INTERNSHIP REPORT

THE POTENTIAL OF INTEGRATED PEST MANAGEMENT (IPM) TO REDUCE PESTICIDE USE
CASE STUDY : STRAWBERRY PRODUCTION IN NORWAY

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SUMMARY

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TABLE AND FIGURE INDEX

Introduction

The European Union has set rules for the sustainable use of pesticides to reduce the risks and impacts of pesticide use on people's health and the environment.
EU countries are tasked with setting objectives and timetables to reduce risks and impacts of pesticide use. France has for example set an objective of a 50% reduction of pesticide use by 2020. In Norway, pesticide use reduction is embedded within a program on innovations for sustainable food production.

As part of my degree in agricultural management of natural and rural areas (e.g. Licence professionnelle “Gestion agricole des espaces naturels ruraux) at the educational institute for agroenvironmental studies in Florac, France (Institut d'éducation à l'agroenvironnement de Florac), I wished to do my three-month internship in an institution that responds to these high stakes regarding the development of sustainable farming practices.

The Norwegian Institute for Bioeconomy Research (NIBIO) aims to develop and demonstrate the efficiency of alternative tools such as Integrated Pest Management (IPM) to be used in the global effort toward the reduction of pesticide use and the sustainable use of our agricultural resources.
My wish was to join this Institute to discover the IPM method and its principles. Thus we will study through this report the potential of IPM as a means to reduce pesticide use through the case study of Norwegian strawberries.

In the first place we will describe the Institute and the different aspects involved in the study, such as the agriculture and strawberry sectors in Norway and pest management, more specifically Integrated Pest Management.
Then we will review my assignments during this internship and the experimental work that took place before evaluating this work.
Finally a discussion will ensue in respect to the prospects of IPM.

1. Context

1.1. The Norwegian Institute for Bioeconomy Research (NIBIO)

1.1.1. About NIBIO

NIBIO was created 1 July 2015 with the merger between the Norwegian Institute for Agricultural and Environmental Research (Bioforsk), the Norwegian Agricultural Economics Research Institute (NILF) and the Norwegian Forestry and Landscape Institute (Skog og landskap).

NIBIO is an administrative agency owned by the Ministry of Agriculture and Food. It is managed by its own supervisory board.

The Institute is one of Norway's largest research institutes with approximately 700 employees working from 18 locations throughout the country.

Bioeconomy is based on the use and management of marine and terrestrial biological resources, rather than the coil, oil and gas of the fossil economy.

The goal of NIBIO is thus to contribute to food security, sustainable resource management, and innovation, through research and knowledge production.

There are five departments within the Institute :

- Biotechnology and plant health
- Environment and natural resources
- Food production and society
- Forest and forest resources
- Geography and statistics

All of them delivering research, managerial support and knowledge for national preparedness, businesses and the society at large, and by doing so working at the forefront of the transition from an oil-based economy to a bioeconomy.

1.1.2. The Smartcrop project

The European Parliament and the Council of the European Union established on the 21st of October 2009 a framework for Community action to achieve a sustainable use of pesticides through the Directive 2009/128/EC.

Norway plans to implement this EU Directive which promotes the use of Integrated Pest Management (IPM) and alternative approaches or techniques to minimize pesticide use.

However there is a lack of practical IPM tools for farmers with verified effect and usefulness, as well as a relevant policy for a successful implementation of IPM.

NIBIO's Smartcrop project aims to answer these challenges.

Its primary objective is to develop new and innovative IPM tools, approaches and policy instruments to increase the adoption of IPM strategies for a sustainable and financially viable food production.

The secondary objectives are as follow :

1) Develop innovative methods for alternative control of plant pests to provide farmers with novel environmentally and financially viable IPM tools.
2) Develop new knowledge on the effects of IPM strategies on yield, profitability, pest and natural enemy situation and environmental risk of pesticides.
3) Develop holistic models and forecasting systems for smarter crop protection choices, and reduced risk and impact on natural enemies and the environment.
4) Investor and consumer involvement for continuous evolvement of strategies and solutions for IPM.
5) Identification of consumers, wholesalers and retailers affiliation with IPM products and policies.
6) Suggest policy instruments for increased adoption of innovative IPM strategies.

One project group has been assigned per secondary objective for a total of six project groups working on the Smartcrop project (Appendix 1).

In practice this means two annual (spring barley and winter wheat) and two perennial (apple and strawberry) crops, representing a wide range of growing techniques, financial risk profiles and opportunities for IPM technology will be studied. Fields for research and demonstration will be established. Detailed investigations on interaction between key organisms will take place in laboratories and growth chambers. Several project partners and a reference group representing investors and key users and consumers, including farmers, agricultural services, IPM toll companies, regulatory authorities, wholesalers and retailers will be actively involved in the project, giving the scientists their opinions and observations on the feasibility of approaches and techniques under development. This will facilitate strong and viable IPM innovations and ensure adoption of advanced IPM strategies.

1.2. Norwegian agriculture

1.2.1. General points

Of Norway's total land area, only 3% is arable land, and 30% of this can be used for grain production, fruits and vegetables. The rest of the area can only be used for grass production (Table 1).

The climate determines which crops can be grown and their yield level. In Norway, the main limitating climatic factor is the length of the growing season and the temperature sum during the latter.

On the other hand, sufficient rainfall and to a certain degree favorable light conditions are beneficial for crop production.

In many parts of Norway, fodder growing, mainly grass, is more or less the only alternative. In addition, the mountains offer good grazing lands for sheep and cattle during a short but intensive summer. Thus, grass-based livestock production can be considered the backbone of Norwegian agriculture (Tables 1 and 2).

Agricultural area by use. 2015

	Hectares	Percent
Agricultural in use, total	**983 701**	**100**
Cultivated land	808 450	82.2
Open fields and gardens	**329 616**	**33.5**
Grain and oil seeds	285 694	29.0
Potatoe	11 824	1.2
Crops for green fodder and silage	9 972	1.0
Vegetables, field grown	7 684	0.8
Strawberries	1 630	0.2
Other crops	11 674	1.2
Fallow land	1 139	0.1
Meadows for mowing and pastures	**654 085**	**66.5**
Cultivated meadows	478 834	48.7
Permanent grassland	175 251	17.8

Source : Statistics Norway

Table 1 : Agricultural area by use

Structure of agriculture. 2015

		Percent
Number of holdings, total	**41 846**	**100**
Natural person	39 629	94.7
Legal person	2 217	5.3
Agricultural area in use (ha)	983 701	-
Agricultural area per holding (ha)	23.5	-
Holdings keeping domestic animals		
Cow	12 946	30.9
Sheep 1 year and over	14 391	34.4
Pigs, total	2 203	5.3
Hens	2 061	4.9
Holdings cultivating various crops		
Grain and oil seeds	11 246	26.9
Meadow for mowing and pastures	32 938	78.7

Source : Statistics Norway

Table 2 : Livestock and holdings

Forestry is also an important part of Norway's agriculture. Some 20% of Norway is cultivated forest, a substantial part of which is owned by family farmers. Nearly 100% of Norwegians farms are owned and run on a family basis. The average farm size is 23ha (Table 2). Behind these figures there is a wide range from very small to substantially larger farms. However farms have to be relatively small-scale due to the country's topography, with fields that are often small, scattered and difficult to cultivate efficiently.

The number of farmers has decreased substantially during recent decades. And farmers expand their production, to some degree by buying neighboring farms, but more often by renting land.

With a very few exemptions, Norwegian farmers produce for the domestic market. Still, the country's degree of self-sufficiency is less than 50% on an energy basis. Norway thus has a substantial net import of food, and national food security is an important issue.

Norwegian agriculture mainly covers the domestic demand for milk and milk products, pig meat, poultry and eggs. Norwegian farmers produce 80-90% of the national demand for beef and sheep meat. The national market share for grain and potatoes is approximately 60%. And only 25% of the demand for vegetables, fruits and berries is produced in Norway.

Organic farmland covers approximately 46 900ha of the agricultural area in use, corresponding in 4.7% of the total agricultural area. Norway's goal is that organic agriculture reaches 15% of the country's total production (OECD, 2008).

Norway has a national objective to maintain domestic production and cover the national demand for those products that naturally grow in the country. The agricultural sector wants to increase in efficiency and productivity but it also has many social objectives. To meet society's needs, agriculture must produce safe and healthy food of high quality, produce public goods such as cultural and environmental benefits, and secure long-term and sustainable food production.

NIBIO's Smartcrop project completely fits into these objectives for the development of sustainable agricultural tools and management.

1.2.2. Pest management

1.2.2.1. Pesticide use

Due to the high altitude and a relatively short growing season, the number of pests in Norway is limited compared with middle and southern Europe. However, some weed species are more dominant due to a general wet and cold climate. Thus the dominant group of pesticides has always been herbicides.

In 2014, Statistics Norway conducted the sixth survey on the use of pesticides in agriculture since 2000. Measured by amount of active substance, the use of pesticides showed an increase of 3% compared with the previous survey in 2011. Herbicides accounted for 70% of the total weight of 328 tonnes of active substances of pesticide applied, fungicides 22%, growth regulators 8% and insecticides less than half a percent (Table 3).

Use of pesticide in agriculture by type of pesticide. 2014

	2014 Tonnes active substance	Percent change from 2011 - 2014
All pesticides	**328**	**3.0**
Herbicides	228	6.4
Fungicides	73	-9.6
Insecticides	1	-7.7
Other	26	16.4

Source : Statistics Norway

Table 3 (left) : Amount of pesticides by type of pesticide – Source : Statistics Norway

From 2011 to 2014, the total quantity of herbicides increased by 6%. While the total quantity of fungicides and insecticides decreased by 10% and 8% respectively.

In 2014, only one third of the total agricultural area in use was sprayed with pesticides. This is related to the fact that only 6% of the 630 000ha of meadows and pastureland was sprayed. For other crops, 94% of the area in use was treated at least one during the growing season.

The pressure from pests (weeds, fungi, insects) differs between crops. Weather conditions will also significantly affect the use of pesticides.

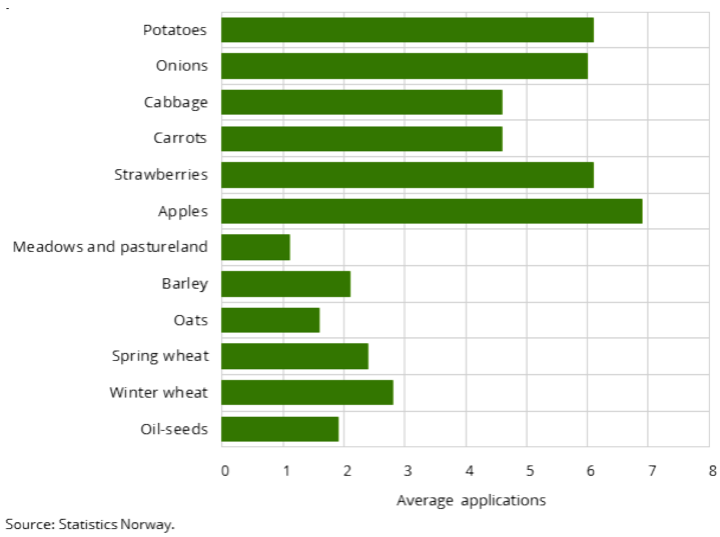


Figure 1 (left) : Average number of treatments applied to crops in 2014

The number of yearly treatments in most of the crops investigated during the survey decreased or were unchanged from 2011 to 2014.

The average number of treatments varied between 1.1 times in meadows and pastureland to 6.9 times in apples (Figure 1). We can note that strawberry crops are the second most treated crops (with potatoes).

1.2.2.2. Integrated Pest Management (IPM)

Integrated Pest Management is an ecosystem-based strategy that focuses on the long-term prevention of pests or their damage.

The fundamental concepts underlying IPM programs can be summarized as such :

- optimization of pest control in an ecologically and economically sound manner
- emphasis on coordinated use of multiple tactics to enhance stable crop production
- maintenance of pest damage below injurious levels while minimizing hazards to humans, animals, plants and the environment (Dover, 1985).

Although IPM programs are generally based on these goals, over the past 40 years the emphasis has changed. Specifically, the most common motivations behind IPM projects in the 1970s and early 1980s were to develop cost-saving production techniques or to reduce the chance that pests would become resistant to pesticides. Whereas the recent emphasis has focused on food safety and environmental sustainability (Rajotte, 1993).

Generally, the first step in developing an IPM program is to move from preventive, calendar-based pesticide applications to pesticide applications made only when there is potential for significant crop damage (Gadoury, 1993). Potential for damage is determined using regular observations of pathogens or arthropods in the field and environmental monitoring to establish criteria for treatment (e.g. action thresholds). Action thresholds may be based on any of several parameters, including pest abundance, environmental conditions, host phenology, or pest development.

Reducing pesticide applications and selecting materials that are less harmful to predators and parasites may encourage the development of natural biological control, particularly for phytophagous mites. This further decreases the need for pesticide applications, developing a momentum toward decreased pesticide use, although most IPM programs remain firmly based on chemicals (Cooley, 1996).

However as IPM programs evolve, policy makers, growers and researchers expect that additional reductions in chemical use will ensue, although such reductions are difficult to attain. To address this problem, IPM programs have been placing increased emphasis on more biologically and culturally based alternatives to chemical control (Zalom and Fry, 1992).

Several factors fostered the introduction of IPM programs for strawberries, including the relatively high value per acre of strawberries and the fact that as an intensively managed crop, daily decisions can have a much greater effect on yields than in other crops.

1.3. Strawberry production

1.3.1. General points and biology

To grow strawberries successfully, you must provide an optimal growing environment. A number of cultural practices can be used to manipulate fruit production pattern, yield, and fruit quality, and each must be applied at specific stages of plant growth. Therefore, a good knowledge of how the plant develops and how development is influenced by the cultural environment is critical to successful strawberry production. Familiarity with the nutritional requirements and structural features of the strawberry plant will help understand how plantings can be managed and how pests influence production. Features of strawberry growth and development that are important to crop management include :

- modifications of the planting bed environment that influence growth and fruit production
- effects of day length and temperature on flower, runner and crown development
- effects of chilling on strawberry growth
- effects of digging and planting dates on plant growth, yield, and fruit quality (Strand, 2008).

The strawberry plant is a perennial that reproduces sexually from seed and vegetatively by sending out stems called stolons or runners, along which new plants form. Reproduction from seed is used in breeding new strawberry cultivars, whereas vegetative reproduction is used to produce the plants used in commercial agriculture and gardening.

Strawberries can be treated as an annual crop and removed after one year of fruit production, but in Norway plants are usually kept in production for two years.

1.3.2. Insects and other invertebrates

A variety of insect and mite can occur in Norwegian strawberries, but only a few are of major concern in each growing area. The two-spotted spider mite (*Tetranychus urticae*) is the most serious pest in all areas. The importance of other mite and insect pests depends on the location, weather conditions, harvest season and market destination of the crops.

Insects and mites usually cause damage when their feeding kills plants or reduces the supply of nutrients available for fruit production. In some cases they reduce fruit quality in any of a number of ways : diminished size, contamination, scarring, or growth distortion, and these fruits are largely unmarketable.

Many insects and mites found in strawberry fields are beneficial predators or parasites that help suppress pest populations. They tend to attack only one or a few types of pests, but they can play a critical role in keeping those pests under control.

<u>Major insect and invertebrate pests</u> :

Figure 2 : Two-spotted spider mite

Source : pestkill.org

The **two-spotted spider mite** (Figure 2) is a serious pest in all strawberry growing areas. Feeding by mites reduces plant vigor, eventually resulting in decreased fruit size and yield. Plants may die if mites remain uncontrolled. They live primarily on the underside of strawberry leaves where they suck juice from the plant. The largest forms are about 0.4mm long. They appear yellowish or pale green with two tiny, red eyespots on the head end and a large, dark blotch on each side of the abdomen. When abundant, spider mites form the webbing that gives them their name. Strawberries must be monitored for mites regularly throughout the season. Spider mites are managed by using cultural practices that favor vigorous plant growth, encouraging biological control, and applying selective miticides only when established monitoring techniques and treatment thresholds indicate they are needed. Native or naturally occurring predators help suppress spider mite populations and can reduce the need for pesticide treatments. Predatory mites are also commercially available. The introduced mites *Phytoseiulus persimilis* is the predatory species most commonly released by strawberry growers and it has become established in a number of growing areas. It can reduce spider mite populations quickly, each individual consuming several mites or mite eggs per day. Because it feeds only on spider mites, it may migrate to adjacent crops and its numbers will drop quickly as soon as spider mite populations decline (Schloemann and Cooley, 1992).


Figure 3 : Cyclamen mites
Source : pestkill.org

The **strawberry mite, or cyclamen mite,** (*Phytonemus pallidus*) (Figure 3) is an important pest of second-year strawberries. Feeding by cyclamen mites causes stunting and distortion of newly emerging strawberry leaves and causes flowers to wither and die. The plants may stop producing berries of mites are not controlled. This mite is extremely small, about ¼mm long. Mature mites are pinkish orange. Cyclamen mites are moved easily between fields on infested transplants, by pickers, birds, or insects, and on field trays and equipment. Natural enemies of the cyclamen mite include predatory mites. Though successful management often requires carefully timed sprays using materials that do not harm natural enemy populations (Strand, 2008).

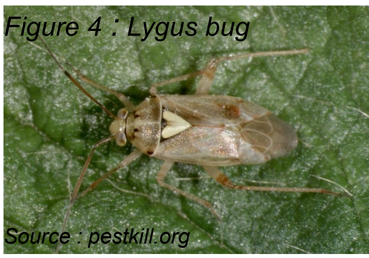


Figure 4 : Lygus bug
Source : pestkill.org

Lygus bugs (*Lygus hesperus*) (Figure 4) are another major pest of Norwegian strawberries. Feeding by lygus bugs reduces berry size and weight and causes severe distortion of the fruit, making unmarketable or of greatly decreased value. Adult lygus bugs are about 6mm long and variable in color. They are identifiable by a conspicuous yellow or pale green triangle in the middle of the back. Successful management of lygus includes control of weed hosts and carefully timed sprays, using degree-day accumulations and monitoring programs to target the nymph stage, when lygus are the most susceptible. Bigeyed bugs are the most important natural enemy of lygus bugs. They feed on eggs and young nymphs. Damsel bugs also feed on eggs and nymphs. However none of these natural enemies can keep lygus from reaching damaging levels when there is a heavy migration of adults into strawberries (Strand, 2008).


Figure 5 : Iris whiteflies
Source : joycegross.com

Whiteflies (*Trialeurodes vaporarorium, Aleyrodes spiroeoides*) (Figure 5) can reduce yields directly by feeding on plant sap, thus stunting the plant's growth and reducing its vigor. Whiteflies also reduce the marketable yield by contaminating fruit surfaces with the sticky honeydew they excrete when feeding, which supports the growth of black sooty mold that can cover both leaf and fruit surfaces. Whitefly adults are about 2.5mm long with four membranous wings that are coated with a white, powdery wax that gives them their name. Successful management of whiteflies in strawberries involves a contamination of cultural controls to prevent infestations and steps to encourage biological control. Insecticide treatments are rarely needed. On most crops greenhouse whiteflies (*T. vaporarorium*) and iris whiteflies (*A. spiroeoides*) are kept below damaging levels by predators such as bigeyed bugs, pirate bugs and lacewing larvaes (Cooley, 1996).


Figure 6 : Western flower thrip
Source : joycegross.com

Western flower thrips (*Frankliniella occidentalis*) (Figure 6) build up on a number of crops and weeds. The tiny slender insects are frequently found feeding on strawberry flowers but probably do not cause significant damage unless numbers get very large. Feeding by large numbers of thrips may cause strawberry blossoms to fall off or cause fruits to remain small and hard. Feeding by thrips can also cause a bronzing of the fruit surface. This pale brown or “bronze” discoloration can constitute economic damage. Management involves monitoring of strawberry blossoms and treatment if large numbers are present. The *Neoseiulus cucumeris* mite is particularly effective against thrips. It is used worldwide for its biocontrol potential against a spectrum of pests (whiteflies, mites, aphids, thrips, etc.) (Schloemann and Cooley, 1992).

These are the main pests found in Norwegian strawberries which were encountered during my internship. Other pests include **garden tortrix** (*Ptycholoma peritana*), **fruit flies** (*Drosophila* spp.) and **root weevils** (*Nemocestes incomptus, Otiorhynchus cribicollis*).

1.3.3. Diseases

Diseases are potentially serious problems in all strawberry growing areas in Norway. Their relative importance depends on local weather and soil conditions, quality of the planting material, cultivar susceptibility and cultural practices. Norway tends to have cool and damp conditions favorable for the development of certain diseases. Gray mold is a major problem in all fruit production areas and usually requires control actions during strawberry flowering and fruit development to prevent serious losses. Gray mold is the main disease in open-field strawberries while powdery mildew is the main disease in tunnel strawberries. Diseases can affect fruits, leaves, roots and crowns.

Temperature, soil moisture, humidity and foliage wetness are the most important environmental factors influencing strawberry diseases. Disease management includes uniform irrigation and good soil drainage, soil fumigation and high-quality, certified transplants.

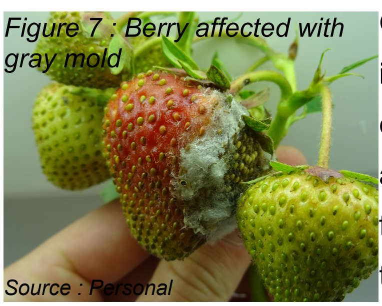


Figure 7 : Berry affected with gray mold

Source : Personal

Gray mold (*Botrytis cinerea*) (Figure 7), also referred to as “Botrytis rot”, is the most common and serious disease of strawberry fruit in Norway, causing losses of fruit both in the field and after harvest. The pathogen also attacks flowers and other parts of the plant when conditions are favorable. It may appear at any stage of fruit development from flowering through marketing. Affected areas turn pale or light brown at first. When the fungus begins to produce spores the diseased tissue is covered with a velvety gray growth. Gray mold that develops in the field reduces yields. Decay after harvest reduces the quantity and quality of marketable fruits and can spread rapidly from diseased to surrounding healthy fruits. This may cause entire loads to be rejected at the market destination. Gray mold is managed by using mulch, appropriate planting densities, proper irrigation techniques, good field sanitation and carefully timed fungicide sprays when needed. Post-harvest losses are reduced by careful handling to avoid injury and remove diseased fruits, rapid cooling of fruits after harvest to limit disease development and use of low holding temperatures (Wilcox, 1991).

Figure 8 : Leaves affected with powdery mildew

Source : ucanr.edu

Powdery mildew (*Sphaerotheca macularis* f.sp. *fragariae*) (Figure 8) is a serious disease in tunnel strawberries. Its development is inhibited y rainy, wet conditions. The disease affects leaves, flowers and fruits, reducing yield and fruit quality. Foliage symptoms usually are the most obvious signs of powdery mildew. The leaf edges curl upward and dry, purplish or brownish patches develop on the lower surface of infected leaves. Reddish discoloration may develop on the upper surface and patches of white, powdery fungus mycelium may appear on the underside of leaves. Yield losses are primarily due to the flower and fruit infections that accompany severe foliage infections. Spraying of fungicides at the very first sign of disease is recommended to control powdery mildew (Bolda and Koike, 2013).

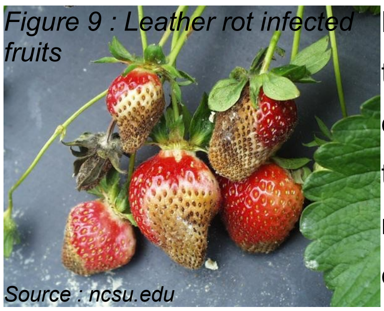


Figure 9 : Leather rot infected fruits

Source : ncsu.edu

Leather rot (*Phytophthora* cactorum) (Figure 9) is a pathogenic fungus that infects strawberry fruits from fruit formation stage to full maturity. The disease is characterized by softening of the tissues, which become tough, leathery and discolored and develop a marked bitter taste. Fruit rot causes direct loss in the economic gain. To reduce leather rot epidemics, excellent water drainage, good air circulation and exposure to sunlight have been recommended. If leather rot reaches damaging levels fungicides may be applied (Louws, and Rahman, 2011).

Figure 10 : Anthracnose affected fruit

Source : fruit.cornell.edu

Anthracnose (*Colletotrichum acutatum*) (Figure 10), which affects fruits, is the disease from the anthracnose family with the highest economic importance in Norway. Symptoms appear as whitish water soaked lesions, which eventually become sunken and black. Symptoms may also appear on leaves, runners and petioles as black irregular lesions. Management for anthracnose fruit rot includes choosing high quality, certified plants, the immediate destruction of all infected plants and fruits through a cautious monitoring of the field, and potential fungicide sprays if needed (Louws, and Rahman, 2011).

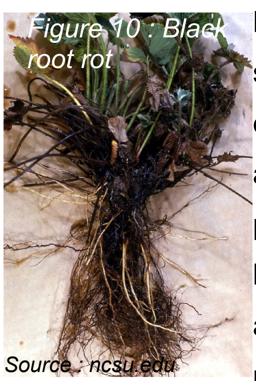


Figure 10 : Black root rot

Source : ncsu.edu

Black root rot (*Thielaviopsis basicola*) is the main disease that affects the roots in strawberry plants. Infected roots have irregular dark patches, eventually becoming entirely black. Plants show poor runner growth, have small berries and in general are stunted and lack vigor. Usually affected plants survive but remain stunted and produce a poor crop. Careful site selection and soil preparation before planting are key in managing black root rot. Soil fumigation, which will reduce the nematode and fungal populations that are the main causes for the development of the black root rot, and good water drainage are also part of a successful management. In general, chemical control is not effective (McManus, 2004).

Other strawberry diseases include, but are not limited to, **angular leaf spot** (*Xanthomonas fragariae*), **common leaf spot** (*Ramularia tulasnei*) and **red stele root rot** (*Phytophthora fragariae*).

1.4. Problem statement and assignments within NIBIO

1.4.1. Global problem statement

The EU has sparked through its Directive on sustainable use of pesticides a global goal to aim towards sustainable food production and minimizing pesticide use by promoting alternative approaches such as IPM.

Thus and as stated before, there is a need for practical IPM tools with verified effects and efficiency. Indeed it is absolutely necessary for a successful implementation of IPM to provide farmers with proof of the potential of IPM to control pest and thus reduce pesticide use.

1.4.2. Internship problem statement

In this spirit, two of NIBIO's Smartcrop project objectives are to :

1) Develop new IPM tools.

2) Test and demonstrate “best practice” IPM and study its effect on pest and natural enemies, yield, profitability and environmental risk.

One of the tasks within the first objective is to study water sprinkling as a way of suppressing selected pests and beneficials. One experiment was conducted at the research facility at Ås from May to August 2016 to study the potential of water as an alternative means to control the two-spotted spider mite in tunnel strawberries. The sprinkling set-up used was identical to one known to prevent the infection of powdery mildew in strawberry. Those are two of the most important pests in tunnel grown strawberry worldwide. This is one of the two experiments studied during this internship.

One of the tasks within the second objective, to study the effects of IPM, is to conduct trials in perennial crops. A two-year trial was started in 2016 with five strawberry growers to investigate the effects of more intensive IPM in open-field strawberries by comparing three levels of IPM with respect to pests, beneficials and yield. This is the second experiment studied.

1.4.3 Assignments

As an intern involved in these two strawberry experiments in NIBIO's Smartcrop project, my general work was to monitor and take charge of the samples.

More specifically, my duties in the first experiment were to :

- help set up the equipment (install the plastic on the tunnel, the fleece to separate the plots, the watering system, the plants)
- manage the weeds
- regularly control the watering system
- collect and assess the samples
- process the data.

In the second experiment, my tasks were to :

- visit the strawberry fields
- collect and assess samples
- give quick feedback to help my supervisor and the growers in the decision making process
- process the data.

The nature of the samples and the assessments will be more thoroughly explained in parts 2.1.2 and 2.2.2.

2. Smartcrop IPM experiments in strawberry growing

2.1. Experiment 1 : control of *Tetranychus urticae* with water sprinkling in tunnel strawberries

This experiment aims to investigate the side effects of overhead water sprinkling of strawberry plants on the two-spotted spider mite, using a set-up previously shown to control powdery mildew. The hypothesis is that this phytophagous arthropod will be suppressed by the increased humidity as it is well known that it is most problematic in relatively hot and dry conditions. It has actually been known for a 100 years or more that water inhibits spider mites but the rise in pesticide use in the second half of the 19th century led to the abandonment of the water method. So this set-up was intended to investigate the effect on powdery mildew in a previous successful experiment and to look at the old water method to control spider mites with a modern technology perspective.

2.1.1. Protocol

The experiment was conducted in a high plastic tunnel (9mx29m) on NIBIO's research facility. The field was composed of six rows of “Korona” strawberry plants, a very productive variety. Only the four middle rows were used in the experiment.

Two-spotted spider mites were cultured in a growth chamber. Mites were introduced in the tunnel by placing an infested piece of leaf from the mite production on each strawberry plant to be used in the experiment. The release took place about two weeks (one mite generation) before the treatments started in order to ensure proper dissemination.

There were four treatments :

- Sulfur spray full dose (750g/100L) once per week
- Acaricide (bifenazat, Floramite) at the recommended rate (60mL/100L/daa)
- Sprinkler irrigation for one minute four times a day (11:00, 12:30, 14:00, 15:30)
- Control (no spray or sprinkling)

Sulfur is mainly used to control powdery mildew but it is not a good spider mite treatment. But as it was stated before the set-up was first made to investigate the effect of water on powdery mildew which explains why it is one of the four treatments used in the experiment.

The acaricide spray would be applied when a threshold was exceeded (e.g. 25% of leaflets with *T.urticae ;* leaflet = one of the trifoliate of a mature leaf).

The sprinkling was scheduled during the warmest time of the day to promote a quick drying of the leaves, thus preventing the development of humidity induced pathogens like grey mold.

There were four replicates of each treatment, resulting in a total of 16 plots with 20 plants per plot. Fleece was used to separate the plots and avoid contamination (Figure 12)

The treatments were randomly distributed within each replicate (block randomization) to avoid bias in the results (Figure 13).

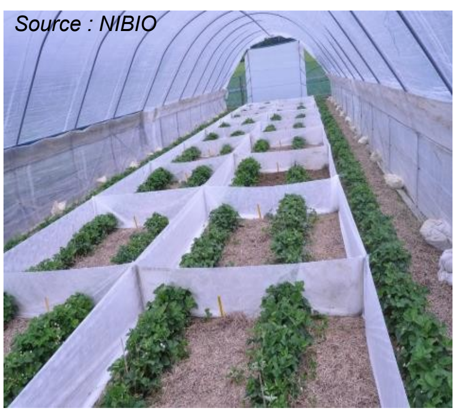


Figure 12 : Experimental set-up

Treatment distribution within the plots :

1) Acaricide
2) Sulfur
3) Water sprinkling
4) Control

Figure 13 : Treatment distribution

Source : NIBIO

2.1.2. Monitoring and sampling

The number of spider mites per leaf was assessed every two weeks, starting just before the sprinkling was turned on, and always carried out before any of the acaricide or sulphur spray that week (and never earlier than 10 days after), by the collecting of leaf samples.
The samples consisted of 20 fully mature trifoliate leaves collected per plot (1 random leaf per plant). Thus, a total of 20 leaves (60 leaflets) per plot were taken into the lab at each sampling. Out of these 60 leaflets, 10 were randomly selected to be placed in a -20°C chamber for the direct counting of spider mites and other invertebrates. The 50 leaflets remaining were submitted to a leaf washing method.

The leaf washing method, or "washing out" method, consists in :

- soaking each sample separately in soapy lukewarm water for roughly 24 hours
- filtering the soaking water with a 105µm filter
- washing the sample twice, still with lukewarm water, each time filtering the used water
- after the second washing and before filtering the water, shaking each leaf to get whatever is left off and into the water (then filtered)
- rinsing the container for any residue and filtering the water
- flushing the content of the filter into a vial with 70% ethanol.

Two-spotted spider mites and other invertebrates were then counted from each of these samples.

The monitoring of this experiment also included regular manual weeding of the field and regular yet random visits especially during sprinkling time to ensure proper functioning of the watering system.

2.2. Experiment 2 : control of the main pests in open-field strawberries with three IPM approaches

As stated before, this commercial trial aims to demonstrate the effects of three IPM approaches based upon a reduced use of pesticides on the main pests of strawberries grown in open-fields. Its goal is also to study the economical effects of these approaches. The hypothesis is that a lower use of pesticides than the regular amount used by growers is just as efficient in controlling the main pests populations and diseases while being economically viable.

2.2.1. Protocol

Five strawberry growers have agreed to take part in this two-year trial (Appendix 2). They all use conventional farming techniques. Since the main goal is to reduce pesticide use, organic farming is not relevant in this trial. Having growers with different farming techniques would have also introduced too many variables (such as the use of different fertilizers) which was not desired.

Each grower has attributed 0.3ha of their field to be used as test-subjects. The experiment uses these areas as three plots of 0.1ha to compare three different techniques : “conventional” (the growers' ordinary practice), “IPM light” and “IPM intensive”.

The light and intensive IPM regimes consisted of slightly different spraying practices than the ordinary one, omitting some sprays and in some cases using other chemicals or lower dosages.

Predatory mites (*Neoseiulus cucumeris*), preying on mites and small insects, were released in all three plots to see how they survived the different spraying regimes.

Also, the two IPM regimes distinguish themselves from the conventional by relying on monitoring to make treatment decisions instead of the conventional automatic spraying, thus reducing the use of pesticides. As stated in part 1.2.2.2, monitoring is a fundamental aspect of any IPM method as it gives critical information for making pest management decisions. “IPM intensive” were more different from the ordinary practice than “IPM light”.

Table 4 sums up the different features of the three techniques.

Table 4 : IPM treatments detail

Source : NIBIO

Stage	Measures	1 : Ordinary practice	2 : IPM-light	3 : IPM-intensive
Before the first spraying	Set correctly spraying equipment	NLR check settings and calibrate the spraying equipment and tractor. If spraying the same day use identical amounts of water, nozzles, settings and drive speed in all systems		
Throughout the year – the same in all systems (if this is used as common practice on the farm	Brushing on the plastic field early spring	X	X	X
	Fertilization and leaf fertilization	X	X	X
	Weed control	X	X	X
	Nemasys H against the root weevil on demand	X	X	X
	Aliette/Resistim/Ridomil againt Phytophtora crown rot and Red stele root rot margin after needs	X	X	X
	Snail control as needed	X	X	X
On small plants	Topaz against mildew	Normal dose = (N)	(N)	(N)
2 weeks after previous	Thiovit against mildew	(N)	(N)	(N)
1-1,5 week before flowering	Against spider mites and mildew	Envidor (N) + Topaz (N)	Envidor (N) + Topaz (N)	If required (up to the beginnings of flowering) : Renol
Just before flowering	Against pests	Fastac/Karate/Decis (N) Calypso (N) when needed	Calypso (N)	Calypso (N)
2 weeks out of flowering – same in all systems	Release of cucumeris-persimilis (about 400-600 per row)	X	X	X
Start of blooming to start of picking	Mushroom sprouting : 1 2 3 4 5	Signum (N) Switch (N) Teldor (N) + Thiovit (N) Switch (N) Signum (N)	Signum (N) Switch (N) Teldor (½) + Thiovit (½) Switch (½) Signum (½)	Signum half dose (½) Switch (½), but 0 if not needed Teldor (½), but 0 if not needed Switch (½), but 0 if not needed Signum (½)
	Spider mites in the flowerings	Floramite (N) 1-2 times as needed	Floramite (N) 1-2 times as needed	Floramite (N) 1-2 times as needed
	Against the strawberry blossom weevil and thrips	Calypso (N) 1-2 times	Calypso (N) on demand only	No = 0 Calypso (N) needs to be considered before harvesting, against thrips if urgently needed
After harvesting	Against mites and other pests	2 times Vertimec (N) + DP-adhesive (N)	Only spraying if symptoms/Strawberry mite in the samples	Only spraying if symptoms/Strawberry mite in the samples
	Fungal diseases	1-2 times Thiovit (N)	1-2 times Thiovit (N)	1-2 times Thiovit (N)

2.2.2. Monitoring and sampling

The monitoring of the fields was performed by all parties involved in the experiment : the growers, the advisory services and the visitors from NIBIO (Researcher and internship supervisor Nina Trandem and myself).

Needless to say that the most frequent scouting is done by the growers. One of the main tasks they agreed to by taking part in the experiment is to keep a diary of everything that is done in the field. The experiment protocol allowed the treatments applied in the IPM light and IPM intensive plots to vary from one field to another in accordance with their needs. Thus it is essential to keep a record of field conditions, cultural practices and the development of pest populations to document the history of each field.

Another task performed by the growers is the registration of yield levels in each plot during the picking season which will be used to evaluate the effects of the techniques on yield. This task was solved differently by each grower, depending on the farm logistics and picking system.

One of the benefits the growers get by contributing to the project is more help from their local advisory service. Usually the farmers must pay for such extra visits, but through the project they got regular visits and expertise scouting of the fields, detecting any problems with pests or fertigation at an early stage. The advisors' knowledge of the field and their general expertise make them highly competent in making pest management decisions. The advisors also collected some of the samples (or all in the case of the field furthest from Ås).

The NIBIO-team took leaf and flower truss samples back to the lab for closer examination. There is a wide range of pests and diseases, each with their own biological and physiological needs and preferences. During my stay, field samples for taken in each field (Table 4). The objective of these registrations was to gather data on selected pests, diseases and beneficials, including weeds, and provide some of the necessary information to make treatment decisions.

Table 5 : Field registration details

Source : NIBIO

Registration	Stage	Protocol
1	1 - 2 weeks before flowering, before Envidor spraying	Take 2 x 30 fully mature leaves per plot (high and low) Take pictures of the whole field and of a typical plant to show the development
2 + 3	1 week before sart of picking	Take 2 x 30 fully mature leaves per plot (high and low) Take 2 x 30 young folded leaves per plot Take 1 x 30 flower trusses per plot Take pictures of plants and of the three plots with surroundings Register presence of fungal diseases (if unknown disease, take a sample) Register major weeds, especially flowering ones Look for signs of important pests not necessarily covered by leaf or flower truss sampling : root weevils (leaves and root), etc.
4	Middle of picking (about 14 days after Reg2+3)	Take 2 x 30 fully mature leaves per plot (high and low) Take 1 x 30 flower trusses per plot Take pictures of plants and of the three plots with surroundings Write the dates for start of picking and last picking before the visit Register occurrence of fungal diseases not covered by the samples Register major weeds, especially flowering ones Look for signs of important pests not necessarily covered by the samples. For example, if a few plants show symptoms of strawberry mite some leaves from these plants could be added in an extra zip bag
5	After picking (before plants are cut)	Take 2 x 30 young folded leaves per plot Take pictures of plants and of the three plots with surroundings

The samples gathered were taken back (or sent by the advisors) to NIBIO for proper evaluation.

The fully mature leaves were submitted to the "washing out" method (c.f 2.1.2) for the counting of two-spotted spider mites and other invertebrates (beneficials such as predatory mites or other pests such as whiteflies).

The young folded leaves were assessed by direct counting with a special focus on strawberry tarsonemid mites *(Phytonemus pallidus)* and predatory mites. These young folded leaves are made up of three to five leaves but only the middle one is counted (all sides). Other invertebrates were also registered.

The direct evaluation of the flower trusses consisted in ascertaining the number of berries per truss and their stage of development (fruits, petal fall flowers, open flowers, buds), the number of damaged berries and the nature of the damage (catface from frost damage or pests rated one (low damage) to three (high), grey mold, bronzing from thrips), and finally the number of thrips (other invertebrates present also registered). For the thrips count, only one berry per truss was checked (the biggest reddening but not ripe berry).

3. Experiment assessment through data analysis

3.1. Results

The two experiments presented in the previous chapter have produced a lot of data. This raw data is composed of the results from every sample collected and assessed throughout both experiments. However the data from the open-field trial in not complete as the "washing out" samples have yet to be counted and the yield data has not been collected from the growers.

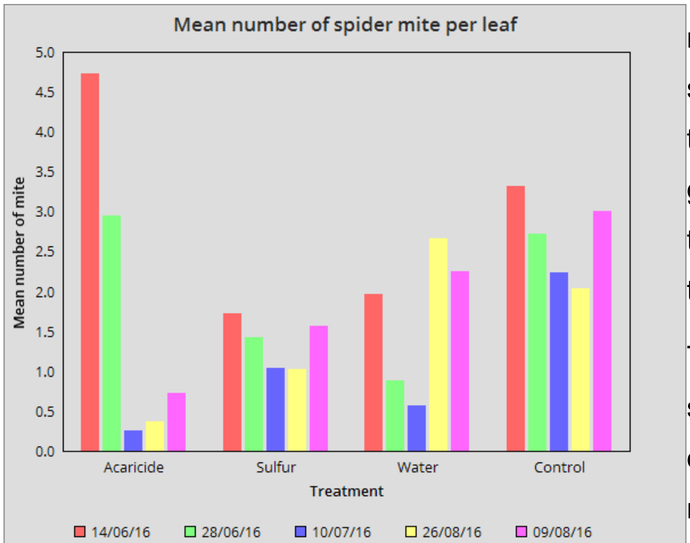
The raw results are confidential and the property of NIBIO thus they won't be exposed here. However some information regarding the field registrations and last year's experiments is available in the appendix.

The analysis and evaluations that follow are based on these results and any other data and information collected in the field.

The analysis of the open-field trial (part 3.3) focuses on the effect of the three treatments on strawberry mites, predatory mites and gray mold.

3.2. Analysis of the effects and evaluation of the experiment on water sprinkling as a means to control two-spotted spider mite populations

Figure 14 : Mean number of spider mite per leaf and treatment



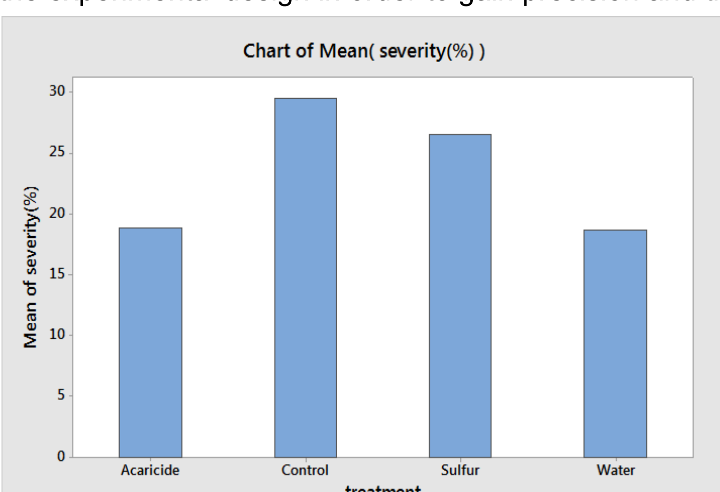
Source : Personal

The mean number of two-spotted spider mites per leaf and per treatment enables us to see the evolution of the mite population throughout the experiment and the treatments' general effect on the population (Figure 14), and to compare the result in 2016 with the identical trial in 2015.

The control, which was neither sprayed nor sprinkled, shows us that there was a natural decrease of the population during the first two months of the experiment followed by a spike in the population in the last two weeks. The population of mites undergoing sulfur treatment follows the same tendency, confirming the assumption that sulfur (used to control powdery mildew) has little effect on the two-spotted spider mite.

The decrease of the mite population is considerably more pronounced in both the acaricide and the water sprinkling treatments, though especially in the acaricide treatment. Thus the latter may seem a lot more effective than any other treatments. However water sprinkling seems to prove itself as a viable means to control spider mite populations as the number of mite per leaf assessed on the 10th of July reached a very low level. The high rise in the population that followed does not disprove this fact.

All that can be made here are assumptions. Indeed the experiment was only made of four replicates of each treatment which is not enough to have consistent results. There needs to be more replicates in the experimental design in order to gain precision and thus getting more reliable results.



Source : NIBIO

However the effect on leaf damage in 2015 is significant (Appendix 3).

The mite severity assessment in 2016 tends to confirm this (Figure 15).

Figure 15 (left) : Mean of mite damage severity per regime

It is shown there that the water sprinkling and the acaricide treatments have much lower rates of damage severity than the sulfur treatment which is closer to the control's rate.

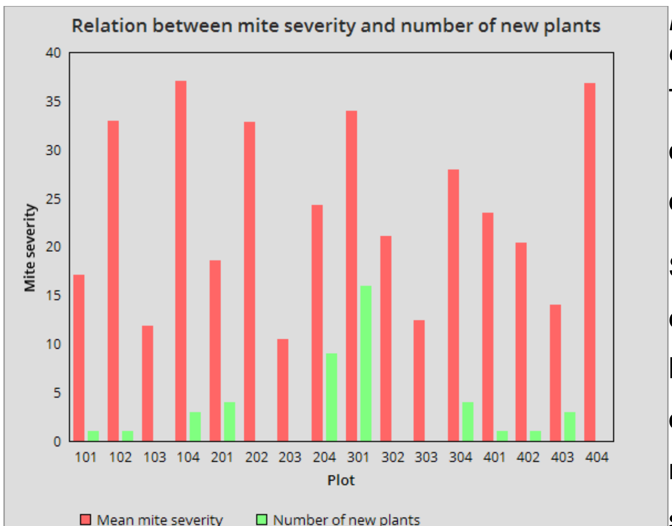
In terms of mite severity this chart shows water to be as effective as acaricide.

These facts give even more credit to the hypothesis that water sprinkling can control two-spotted spider mite populations.

The insufficient number of replicates was not the only issue raised in this experiment.

The strawberry plants used in the experiment are mostly six to seven years old, and some of them had to be replaced only three weeks before the start of the experiment. These new plants were not evenly distributed within the field which means they were not evenly distributed within the plots or treatments. This led to believe that these new plants might have biased the results in some way thus adding to the already large variation in mite numbers.

However if we put the number of new plants in relation to mite damage severity (Figure 16) we cannot see any link between the two.



Source : Personal

Figure 16 (left) : Relation between new plants and mite damage

This fact suggests that if the presence or absence of new plants in each plot had any effect on the development of mites, it was a minor one.

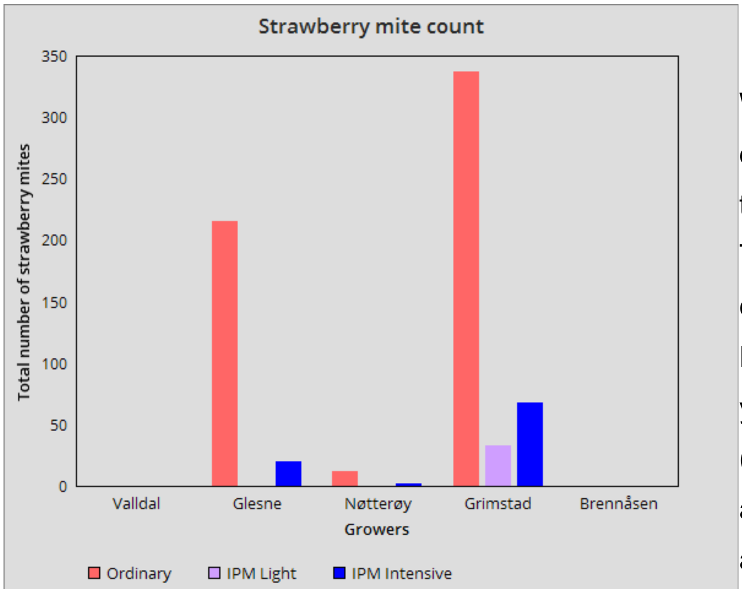
So far, though without any certainty, the experiment leans toward the validation of its hypothesis that the action of water through overhead sprinkling is an efficient means to manage the two-spotted spider mite in tunnel strawberries.

The results from previous experiments (Appendix 3) only add consistency and reliability to this assumption. The mean number of spider mites per leaf and the damage severity assessment in 2016 indicate that water is as effective as acaricide.

Plans have been made to repeat the experiment next year with new plants, using this year's issues to ensure proper, consistent and usuable results, in order to provide a proof of concept that water sprinkling is a viable technique for simultaneous management of two-spotted spider mites and powdery mildew in tunnel strawberries. However, judging from what we have seen so far, as well as known from the literature, the technique seems sound. Still there is some remaining work to make it a practical technique. For example the economical aspect has yet to be studied. Tunnel set-ups are already costly. Adding a water system to implement this technique could prove too expensive and thus not viable for growers.

3.3. Analysis of the effects of three IPM regimes on two pests (the strawberry mite and gray mold) and beneficials (predatory mites)

Strawberry mites were present in three of the five fields studied. In two of those three fields they were present in relatively high numbers (Figure 17).



Source : Personal

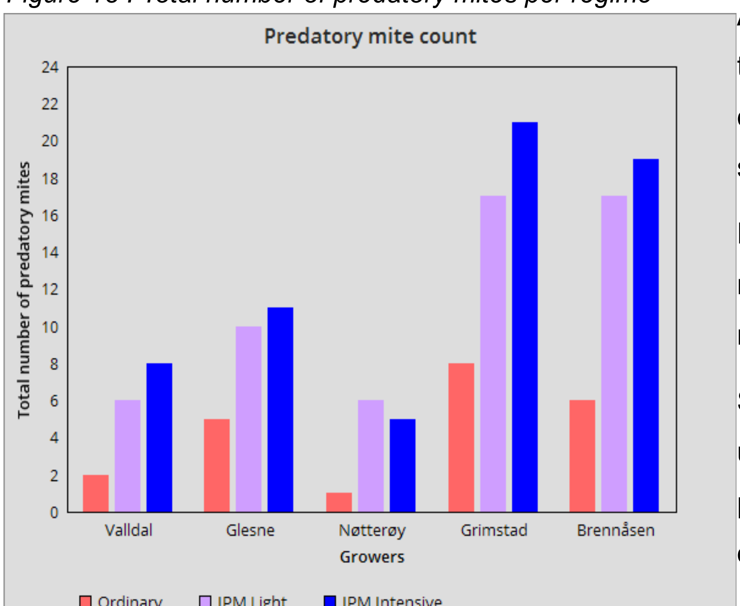
Figure 17 (left): Total of strawberry mites per regime

We can see that there is a consistent difference between the ordinary practice and the light and intensive alternative practices. The number of strawberry mites is considerably higher in the former.

However these results are based on the young leaf samples from Reg2+3 and Reg5 (Table 5). Samples which were taken before any sprays targeting strawberry mites were applied (this species is controlled after harvest).

So what is successfully keeping the strawberry mite levels so low in the IPM light and IPM intensive regimes ?

Figure 18 : Total number of predatory mites per regime



Source : Personal

After flowering predatory mites were released to study how they would be affected by the different treatments. All five fields show the same outcome (Figure 18).

Predatory mites are present in higher numbers in the IPM light and intensive regimes than in the ordinary.

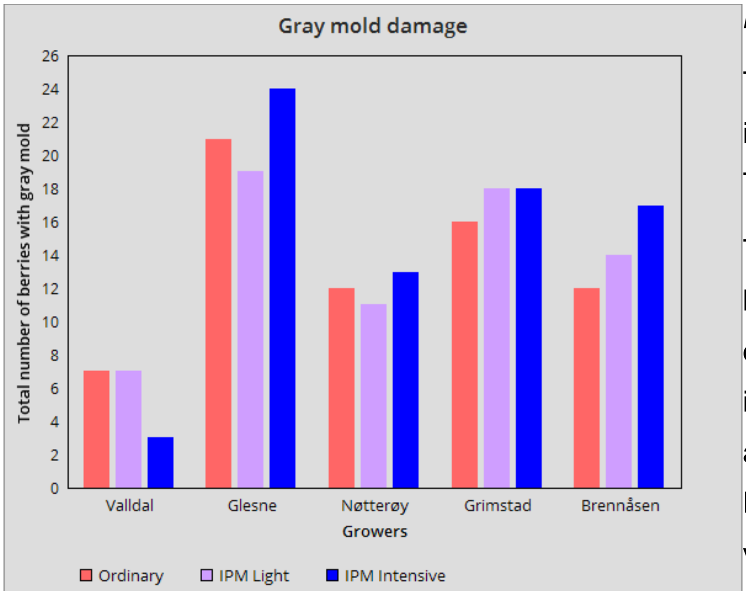
So what we see in Figure 8 is actually an unfortunate side effect of controlling other pests, especially the use of pyrethroids in the ordinary regime which kills predatory mites.

The number of predatory mites in relation to the number of strawberry mites in each regime indicates that a sound predatory mite population can prevent the development of strawberry mites.

The added spraying in the ordinary regime has negative effects on the predatory mite population, thus enabling the strawberry mite population to grow. Whereas in the IPM intensive and IPM light regimes which are subject to less spraying (or in lower dosages), the predatory mite population is substantial enough to maintain low numbers of strawberry mites.

To conclude on this matter, the alternative practices are here more effective than the ordinary practice.

Regarding gray mold, which is a major issue in open-field strawberries, there is no consistent difference between the three regimes (Figure 19).



Source : Personal

Figure 19 (left) : Gray mold damage per regime

The amount of berries affected by gray mold in each regime doesn't vary substantially. This is consistent in all five fields.

The results seem to indicate that applying lower dosages of fungicides (some sprayed only if symptoms are present) is as effective in controlling the development of gray mold as the automatic spraying of full dosages. However this assumption cannot be validated yet. For example the results from the Valldal field show there is approximately 60% less gray mold damage in the IPM intensive regime than in the ordinary and IPM light regimes. While the results from Brennåsen indicate that there is about 30% more damage in the IPM intensive regime than in the ordinary one.

Thus a proper statistical test should be done before coming to any conclusion.

Overall these results lead us to conclude that both the IPM light and IPM intensive regimes are viable strategies that would allow growers to control pests while minimizing their use of pesticides.

However some of the effects of the treatments have yet to be analyzed, such as the effects on the two-spotted spider mite and on yield. These will have to be studied before any conclusion can be validated beyond doubt.

4. Discussion

4.1. Effects on agricultural and environmental management

The IPM paradigm redefines agricultural management.

Important components are cultural and biological controls. Cultural control is the reduction of pest damage or abundance through the purposeful manipulation of the environment.

The experiments on the effects of water sprinkling on the two-spotted spider mite and powdery mildew are a perfect example of cultural control. In these experiments the tunnel's environmental characteristics (hot and dry) were modified by adding water sprinkles, thus creating a wet environment that inhibits spider mites and mildew. However cultural control can have unexpected effects.

Indeed, ecosystems are composed of an unthinkable number of biotic and abiotic elements, all linked in so many different ways that it makes it very difficult to predict how changing one of these elements can affect the rest.

Figure 20 : Effects on weeds of the water sprinkling

Source : NIBIO

For example, in the tunnel experiment, the water sprinkling had effects on weeds that were not foreseen. The amount of weeds and the speed at which they grew were far more important in the plots subject to water sprinkling than in the other treatments.

Figure 20 shows the strawberry field right after the experiment had ended and the fleece around the plots been removed. This gives us an overview of all treatments. We can see areas with virtually no weeds and relatively small strawberry plants (those are the sulfur plots) and areas with substantially more weeds and bigger strawberry plants (in the figure the areas with water sprinklers). Of course in this case the side effect of the cultural control used could have been anticipated. The important fact here is that IPM strategies such as cultural control can lead to other changes in agricultural management. Here the change from a dry to a wet environment meant the weed management had to be adapted.

This principle also applies to biological control. Hence the importance in the IPM paradigm of integrating cautious monitoring and understanding of agroecosystems to practical agricultural management.

Cultural and biological controls may require significant modification in farming practices.

When cultural control practices are integrated easily with other cultural practices, they are usually readily adapted by the growers. However, when these practices demand significant modifications to be made in farming practices, the advantages and disadvantages must be weighed carefully.

Reporting the impact of IPM programs remains problematic for several reasons. When comparing costs on pesticide use for an IPM program versus a standard pest management program, each set of practices must be defined. Over time, these definitions lose relevance as IPM methods known to be useful and practical are adopted by most growers and become the new standard.

Measuring the environmental impacts of pesticides, such as water contamination or reduction of non-target species, is particularly difficult (Kovach, et al., 1992), and as a result so is quantifying the environmental impacts of an IPM program.

4.2 The future of IPM

IPM programs are supported by both large international institutions such as the European Union and public bodies such as the Ministry of Agriculture. They have resulted in a decrease of pesticide use in many cases. In spite of these obvious successes and apparent benefits of IPM, insecticide usage as also increased in past years.

Classical IPM, centered primarily around the use of intensive monitoring and judicious application of needed pesticides, may have taken us about as far as it can in terms of pesticide reduction within conventional, high-input farming systems. Further reductions will require new IPM technology, such as non-pesticide alternatives. ”Biointensive” approaches to IPM, emphasizing biological and cultural controls will hopefully be the next phase in the evolution of many IPM programs.

How does IPM fit in the development of low external input, sustainable agriculture systems ?

Although the driving motivation of IPM has been to reduce environmental contamination through reduced pesticide use, unfortunately, many IPM programs increase and justify pesticide use through economic analyses that, by ignoring negative external costs such as pesticide pollution and clean-up costs, ignore the total costs of pesticide use (Luna, and House, 1990). More importantly, IPM programs have been centered around single commodities (soybeans, cotton, apples, strawberries, etc.) rather than being centered around whole farming systems, for example a mixed cropping/livestock system or a fruit and vegetable truck-farming system.

We need to be looking at whole farming systems with interdisciplinary cooperation in research and extension. Indeed, rather than continuing to study conventional high-input systems in an effort to manage these systems more efficiently, sustainable agriculture (and future IPM) should place a renewed emphasis on designing and developing new agroecosystems that maximize beneficial ecological processes and minimize expensive off-farm inputs.

As agricultural chemical inputs are lowered, there is a concomitant increase in the need for fundamental understanding and management of ecological processes in agricultural systems. Since sustainable agricultural systems are associated with lower inputs of fossil-based chemicals, they require increased knowledge about and management of ecological processes.

High chemical input practices mask the ecological processes occurring in agricultural systems. For example, using large quantities of inorganic fertilizer allows a farmer to ignore or pay little attention to nutrient cycling processes.

In other words we need to replace large energy and chemical subsidies with knowledge and management of ecological processes. The extensive funding of research and the propagation of information to all end-users are essential to this (Rajotte, 1993).

With the current groundswell of interest in low-input, sustainable agriculture, we are at a historical juncture. There is an increasing willingness to question how we grow and market crops. We have the potential and tools to create an agriculture that can reduce the dependency on agricultural chemical inputs dramatically by turning to information-intensive, ecologically compatible alternatives. To realize this potential we must have vision and the commitment to explore alternative approaches to agricultural production.

If the challenge of moving the basis of IPM from relatively simple and predictably effective chemicals to much more complex alternatives is to be met, it will require a public commitment. A commitment from public bodies through the funding of research, the incentives and policies for large-scale implementation of alternative approaches such as low-input IPM strategies, and just as importantly a commitment from consumers. The adaptation of IPM by growers depends as much on societal pressure as on cost-saving motives. Many growers have an interest in using IPM as a marketing tool, and this interest may be a major factor influencing growers to adopt IPM. To help growers in this effort while maintaining the integrity of the IPM designation, the creation of an IPM label or certification could be considered. How willing growers will be to cover the costs of scouting and research in IPM practices and marketing remains to be seen, but they probably will not be. If society and institutions wants to reduce pesticide use significantly, it must be willing to make significant investments in developing and implementing reliable alternatives.

Sustainable agriculture, through redefined tools such as IPM, has the potential to achieve a common ground between environmental and economical goals.

Success ultimately depends on our willingness to accept and implement a new philosophy of agricultural production.

Conclusion

This internship has been highly enriching for me as it enabled me to discover in detail the IPM strategy and what it means in terms of agricultural management, as well as the policies and confines behind its implementation. It also enabled me to take part in the development and evaluation of IPM tools through my assignments in the experimental work.

Thus this internship has reinforced my will to find my way in alternative and sustainable management through research and advisory work.

The Institute that welcomed me is facing a transitional period from oil-based agriculture to low-input sustainable agriculture and I am very proud of having contributed and taken part in this revolution.

Clearly, the IPM paradigm has been extremely useful and has a lot of potential in reducing pesticide use. Societal and environmental needs demand the evolution of farming practices which IPM can successfully provide.

With this experience behind me and to meet with the major challenge that is the development of sustainable agriculture, my wish for the future is to turn towards whole-farming, bio-integrated systems with small-scale stakeholders and full of future promise.

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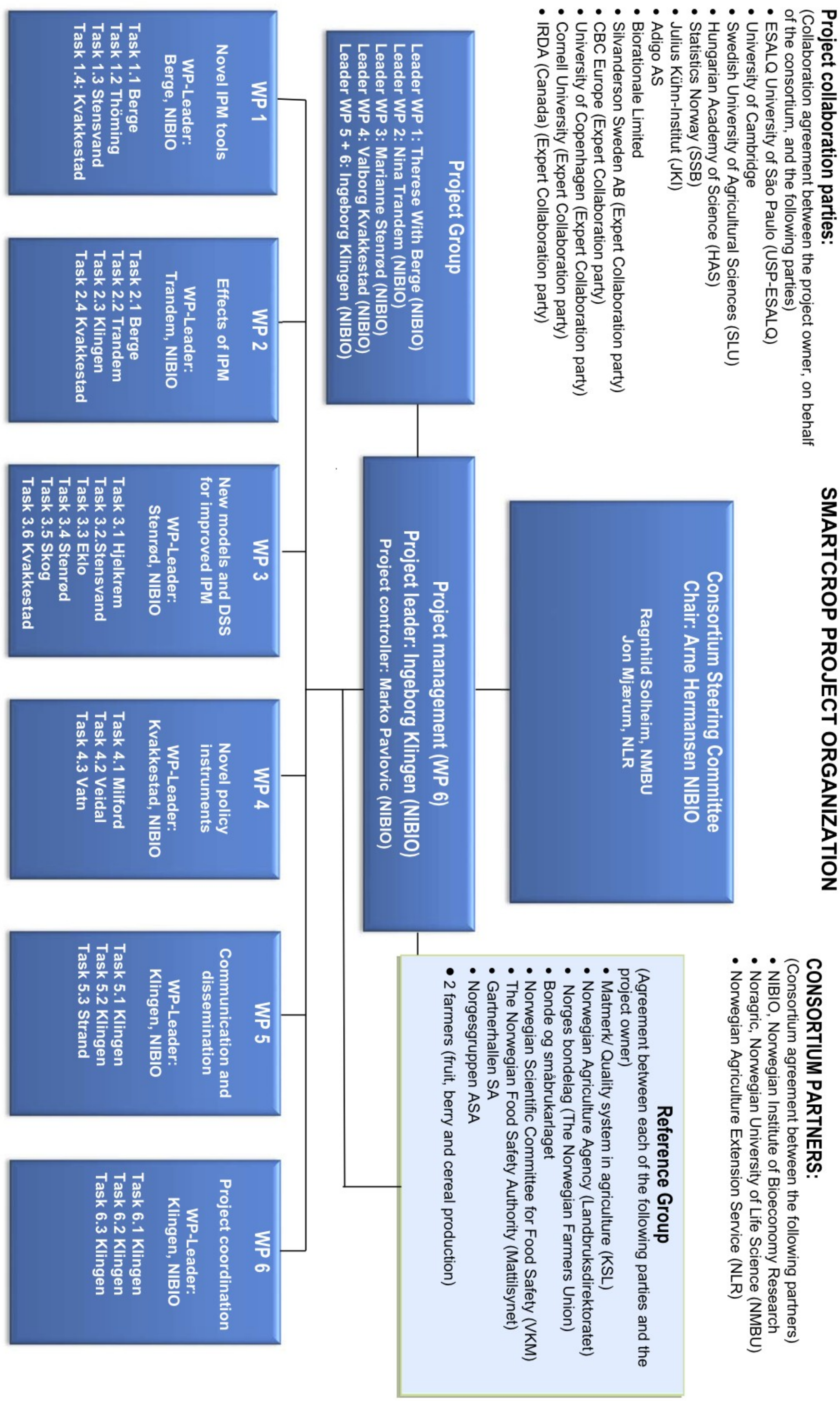
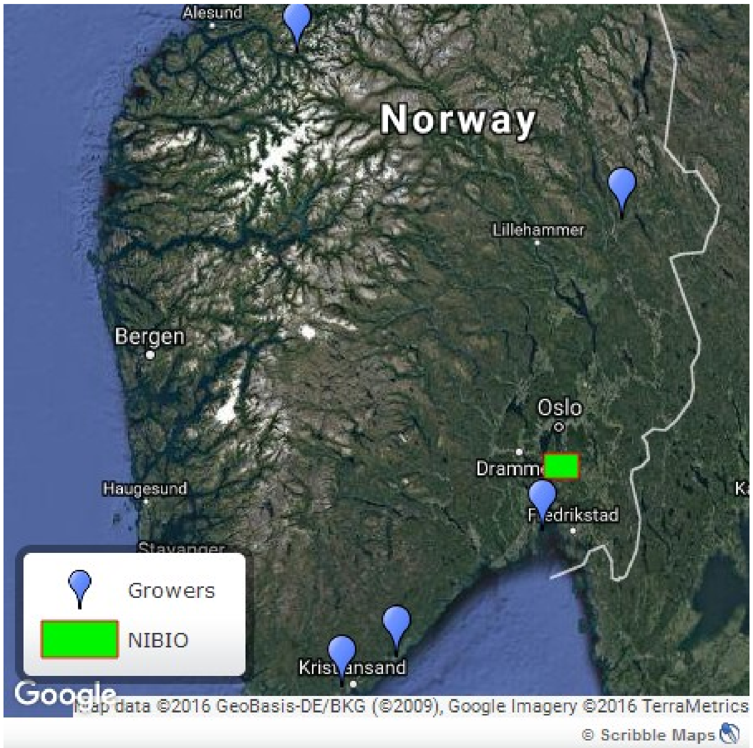
APPENDIX

Appendix 1 : Smartcrop project organization
Appendix 2 : Map of growers and notes from field visits
Appendix 3 : 2015 Water trial analysis

Appendix 1 : Smartcrop project organization



Appendix 2 : Map of growers and notes from field visits



Brennasen :

- Reg 2 + 3 : visit on 02.06.16, a substantial amount of weeds : *Stellaria media, Epilobium hirsutum, Vicia cracca, Senecio vulgaris, Capsella bursa-pastoris* are the main species.
- Reg 4 : visit on 23.06.16, even more weeds but same species, substantial grey mold in all plots (though it seems a bit less in the Ordinary regime), a lot of white flies flying around everywhere, field not picked on day of visit, a lot of ripe fruits.

Grimstad :

- Reg 2 + 3 : visit on 02.06.16, some weeds, main species same as Brennasen, smaller plants and more weeds at the end of the rows
- Reg 4 : visit on 23.06.16, not much damage from spider mites, some weeds but not more than on 1st visit, same species, lots of grey mold everywhere but grower says worse in IPM Intensive, field being picked on visit

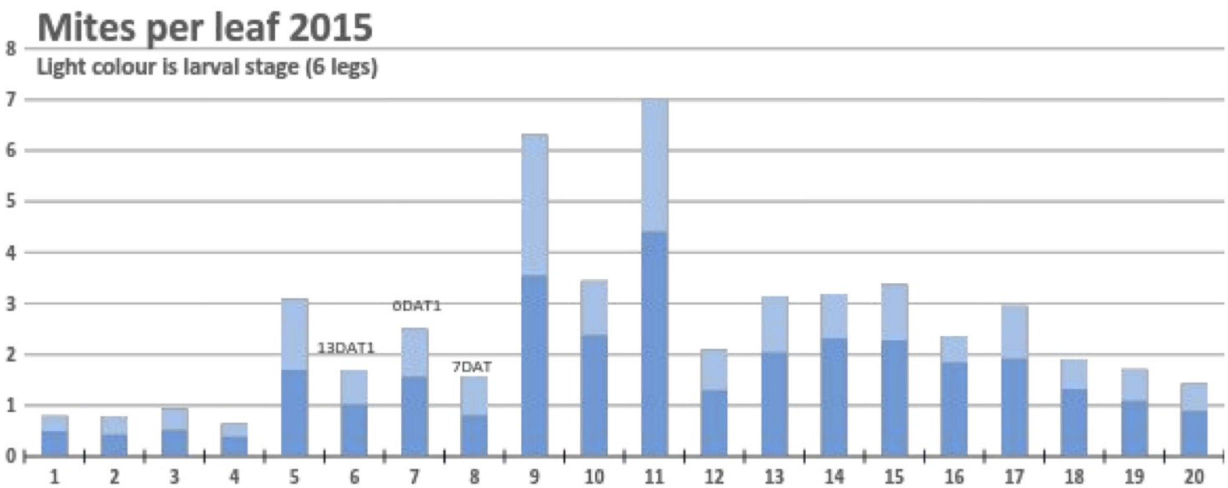
Notteroy :

- Reg 2 + 3 : visit on 09.06.16, field covered in straw, no weeds.
- Reg 4 : visit on 30.06.16, not much damage from spider mites, still no weeds (straw), a lot of grey mold in all plots, field not picked on day of visit, lots of ripe fruits

Glesne :

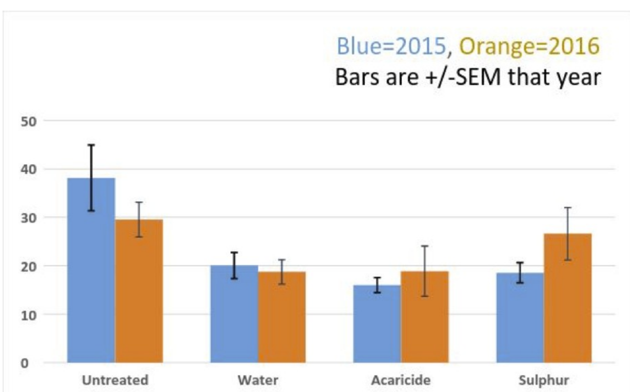
- Reg 2 + 3 : visit on 28.06.16, smaller plants than other growers, no weeds (straw).
- Reg 4 : visit on 21.07.16, still no weeds (straw), few berries left, some grey mold, field not picked on day of visit, not much damage from spider mites.

Appendix 3 : 2015 Water trial analysis



Treatment (but not block) is significant for the total (summing the dates => mite days). Sulfur and untreated is sign diff from acaricide. Water is not sign. different from any other treatment. The picture is dominated by one date (16 July), the analysis for the whole season is also true for this date.

Results: % leaf surface with damage



In total, 30-40% of this damage is avoided with the water sprinkling.
The acaricide is not better.
Sulfur has a very variable effect.

Treatment is a significant factor in 2015 and if both years are analysed together (year is not a significant factor). Block is not significant in any of the years.

In 2016 there was a large variation in the acaricide treatment, which had the plot with 16 new plants. If this plot (301) is removed, the SEM for the three remaining plots is only 1,6. The smaller number of new plants in the other plots did not affect the results.

In 2015 the significance is about the untreated being bigger than the other three treatments.