatabanken. SLU. n.d. (In Swedish)
https://www.artdatabanken.se/

Artsdatabanken. n.d. (In Norwegian)
Retrieved from:
https://www.artsdatabanken.no/#_s::1559639783895

Bees Wasps & Ants Recording Society. (2016).
Retrieved from:
http://www.bwars.com/category/taxonomic-hierarchy/bombus-ruderarius-bombus-apidae-bee

Hummel-Arten: Bombus spec. n.d. (In German)
Retrieved from:
http://www.wildbienen.de/huarten.htm

Pistiäistyöryhmä: kimalaisten tunnistusohjeet. n.d. (In Finnish)
Retrieved from:
http://pistiaistyoryhma.myspecies.info/sites/pistiaistyoryhma.myspecies.info/files/Kimalaisten_tunnistusohjeet.pdf