Disclaimer: This report is part of a project that has received funding by the European Union's Horizon 2020 research and innovation program under grant agreement number 862568.

SPRINT
SUSTAINABLE PLANT PROTECTION TRANSITION

Internal report on farm level impacts of different pesticide reduction strategies

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Deliverable number: D6.3
Due date: 29.02.2024
Dissemination level: Internal
Lead beneficiary: FiBL
Deliverable type: Internal Report

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PROJECT INFORMATION	
Project Title	Sustainable Plant Protection Transition; A global health approach
Project Acronym	SPRINT
Call Identifier	H2020-SFS-2019-2; Sustainable Food Security
Grant Agreement no.	862568
Starting Date	01-09-2020
End Date	31-08-2025
Project duration	60 months
Website address	www.sprint-h2020.eu
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REPORT INFORMATION	
Report Title	Internal report on farm level impacts of different pesticide reduction strategies
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Deliverable Number	D6.3
Work Package	6
WP Leader	Jennifer Mark, Claudia Meier

Other partners involved	DTU
Nature	Report
Dissemination	Public
Editor(s)	Peter Fantke, Farshad Soheilifard
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Report Due Date	M42
Report publish date	M60

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1 Highlights

- The experience in Slovenia shows, that product substitution can be a cost-effective way for conventional/ IPM arable farms to reduce their environmental and health impacts.
- Disease resistant varieties are perceived as a cost-effective way for conventional/ IPM farms to reduce their reliance on synthetic pesticides, if there is sufficient market demand and AOC (controlled designation of origin) specifications are relaxed.
- The low residue strategy is perceived as an economically viable option for conventional/ IPM farms producing fruits, if appropriate financial incentives are provided and if there is a cost-effective way for handling storage diseases.
- Mechanical weeding only is perceived as an economically viable option for conventional/ IPM arable farms, if they have access to appropriate machinery and technical assistance.
- Generally, farming without synthetic pesticides is perceived as very risky. Thus, reducing the reliance on synthetic pesticides implies reducing farms' perceived production risk.
- Generally, to reduce the reliance on synthetic pesticides (and perceived production risk), farms need access to effective machinery, technical assistance, financial support, and effective non-synthetic product alternatives.
- Generally, to reduce the reliance on synthetic pesticides (and perceived production risk), the demand for disease resistant varieties and low-residue, pesticide-free, and organic products needs to be strengthened.
- Alternative production systems such as organic farming significantly reduce crop protection expenditures and provide higher returns on these expenditures.
- Our results, based on a comprehensive analysis of a large sample of farms across the EU, counter the widely held belief that organic farming involves increased labor demands and costs.
- The analysis clearly reveals the key role of subsidies in ensuring a viable economic performance of organic farms.

2 Introduction

All around the world, massive use of plant protection products (PPPs) led to current issues regarding negative impacts on human health, soil and water contaminations. It is of high necessity to reduce PPP use and find novel strategies to control pest and diseases. Several studies showed how the transformation of agriculture could lead to more sustainable use of pesticides (Hofmann et al., 2023; Lee et al., 2019). A range of plant protection tools and strategies to reduce pesticide use are available (Pertot et al., 2017). Those methods include resistant varieties, crop rotation, mechanical weed control, biocontrol agents (macrobials, microbials and natural substances, use of semiochemicals and physical mating disruption, decision support systems (Delière et al., 2015) and monitoring. For example, diverse crop rotations are an essential tool to increase the resilience of crops and to preventively reduce risks due to pests and diseases. Today, the adoption of available tools and techniques is still limited especially in mainstream agriculture. Hurdles for adoption include availability of tools for key pests, high costs, limitations in efficacy and trust by farmers.

The objective of the current deliverable is to assess the costs and benefits of agronomic interventions to reduce the reliance on synthetic pesticides at microeconomic level. We collected farm level data on crop protection strategies and agronomic management practices, and we performed so called expert interviews to collect additional information from Sprint case study sites (chapter 2 and 3). In addition, we worked with FADN (Farm Accountancy Data Network) data (chapter 4) to analyze the differences in crop protection and total labour input costs as well as gross farm income between conventional and organic farms.

Chapter 2 provides a snapshot of current agronomic practices and strategies to reduce the reliance on synthetic pesticides for each of the 11 Sprint case study sites. Chapter 3 looks into the farm-level impacts of selected agronomic interventions in four Sprint case study sites (France - grapes, Switzerland - apples, Slovenia – silage maize, and the Netherlands – potatoes). Chapter 4 looks at farm-level impacts of organic conversion for farms using an econometric modeling approach and FADN data across multipe countries and cropping systems. As chapter 3 and 4 represent two separate studies, each chapter has its own conclusion section.

3 Status Quo and strategies to reduce the reliance on synthetic pesticides

Eleven case study sites (CSS) were selected within SPRINT project to be studied at different levels. A part of our study and WP focuses on the analysis of agronomic management practices in each CSS. We tried to identify for each CSS promising agronomic management practices to reduce the use of PPPs but also problematic practices which enhance use of such PPPs. In parallel to farm level data collection, we set up a strategy to collect data on novel alternatives including product substitution/replacement, technical alternatives, physical alternatives and novel technologies which aim to reduce use of PPP. The

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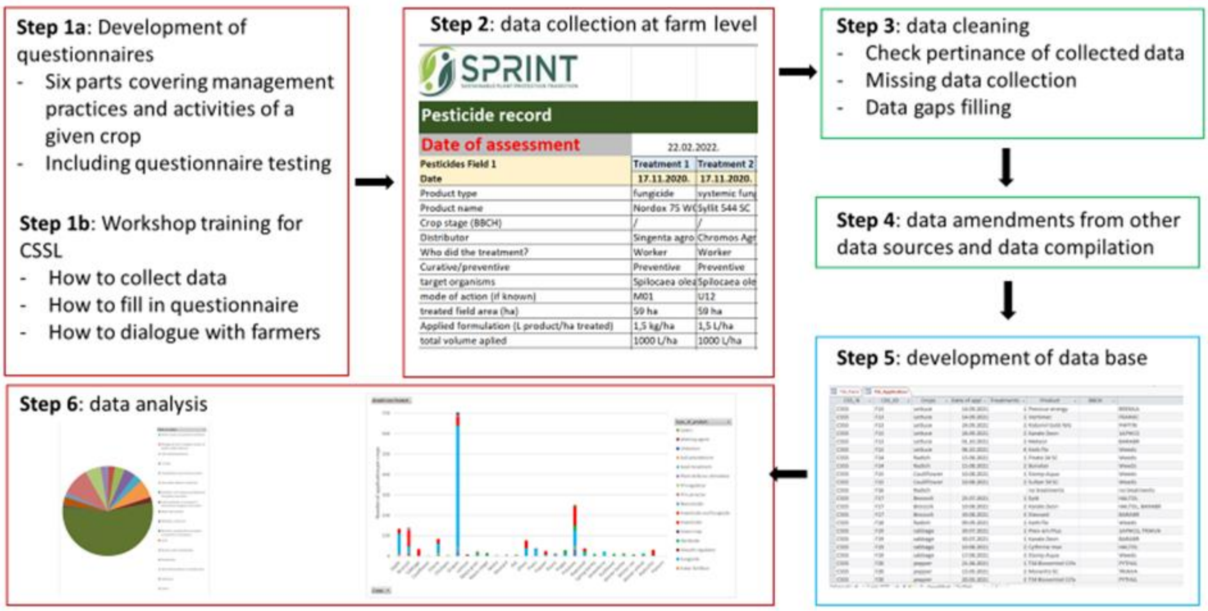
combination of both data collection methods and deep analysis of CSS allowed us to design strategies for each CSS to reduce the reliance on synthetic pesticides.

3.1 Data collection at farm level

WP6 designed questionnaires to collect farm level data at each CSS in 2021 (selection of CSS is described in (Silva et al., 2021)). In total 135 farms were selected across 11 CSS and 178 study fields analyzed. Questionnaires contained questions on farm characteristics, including an inventory of all fields and crops, infrastructure, and employees of a farm. In addition, data was gathered on CSS crop characterization with detailed information of the crop studied (place in crop rotation, density of the crop, sowing dates), pesticide and fertilizer records with detailed data on the dates of each application, product and volumes used, BBCH stage, and machinery used. A crop logbook was completed by each farm containing all agronomic management practices done during the cropping season. Finally, questionnaires contained a cost-benefit sheet to collect data on prices of PPPs and yields. Questionnaires were supplied to CSS leaders after a WP6 training on how to collect data, in order to facilitate interviews. The data sets were checked for completeness and submitted to quality checks. Missing data were identified and CSSL went back to farmers to complete the gaps. Additional complementary data was provided based on other sources e.g. literature search and analysis of PPP databases, technical leaflets on product use. An Access database was programmed to allow for subsequent detailed data analysis. Database will be available in the SPRINT repository.

Figure 1: Conceptual workflow of assessment of agronomic practices on CSS farms in Task 6.1. Step 1a: Questionnaires were developed by FiBL and DTU. Step1b: Workshop trainings were performed individually with each responsible person per CSS, based on selected crops. Step2: interviews were performed at farm level with farmers for data collection and answers were reported in the interview sheets. Each interview was 2 to 3 hours long depending on the crop. Data was sent to WP6. Step3: data was cleaned, checked for plausibility and discussions with CSSL were realized to fill data gaps. Step4: data was amended with other data sources e.g: PPP application recommendations. Step5: database was developed and queries were created for data analysis. Step6: data was analysed.



In total data from 178 farms were collected across selected CSS including farm and crop details (e.g. size of field, farm type, crop rotation), field activities (e.g. soil work, mechanical weeding), fertilizer, non-plant protection products (e.g. growth regulator, chelators), and pesticide use data. Three perennial crops were assessed i.e. vineyards in France and Portugal, olives in Croatia and fruits in Switzerland. Annual crops were assessed in Spain and Italy for vegetables, potatoes in Netherlands and arable crops (cereals, oilseed crops) in Czech Republic, Denmark, Slovenia and Argentina. A total of 28 different crops and their related production practices were assessed covering the 2021 cropping season. Some crops were addressed in several CSS, e.g. grapes in CSS2 and CSS3. Number of farms per crops is variable ranging from 1 e.g. chickpea to 22 e.g. grapes. Farming systems included conventional, organic and IPM (Integrated Pest Management) production but also transition systems as in transition to organic, and some farms having two production systems. Usage of 177 different active ingredients was reported across all CSS with 51 a.i. authorized in organic production and 126 used in conventional/IPM production. Variation in size of production area per farm was high, with small farms (1 ha in Portugal for grape production) up to large farms (e.g. 2000 ha in Argentina for cereal production). The average farm size varied depending on crop and country, i.e. Portugal, Italy, Croatia < 20 ha, Spain, France, Switzerland, Slovenia, Netherlands between 20 ha and 100 ha, and Czech Republic, Denmark, Argentina > 100 ha. In total, surface analyzed in this study across all crops was more than 794 ha. Regarding working capacity of each farm, number of permanent and temporary employees is different depending on the crop, size of farm and farm practices. Animal husbandry are most important in farms producing cereals, as Czech Republic, Denmark and Slovenia. It was also reported that some farms use decision making toolbox e.g. periodic visual sampling, predictive tools, weather stations, advisors. Information on field equipment as nets and irrigation systems were collected. To each pesticide application reported, information on the pest or disease targeted was collected.

3.2 Results

Data collection at CSS allows state of the art of current agronomic practices in relevant EU crops and application patterns can be determined for each crop in organic, IPM and conventional farming practices. Our aim is to develop and propose alternative strategies to PPP use in general and replacement of harmful pesticides. For this, we collected data on products which are still in the pipeline, under development or already on the market and which are good candidates for substitution. In parallel to those products, we also tried to identify new technics (robotics, decision support systems) which can be used in complete replacement of products or in combination with application strategies. Data collection was mainly performed during ABIM congress in Basel in 2022 and 2023. Identified products or technics are listed in Appendix O Table A 15.

3.2.1 CSS 1: Broccoli in Spain

In this CSS a total of 12 farms producing broccoli were analyzed including 6 organic and 6 conventional producing farms. Current pest and disease control strategies are based on PPP use and regular visual sampling methods. Most PPP used were insecticides. Alternative control strategies are first of all based on crop rotation. In vegetables conventional producing farms this is easily manageable, planting carrots, potatoes, salads or arable crops in rotation. In case of insecticide product replacement, alternatives would be FLiPPER (Bayer, bio insecticide based on extra virgin olive oil, approved by FiBL and Demeter), Spexit (Andermatt, bio insecticide based on Spodoptera exigua multicapsid nucleopolyhedrovirus (SeMNPV)), Plutex (Andermatt, bio insecticide based on Plutella xylostella granulovirus (PlxyGV)), Loopex (Andermatt, bio insecticide based on autographa californica nucleopolyhedrovirus (AcMNPV)). Use of physical barriers as nettings is also an option to prevent insects. Regarding fungicide replacement, Garnet (Bioconsortia, bio insecticide based on microbes, not yet registered), Vigilance (Gopro, bio insecticide based on geraniol), Kitae (GreenImpulse, bio insecticide based on chitosan chlorhydrate)

Only 1 farm used predictive tools, so another option in the control strategy would be to implement such predictive tools as standard use.

3.2.2 CSS 2: Grapes in Portugal

In this CSS, a total of 10 farms were analyzed including 3 organic, 1 conventional and 6 IPM farms. Data collection on current plant protection strategies over those farms revealed use of 47 different active ingredients. Alternative control strategies include use of robust grapevine varieties in organic, IPM and conventional farming systems, which means replacing current vineyards with new resistant varieties (e.g. Botrytis cinerea resistant). Planting resistant varieties against fungal pathogens would reduce use of fungicides (in CSS2 38 different fungicidal a.i. for 212 application timings) by approximately 75%. Costs for planting new vineyard plants are about 17'000€/ha (viticulturevignoble.fr). Another alternative control strategy is based on the replacement of PPPs. In the case of replacing herbicide (glyphosate) use in conventional farming practices with greening between rows and practicing mechanical weeding, which is already done in organic farms and increasingly in IPM farms. In the case of replacing chemical PPPs after flowering time by bio fungicides to be at low residue level. In this regard, a new product will be available by 2024 (authorization in 2024), Amoeba (also COS/OGA) (manufacturer Amoéba) containing active ingredient amoeba lysate which stimulates plant defenses and inhibits germination of pathogen spores (downy and powdery mildew). Other Product based on e.g. D-Tagatose may become available 2025ff. Two other bio fungicide alternative products could be T-77 (Andermatt). Insecticides can be replaced by pheromonal confusion. From a more technical point of view, vineyards can be covered to protect against pathogens and insects in conventional and organic farming systems. In this CSS some farms are using weather stations or Decision Support Systems (DSS) as warning tools. Those tools should be used in control strategies. A recently developed robotic technology called UV Boosting (UV Boosting - Stimulation des défenses naturelles des plantes par flashs UV) to stimulate plant defenses might be an option.

3.2.3 CSS 3: Grapes in France

In this CSS, a total of 10 farms were analyzed including 5 organic and 5 conventional farms. Data collection on current plant protection strategies over those farms revealed use of 39 different active ingredients, mainly fungicidal a.i. Alternative control strategies include use of robust grapevine varieties in organic, IPM and conventional farming systems, which means replacing current vineyards with new resistant varieties (e.g. Botrytis cinerea resistant). Planting resistant varieties against fungal pathogens would reduce use of fungicides (in CSS3 26 different fungicidal a.i. for 520 application timings) by approximately 75%. Costs for planting new vineyard plants are about 17'000€/ha (viticulturevignoble.fr). Such robust varieties include 5 new varieties from INRAE ReSdur 2 with Coliris N, Lilaro N, Sirano N, Selenor B and Opalor B, or PIWI varieties. Another alternative control strategy is based on the replacement of PPPs. In the case of replacing herbicide (glyphosate) use in conventional farming practices with greening between rows and practicing mechanical weeding, which is already done in organic farms and increasingly in IPM farms. In the case of replacing chemical PPPs after flowering time by bio fungicides to be at low residue level. In this regard, a new product will be available by 2024 (authorization in 2024), Amoeba (also COS/OGA) (manufacturer Amoéba) containing active ingredient amoeba lysate which stimulates plant defenses and inhibits germination of pathogen spores (downy and powdery mildew). Other Product based on e.g. D-Tagatose may become available 2025ff. Two other bio fungicide alternative products could be T-77 (Andermatt). Insecticides can be replaced by pheromonal confusion. From a more technical point of view, vineyards can be covered to protect against pathogens and/ or insects in conventional and organic farming systems. In this CSS some farms are using weather stations or Decision Support Systems (DSS) as warning tools. Those tools should be used in control strategies. A recently developed robotic technology called UV Boosting (UV Boosting - Stimulation des défenses naturelles des plantes par flashs UV) to stimulate plant defenses might be an option.

3.2.4 CSS 4: Fruits in Switzerland

In CSS 4 a total of 12 farms producing fruits were selected and analysed including 6 organic, 2 IPM and 4 conventional producing farms. In this analysis we focused on apple producing farms which include 2 organic and 1 IPM farms. During 2021 season treatments reached 25 application timings and a total of 22 different a.is. were applicated Current disease control strategies based on our data collection are based on PPP use, field infrastructure like nets, expert advice, damage control thresholds and weather forecasts. Different alternative strategies can be adopted by farmers to reduce use of PPP or impact of certain product used. In regards to product replacement, including product replacement alternatives would be FLiPPER (Bayer, bio insecticide based on extra virgin olive oil, approved by FiBL and Demeter), Garnet (Garnet, bio fungicide used in post harvest), Madex and Capex (Andermatt biocontol, both based on Cydia pomonella granulosisvirus). Another valuable strategy would be to plant more resistant varieties (e.g. Topaz which is scab resistant) and which would allow to spray less against apple scab.

3.2.5 CSS 5: Vegetables in Italy

In this CSS a total of 18 farms producing different vegetables were analyzed including 10 organic and 8 IPM producing farms. Current pest management strategy is based on PPP use and expert (Agribologna technicians, PPP salers) advices. In case of insecticide product replacement, alternatives would be FLiPPER (Bayer, bio insecticide based on extra virgin olive oil, approved by FiBL and Demeter), Spexit (Andermatt, bio insecticide based on Spodoptera exigua multicapsid nucleopolyhedrovirus (SeMNPV)), Plutex (Andermatt, bio insecticide based on Plutella xylostella granulovirus (PlxyGV)), Loopex (Andermatt, bio insecticide based on autographa californica nucleopolyhedrovirus (AcMNPV)). Use of orange oil as Prev-AM is also an option (Biopesticides – Oro Agri Europe). Regarding fungicide replacement, Garnet (Bioconsortia, bio insecticide based on microbes, not yet registered), Vigilance (Gopro, bio insecticide based on geraniol), Kitae (GreenImpulse, bio insecticide based on chitosan chlorhydrate). Regarding herbicide application, replace PPP use by mechanical weeding. Another option in the control strategy would be to implement predictive tools as standard use to target right application timing.

3.2.6 CSS 6: Olives in Croatia

In this CSS a total of 19 farms producing olives were analysed including 8 organic and 6 IPM and 6 conventional producing farms. Current plant protection strategy is based on PPP use, predictive tools and monitoring. Use of resistant/tolerant varieties is an option to reduce fungicide use (costs?). Use of sexual confusion is an option to reduce insecticides. Use of product based on bacillus thuringiensis against olive moth can replace chemical insecticide (only one application with bacillus thuringiensis was performed in this study, could be improved here), use of Kaolin against med fly.

3.2.7 CSS 7: Silage maize in Slovenia

In CSS Slovenia a total of 12 farms were analysed including 6 organic and 6 conventional producing farms. In this CSS silage maize crop was studied (7 of 12 farms) and herbicide PPP were used as control strategy including Adengo and Lumax SE products. Different alternatives can be proposed. In terms of product substitution, replacing Lumax SE use by Adengo if herbicides are used. Other control strategies are based on mechanical weeding instead of using PPPs and increasing crop rotation from silage maize- grass-clover to silage maize- grass-clover- and other crops e.g. oilseed crops, cereals, grass.

3.2.8 CSS 8: Oilseed crops in Czech Republic (rapeseed, sunflower, poppy, mustard)

In this CSS a total of 18 farms producing oilseed crops were analyzed. In terms of farming type, in this CSS some farms have two different producing systems, organic/conventional, IPM/conventional, organic or conventional. Current plant protection strategies are set on use of PPPs use and mechanical weeding. In conventional and IPM farming systems until 4 different a.is and 3 different application timings are used for weeding. In some farms one herbicide application is replaced by mechanical weeding. In this regard, some strategies can be adopted to replace use of chemical herbicides beside mechanical weeding. First of all, a deeper analysis of the type of weeds (dicotyledons, Gramineae plants) can give a first direction if soil should be laboured or not. If Gramineae plants are in majority, soil tillage should be performed to put seeds deeper in the soil. If dicotyledons are in majority, sowing of rapeseed should be performed without any previous tillage. In rapeseed production, intercropping strategy such as sowing winter wheat can also be adopted to control weed plants. Variety choice of rapeseeds should be selected in regards to fast germination capacity, so that seeds germinate faster than weed seeds and be able to compete soil space. Last strategy is set on companion plants to be sowed in the same time as rapeseed is sown e.g. fava beans, lentils which limits germination of weeds around rapeseed. In sunflower and other oilseed crops, having alfalfa 2 years on the same field can significantly help to reduce weed pressure.

Regarding fungicide and insecticide use, some a.is. were used which are either candidates for substitution or not approved by the EU, e.g. mancozeb (fungicide), tebuconazole (fungicide), lambda-cyhalothrin (insecticide). As fungicide replacement, Contans WG (Coniothyrium minitans) can be used. Spinosad can be used in organic production systems against some insects but its low persistence in field can decrease the efficacy especially as flight times of insects can reach 3 weeks. The combination with a predictive tool (e.g. Terres Inovia) might be of interest to target right application timing and reduce use of PPPs.

3.2.9 CSS 9: Potatoes in the Netherlands

In this CSS, data from 15 farms were collected. 7 organic producing farms, where no treatments were done, 3 IPM and 5 conventional producing farms where we collected up to 17 different application timings during whole season, including 31 different a.is. Control alternative strategies are based on resistant varieties, e.g. Alouette, Ardeche, Jacky which are resistant against Phytophthora infestans. Another strategy to be adopted is increasing crop rotation potatoes-mustard-wheat-buckwheat, or potatoes-salad-carrots-cauliflower. Regarding product substitution, insecticides could be replaced by Wrath product (Gopro, based on geraniol, peppermint oil, cotton seed oil, rosemary oil), and fungicides can be replaced by Serenade (Bayer, based on bacillus amyloliquefaciens). Product substitution can be combined with predictive tools which allow a strategic approach on best application timing and necessity of application.

3.2.10 CSS 10: Wheat in Denmark

In CSS 10 a total of 12 farms were analyzed including 6 organic producing farms and 6 conventional producing farms. We focused here on wheat production. Current crop protection strategies are based on PPP use, expert advice and notifications. In terms of alternatives, use of tebuconazole as a fungicide can be replaced by seed treatments based on Trichoderma. Herbicide use (which is in majority in this CSS) can be replaced by mechanical weeding and crop rotation can be targeted e.g. wheat-barley/rye-rapeseed oil-wheat.

3.2.11 CSS 11: Cereals in Argentina

In this CSS, 14 farms were analyzed including 2 organic and 12 conventional farms producing cereals (oat, winter barley, chickpea, maize grain, moha, winter wheat). Current agronomic practices are only based on herbicide application. Strategies to reduce herbicide use are first of all increasing crop rotation by adding oilseed crops in the rotation as sunflower or rapeseed. Secondly identification of the type of weeds on field e.g. if Gramineae plants are in majority, soil tillage should be performed to put seeds deeper in the soil. If dicotyledons are in majority, sowing of rapeseed should be performed without any previous tillage. Including mechanical weeding to replace herbicide use in total or replace 1 or 2 application timings.

4 Farm level impacts of pesticide reduction strategies

To analyse the economic farm-level impacts of agronomic interventions to reduce the reliance of synthetic pesticides, four of the eleven case studies were selected including France (grapes), Switzerland (fruits: apples), Slovenia (silage maize), and the Netherlands (potatoes). The selection was based on data availability and quality considerations as well as the crop grown. Farm-level impacts were assessed using qualitative multicriteria analysis. At first, the agronomic practices as well as costs and benefits – if available – of the farms who formed part of the Sprint Farm Survey were contrasted and ranked based on selected criteria to identify a gradient from 'bad' to 'good' practices for each of the four case study sites (criteria included e.g. crop rotation width, environmental and health impacts, pesticide costs, production system). The farms with the lowest ranking or 'bad' practices were then chosen to construct the baseline for the multicriteria assessment of farm level impacts. The 'good' practices were used as a starting point to identify three agronomic interventions in an internal workshop. Table 1 lists the agronomic interventions which were assessed in each case study site.

Table 1: Agronomic interventions which were assessed in case study sites.

Case study site	Crop	Focus	Agronomic intervention
Slovenia	Silage maize	Weed control	Subsituting the synthetic herbicide Lumax by the less toxic synthetic herbicide Adengo (both broad spectrum activity herbicides).
			Mechanical weeding only (no herbicides)
			Wider crop rotation (twice or three times grass-clover mixture instead of only once in five years)
France	Grapes	Fungus disease control	Robust grape varieties (against mildew)
			Low residue strategy (no synthetic, only organic fungicides after flowering)
			Foil coverage (rain protection against mildew)
			Changing to organic production system
Switzerland	Apples	Fungus disease control	Robust apple varieties (example variety: Topaz, resistant against fire blight and scab)
			Low residue strategy (no synthetic, only organic fungicides after flowering)
			Foil coverage (rain protection against mildew)

Netherlands	Potatoes	Fungus disease control	Robust potato varieties (example varieties: Alouette and Jacky, resistant against Phytophtera infestans)
			Wieder crop rotation (1:4, 1:5, 1:6 instead of 1:3)
			Changing to organic production system

The indicators for the qualitative multicriteria assessment were selected from DEXiPM (Pelzer et al., 2012) and supplemented by indicators of interest for project partners. Selected indicators span the following criteria: 'production value', 'herbicide/ fungicide application', 'weed/ fungus disease control related variable costs', 'fixed costs (requirement for additional agricultural equipment)', 'resilience to extreme weather events', 'subsidies', 'current share of cultivated land', 'future share of cultivated land'. The constructed baseline as well as the list of indicators used for each case study site can be found in chapter 4.1.3.4 (Slovenia: silage maize), chapter 4.2.3.3 (France: grapes), chapter 4.3.3.3 (Switzerland: apples), and chapter 4.4.3.3 (Netherlands: potatoes), respectively. Indicators were assessed by up to five local experts, including mostly farm advisors and a few researchers. Indicators were not aggregated and therefore not weighted by the experts.

Depending on the main crop, agronomic interventions were either chosen to reduce the reliance on synthetic herbicides, i.e. to change weed control practices (Slovenia: silage maize), or the reliance on synthetic fungicides, i.e. to change fungus disease control practices (France: grapes; Switzerland: apples; the Netherlands: potatoes). Consequently, indicators were specifically chosen to assess the economic impacts of changes in weed and fungus disease control, respectively. Hence, cost related indicators were chosen to either relate to weed control costs or fungus disease control costs.

In the following sections, which are separated by the four case study sites, we present the current agronomic practices and the farm ranking, and the results of the expert interviews, including the qualitative multicriteria assessment of farm impacts of agronomic interventions identified to reduce the reliance on synthetic herbicides and fungicides, respectively.

4.1 Silage maize production in Slovenia

4.1.1 Current agronomic practices

In Slovenia agronomic data on a total of 22 silage maize producing farms was collected during the 2021 cropping season – for 7 farms all data as described in chapter 2 was collected, for the remaining 15, only data on pesticide application and farm characteristics was collected. All of the farms surveyed use the silage maize as feedstuff on their own farm. Except for one farm (F03), which produces silage maize following organic production practices, all farms follow integrated pest management (IPM) production practices. Table A 1 of Appendix A shows the agronomic practices of each farm.

Generally, farms tilled the soil in April/ Mai using a plough. Cow slurry was applied either before or after tilling, using a slurry tank. A few days after tilling, farmers prepared the seed bed using a rotary harrow. Then, they sowed the maize a few days later using a seeder. A lot of the surveyed farms (11 of 21 IPM farms) applied a mineral fertilizer at the same time (combination of sowing and fertiliser amendment). Most farms prepared the seed bed and sowed the maize in April or Mai (including the organic farm). Only two IPM farms sowed in June only. About 20 days after sowing (BBCH 7 (Coleoptile emerged from caryopsis) to BBCH 17 (7 leaves enfolded, 8th leaf visible)) IPM farms applied herbicide. Most IPM farms applied either Adengo or Lumax, both broad spectrum herbicides. Some of them combined it with another herbicide. Lumax was sometimes combined with Peak. Adengo was sometimes combined with Banvel or Temsa. On all IPM farms surveyed there was only one herbicide treatment reported, usually using a single product. Between sowing and harvest, two IPM farms indicated to use mechanical weeding once. The organic farm indicated to use mechanical weeding twice between sowing and harvest. For the whole season no fungicide or insecticide treatments and no pest/ disease infection were reported. All farms harvested the silage maize in September or October (kernel content soft, about 45% dry matter) (BBCH 83). Only one farm (F20) harvested the silage maize with a lower kernel soft content (kernel content soft, about 37% dry matter). Most farms used cover crops during winter.

Most farms indicated that they rent the harvesting machine. Some also indicated that they rent the sowing machine (seeder).

Within a period of 5 years, farms indicated to grow silage maize, once, twice or three times. Almost all farms grew a grass-clover mixture at least once in five years. More than half of the farms grew a grass-clover mixture twice or three times in five years. The organic farm grows grass-clover mixture three times a year. Other crops grown in the crop rotation included: wheat, barley, triticale, oat, potato, rape, and sorghum.

Principle weeds affecting maize silage growth were reported to be: *Cirsium vulgare, Amaranthus retroflexus, Setaria viridis, Convolvulus arvensis, Sorghum halepense, Rumex obtusifolius, and Echinochloa crus-galli.*

4.1.2 Ranking of current weed control strategies

20 out of 22 farms were ranked based on (1) the environmental and human health impacts and damage costs[1] of their weed control strategy (variable: Clustertox, 1st priority), based on (2) the crop rotation (variable: Crop rotation score, 2nd priority), and based on (3) the costs they incur for herbicide use (variable: Herb cost class[2], 3rd priority). Two farms (F21

[1] From Sprint deliverable D6.1 (Fantke et al., 2023). Note: damage costs are associated with environmental impacts that are not included in the market prices of agricultural production and are therefore costs that are 'external' to the product market.

[2] The variable 'herb cost class' consists oft he following four classes: 1 = 0 to 50 EUR/ha; 2 = 51 to 100 EUR/ha; 3 = 101 to 150 EUR/ha; 4 = 151 to 200 EUR/ha.

and F22) were excluded from this ranking due to missing data on environmental and health impacts and damage costs[3].

The variable 'Crop rotation score' ranks the farms from 1 (best) to 8 (worst), depending on the number of times they grew grass-clover mixtures and maize in five years. The more often grass-clover mixtures are grown and the less often maize is grown, the better a farm's crop rotation score. This score is mainly motivated by the good weed suppression properties of grass monocultures and the increased agro-ecological functions of grass-clover mixtures (R. De Haas et al., 2019). According to Brask-Pedersen et al. (2022) a high proportion of grass-clover silage does only have a minor effect on milk yield in lactating dairy cows. The variable Clustertox divides all farms into two clusters based on the six variables related to environmental and health impacts and damage costs. The weed control strategies of farms in cluster 1 have significantly higher environmental and health impacts and damage costs than the weed control strategies of farms in cluster 2. For all six impact and damage cost variables the p-value is lower than 0.001.

For this report the whole table with the ranked farms was split into three sub tables, one focusing on the crop rotation practice (Table 2) one focusing on the weed control practice and corresponding impacts (Table 3) and one focusing on the costs (herbicide costs) and benefits (yield) of the farming practice as well as farm characteristics (Table 4).

Table 2 shows, for each surveyed farm (Farm_ID), the farming system (Organic, yes = organic, no = IPM), the 5-year crop rotation (Crop 1 to Crop 5), and the number of times maize (Maize count) and grass-clover mixture (Grass count) were grown within this 5-year-period. Table 3 shows the herbicide(s) applied, the number of treatments, the number of different herbicides applied, the number of herbicidal active ingredients, the corresponding impacts and damage costs regarding human health, ecosystem quality and natural resource use, and the variable clustertox. Table 4 repeats the Farm_ID and the Clustertox variable and shows the costs of herbicides per hectare, the yield per hectare, the farm size as well as the area used for growing silage maize, and the farm manager's education level.

[3] 15 out of 22 farm observations were provided after deliverable 6.1 had already been submitted. For 13 out of these 15 farms environmental and health impacts and damage costs could be inferred from D6.1 results, as these 13 farms reported to use products for which environmental and health impacts and damage costs had been computed. For two farms this could not be done, as they reported to use Nicosh, Dicash, and Laudis, for which no environmental impact and damage cost levels were computed.

Table 2: Ranking of silage maize producing farms based on crop rotation practices, environmental and health impacts and damage costs, and total herbicide costs, Slovenia (Part 1: Farming system and crop rotation practice).

Farm _ID	Organic	Crop 1	Crop 2	Crop 3	Crop 4	Crop 5	Maize count	Grass count	Crop rotation score	Rank
F03	yes	Grass_clover	Grass_clover	Maize	Barley	Grass_clover	1	3	1	1
F18	no	Maize	Grass_clover	Maize	Grass_clover	Grass_clover	2	3	2	2
F26	no	Grass_clover	Potato	Maize	Grass_clover	Potato	1	2	3	3
F23	no	Barley	Grass_clover	Maize	Triticale	Grass_clover	1	2	3	4
F06	no	Barley	Grass_clover	Maize	Barley	Grass_clover	1	2	3	4
F04	no	Grass_clover	Grass_clover	Maize	Barley	Maize	2	2	4	5
F24	no	Maize	Grass_clover	Maize	Maize	Grass_clover	3	2	5	6
F19	no	Grass_clover	Barley	Maize	Wheat	Maize	2	1	6	7
F14	no	Barley	Grass_clover	Maize	Oat	Maize	2	1	6	7
F25	no	Maize	Grass_clover	Maize	Wheat	Maize	3	1	7	8
F16	no	Grass_clover	Maize	Maize	Wheat	Maize	3	1	7	9
F08	no	Wheat	Rape	Maize	Wheat	Rape	1	0	8	10
F02	no	Sorghum	Barley	Maize	Barley	Sorghum	1	0	8	10
F12	no	Grass_clover	Grass_clover	Maize	Maize	Grass_clover	2	3	2	11
F20	no	Maize	Grass_clover	Maize	Grass_clover	Barley	2	2	4	12
F27	no	Maize	Grass_clover	Maize	Grass_clover	Barley	2	2	4	12
F17	no	Grass_clover	Maize	Maize	Grass_clover	Maize	3	2	5	13
F15	no	Wheat	Maize	Maize	Grass_clover	Barley	2	1	6	14
F10	no	Maize	Triticale	Maize	Barley	Grass_clover	2	1	6	14
F13	no	Grass_clover	Barley	Maize	Wheat	Maize	2	1	6	15

Table 3: Ranking of silage maize producing farms based on crop rotation practices, environmental and health impacts and damage costs, and total herbicide costs, Slovenia (Part 2: weed control practice and corresponding environmental and human health impacts and damage costs).

Farm_ ID	Herbicide	Treatment count	Herbicide count	H.AI count	H.AI count organic	Human Health Impacts (µDALY/ha)	Ecosystem Quality Impacts (PDF.m2.yr/ha)	Resource Use Impacts (MJ/ha)	Human Health Damage costs (EUR/ha)	Ecosystem Quality Damage Costs (EUR/ha)	Resource Use Damage Costs (EUR/ha)	Clustertox	Rank
F03	None	0	0	0	0	0	0	0	0	0	0	Cluster2	1
F18	ADENGO	1	1	2	0	479	23.7	3.47	35.44	3.32	0.01	Cluster2	2
F26	ADENGO	1	1	2	0	556.8181818	27.89393939	4.093939394	41.17	3.91	0.02	Cluster2	3
F23	ADENGO	1	1	2	0	479	23.7	3.47	35.44	3.32	0.01	Cluster2	4
F06	ADENGO	1	1	2	0	479	23.7	3.47	35.44	3.32	0.01	Cluster2	4
F04	ADENGO	1	1	2	0	525	26.3	3.86	38.81	3.68	0.02	Cluster2	5
F24	ADENGO	1	1	2	0	468.3555556	23.17333333	3.392888889	34.66	3.24	0.01	Cluster2	6
F19	ADENGO	1	1	2	0	468.3555556	23.17333333	3.392888889	34.66	3.24	0.01	Cluster2	7
F14	ADENGO&BANVEL	1	2	3	0	425.7777778	21.06666667	3.084444444	31.5	2.95	0.01	Cluster2	7
F25	ADENGO	1	1	2	0	468.3555556	23.17333333	3.392888889	34.66	3.24	0.01	Cluster2	8
F16	ADENGO&TEMSA	1	2	3	0	425.7777778	21.06666667	3.084444444	31.5	2.95	0.01	Cluster2	9
F08	MONSOON&HERBOCID	1	2	3	0	489	23	3.38	36.15	3.23	0.01	Cluster2	10
F02	MONSOON ACTIVE	1	1	2	0	284	12.8	1.88	20.99	1.8	0.01	Cluster2	10
F12	LUMAX	1	1	2	0	3168	173.6	25.72	234.4	24.3	0.11	Cluster1	11
F20	LUMAX	1	1	2	0	3168	173.6	25.72	234.4	24.3	0.11	Cluster1	12
F27	LUMAX	1	1	2	0	3168	173.6	25.72	234.4	24.3	0.11	Cluster1	12
F17	LUMAX&PEAK	1	2	3	0	2986.971429	163.68	24.25028571	221.01	22.92	0.1	Cluster1	13
F15	LUMAX	1	1	2	0	2709	148.8	22.05	200.44	20.83	0.09	Cluster1	14
F10	LUMAX	1	1	2	0	2709	148.8	22.05	200.44	20.83	0.09	Cluster1	14

F13	LUMAX&PEAK	1	2	3	0	3168	173.6	25.72	234.4	24.3	0.11	Cluster1	15

Note: damage costs are associated with environmental impacts that are not included in the market prices of agricultural production and are therefore costs that are 'external' to the product market.

Table 4: Ranking of silage maize producing farms based on crop rotation practices, environmental and health impacts and damage costs, and total herbicide costs, Slovenia (Part 3: Toxicity cluster, herbicide cost, yield, and farm characteristics).

Farm _ID	Clusterto x	Herbicide cost (EUR/ha)	Herb cost class	Yield (ton/ha)	Farm Size (ha)	Total crop area (ha)	Education	Rank
F03	Cluster2	0	1	35	40	2.2	low	1
F18	Cluster2	56.25	2	25	65	25	high	2
F26	Cluster2	43.75	1	60	40	13	rather high	3
F23	Cluster2	56.25	2	55	90	25	rather high	4
F06	Cluster2	56.25	2	37.5	60	24	high	4
F04	Cluster2	41.25	1	40	55	12	rather high	5
F24	Cluster2	55	2	54	65	12	high	6
F19	Cluster2	55	2	65	25	7.5	high	7
F14	Cluster2	85	2	45	18	7.59	rather low	7
F25	Cluster2	55	2	50	39	21.53	high	8
F16	Cluster2	124.16	3	50	41	16	high	9
F08	Cluster2	53	2	30	80	12	rather high	10
F02	Cluster2	54	2	35	86	28	high	10
F12	Cluster1	161	4	37.5	25	8	rather high	11
F20	Cluster1	161	4	50	33	12	rather high	12
F27	Cluster1	161	4	60	22	6.5	rather high	12
F17	Cluster1	165.98	4	55	22	6	rather high	13
F15	Cluster1	138	3	50	30	8.5	rather high	14
F10	Cluster1	138	3	35	70	16	high	14
F13	Cluster1	175.18	4	35	30	7.59	rather low	15

Based on the production system (Organic) and impacts and damage costs regarding human health, ecosystem quality and natural resource use, three farm types can be distinguished: Organic farms (OF) – only one farm in the sample -, Conventional farms with a low toxicity (CVLT) – 12 farms in the sample - and conventional farms with a high toxicity (CVHT) – 7 farms in the sample. Overall, CVLT represent the most common farm type in the sample. CVLT farms mostly use the herbicide Adengo – mostly without combining it with another herbicide -, whereas CVHT mostly use the herbicide Lumax – mostly without combining it with another herbicide. Lumax contains the active ingredients s_metolachlor and terbuthylazine, which are significantly more toxic (with significantly higher impacts and damage costs) than the active ingredients of Adengo, isoxaflutole and thiencarbazone_methyl. CVLT have significantly lower herbicide costs than CVHT (p-value

< 0.001). The crop rotation used by conventional farms is highly variable and does not systematically differ between CVLT and CVHT farms. Both farm types use very short (1:2) as well as very long (1:5) crop rotations and include at least once a grass-clover mixture in their rotation. The most common crop rotation used by conventional farms is of the type 1:3. The organic farm uses a long crop rotation (1:5), growing three times a grass-clover mixture. The CVLT and CVHT farms significantly differ regarding farm size (p-value of 0.043). Whereas CVLT farms have an average farm size of 55 hectares, CVHT farms have an average farm size of 33 hectares. The organic farm has a size of 40 hectares. CVLT and CVHT farms both have an average yield of 46 tonnes per hectare (no significant difference). The organic farm has a yield of 35 tonnes per hectare. CVLT and CVHT farms do not significantly differ regarding education. However, a farm manager with a high education tends to be more likely to manage a CVLT than a CVHT farm.

4.1.3 Impacts of agronomic interventions

To assess the impacts of three agronomic interventions to reduce the dependence on synthetic herbicides in silage maize farming in Slovenia, we conducted five expert interviews with farm advisors from Slovenian public advisory service providers. The experts collectively cover regions in the North-East and East of Slovenia, including Prekmurje (Murska Sobota), Gorenjska (Kranj), and Štajerska (Maribor and Ptuj). All five experts stated to be knowledgeable in silage maize farming and to be specialized in conventional farming systems. Three of the interviewed experts were male and two were female. All five interviews were conducted in November 2023 using the online platform Zoom.

The interview was divided into four sections: general information; description of advisory service provided; agronomic interventions to reduce the reliance on synthetic herbicides in silage maize farming in Slovenia; and assessment of ease and impacts of implementation of three selected agronomic interventions.

The following three agronomic interventions were assessed:

1. Subsituting the synthetic herbicide Lumax by the less toxic synthetic herbicide Adengo[4].
2. Use mechanical weeding only - no synthetic herbicides.
3. Use a wider crop rotation (silage maize once in four or five years instead of once in two or three years).

The results of the interviews are presented in the following sub sections.

4.1.3.1 General information

Conventional silage maize production is very widely spread in Slovenia, whereas organic silage maize production is still relatively modest, with a maximum of 1% of farms following organic production practices. Organic livestock farms are especially prevalent in the hilly areas, rearing livestock mainly on pasture and focusing on small livestock, with farm sizes ranging from 5 to 10 hectares. According to the experts, organic farms do rather not choose to grow silage maize due to the difficulty of growing silage maize without synthetic

[4] Both Lumax and Adengo are known for their broad-spectrum activity, able to control a range of weed species.

herbicides. As weed control in silage maize production is a significant challenge for organic farms, they favour grass silage over maize silage, as grass cultivation allows for easier weed control through regular ploughing and mowing. According tot he expterts, conventional farms also use grass silage, but rely on maize silage for its energy content, whereas organic farms use wheat and barley as energy-rich alternatives. Overall, the demand for organic milk as well as organic milk prices are low in Slovenia.

4.1.3.2 *Advisory on weed control in silage maize farming:*

Overall, interactions between farmers and extension services on weed control show variability in frequency and channels. While some farmers actively initiate direct contact with advisory services, others rely more on digital platforms and other media that are used by advisory service providers to disseminate information on herbicide use. One expert mentioned that he visits farms, proactively calls farms and gives talks and workshops on maize production.

Weed control remains a consistent concern for farmers, with questions typically peaking in April and May, reflecting seasonal variations. Questions about which herbicide products to use are often common. In particular, perennial weeds such as ambrosia and wild sorghum are recurring challenges in all regions. Apart from these two, the most common weeds are Cyperus esculentus (perennial), Chenopodium polyspermum, Chenopodium album, Digitaria sanguinalis, Lamium purpureum (main weed on well-fertilized fields) and Artemisia vulgaris. The emergence of stricter regulations is also driving farmer enquiries, for example in the water protection areas of the KOPOP program[5].

4.1.3.3 *Agronomic interventions to reduce the reliance on synthetic herbicides in silage maize farming proposed by the experts*

Experts advocate a number of strategies to reduce reliance on synthetic herbicides in silage maize, with a focus on minimizing weed populations. One such strategy is blind seeding, a method of preparing the field and allowing weeds to germinate, followed by mechanical destruction with a harrow and simultaneous fertilizer amendement. This approach allows a single application of herbicide and provides better control of weed growth. Currently, most farms opt for a single herbicide treatment, reserving a second treatment for specific weed problems, highlighting the importance of timing and conditions for weed control. The experts emphasise that a combination of mechanical and chemical treatments can be used to control weeds. Using mechanical weeding alone, is seen as a big challenge.

Another strategy is diversification of agricultural practices. This involves improving crop rotation by incorporating silage maize into the cycle every 2-3 years and growing a variety

[5] The aim of the KOPOP program is to increase water safety. Although participation in the KOPOP Project is voluntary, a majority of farmers choose to engage. The program offers incentives of €340/350 per hectare, encourages farmers to adopt various sustainable production practices going beyond the selection of less toxic herbicide products, such as wider crop rotations with at least three different crops, and the use of cover crops. Farmers are motivated to combine mechanical weeding and chemical spraying. Prior to the introduction of KOPOP in 2015, which banned the use of the active ingredient 'terbuthylazine', Lumax was the dominant herbicide sprayed (80-90% of farms), but trials revealed water contamination problems associated with Lumax.

of crops such as cereals, potatoes, grass-clover mixtures, lucerne mixtures or legumes such as forage peas. Including grass in the crop rotation was highlighted by the experts as a strong measure to better control perennial weeds, as grass is mowed several times a year.

Another mentioned best practice is the use of cover crops in winter to suppress weeds. Precision farming techniques and planting in May instead of April are other strategies recommended by the experts. The latter accelerates crop germination (due to higher temperatures), allowing faster soil coverage and therefore better weed control.

4.1.3.4 Impacts of the three proposed agronomic interventions

Based on the agronomic data collected in 2021, the baseline farming system was defined as shown in Table 5:

Table 5: Baseline farming system for silage maize production, Slovenia.

System description baseline, silage maize production, Slovenia (year 2021)	
Farm size:	Medium sized: between 10 and 50 ha
Family farm:	Yes
Crop:	Silage maize
Variety:	Hybrid
Product:	Maize harvested green/ Green maize (fresh matter)
Production System:	Integrated pest management (IPM)
Most important weeds:	Cyperus esculentus (perennial), wild sorghum (perennial), chenopodium polyspermum, chenopodium album, digitaria sanguinalis, Lamium purpureum (main weed on well fertilised fields), Artemisia vulgaris, Ambriosia (perennial).
Mechanical weeding:	No
Herbicides:	Yes: Lumax
Active ingredients:	s_metolachlor; terbuthylazine
Number of treatments with herbicides:	1 treatment
Growing stage of herbicide application:	BBCH 7 (no leaves) to 17 (7 leaves enfolded, 8th leaf visible)
Width of crop rotation:	1:2 (3 times maize and 3 different crops in five years), e.g. silage maize, grass-clover mixture, silage maize, barley, silage maize.
Other crops in crop rotation:	Grass-clover mixture and cereals (e.g. barley, wheat, triticale)
Use of legumes in crop rotation:	Yes (once grass-clover mixture)
Use of cover crops during winter season:	Yes
Buyer:	Own use as feed (cattle farm)

All the experts confirmed that one herbicide treatment is very common, as farms pay a lot of attention to the right timing. Farms would only use a second treatment, if they have some special weeds.

All the experts stated that Lumax used to be the dominant herbicide sprayed in silage maize farming before the introduction of the KOPOP program in 2015, but significantly decreased since then. Nowadays only about 10 to 20% of the silage maize farms in Slovenia still use Lumax.

Some of the experts also insisted that most silage maize growing farms also do some kind of mechanical weeding. One expert explicitly stated that the majority of farms use hoeing when the maize has 5 to 6 leaves. Another expert stated that 90% of silage maize producing farms would use hoeing in combination with fertilization in the growing stage of 8 to 10 leaves. The expert specified that also farms who spray Lumax use hoeing. It was said that only farms on higher slopes would not use mechanical weeding at all. Mechanical weeding can do a lot of damage to the crop and the soil in hilly areas.

Some experts stated that silage maize producing farms apply glyphosate once in five years to control perennial weeds. One expert emphasized that perennial weeds can be very well controlled by growing grass in the crop rotation. As most farms in the farm survey grow grass at least once, it is not clear, if they do not use glyphosate or if they use it and did not indicate to use it, as the survey assessed the use of pesticides in one single year. For the further evaluation, we here assume that farms in the Sprint Farm Survey use glyphosate once in five years and that the use of glyphosate can be eliminated if grass is grown more than once in five years.

Table 6 shows the indicators which were used for the qualitative multicriteria assessment and associated values for the baseline, which are based on the Sprint Farm Survey.

Table 6: Impact assessment indicators and baseline values for silage maize production, Slovenia.

Criteria	**Indicator**	**Value**
Production value	Yield (tons/ha/year)	45 to 65
	Production risk/ risk of yield loss	NA
	Product quality (nutritional quality, size of cobs, corn on the cobs)	NA
Herbicide application	Number of different synthetic herbicides used (#/year)	1 (LUMAX)
	Number of treatments with synthetic herbicides (#/year)	1
Mechanical weeding	Number of passes with weeding machine (#/ha/year) - harrowing	0
	Number of passes with weeding machine (#/ha/year) - hoeing	1
Total weed control related variable costs	Total costs for herbicide products (EUR/ha/year) - LUMAX	60 to 138 if 3 litres/ ha/ year; 70 to 161 if 3.5 litres/ ha/ year

Disclaimer: This report is part of a project that has received funding by the European Union's Horizon 2020 research and innovation program under grant agreement number 862568.

	Total costs for chemical weed control (EUR/ha/year) – *sum of costs for herbicide products and machine labour*	76.50 to 154.50 if 3 litres/ ha/ year; 86.50 to 171 if 3.5 litres/ ha/ year
	Total costs for mechanical weed control (EUR/ha/year)	0
	Total costs for weed control (EUR/ha/year)	76.50 to 154.50 if 3 litres/ ha/ year; 86.50 to 171 if 3.5 litres/ ha/ year
	Total labour (hours/ha/year)	0.2 to 0.3
Fixed costs	Requirement for additional agricultural equipment	NA
Resilience	Resilience against extreme weather events	NA
Subsidies	Subsidies provided for agronomic intervention	Yes (IPM)
Current share of farms following this practice[1]	Current share of farms following this practice (%)	10 to 20
Future share of farms following this practice[1]	Future share of farms following this practice (5 to 10 years) (%)	5 to 10
Environmental and health impacts[2]	Human health impacts (µDALY/ha)	2'709 to 3'168
	Ecosystem quality impacts (PDF.m2.yr/ha)	149 to 174
	Resource use (MJ/ha)	22 to 26
Environmental and health damage costs[2]	Human health damage costs (EUR/ha)	200 to 234
	Ecosystem damage costs (EUR/ha)	21 to 24
	Resource use damage costs (EUR/ha)	0.09 to 0.11

[1]This value was obtained from the experts.

[2]Values are taken from Sprint Deliverable D6.1 (Fantke et al., 2023). These indicators were not assessed by experts. Note: damage costs are associated with environmental impacts that are not included in the market prices of agricultural production and are therefore costs that are 'external' to the product market.

For Slovenia we also collected data on prices and inputs per hectar to assess the impacts in monetary terms, partly from the farm survey, partly validated by experts, and partly from literature. These are presented in Table 7. They are assumed to stay fixed.

Table 7: Prices and inputs per hectar relevant for silage maize production, Slovenia.

Criteria	**Indicator**	**Value**	**Ex**	**FS**	**KT**
Production value	Price per ton of product (EUR/ton)	38		*x*	
Herbicide application	Labour (hours/ha/treatment) – spraying	0.2 to 0.3			x
	Price for machine labour (EUR/ha/treatment) - spraying	16.50			x
	Price of synthetic herbicides (EUR/litre) - LUMAX	20 to 46	x	x	

	Volume applied per treatment (litres/ha/treatment) - LUMAX	3 to 3.5	x	x	
	Price of synthetic herbicides (EUR/litre) - ADENGO	125 to 163	x	x	
	Volume applied per treatment (litres/ha/treatment) - ADENGO	0.33 to 0.45	x	x	
	Price of synthetic herbicides (EUR/litre) - Glyphosate	16.45			x
	Volume applied per treatment (litres/ha/treatment) - Glyphosate	4 (only once in 5 years)			x
Mechanical weeding	Labour (hours/ha/pass) - harrowing	0.6			x
	Labour (hours/ha/pass) – hoeing	1 to 1.2			x
	Price for machine labour (EUR/ha/pass) - harrowing	30			x
	Price for machine labour (EUR/ha/pass) - hoeing	50			x

Ex: validated by experts; FS: collected in Sprint Farm Survey; KT: from KTBL (Kloepfer, 2019).

Figure 2 shows the evaluation of the baseline at given prices (Table 7). Note: Glyphosate was included in the baseline, as some experts stated that glyphosate is used by silage maize growing farms once in five years to suppress perennial weeds. The Sprint Farm Survey did not capture this treatment, as it only assessed one single year.

Figure 2: Evaluation of silage maize production baseline at given prices.

			Baseline				
COSTS							
Direct costs		*Amount*					
	herbicides						
	Lumax	3.5	l/ha/yr	46.00	€/l	161.00	€/ha/yr
	Adengo	0	l/ha/yr	163.00	€/l	0.00	€/ha/yr
	Glyphosate (once every 5 years)	0.8	l/ha/yr	16.45	€/l	13.16	€/ha/yr
	Other	0	l/ha/yr	0.00	€/l	0.00	€/ha/yr
Machinery and labour costs							
	machinery						
dropDown	Spraying, 1000 l, 15 m (200 l water/ha), contractor	1	# of times applied	16.50	€/ha/procedure	16.50	€/ha/yr
dropDown	Corn hoeing, 4 rows, contractor	1	# of times applied	50.00	€/ha/procedure	50.00	€/ha/yr
dropDown		0	# of times applied	#NV	€/ha/procedure	0.00	€/ha/yr
dropDown		0	# of times applied	#NV	€/ha/procedure	0.00	€/ha/yr
dropDown		0	# of times applied	#NV	€/ha/procedure	0.00	€/ha/yr
	manual labour						
dropDown		0	h/ha	10.00	€/h	0.00	€/ha/yr
dropDown		0	h/ha	10.00	€/h	0.00	€/ha/yr
TOTAL direct and variable costs weed control						**240.66**	**€/ha/yr**
Environmental and health damage costs							
	Human health damage costs					234.00	€/ha/yr
	Ecosystem quality damage costs					24.00	€/ha/yr
	Resource use damage costs					0.11	€/ha/yr
TOTAL direct and variable costs weed control including damage costs						**498.77**	**€/ha/yr**
BENEFITS							
Yield							
	Minimum yield	45	tons/ha/yr	38.00	€/ton	**1'710.00**	€/ha/yr
	Maximum yield	65	tons/ha/yr	38.00	€/ton	**2'470.00**	€/ha/yr
	Average yield	55	tons/ha/yr	38.00	€/ton	**2'090.00**	€/ha/yr

Agronomic Intervention 1: Replacing synthetic herbicide Lumax by synthetic herbicide Adengo

The two synthetic herbicides, Lumax and Adengo, are known for their broad-spectrum activity, able to control a range of weed species. Since the launch of KOPOP in 2015 and its subsequent update in 2023, there has been a significant reduction in the use of the herbicide Lumax and a significant increase in the use of Adengo. Based on the experts' estimate, Lumax is nowadays used by only 10 to 20% of silage maize producing farms. These are often farms with older farm managers that are used to Lumax, driven by long-standing habits and traditions, and reluctant to report figures to obtain subsidies (burocracy). Generally, farmers tend to stick with a herbicide once they are comfortable with it.

The reason for the strong drop in the use of Lumax is the KOPOP programme that does not allow the use of the active ingredient 'terbuthylazine'. Experts stated that replacing the synthetic herbicide Lumax with the synthetic alternative Adengo is straightforward and that therefore most farms have already stopped using Lumax. According to the experts, it's worth noting that Lumax has a bit of a wider window of application than Adengo. There is a perception among some growers that Lumax is more effective, when in fact both Lumax and Adengo offer comparable efficacy at similar prices. In fact, Lumax is even slightly more expensive.

About the KOPOP program: The aim of the KOPOP program is to increase water safety. Although participation in the KOPOP Project is voluntary, a majority of farmers choose to engage. The program offers incentives of €340/350 per hectare, encourages farmers to adopt various sustainable production practices going beyond the selection of less toxic herbicide products, such as wider crop rotations with at least three different crops, and the use of cover crops. Farmers are motivated to combine mechanical weeding and chemical spraying. Prior to the introduction of KOPOP in 2015, which banned the use of the active ingredient 'terbuthylazine', Lumax was the dominant herbicide sprayed (80-90% of farms), but trials revealed water contamination problems associated with Lumax.

Table 8 shows the experts' assessment of indicators. Figure 3 shows the evaluation of agronomic intervention 1 at prices shown in Table 7.

Table 8: Impacts of Agronomic Intervention 1 in silage maize production, Slovenia: Replacing synthetic herbicide Lumax by synthetic herbicide Adengo

Criteria	**Indicator**	**Ex1**	**Ex2**	**Ex3**	**Ex4**	**Ex5**
Production value	Yield (tons/ha/year)	nc	nc	nc	nc	nc
	Production risk/ risk of yield loss	+	+	nc	nc	nc
	Product quality (nutritional quality, size of cobs, corn on the cobs)	nc	nc	nc	nc	nc
Herbicide application	Number of different synthetic herbicides used (#/year)	nc	nc	nc	nc	nc
	Number of treatments with synthetic herbicides (#/year)	nc	nc	nc	nc	nc
Mechanical weeding	Number of passes with weeding machine (#/ha/year) - harrowing	nc	nc	nc	nc	nc
	Number of passes with weeding machine (#/ha/year) - hoeing	nc	nc	nc	nc	nc
Variable costs	Total costs for herbicide products (EUR/ha/year)	-	-	-	--	-
	Total costs for chemical weed control (EUR/ha/year) – *sum of costs for herbicide products and machine labour*	-	-	-	--	-
	Total costs for mechanical weed control (EUR/ha/year)	nc	nc	nc	nc	nc
	Total costs for weed control (EUR/ha/year)	-	-	-	--	-
Fixed costs	Requirement for additional agricultural equipment	No	No	No	No	No
Resilience	Resilience against extreme weather events	nc	nc	nc	nc	nc
Subsidies	Subsidies provided for agronomic intervention	Yes	Yes	Yes	Yes	Yes

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Current share of farms following this practice	Current share of farms following this practice (%)	80 to 85	90	80 to 90	80	80
Future share of farms following this practice	Future share of farms following this practice (5 to 10 years) (%)	>85	90	100	90	95

Ex1 to Ex5: Expert 1 to expert 5.

Scale: ++++ = very strong increase of 80% or more; +++ = strong increase of 50 to 70%; ++ = moderate increase of 30 to 40%; + = slight increase of 10 to 20%; nc = no change; - = slight decrease of 10 to 20%; -- = moderate decrease of 30 to 40%; --- = strong decrease of 50 to 70%; ---- = very strong decrease of 80% or more. A minus in brackets, (-) means decrease, a plus in brackets (+) means increase, without specifying the amount of decrease or increase. NA means the expert did not give an answer.

Figure 3: Evaluation of agronomic intervention 1 at given prices.

		A1: Product substitution					
Direct costs		*Amount*					
	herbicides						
	Lumax	0	l/ha/yr	46.00	€/l	0.00	€/ha/yr
	Adengo	0.45	l/ha/yr	163.00	€/l	73.35	€/ha/yr
	Glyphosate (once every 5 years)	0.8	l/ha/yr	16.45	€/l	13.16	€/ha/yr
	Other	0	l/ha/yr	0.00	€/l	0.00	€/ha/yr
Machinery and labour costs							
	machinery						
dropDown	Spraying, 1000 l, 15 m (200 l water/ha), contractor	1	# of times applied	16.50	€/ha/procedure	16.50	€/ha/yr
dropDown	Corn hoeing, 4 rows, contractor	1	# of times applied	50.00	€/ha/procedure	50.00	€/ha/yr
dropDown		0	# of times applied	#NV	€/ha/procedure	0.00	€/ha/yr
dropDown		0	# of times applied	#NV	€/ha/procedure	0.00	€/ha/yr
dropDown		0	# of times applied	#NV	€/ha/procedure	0.00	€/ha/yr
	manual labour						
dropDown		0	h/ha	10.00	€/h	0.00	€/ha/yr
dropDown		0	h/ha	10.00	€/h	0.00	€/ha/yr
TOTAL direct and variable costs weed control						**153.01**	**€/ha/yr**
Environmental and health damage costs							
	Human health damage costs					41.00	€/ha/yr
	Ecosystem quality damage costs					4.00	€/ha/yr
	Resource use damage costs					0.02	€/ha/yr
TOTAL direct and variable costs weed control including damage costs						**198.03**	**€/ha/yr**
BENEFITS							
Yield							
	Minimum yield	45	tons/ha/yr	38.00	€/ton	**1'710.00**	€/ha/yr
	Maximum yield	65	tons/ha/yr	38.00	€/ton	**2'470.00**	€/ha/yr
	Average yield	55	tons/ha/yr	38.00	€/ton	**2'090.00**	€/ha/yr

The assessment with experts shows:

Agronomic intervention 1 can lead to a slight increase in production risk due to the shorter half-life of Adengo (compared to Lumax). In the case of Adengo, the window of application is narrower than with Lumax and therefore the timing of application can be less flexible than with Lumax. Agronomic intervention 1 leads to a slight decrease in herbicide product costs. For agronomic intervention 1 no additional agricultural equippment is needed. The resilience remains unchanged. Subsidies can be obtained through the KOPOP program, if the other program requirements are met. Currently the majority of silage maize growing farms uses Adengo instead of Lumax. The future share is likely to increase. Some farms will continue using Lumax, however, as long as it is on the market.

The evaluation at current prices shows:

Substituting Lumax by Adengo leads to a decrease in weed control costs of 36%. This stands in contrast to expert opinions, who expect only a slight decrease. Considering environmental and health damage costs, the decrease in weed control costs amounts to 60%. Based on experts' opinion, yield stays unchanged.

Agronomic intervention 2: Mechanical weeding only

According to the experts, moving away from synthetic herbicides and towards exclusively mechanical weeding is very difficult and requires a gradual transition. According to experts, it is not possible to maintain the same level of yield with mechanical treatment alone. Factors such as increased weather dependency, mainly in excessively wet conditions, contribute to a potentially serious yield loss. Particularly in very wet years, the critical days before weeds overtake the maize can be missed, as it takes at least a few days without rain to hoe. In contrast, herbicide application remains a viable option even if it rains 5 hours after application. Apparently, according to the experts, mechanical weeding is also limited in its effectiveness against perennial weeds and more effective against annual weeds. A combination of mechanical weeding with more grass in the crop rotation to control perennial weeds could be an effective strategy.

Another challenge is the financial aspect, as, according to experts, more labor and fuel are needed for the increased number of passes with the tractor. In particular, experts indicated that farms would have to purchase new machinery for effective weeding. Current machinery is not effective enough to fully rely on mechanical weeding.

Table 9 shows the experts' assessment of indicators. Figure 4 shows the evaluation of agronomic intervention 2 at prices shown in Table 7.

Table 9: Impacts of Agronomic Intervention 2 in silage maize production, Slovenia: Mechanical weeding only

Criteria	**Indicator**	Ex1	Ex2	Ex3	Ex4	Ex5
Production value	Yield (tons/ha/year)	-	+/-	---	---	--
	Production risk/ risk of yield loss	+++	+++	+++	+++	++
	Product quality (nutritional quality, size of cobs, corn on the cobs)	nc	nc	--	--	nc
Herbicide application	Number of different synthetic herbicides used (#/year)	----	----	----	----	----
	Number of treatments with synthetic herbicides (#/year)	----	----	----	----	----
Mechanical weeding	Number of passes with weeding machine (#/ha/year) - harrowing	(+) 2	(+) 2	(+) 1	(+) 1	(+) 1

	Number of passes with weeding machine (#/ha/year) - hoeing	(+) 2 to 3	(+) 2 to 3	(+) 2 to 3	(+) 2 to 3	(+) 2 to 3
Variable costs	Total costs for herbicide products (EUR/ha/year)	----	----	----	----	----
	Total costs for chemical weed control (EUR/ha/year) – *sum of costs for herbicide products and machine labour*	----	----	----	----	----
	Total costs for mechanical weed control (EUR/ha/year)	(+)	(+)	(+)	(+)	(+)
	Total costs for weed control (EUR/ha/year)	(+)	(+)	(+)	(+)	(+)
Fixed costs	Requirement for additional agricultural equipment	Yes	Yes	Yes	Yes	Yes
Resilience	Resilience against extreme weather events	nc	nc	+	nc	nc
Subsidies	Subsidies provided for agronomic intervention	Yes	Yes	Yes	Yes	Yes
Current share of farms following this practice	Current share of farms following this practice (%)	<1	<1	0	0	5
Future share of farms following this practice	Future share of farms following this practice (5 to 10 years) (%)	<1	<1	<1	<1	20+

Ex1 to Ex5: Expert 1 to expert 5.

Scale: ++++ = very strong increase of 80% or more; +++ = strong increase of 50 to 70%; ++ = moderate increase of 30 to 40%; + = slight increase of 10 to 20%; nc = no change; - = slight decrease of 10 to 20%; -- = moderate decrease of 30 to 40%; --- = strong decrease of 50 to 70%; ---- = very strong decrease of 80% or more. A minus in brackets, (-) means decrease, a plus in brackets (+) means increase, without specifying the amount of decrease or increase. NA means the expert did not give an answer.

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Figure 4: Evaluation of agronomic intervention 2 at given prices.

		A2: Only mechanical weeding					
Direct costs		*Amount*					
	herbicides						
	Lumax	0	l/ha/yr	46	€/l	0.00	€/ha/yr
	Adengo	0	l/ha/yr	163	€/l	0.00	€/ha/yr
	Glyphosate (once every 5 years)	0.8	l/ha/yr	16.45	€/l	13.16	€/ha/yr
	Other	0	l/ha/yr	0	€/l	0.00	€/ha/yr
Machinery and labour costs							
	machinery						
dropDown	Harrowing, 12 m, contractor	2	# of times applied	30	€/ha/procedure	60.00	€/ha/yr
dropDown	Corn hoeing, 4 rows, contractor	3	# of times applied	50	€/ha/procedure	150.00	€/ha/yr
dropDown		0	# of times applied	#NV	€/ha/procedure	0.00	€/ha/yr
dropDown		0	# of times applied	#NV	€/ha/procedure	0.00	€/ha/yr
dropDown		0	# of times applied	#NV	€/ha/procedure	0.00	€/ha/yr
	manual labour						
dropDown		0	h/ha	10	€/h	0.00	€/ha/yr
dropDown		0	h/ha	10	€/h	0.00	€/ha/yr
TOTAL direct and variable costs weed control						**223.16**	**€/ha/yr**
Environmental and health damage costs							
	Human health damage costs					0.00	€/ha/yr
	Ecosystem quality damage costs					0.00	€/ha/yr
	Resource use damage costs					0.00	€/ha/yr
TOTAL direct and variable costs weed control including damage costs						**223.16**	**€/ha/yr**
BENEFITS							
Yield							
	Minimum yield	22	tons/ha/yr	38	€/ton	**836.00**	€/ha/yr
	Maximum yield	44	tons/ha/yr	38	€/ton	**1'672.00**	€/ha/yr
	Average yield	33	tons/ha/yr	38	€/ton	**1'254.00**	€/ha/yr

The assessment with experts shows:

The elimination of synthetic herbicides (except for using glyphosate every 5 years) and the use of mechanical weeding only, leads to a slight, moderate, or strong decrease in yield. The production risk moderately or strongly increases. The product quality can moderately decrease. All due to a higher weed pressure. Harrowing would have to be done once or twice, hoeing two to three times. The total costs for weed control would increase. New agricultural equippment would be urgently needed. Subsidies can be obtained, if the farm converts to organic production. The current share of silage maize growing farms relying on mechanical weeding is very low (as is the current share of organic silage maize growing farms). Except for one expert who expects an increase of this practice from 5 to at least 20% in 5 to 10 years time, experts agree that this practice will not or only very slightly increase in the near future.

The evaluation at current prices shows:

Using mechanical weeding only (except for using glyphosate every 5 years), leads to a slight decrease in weed control costs of 7% compared to the baseline, which stands in contrast to the expert assessment. Considering environmental and health damage costs, the decrease in weed control costs amounts to 55%. Based on experts' opinion, yield decreases from 30 up to 50%.

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Agronomic intervention 3: Wider Crop Rotation (replacing once silage maize with once grass)

According to the experts, conventional farms typically follow a five-year rotation including three times silage maize (the maximum possible), once grass-clover mixture, and once a cereal like wheat, barley, or triticale. Current incentive schemes like the KOPOP program or the crop rotation subsidy demand at least three crops and at least once grass in five years. Experts confirmed, that a still broader crop rotation with less silage maize and more grass would be a robust strategy in silage maize farming to better control weeds but also other pests. One expert indicated that organic farms usually grow grass in two consecutive years and with that succeed to improve the control of perennial weeds. Despite its advantages, experts highlighted the limitations to this approach. The low price for milk and the high number of animals allowed per hectare pushes farms to grow a lot of silage maize. Depending on the area for cultivation each farm has, the extension of the crop rotation can be a serious challenge. Of course, farms' adherence to habits and traditional practices can also hinder the change of practices more generally.

Table 10 shows the experts' assessment of indicators. Figure 5 shows the evaluation of agronomic intervention 2 at prices shown in Table 7.

Table 10: Impacts of Agronomic Intervention 3 in silage maize production, Slovenia: Wider crop rotation (replacing once silage maize with once grass)

Criteria	**Indicator**	Ex1	Ex2	Ex3	Ex4	Ex5
Production value	Yield (tons/ha/year)	(+)	NA	+	NA	nc
	Production risk/ risk of yield loss	nc	nc	nc	nc	nc
	Product quality (nutritional quality, size of cobs, corn on the cobs)	nc	nc	nc	nc	nc
Herbicide application	Number of different synthetic herbicides used (#/year)	nc	nc	nc	nc	nc
	Number of treatments with synthetic herbicides (#/year)	nc	nc	nc	nc	nc
Mechanical weeding	Number of passes with weeding machine (#/ha/year) - harrowing	nc	nc	nc	nc	nc
	Number of passes with weeding machine (#/ha/year) - hoeing	nc	nc	nc	nc	nc
Variable costs	Total costs for herbicide products (EUR/ha/year)	nc	nc	nc	nc	nc
	Total costs for chemical weed control (EUR/ha/year) – *sum of costs for herbicide products and machine labour*	nc	nc	nc	nc	nc
	Total costs for mechanical weed control (EUR/ha/year)	nc	nc	nc	nc	nc
	Total costs for weed control (EUR/ha/year)	nc	nc	nc	nc	nc
Fixed costs	Requirement for additional agricultural equipment	No	No	No	No	No
Resilience	Resilience against extreme weather events	+	++	++	++	+

Subsidies	Subsidies provided for agronomic intervention	Yes	Yes	Yes	Yes	Yes
Current share of farms following this practice	Current share of farms following this practice (%)	30 to 40	30	30 to 40	35	40
Future share of farms following this practice	Future share of farms following this practice (%)	nc	nc	nc	nc	nc

Ex1 to Ex5: Expert 1 to expert 5.

Scale: ++++ = very strong increase of 80% or more; +++ = strong increase of 50 to 70%; ++ = moderate increase of 30 to 40%; + = slight increase of 10 to 20%; nc = no change; - = slight decrease of 10 to 20%; -- = moderate decrease of 30 to 40%; --- = strong decrease of 50 to 70%; ---- = very strong decrease of 80% or more. A minus in brackets, (-) means decrease, a plus in brackets (+) means increase, without specifying the amount of decrease or increase. NA means the expert did not give an answer.

Figure 5: Evaluation of agronomic intervention 3 at given prices.

	A3: Replace silage maize by grass						
Direct costs		*Amount*					
	herbicides						
	Lumax	3.5	l/ha/yr	46.00	€/l	161.00	€/ha/yr
	Adengo	0	l/ha/yr	163.00	€/l	0.00	€/ha/yr
	Glyphosate (once every 5 years)	0	l/ha/yr	16.45	€/l	0.00	€/ha/yr
	Other	0	l/ha/yr	0.00	€/l	0.00	€/ha/yr
Machinery and labour costs							
	machinery						
dropDown	Spraying, 1000 l, 15 m (200 l water/ha), contractor	1	# of times applied	16.50	€/ha/procedure	16.50	€/ha/yr
dropDown	Corn hoeing, 4 rows, contractor	1	# of times applied	50.00	€/ha/procedure	50.00	€/ha/yr
dropDown		0	# of times applied	#NV	€/ha/procedure	0.00	€/ha/yr
dropDown		0	# of times applied	#NV	€/ha/procedure	0.00	€/ha/yr
dropDown		0	# of times applied	#NV	€/ha/procedure	0.00	€/ha/yr
	manual labour						
dropDown		0	h/ha	10.00	€/h	0.00	€/ha/yr
dropDown		0	h/ha	10.00	€/h	0.00	€/ha/yr
Loss of income							
	Income silage maize					666.00	€/ha/yr
	Income grass					973.92	€/ha/yr
	Difference in incomes					-307.92	€/ha/yr
	Difference in incomes divided by 5 years					-61.58	€/ha/yr
TOTAL direct and variable costs weed control						**165.92**	**€/ha/yr**
Environmental and health damage costs							
	Human health damage costs					234.00	€/ha/yr
	Ecosystem quality damage costs					24.00	€/ha/yr
	Resource use damage costs					0.11	€/ha/yr
TOTAL direct and variable costs weed control including damage costs						**424.03**	**€/ha/yr**
BENEFITS							
Yield							
	Minimum yield	45	tons/ha/yr	38.00	€/ton	**1710.00**	€/ha/yr
	Maximum yield	65	tons/ha/yr	38.00	€/ton	**2470.00**	€/ha/yr
	Average yield	55	tons/ha/yr	38.00	€/ton	**2090.00**	€/ha/yr

The assessment with experts shows:

A five-year crop rotation with two times grass in it, can have a positive effect on yield. Furthermore, it slightly or moderately increases the resilience of the farm. Additional agricultural equippment is not needed. Subsidies can be obtained if the farm changes to organic. The current share of farms with two times grass in their crop rotation is about 30 to 40%. So, not only organic farms take advantage of more frequently growing grass in their crop rotation. A further increase is not expected by the experts, however, due to the restriction of cultivation area in the case of smaller farms and the current political environment.

The evaluation at current prices shows:

Assuming the once in five-year treatment of glyphosate can be eliminated if grass is grown twice instead of only once in five years, as the latter helps to suppress perennial weeds, and assuming that grass is grown instead of silage maize, the weed control costs, which are computed for 1 year of silage maize, are 31% lower. Considering environmental and health damage costs, the decrease in weed control costs amounts to 15%. Note: The difference in revenue of growing grass instead of silage maize was computed to be 308 EUR/ha based on data from KTBL. As this difference in revenu is incured over a period of 5 years, it was divided by five. As we only look at silage maize production here and exclude the milk production, the effect on milk yield was not considered. The yield of silage maize was left unchanged, even though it can be positively affected by the intervention according to two experts.

4.2 Viticulture in France

4.2.1 Current agronomic practices

In France agronomic data on a total of 10 grapevine growing farms in the region of 'La Gironde' was collected during the 2021 cropping season.

Table A 2 of Appendix B shows the agronomic practices of one exemplary conventional and one exemplary organic farm.

Of the total of 10 farms, five produce grapevines following conventional production practices and five farms produce grapevines following organic production practices.

According to the 'Enquête pratiques culturales en viticulture 2019', 88% of the vineyard area in the 'Bordelais' region (= department of 'La Gironde') is managed following conventional and 12% following organic production practices, of which 3% are managed according to biodynamic principles (Agreste, 2019). Based on the same publication, 4% of the vineyard area is populated by farms with a size of less than 5 ha, 18% with farms between 5 and less than 15 ha, 23% with farms between 15 and less than 30 ha, 22% with farms between 30 and less than 50 ha, and 33% with farms of 50 ha or more (Agreste, 2019).

Table A 3 of Appendix C shows for each farm the reported total number of chemical treatments (fungicides, herbicides and insecticides) separated by farming system. Table A 4 of Appendix D shows the number of times each farm applied a particular fungicide product, separated by farming system (organic and conventional), and type of product (organic or synthetic). Table A 5 of Appendix E shows the number of synthetic and/ or organic fungicides each farm applied by farming system and growing stage (BBCH). Table A 6 of Appendix F shows the quantity of active ingredients each farm applied in grams per hectar, separated by farming system (organic and conventional), and type of active (organic or synthetic).

Usually, vineyards in France are very susceptible to fungal diseases and fungicides are mainly used compared to other plant protection products. Conventional farms reported between 9 and 16 chemical treatments and organic farms between 15 and 20 chemical treatments, all including fungicides (but not only). The main target organisms of the fungicides reported are powdery and downy mildew. Altogether, conventional farms applied 21 different organic fungicide products, containing 7 different active ingredients, and 32 different synthetic fungicide products, containing 19 different active ingredients. An individual conventional farm applied between 2 and 5 organic fungicide products (up to 6 times), containing 2 to 5 active ingredients, and between 5 to 14 synthetic fungicide products (up to 6 times), containing 6 to 16 active ingredients. The total number of fungicide product applications by (conventional) farm range between 24 and 30 (the same product may be applied several times), of which between 6 and 19 product applications are organic and 10 to 18 synthetic. Organic farms all together applied 20 different organic fungicide products, containing 6 different active ingredients. An individual organic farm applied between 3 and 8 organic fungicide products (up to 16 times), containing 3 to 6 active ingredients. For organic farms, the total number of organic fungicide product applications by farm range between 28 and 62. Conventional farms started applying fungicides in growing stage 15 (BBCH 15). Except for one farm, all of the organic farms started applying fungicides in growing stage 13 or 14 (BBCH 13 and 14). Most conventional farms apply synthetic fungicides until growing stage 76 (BBCH 76). The last synthetic fungicide is applied in growing stage 86 (BBCH 86). The last organic chemical is applied in growing stage 86.

The number of chemical treatments reported by the surveyed farms are higher than the number of chemical treatments used as a basis for the calculation of production costs in the 'Référentiel Economique du Vigneron 2021' which is published on a yearly basis by the chamber of agriculture of 'la Gironde' (Chambre d'Agriculture de la Gironde, 2022). Based on their information, a conventional farm uses 10 chemical treatments to treat fungus diseases (in 9 of 10), grape worms (1 of 10), and grape yellows disease (French: flavescence dorée) (2 of 10), and three chemical treatments to control weeds. (The surveyed conventional farms reported to use 9 to 16 chemical treatments, all including fungicides.) Based on the same publication, an organic farm uses 14 chemical treatments to treat fungus disease (4kg of copper – number of copper treatments not mentioned), grape worms (1 of 14), grape yellows disease (2 of 14), and to apply calcinated clay (4 of 14). (The surveyed organic farms reported to use 15 to 20 chemical treatments, all including fungicides.)

4.2.2 Ranking of current agronomic practices

9 out of the 10 farms were ranked based on the environmental and health impacts and damage costs[6] of each farm's chemical control strategy (farm EF15 is excluded from this ranking due to missing impact and damage cost data). The ranking table was divided into two subtables. Table 11 shows, for each surveyed farm (Farm_ID), the farming system (Organic), the number of treatements, the number of different fungicide products applied, the corresponding number of total and organic fungicidal active ingredients, and the environmental and health impacts and damage costs. In Table 12 the production system (Organic), the fungicide costs per hectare (S.Fungicide = synthetic fungicides; O.Fungicide = organic fungicides; T.Fungicide = Total fungicides), the number of treatments, the yield per hectare in tonnes and litres, the farm size as well as the area used for vinyards, and the farm manager's education level are visible. The active ingredients are not listed here, but can be found in Appendix F, Table A 6.

Table 11: Ranking of viticulture farms by environmental and human health impacts and damage costs, France (Part 1: Farming system, fungus control practice, and environmental and health impacts and damage costs).

Farm_ID	Organic	Treatment count	Fungicide count	F.AI count	F.AI count organic	Human Health Impacts (µDALY/ha)	Ecosystem Quality Impacts (PDF.m2.yr/ha)	Resource Use Impacts (MJ/ha)	Human Health Damage costs (EUR/ha)	Ecosystem Quality Damage Costs (EUR/ha)	Resource Use Damage Costs (EUR/ha)	Rank
EF10	Yes	15	7	6	6	7'396	409	60	547	57	0.26	1
EF09	Yes	20	8	5	5	9'654	533	78	714	75	0.33	2
EF16	Yes	16	3	3	3	10'256	562	82	759	79	0.35	3
EF08	Yes	16	8	4	4	10'641	584	86	787	82	0.37	4
EF02	No	15	16	15	3	13'123	835	121	971	117	0.52	5
EF07	No	9	11	6	3	13'385	850	124	990	119	0.53	6
EF06	No	11	16	16	3	17'372	1'149	167	1'286	161	0.72	7
EF03	No	16	12	12	5	18'071	1'210	176	1'337	169	0.75	8
EF04	No	10	9	10	4	18'618	1'248	181	1'378	175	0.78	9

Note: damage costs are associated with environmental impacts that are not included in the market prices of agricultural production and are therefore costs that are 'external' to the product market.

Table 12: Ranking of viticulture farms by environmental and human health impacts and damage costs, France (Part 2: farming system, total fungicide costs, yield, and farm characteristics).

Farm_ID	Organic	S.Fungicide cost	O.Fungicide cost	T.Fungicide cost	Yield (tons/ha)	Yield (litre/ha)	Farm size	Total crop area	Education	Rank

[6] Taken from Sprint deliverable D6.1 (Fantke et al., 2023). Note: damage costs are associated with environmental impacts that are not included in the market prices of agricultural production and are therefore costs that are 'external' to the product market.

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		(EUR/ha)	(EUR/ha)	(EUR/ha)						
EF10	Yes	0	445.12	445.12	3.32	2'500	126	35	BTS viti oeno	1
EF09	Yes	0	359.41	359.41	1.33	1'000	?	12	BEPA viti oeno	2
EF16	Yes	0	352.24	352.24	8.10	6'100	?	23	Master de gestionnaire de domaine viticole	3
EF08	Yes	0	371.40	371.40	3.32	2'500	79	4	BTA agricole (brevet de technicien agricole)	4
EF02	No	458.25	256.60	714.85	5.33	4'000	60	52	BTS viti oeno	5
EF07	No	500.42	150.16	650.58	4.12	3'100	?	8	BTS viti oeno	6
EF06	No	556.02	117.47	673.49	5.32	4'000	?	14	BTS viti oeno	7
EF03	No	390.52	217.02	607.54	5.06	3'800	?	12	BEPA viti oeno (not finished)	8
EF04	No	298.33	140.08	438.41	5.99	4'500	?	50	BEPA viti oeno	9

Farm impacts and damage costs are significantly lower for organic than for conventional farms. Organic farms tend to have a higher number of treatments, but they use a considerably lower number of different fungicides and active ingredients, all of which are non-synthetic. Whereas organic farms spend between 350 and 450 Euros per hectare for fungicides, conventional farms spend between 440 and 720 Euros per hectare. In addition, conventional farms tend to have larger production areas and yields. However, the sample is too small and the variation in production area and yields too large to find significant differences in these variables. In terms of education, farm managers of organic and conventional farms seem to have a similar level of training.

4.2.3 Impacts of agronomic interventions

To assess the impacts of three agronomic interventions to reduce the dependence on synthetic fungicides in viticulture in the region of 'La Gironde', we conducted four expert interviews with farm advisors active in that region of France. All four experts stated to be knowledgeable in viticulture, with three experts specialised in organic viticulture. Two of the interviewed experts were male and two were female. All four interviews were conducted in November 2023 using the online platform Zoom.

The interview was divided into four sections: general information; description of advisory service provided; agronomic interventions to reduce the reliance on synthetic fungicides in viticulture in France; and assessment of ease and impacts of implementation of three selected agronomic interventions.

The following four agronomic interventions were assessed:

1. Robust varieties[7] (against mildew)
2. Low residue strategy (no synthetic, only organic fungicides after flowering) – only 3 out of 4 experts, as one expert interpreted this intervention as 'organic'.
3. Foil coverage (rain protection against mildew) – only 3 out of 4 experts, as we run out of time with one expert.
4. Changing to organic – this intervention was not planned to be assessed, but one expert interpreted the Low Residue Strategy as 'Organic' and one expert assessed 'changing to Organic' as an additional intervention.

The results of the interviews are presented in the following sub sections.

4.2.3.1 Advisory on viticulture

All experts indicated to be in frequent contact with farms advising them on the handling of fungus diseases, mainly powdery and downy mildew, but also black rot. Farm advisors undertake individual field visits and (on-farm) group meetings to effectively address and manage fungal disease issues. In the case of individual field visits, they give advice on phytosanitary interventions on a weekly basis. (On-farm) group meetings happen less frequently, about three times a year. These consultations happen to a large extent within the 'Dephy[8]' farm network, which is an important voluntary initiative in the realm of the 'Ecophyto[9]' plan.

4.2.3.2 Agronomic interventions to reduce the reliance on synthetic fungicides in viticulture proposed by experts

According to the experts, growers are implementing various agronomic measures and best practices to reduce the reliance on synthetic fungicides in French viticulture. The current measures mainly include indirect measures called 'green works' (French: travaux en vert) such as weed control at the base of the grapevines (french: Cavaillon) to reduce the

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[7] For grapes no reference variety was defined. This is a limitation if the evaluation of some indicators (e.g. yield) is sensitive to the variety evaluated.

[8] The network 'FERME DEPHY' brings together 3'000 farms that are engaged in a voluntary initiative to reduce the use of pesticides. It is a major action of the Ecophyto plan. In viticulture, there are 36 farm groups participating (20% of all groups in the Dephy network. Source: https://agriculture.gouv.fr/les-fermes-dephy-partout-en-france-des-systemes-de-production-performants-et-economes-en-0; (Cellule d'Animation Nationale DEPHY Ecophyto, 2023). An organic farmer in viticulture was able to reduce her copper use from the allowed 6kg/ha to 2kg/ha through the participation in the Dephy network, where she received weekly visits from a technician of the chamber of agriculture during 5 years. Source: https://agriculture.gouv.fr/le-zero-chimie-y-arrive-mais-il-faut-un-temps-dadaptation.

[9] Ecophyto is a governmental plan, first lauched in 2008 and relaunched in 2015, to reduce the use of synthetic pesticides by 50% until 2025. Source: https://agriculture.gouv.fr/le-plan-ecophyto-quest-ce-que-cest

humidity at the base of the vines, pruning/ trimming of branches (to make sure, grapes are well distributed), leaf cutting/ removal, de-budding, lifting of the plants (to allow more efficient/ precise chemical treatments), and removing leaves from the soil. Other measures include optimal fertilization (plant health), avoidance of CMR products such as Folpet (CMR = carcinogenic, mutagenic or toxic to reproduction), observation and adherence to threshold values, optimal timing of synthetic pesticide applications/ optimal treatment calendar (e.g. only in the 'middle', not at the beginning and not at the end of the season), and application volumes that are optimally adapted to the growing stage (and the amount of leaves in that stage).

The experts point out that future measures to reduce the reliance on synthetic fungicides in viticulture, include the use of robust varieties, product substitution, increase in efficiency, and new technologies in the area of precision spraying, coverage systems, and decision support tools. The shift to fungus resistant grape varieties is seen as an important future measure. In fact, the incorporation of disease resistant vines is being considered as part of a future strategy in the pursuit of sustainable viticultural practices. Innovative measures such as foil covers, which act like umbrellas over vineyards, are showing positive results against powdery mildew, but with limitations against other pests and diseases. Product use efficiency can be increased by adapting the pesticide dosage to the leaf area, by using precise and targeted spraying, e.g. using sprayers with recovery panels, and by using decision support tools. Product substitution should be done by switching to products with better ecotoxicological profiles, PNPP (natural preparations of low concern) such as purins, plant-based products, mineral products (talc, silica, bicarbonates), and organic/biocontrol alternatives. Also, an alternative to copper considered a future need. One expert points out that instead of banning CMR products, a Zero Pesticide Residue (ZRP) strategy should be adopted, aiming for end-use products with no quantifiable pesticide residues. In addition to these current measures, experts put emphasis on the combination of different practices ('smart-mix') to effectively control fungal diseases.

4.2.3.3 Impacts of four proposed agronomic interventions

Based on the agronomic data collected in 2021 and the data provided in the publication 'Référentiel Economique du Vigneron 2021' (Chambre d'Agriculture de la Gironde, 2022), Table 13 shows the baseline grapevine production system proposed (the number of fungicide treatments and products could be adjusted by the expert):

Table 13: Baseline farming system for viticulture, France.

System description baseline, viticulture, France (year 2021)	
Region (french: appellation):	Bordeaux
Bordeaux grape variety:	Red wine (e.g. Merlot, Cabernet Franc, Cabernet Sauvignon)
Vinyard surface:	15 to 30ha (Note: 23% of the vinyards are between 15 and 30ha in the Bordelais region (Agreste, 2019)
Planting density:	1.50 to 2 metres (narrow) (Note: The planting density can either be narrow, between 1.5 to 2 metres or large,

	between 2 to 3 metres (Chambre d'Agriculture de la Gironde, 2022)
Production System:	Conventional, integrated viticulture (french: conventionnel "raisonné")
Fungus disease pressure (mildew):	Medium (Note: On 45% of the vineyard area in Bordelais the pressure of mildew is perceived as medium, as opposed to weak (48%) and strong (7%) (Agreste, 2019).
Fungicide application:	No chemical treatment in winter. No chemical treatment during the development of the first leaves. First treatment in BBCH15. Total of 13 chemical treatments with fungicides, 8 treatments with synthetic fungicides, 9 treatments with organic fungicides. Total of 5 organic and 10 synthetic fungicide products, .
Family farm:	Yes
Production of Wine at the farm:	Yes

Table 14 shows the indicators which were used for the qualitative multicriteria assessment and associated values for the baseline, which are based on the Sprint Farm Survey (FS), literature (Lit), and experts' opinion (Ex). If values are used from the Sprint Farm Survey, we used the highest values reported (worst case scenario).

Table 14: Impact assessment indicators and baseline values for viticulture, France.

Criteria	**Indicator**	**Value**	**Ex**	**FS**	**Lit**
Production value	Yield (hl/ha/season) - normal year	50 to 60	x		x[2]
	Yield stability	NA	NA	NA	NA
	Product quality	NA	NA	NA	NA
	Full cost of bulk wine (EUR/Hl)	180 (25ha) to 220 (15ha)			x[2]
Fungicide application	Number of different synthetic fungicide products used (#/season)	10		x	
	Number of treatments with synthetic fungicides (#/season)	8		x	
	Number of different non-synthetic fungicide products used (#/season)	5		x	
	Number of treatments with non-synthetic fungicides (#/season)	9		x	

	Number of total treatments with synthetic and non-synthetic fungicides (#/season) - IFT (frequency of treatments with pesticides)	13		x	
Variable costs	Costs for synthetic fungicides (EUR/ha/season)	500	x		
	Costs for non-synthetic fungicides (EUR/ha/season)	100	x		
	Costs for mechanisation (machine costs) (EUR/ha/season) - all machines	840 (25ha) to 1'400 (15ha)			x[2]
	Costs for labour/ workforce (french: main d'oeuvre) (EUR/ha/season) - all labour	2'770 (25ha) to 3'330 (15ha)			x[2]
Fixed costs	Requirement for additional agricultural equipment	NA	NA	NA	NA
Resilience	Resilience against extreme weather events	NA	NA	NA	NA
Subsidies	Subsidies provided for agronomic intervention	IPM (french: conventionnel "raisonné")	x	x	
Current share of vinyard surface following this practice	Current share of vinyard surface following this practice (%) – includes all conventional farms.	80 to 90	x		x[1]
Future share of vinyard surface following this practice	Future share of vinyard surface following this practice (5 to 10 years) (%)	NA	NA	NA	NA
Environmental and health impacts	Human health impacts (µDALY/ha)	13'100 to 18'600			x[3]
	Ecosystem quality impacts (PDF.m2.yr/ha)	835 to 1'250			x[3]
	Resource use (MJ/ha)	121 to 181			x[3]
Environmental and health damage costs	Human health damage costs (EUR/ha)	971 to 1378			x[3]
	Ecosystem damage costs (EUR/ha)	117 to 175			x[3]
	Resource use damage costs (EUR/ha)	0.5 to 0.8			x[3]

Ex: expert opinion; FS: Sprint Farm Survey; Lit: from [1]Agreste, 2019; [2]Chambre d'Agriculture de la Gironde, 2022; [3]Fantke et al., 2023.

Note: The indicators for environmental and health impacts and damage costs were not assessed by experts.

Agronomic intervention 1: Robust varieties

According to experts, the integration of robust varieties into viticulture is rather or very difficult and faces significant barriers, with the economic burden seen as the biggest obstacle for growers. The cost of removing old vines, coupled with a three-year waiting period before returning to production, is a financial constraint. Growers would need financial support and technical assistance. Currently advice and technical support is provided by the agricultural chamber and the French National Institute for Agriculture, Food and the Environment (INRAE: institut national de recherche agronomique).

Another challenge to introduce robust varieties into viticulture are according to the experts the restrictions coming from the AOC production standards (AOC: controlled designation of origin; French: appellation d'origine controlée), limiting the cultivation of robust varieties to 5% of the vineyard. If farmers currently want to cultivate more than 5%, they have to step out of the standard and will in turn be declassified. So, the allowed area share for the cultivation of robust varieties would need to be increased in the specifications for the 'controlled designation of origin' production standards. The lack of historical roots and the international nature of robust varieties call for simplified AOC rules. The French National Research Institute for Agriculture, Food, and the Environment (INRAE) and the French Vine Institute (IFV) have projects to evaluate during 10 years the efficacy and tasting of new varieties. This may influence the regulations for robust varieties under the AOC standard.

Another challenge is, that a new variety means a new product with a new taste and therefore involves significant marketing efforts to gain consumer acceptance. Wine tastings would be needed to introduce consumers to the unique qualities of robust varieties.

In addition, the industry is afraid of resistance breakdowns. To deal with the risk of resistance breakdowns a disease monitoring tool is currently being developed (OSCAR[10]). An expert states, that no more than 20% of the total vineyard should be used for resistant varieties to prevent a resistance breakdown.

Experts also pointed out that robust varieties are 'only' resistant against mildew and oïdium, but not against black rot. So, chemical treatments would still be needed. Also, chemical treatments against insects would still be needed.

Table 15 shows the experts' assessment of indicators:

Table 15: Impacts of agronomic intervention 1 in viticulture, France: Robust varieties

Criteria	**Indicator**	**Ex1**	**Ex2**	**Ex3**	**Ex4**
Production value	Yield (hl/ha/season) - normal year	++	+	nc	+++
	Yield stability	++	(+)	NA	(+)
	Product quality	NA	(-)	-	-
	Full cost of bulk wine (EUR/Hl)	-	-	+	nc
Fungicide application	Number of different synthetic fungicide products used (#/season)	(-)	---	(-) 2	---
	Number of treatments with synthetic fungicides (#/season)	(-)	----	(-) 2	--

[10] National 'Observatory for the Deployment of Resistant Cultivars' (OSCAR; https://observatoire-cepages-resistants.fr/en/).

	Number of different non-synthetic fungicide products used (#/season)	(-)	---	(-) 2	---
	Number of treatments with non-synthetic fungicides (#/season)	(-) 3 to 4	----	(-) 2	--
	Number of total treatments with synthetic and non-synthetic fungicides (#/season) - IFT (frequency of treatments with pesticides)	(-)	----	(-)	--
Variable costs	Costs for synthetic fungicides (EUR/ha/season)	(-)	----	---	--
	Costs for non-synthetic fungicides (EUR/ha/season)	(-)	----	---	--
	Costs for mechanisation (machine costs) (EUR/ha/season) - all machines	---	----	nc	nc
	Costs for labour/ workforce (french: main d'oeuvre) (EUR/ha/season) - all labour	---	(-)	nc	nc
Fixed costs	Requirement for additional agricultural equipment	No	No	No	No
Resilience	Resilience against extreme weather events	NA	NA	++++	NA
Subsidies	Subsidies provided for agronomic intervention	No	No	No	No
Current share of vinyard surface following this practice	Current share of vinyard surface following this practice (%) – includes all conventional farms.	1 to 2	0.1	0	<10
Future share of vinyard surface following this practice	Future share of vinyard surface following this practice (5 to 10 years) (%)	15 to 20	5 to 10	30 to 40	30 to 40

Ex1 to Ex4: Expert 1 to expert 4.

Scale: ++++ = very strong increase of 80% or more; +++ = strong increase of 50 to 70%; ++ = moderate increase of 30 to 40%; + = slight increase of 10 to 20%; nc = no change; - = slight decrease of 10 to 20%; -- = moderate decrease of 30 to 40%; --- = strong decrease of 50 to 70%; ---- = very strong decrease of 80% or more. A minus in brackets, (-) means decrease, a plus in brackets (+) means increase, without specifying the amount of decrease or increase. NA means the expert did not give an answer.

The assessment with experts shows:

Growing robust varieties leads to a slight, moderate, or strong increase in yield as well as an increase in yield stability. Product quality slightly decreases. The latter, however, rather reflects the change in product than the change in the product quality. Growing a robust variety means producing a different product with different organoleptic qualities. Overall, growing robust varieties does not seem to increase the full cost of bulk wine. Growing robust varieties leads to a strong decrease both in the number of different synthetic and non-synthetic fungicides applied as well as in the number of treatments. Consequently, the costs for synthetic and non-synthetic fungicides moderately, strongly, or very strongly decrease. Costs both for mechanisation as well as labour rather decrease. No additional agricultural equipment is required. The resilience of the vinyard may increase. There are no subsidies for growing robust varieties. Robust varieties are currently grown on a very low share of land. Experts expect the area to increase in the near future to 10, 20 or even 40%.

Agronomic intervention 2: Low residue strategy

According to experts it is rather or even very easy to remove synthetic pesticides before and after the flowering period. But the flowering period itself is critical and the removal of synthetic pesticides during flowering is very difficult. A barrier mentioned is growers' distrust in the effectiveness of copper. One expert advocates for the 'zero pesticide residue' (ZRP) strategy that ensures no quantifiable residues in final products. To the authors of this report it is, however, not clear how this would be implemented and how it would differ from the low residue strategy proposed.

A driver for the implementation of the low residue strategy is the conversion to organic farming. The low residue strategy can be seen as one first step into the direction of a viticulture without synthetic pesticides. In addition, the implementation of the low residue strategy is facilitated by many good examples in practice – there is already substantial experience growers can profit from. The provision of technical advice should still not be neglected.

Table 16 shows the experts' assessment of indicators:

Table 16: Impacts of agronomic intervention 2 in viticulture, France: Low Residue Strategy

Criteria	**Indicator**	**Ex1**	**Ex2**	**Ex3**	**Ex4**
Production value	Yield (hl/ha/season) - normal year	NA	-	nc	-
	Yield stability	NA	(-)	NA	NA
	Product quality	NA	nc	nc	nc
	Full cost of bulk wine (EUR/Hl)	NA	+	nc	nc
Fungicide application	Number of different synthetic fungicide products used (#/season)	NA	-	(-) 2	-
	Number of treatments with synthetic fungicides (#/season)	NA	-	(-) 2	nc
	Number of different non-synthetic fungicide products used (#/season)	NA	++	(-) 2	+
	Number of treatments with non-synthetic fungicides (#/season)	NA	++	(+) 10	+
	Number of total treatments with synthetic and non-synthetic fungicides	NA	+	- 10	nc

	(#/season) - IFT (frequency of treatments with pesticides)				
Variable costs	Costs for synthetic fungicides (EUR/ha/season)	NA	-	-	-
	Costs for non-synthetic fungicides (EUR/ha/season)	NA	++	+	+
	Costs for mechanisation (machine costs) (EUR/ha/season) - all machines	NA	++	++	nc
	Costs for labour/ workforce (french: main d'oeuvre) (EUR/ha/season) - all labour	NA	(+)	++	nc
Fixed costs	Requirement for additional agricultural equipment	NA	No	Yes	Yes
Resilience	Resilience against extreme weather events	NA	NA	nc	NA
Subsidies	Subsidies provided for agronomic intervention	NA	No	No	No
Current share of vinyard surface following this practice	Current share of vinyard surface following this practice (%) – includes all conventional farms.	NA	15 to 20	50	10 to 20
Future share of vinyard surface following this practice	Future share of vinyard surface following this practice (5 to 10 years) (%)	NA	60 to 75	30	50 to 80

Ex1 to Ex4: Expert 1 to expert 4.

Expert 1 is missing here, as the expert evaluated 'changing to organic' and not 'low residue strategy'.

Scale: ++++ = very strong increase of 80% or more; +++ = strong increase of 50 to 70%; ++ = moderate increase of 30 to 40%; + = slight increase of 10 to 20%; nc = no change; - = slight decrease of 10 to 20%; -- = moderate decrease of 30 to 40%; --- = strong decrease of 50 to 70%; ---- = very strong decrease of 80% or more. A minus in brackets, (-) means decrease, a plus in brackets (+) means increase, without specifying the amount of decrease or increase. NA means the expert did not give an answer.

The assessment with experts shows:

The low residue strategy leads to no change or only a slight decrease in yield. Yield stability may decrease. The product quality stays unchanged. The full cost of bulk wine remains unchanged or slightly increases. There is a decrease in the number of different synthetic fungicides used as well as in the number of treatments with synthetic fungicides. The number of different non-synthetic fungicides used may increase or decrease. The number of treatments with non-synthetic fungicides increases. The number of total treatments remains unchanged or may slightly increase or decrease. The costs for synthetic fungicides slightly decreases, the costs for non-synthetic fungicides slightly or moderately increases. The costs for mechanisation remain unchanged or moderately increase. The costs for labour remain unchanged or increase, up to a moderate increase. Additional agricultural equipment is rather needed. The resilience of the farm seems to remain unchanged. Subsidies are not provided. Regarding the current share of vinyard surface where the low residue strategy is implemented, experts' opinions differed quite substantially from up to

20 or up to 50%. Also, future expectations vary quite a lot. From up to 30 to up to 75 or 80%. Some experts might have included organic vinyard surfaces in their estimates. The expert who stated a current share of 50 and a future share of 30, explained that farms following the low residue strategy would convert to organic in the medium or long run.

Agronomic intervention 3: Foil coverage

According to the experts, the implementation of foil coverage to mitigate the effects of rain and heat in viticulture is rather or very difficult and faces significant challenges, first and foremost very high investment costs, but also additional costs for workforce, landscape disruption (Bordeaux is a wine-growing landscape, UNESCO World Heritage site), uncertainties about long-term effectiveness, and authorisation are major barriers. Apparently, the use of frost protection such as netting is prohibited in AOC (controlled designation of origin) areas. One expert states that the use of foil coverage will also increase the oidium effect, due to an increase in temperature under the foil. Another expert is concerned about the amount of plastic use this would cause and the electricity costs. No expert mentioned irrigation costs as barrier.

Potential drivers to overcome these challenges include the establishment of demonstration sites and research projects aimed at exploring and optimising the practicality and effectiveness of foil covers in vineyards.

Table 17 shows the experts' assessment of indicators:

Table 17: Impacts of agronomic intervention 3 in viticulture, France: Foil coverage

Criteria	**Indicator**	**Ex1**	**Ex2**	**Ex3**	**Ex4**
Production value	Yield (hl/ha/season) - normal year	NA	+	nc	+
	Yield stability	NA	(+)	NA	NA
	Product quality	NA	nc	nc	nc
	Full cost of bulk wine (EUR/Hl)	NA	nc	++++	+
Fungicide application	Number of different synthetic fungicide products used (#/season)	NA	--	----	--
	Number of treatments with synthetic fungicides (#/season)	NA	--	----	--
	Number of different non-synthetic fungicide products used (#/season)	NA	--	----	--
	Number of treatments with non-synthetic fungicides (#/season)	NA	--	----	--
	Number of total treatments with synthetic and non-synthetic fungicides (#/season) - IFT (frequency	NA	--	----	--

	of treatments with pesticides)				
Variable costs	Costs for synthetic fungicides (EUR/ha/season)	NA	--	----	--
	Costs for non-synthetic fungicides (EUR/ha/season)	NA	-	----	--
	Costs for mechanisation (machine costs) (EUR/ha/season) - all machines	NA	-	+++	--
	Costs for labour/ workforce (french: main d'oeuvre) (EUR/ha/season) - all labour	NA	(-)	+	+++
Fixed costs	Requirement for additional agricultural equipment	NA	Yes	Yes	Yes
Resilience	Resilience against extreme weather events	NA	(+)	++++	+++
Subsidies	Subsidies provided for agronomic intervention	NA	No	Yes	No
Current share of vinyard surface following this practice	Current share of vinyard surface following this practice (%) – includes all conventional farms.	NA	0	0	NA
Future share of vinyard surface following this practice	Future share of vinyard surface following this practice (5 to 10 years) (%)	NA	0.1	2 to 3	NA

Ex1 to Ex4: Expert 1 to expert 4.

Expert 1 is missing here, as interview had to be terminated earlier.

Scale: ++++ = very strong increase of 80% or more; +++ = strong increase of 50 to 70%; ++ = moderate increase of 30 to 40%; + = slight increase of 10 to 20%; nc = no change; - = slight decrease of 10 to 20%; -- = moderate decrease of 30 to 40%; --- = strong decrease of 50 to 70%; ---- = very strong decrease of 80% or more. A minus in brackets, (-) means decrease, a plus in brackets (+) means increase, without specifying the amount of decrease or increase. NA means the expert did not give an answer.

The assessment with experts shows:

Using foil coverage can lead to a slight increase in yield as well as yield stability. Product quality remains unchanged. The costs for synthetic and non-synthetic will decrease, either slightly, moderately, or very strongly. The costs for mechanisation and labour can either increase or decrease. Overall, the full cost of bulk wine may remain unchanged or increase due to the increase in mechanisation and/ or labour costs. There will be a decrease in the number of different synthetic and non-synthetic fungicides used as well as in the number of treatments – either a moderate or very strong decrease. The intervention requires additional agricultural equipment (the infrastructure for the foil coverage as well as irrigation). The resilience of the vinyard will increase rather strongly. It is not entirely sure, whether grapevine growers would be able to receive financial support for the investment in infrastructure. All experts agreed, that the investment would be high. Currently, foil coverage is not used. Experts expect that a maximum of 3% of the vinyard surface could be covered with foils in 5 to 10 years time.

Agronomic intervention 4: Changing to Organic

Two experts evaluated the ease of implementation and impacts of changing to organic.

According to the experts, changing to organic can be rather easy but also rather hard. Barriers to changing to organic mentioned are the additional equipment/ machinery and workforce needed, the additional requirements that have to be met, and the corresponding skills and knowledge that are needed, e.g. on the timing and 'positioning' of chemical treatments. In addition, organic is stricter on 'green work' (French: travaux vert) and more dependent on weather conditions. But the good number of organic farms in La Gironde shows that changing to organic is feasible, at least for some farms.

Table 18 shows the experts' assessment of indicators:

Table 18: Impacts of agronomic intervention 4 in viticulture, France: Changing to organic

Criteria	Indicator	Exp1	Exp 2	Exp 3	Exp 4
Production value	Yield (hl/ha/season) - normal year	-	NA	nc	NA
	Yield stability	NA	NA	NA	NA
	Product quality	nc	NA	nc	NA
	Full cost of bulk wine (EUR/Hl)	++	NA	++	NA
Fungicide application	Number of different synthetic fungicide products used (#/season)	----	NA	----	NA
	Number of treatments with synthetic fungicides (#/season)	----	NA	----	NA
	Number of different non-synthetic fungicide products used (#/season)	nc/(+)	NA	(-) 2	NA
	Number of treatments with non-synthetic fungicides (#/season)	(+) 15	NA	(+) 18	NA
	Number of total treatments with synthetic and non-synthetic fungicides (#/season) - IFT (frequency of treatments with pesticides)	(+) 15	NA	(+) 18	NA
Variable costs	Costs for synthetic fungicides (EUR/ha/season)	----	NA	----	NA
	Costs for non-synthetic fungicides (EUR/ha/season)	(+)	NA	+	NA
	Costs for mechanisation (machine costs) (EUR/ha/season) - all machines	++	NA	++	NA
	Costs for labour/ workforce (french: main d'oeuvre)	(+)	NA	++	NA

	(EUR/ha/season) - all labour				
Fixed costs	Requirement for additional agricultural equipment	Yes	NA	Yes	NA
Resilience	Resilience against extreme weather events	NA	NA	-	NA
Subsidies	Subsidies provided for agronomic intervention	Yes	NA	Yes	NA
Current share of vinyard surface following this practice	Current share of vinyard surface following this practice (%) – includes all conventional farms.	20	NA	20	NA
Future share of vinyard surface following this practice	Future share of vinyard surface following this practice (5 to 10 years) (%)	25	NA	60	NA

Ex1 to Ex4: Expert 1 to expert 4.

Scale: ++++ = very strong increase of 80% or more; +++ = strong increase of 50 to 70%; ++ = moderate increase of 30 to 40%; + = slight increase of 10 to 20%; nc = no change; - = slight decrease of 10 to 20%; -- = moderate decrease of 30 to 40%; --- = strong decrease of 50 to 70%; ---- = very strong decrease of 80% or more. A minus in brackets, (-) means decrease, a plus in brackets (+) means increase, without specifying the amount of decrease or increase. NA means the expert did not give an answer.

The assessment with experts shows:

Changing to organic may lead to a slight decrease in yield. Product quality remains unchanged. The full cost of bulk wine will moderately increase. No synthetic fungicides will be used. The number of different non-synthetic fungicides used may increase or decrease. The number of treatments will moderately increase by up to 40%. Costs for non-synthetic fungicides will increase but overall, as added by the experts, the costs for fungicide products will decrease, which is in line with the findings of the Sprint Farm Survey. Total costs for mechanisation as well as for labour will moderately increase. There is a requirement for additional agricultural equipment. The resilience of the vinyard may slightly decrease. Subsidies are provided. The current share of organic vinyards is 20% (in terms of surface) and is expected to increase to 25 or even 60%.

The following two figures were assembled based on an economic impact assessment done for Bordeaux by the chamber of agriculture from La Gironde. They evaluated two interventions: 'zero herbicide' and organic. Based on this evaluation, changing to organic leads to a decrease in yield of 17% (hl/ha). Workforce hours per hectar increase by 15 to 18% and mechanisation hours per hectar increase by 22 to 50%. The size and row spacing seems to have an important, but non-linear, effect on the amount of additional labour. Costs for supplies increase by 41 to 45% (EUR/ha). Costs for services increase by up to 11% (EUR/ha). Costs for mechanisation increase by 10 to 51% (EUR/ha), whereas the smallest vinyard (15ha) has the lowest and the largest vinyard (60ha) the highest increase in mechanisation costs per hectar. The costs for the workforce increase by 16 to 20% (EUR/ha). The full cost of the vinyard increase by 17 to 22% (EUR/ha). The vinification costs decrease by 7%. The full cost of bulk wine increases by 11 to 15% (EUR/ha). Per hecto litre the cost of bulk wine increases by 35 to 38% (EUR/hl).

Figure 6: Evaluation of economic impacts by the chamber of agriculture of La Gironde for the year 2021 (Chambre d'Agriculture de la Gironde, 2022). Farm size 15 and 25ha.

	15ha - 50% at 1.50 metres and 50% at 1.80 metres					25ha - 2 metres				
	CONV	ZERO HERB	Δ ZERO HERB - CONV	ORG	Δ ORG - CONV	CONV	ZERO HERB	Δ ZERO HERB - CONV	ORG	Δ ORG - CONV
Yield Hl/ha	54	50	**-7%**	45	**-17%**	54	50	**-7%**	45	**-17%**
LABOUR hours/ha										
Workforce	194	227	**17%**	228	**18%**	163	184	**13%**	188	**15%**
Mechanisation	24	30	**25%**	34	**42%**	23	24	**4%**	28	**22%**
COST €/ha										
Supplies	1415	1932	**37%**	2017	**43%**	1309	1817	**39%**	1897	**45%**
Services	600	635	**6%**	635	**6%**	495	530	**7%**	530	**7%**
Mechanisation	1413	1546	**9%**	1552	**10%**	838	1033	**23%**	1107	**32%**
Workforce	3326	3936	**18%**	3976	**20%**	2771	3139	**13%**	3210	**16%**
Full cost vineyard €/ha	8792	10105	**15%**	10299	**17%**	7100	8276	**17%**	8534	**20%**
Vinification costs €/ha - excluding barrel ageing	3039	2960	**-3%**	2841	**-7%**	2405	2341	**-3%**	2241	**-7%**
Full cost of bulk wine €/ha	11830	13065	**10%**	13140	**11%**	9504	10616	**12%**	10775	**13%**
Full cost of bulk wine €/hl	219	261	**19%**	292	**33%**	176	212	**20%**	239	**36%**

Figure 7: Evaluation of economic impacts by the chamber of agriculture of La Gironde for the year 2021 (Chambre d'Agriculture de la Gironde, 2022). Farm size 45 and 60ha.

	45ha - 3 metres					60ha - 50% at 2 metres and 50% at 2.50 metres				
	CONV	ZERO HERB	Δ ZERO HERB - CONV	ORG	Δ ORG - CONV	CONV	ZERO HERB	Δ ZERO HERB - CONV	ORG	Δ ORG - CONV
Yield Hl/ha	54	50	**-7%**	45	**-17%**	54	50	**-7%**	45	**-17%**
LABOUR hours/ha										
Workforce	107	123	**15%**	126	**18%**	143	164	**15%**	169	**18%**
Mechanisation	14	16	**14%**	19	**36%**	18	22	**22%**	27	**50%**
COST €/ha										
Supplies	1164	1532	**32%**	1636	**41%**	1283	1746	**36%**	1823	**42%**
Services	330	365	**11%**	365	**11%**	440	475	**8%**	475	**8%**
Mechanisation	540	615	**14%**	701	**30%**	543	706	**30%**	821	**51%**
Workforce	1829	2089	**14%**	2148	**17%**	2425	2793	**15%**	2901	**20%**
Full cost vineyard €/ha	5149	5893	**14%**	6183	**20%**	6211	7267	**17%**	7571	**22%**
Vinification costs €/ha - excluding barrel ageing	1982	1927	**-3%**	1841	**-7%**	1850	1798	**-3%**	1716	**-7%**
Full cost of bulk wine €/ha	7131	7821	**10%**	8024	**13%**	8061	9065	**12%**	9287	**15%**
Full cost of bulk wine €/hl	132	156	**18%**	178	**35%**	149	181	**21%**	206	**38%**

4.3 Apple orchards in Switzerland

4.3.1 Current agronomic practices

In the farm survey, only 3 apple cultivating farms were interviewed in Switzerland, one IPM farm and two organic farms.

According to the department of agriculture, organic apples are cultivated on an area of around 600ha in Switzerland. With a total apple orchard area of 3'700ha, the organic area share is 16% (Bundesamt für Landwirtschaft (BLW), 2023).

In Switzerland, all apples (that are not further processed to juice, so-called table apples) are produced using low trunk systems. The apple production area per farm is about 2 to 6ha. The variety Gala is leading in terms of quantity produced and consumed. Other important varieties are Golden Delicious, Braeburn, Jonagold, and Boskoop (Schweizer Obstverband, 2019).

Table A 7 in Appendix G shows for each farm the reported total number of chemical treatments (fungicides, herbicides and insecticides) separated by farming system. Table A 8 in Appendix H shows the number of times a farm applied a fungicide product, separated by farming system (organic and conventional/IPM), and type of product (organic or synthetic). Table A 9 in Appendix I shows for each growing stage (BBCH) and treatment number the number of times a farm applied a synthetic and/or organic fungicide. Table A 10 in Appendix J shows the quantity of active ingredients each farm applied in grams per hectar, separated by farming system (organic and conventional/IPM), and type of active (organic or synthetic).

The IPM farm reported 22 chemical treatments and the organic farms 25 treatments. The IPM farm applied 3 different organic fungicide products and 5 different synthetic fungicide products (total of 8 fungicide products). In total, it reported 30 fungicide product applications. The organic farms applied 3 and 4 different organic fungicides, respectively. In total, each organic farm reported 30 and 31 fungicide product applications, respectively. The IPM farm started applying fungicides in growing stage 53 (BBCH 53). The organic farms started applying fungicides in growing stage 53 and 56 (BBCH 53 and BBCH 56), respectively. The last synthetic fungicide application the IPM farm made was in growing stage 77 (BBCH 77).

4.3.2 Ranking of current agronomic practices

Due to the low number of apple cultivating farms surveyed (only 3 farms), no ranking could be made.

4.3.3 Impacts of agronomic interventions

To assess the impacts of three agronomic interventions to reduce the reliance on synthetic fungicides in apple orchards in Switzerland, we conducted four expert interviews with two farm advisors, one information broker, and one researcher. The two farm advisors work in the regions of Basel and Aargau, Lucerne and Zug in central Switzerland, while the information broker and researcher focus on the national level. All four experts stated to be knowledgeable in apple cultivation in Switzerland, without being specialized in a certain farming system. Two of the four interviewed experts were male and two were female. All four interviews were conducted in November and December 2023, three using the online platform Zoom and one face-to-face.

The interview was divided into four sections: general information; description of advisory service provided (if any); agronomic interventions to reduce the reliance on synthetic fungicides in apple cultivation in Switzerland; and assessment of ease and impacts of implementation of three selected agronomic interventions.

The following three agronomic interventions were assessed:

1. Robust varieties: reference variety: Topaz (resistant to fire blight and scab)
2. Low residue strategy (no synthetic, only organic fungicides after flowering)
3. Foil coverage (rain cover against mildew)

A detailed economic assessment of a conventional and organic apple orchard has been conducted elsewhere. The interested reader can refer to: Bravin E. et al., 2023.

The results of the interviews are presented in the following sub sections.

4.3.3.1 Advisory on fungus disease control in apple production

Extension services use a variety of communication channels to engage with farmers on apple orchards and disease control. Methods include one-to-one interactions, experience-sharing events, workshops, email newsletters, training courses, information evenings and contributions to fruit associations. Interactions on plant protection often intensify in spring to coincide with key crop protection periods.

In the field of disease control in apple orchards, organic and conventional approaches face common challenges. Common problems include apple scab (*Venturia inaequalis*), powdery mildew (*Podosphaera leucotricha*), apple brown rot (*Monilinia fructigena*) and apple leaf spot (*Phoma/Didymella pomorum*) which affect orchards regardless of the production method. However, specific issues arise when considering each approach. In the context of organic orchards, specific challenges include the prevalence of sooty blotch (*Gleodes pomigena*), bitter rot (*Gloeosporium*) and as a significant problem apple blotch (*Marssonina coronaria*) as it attacks leaves and can cause leaf loss by September.

4.3.3.2 Agronomic interventions to reduce the reliance on synthetic fungicides in apple production

According to experts, apple growers in Switzerland are actively using a range of agronomic measures to minimise reliance on synthetic fungicides. Current measures include various 'green works' like pruning, trimming, and thinning out to ensure that trees dry quickly after rainfall. Further rather hygienic measures include the removal of fallen fruit, removal of fruit mummies (Monilia fruit rot), and removal of fallen leaves which are recycled as mulch. According to experts, finding an optimal location for the orchard is key. In addition, a low tree density can help improve aeration and minimise leaf wetness (3000 trees per ha is the absolute maximum). Hot water treatment is an effective measure currently used in organic production with promising results against storage diseases. Another measure, according to the experts, is a product called Armicarb, which is used in organic production against scab and powdery mildew, and also appears to be useful for fruit regulation/thinning out excess flowers.

The experts also point out that robust apple varieties are an important measure to control fungus disease. The indicated that robust apple varieties form an important share of the Swiss apple orchard surface already (at least 10 to 15% of conventionally managed apple orchards). Depending on the variety, the resistance is to scab, fire blight and/or powdery mildew. Some of the resistant/tolerant varieties used are Topaz (resistant to fire blight and scab), Rustica, Ladina (resistant to scab and fire blight and low susceptibility to mildew, but not good for storage), and Natyra (resistant to scab). For other examples and their resistance to diseases and pests, see Hunziker & Kellerhals, 2019. There is government support since 2024 for certain listed robust varieties such as Topaz, Bonita or Natyra. However, some of these are not marketable (no demand, no marketing concept) or are not resistant to storage diseases, which is particularly important for sales to wholesalers. One main barrier for an increase of grown robust apple varieties is the lack of demand on the side of traders, wholesalers, and retailers.

Experts also recommend that growers monitor and maintain disease management tolerances to ensure effective control. Another option is to use copper to control fungus disease, but as copper is sprayed at almost twice the rate, there can be substantial residues in the soil. One alternative to copper that is already being used is compost tea.

Two experts explicity mentioned the difficulty to get away from synthetic fungicides. Losses in storage as well as the doubling of fungicide treatments if converting to organic were mentioned as important barriers.

4.3.3.3 Impacts of three proposed interventions

Based on the agronomic data collected in 2021, the baseline farming system was defined as shown in Table 19:

Table 19: Baseline farming system for apple orchards, Switzerland

System description baseline, apple orchard, Switzerland (year 2021)	
Orchard system:	Low stem/ trunk orchard/ dwarf tree orchard
Orchard surface:	2 to 6ha
Fruit:	Apple
Variety:	Gala
Production system:	Conventional, integrated production (IPM) (dt. ÖLN)
Trees/ha (planting density):	3000
Most important fungus diseases:	Scab, mildew, storage diseases
Fungicide application:	About 18 treatments (Sprint farm survey). 7 (Bravin E. et al., 2023) to 8 (Sprint farm survey) fungicides, of which 1 (Bravin E. et al., 2023) to 3 (Sprint farm survey) organic fungicides.
Buyer:	Wholesale

The experts have differing views on the ideal density of trees per hectare. One expert argues that 3000 trees per hectare is about right for effective orchard management. Another expert emphasises that 3000 trees per hectare is the absolute maximum and prefers a lower density for optimal orchard management, supported by another expert who suggests an even lower range of 2000 to 2500 trees per hectare.

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According to one expert (expert 4), apple growers follow the credo 'the more active substances or fungicide products the broader the effect' and therefore rather use 10 to 14 different fungicide products instead of 7 to 8. The expert emphasizes that this 'credo' is not entirely wrong, but that is also makes sense to spray in blocks with the same products. One expert points out the importance of using several active substances for an effective resistance prevention.

Table 20 shows the indicators which were used for the qualitative multicriteria assessment and associated values for the baseline, which are based on the Sprint Farm Survey (FS), literature (Lit), and experts' opinion (Ex).

Table 20: Impact assessment indicators and baseline values for apple orchards, Switzerland.

Criteria	Indicator	Value	Ex	FS	Lit
Production value	Average yield (tons/ha/season) - normal year	40	x	x	x[2]
	Risk of yield loss due to fungus diseases (Scale)	Low	x		
	Share of quality class 1 (%)	70			x[2]
	Fungicide residues in final product (Scale)	High	x		
	Price of class 1 (CHF/kg)	1.10	x		x[1,2]
Fungicide application	Number of different fungicide products used (#/season)	7[2],8[FS],10 to 14[Ex4]	x	x	x[2]
	Of which organic (%)	33	x		
	Number of treatments with fungicides (#/season)	18	x	x	
	Of which with organic fungicides (%)	33[Ex] to 50[FS]	x	x	
	Of which synthetic (%)	>50	x	x	
Variable costs	Costs for fungicides (CHF/ha/season)	1'200			x[2]
	Costs for mechanisation (machine costs) (CHF/ha/season) - only related to fungus disease	About 670			x[2]
	Costs for labour/ workforce (EUR/ha/season) - only related to fungus disease	About 1'540			x[2]
Fixed costs	Requirement for additional agricultural equipment/ infrastructure	NA	NA	NA	NA
Research costs	Requirement for research	NA	NA	NA	NA
Resilience	Resilience against extreme weather events	NA	NA	NA	NA
Subsidies	Subsidies provided for agronomic intervention	IPM (CH: ÖLN)	x	x	
Current share of apple orchard surface following this practice	Current share of apple orchard surface following this practice (%).	80	x		

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Future share of apple orchard surface following this practice	Future share of apple orchard surface following this practice (5 to 10 years) (%)	NA	NA	NA	NA
Environmental and health impacts[3]	Human health impacts (μDALY/ha)	26'700			x[3]
	Ecosystem quality impacts (PDF.m2.yr/ha)	1'400			x[3]
	Resource use (MJ/ha)	200			x[3]
Environmental and health damage costs[3]	Human health damage costs (EUR/ha)	1'980			x[3]
	Ecosystem damage costs (EUR/ha)	200			x[3]
	Resource use damage costs (EUR/ha)	0.89			x[3]

Ex: expert opinion; FS: Sprint Farm Survey; Lit: from (Binswanger & Flückiger, 2023; Bravin E. et al., 2023; Fantke et al., 2023).

Note: The indicators for environmental and health impacts and damage costs were not assessed by experts.

Agronomic intervention 1: Robust varieties

According to the experts, growing robust apple varieties is easy for a farm, if the farm does not grow more than 20% and if it is able to sell the robust apple varieties directly to consumers or small retailers. If a farm is used to selling its whole produce to traders, wholesalers and/or retailers, growing robust apple varieties is a challenge due to the reluctance on the part of traders, wholesalers and retailers to buy these varieties, as they are unkown to consumers. Traders, wholesalers, and retailers demand non-robust varieties like Gala. Gala is probably the apple variety that is most susceptible to fungus disease. In spite of its susceptibility, it is high in demand, and even organic apple producers cannot get around it. Also, the lack of production experience (only about 5 years) with robust varieties and high management costs are seen as limiting factors by the experts. Also, the fact that these varieties are only resistant to certain fungus diseases (like scab and mildew) but not to others, is seen as a barrier, as spraying is then still needed for the other diseases. In fact, most robust varieties are resistant to scab but not to storage diseases, a very important requirement to sell apples to traders, wholesalers, and retailers. So, even when using robust varieties, the last treatments before harvest, which are very important to prevent storage diseases, cannot be eliminated. Another barrier mentioned is resistance breakdown.

For organic farms and farms with direct marketing, growing resistant apple varieties is more straightforward. Demand from the consumer side and financial incentives from wholesale traders/ retailers would help to promote the growth of resistant apple varieties on conventional farms without direct marketing.

Currently, there is a lot of effort from the side of the government to promote the use of robust varieties in the form of financial support for the growth as well as the development of new robust varieties. Since 2024, growers of robust apple varieties receive financial contributions within the 'structural improvement contributions' program. At FiBL (the research institute of organic agriculture) a flavour type/ group concept has been developed to facilitate the introduction of new (robust or not) varieties to consumers. IP Suisse is planning a label for robust varieties.

Table 21 shows the experts' assessment of indicators:

Table 21: Impacts of agronomic intervention 1 in apple orchards, Switzerland: Robust varieties (reference variety: Topaz).

Criteria	Indicator	Ex1	Ex2	Ex 3	Ex 4
Production value	Average yield (tons/ha/season) - normal year	-	nc	nc/ -	nc
	Risk of yield loss due to fungus diseases (Scale)	(-)	(-)	--	nc
	Share of quality class 1 (%)	nc	(+)	(+)	nc
	Fungicide residues in final product (Scale)	---	(-)	--	-
	Price of class 1 (CHF/kg)	nc	nc	nc	nc
Fungicide application	Number of different fungicide products used (#/season)	--	-/--	-	(-) 7 to 11
	Of which organic (%)	++++	nc	nc	nc
	Number of treatments with fungicides (#/season)	nc	-/--	-	- 14 to 15
	Of which with organic fungicides (%)	++++	nc	nc	nc
	Of which with synthetic fungicides (%)	----	(-)	-	(-)
Variable costs	Costs for fungicides (CHF/ha/season)	(-)	(-)	-	--
	Costs for mechanisation (machine costs) (CHF/ha/season) - only related to fungus disease	nc	(-)	-	nc
	Costs for labour/ workforce (EUR/ha/season) - only related to fungus disease	nc	(-)	-	nc
Fixed costs	Requirement for additional agricultural equipment/ infrastructure	No	No	No	No
Research costs	Requirement for research	Yes	NA	NA	Yes
Resilience	Resilience against extreme weather events	nc	++/+++	nc	nc
Subsidies	Subsidies provided for agronomic intervention	Yes	Yes	Yes	Yes
Current share of apple orchard surface following this practice	Current share of apple orchard surface following this practice (%).	C: 10 to 15 O: 40	C: 30 to 40 O: 50	NA	C: 10 O: 30

					to 40
Future share of apple orchard surface following this practice	Future share of apple orchard surface following this practice (5 to 10 years) (%)	C: 30	C:>30	NA	C: 30

Ex1 to Ex4: Expert 1 to expert 4.

Scale: ++++ = very strong increase of 80% or more; +++ = strong increase of 50 to 70%; ++ = moderate increase of 30 to 40%; + = slight increase of 10 to 20%; nc = no change; - = slight decrease of 10 to 20%; -- = moderate decrease of 30 to 40%; --- = strong decrease of 50 to 70%; ---- = very strong decrease of 80% or more. A minus in brackets, (-) means decrease, a plus in brackets (+) means increase, without specifying the amount of decrease or increase. NA means the expert did not give an answer.

The assessment with experts shows:

Growing robust apple varieties leads to rather no change in yield, but may have a slight negative effect on it, depending on the variety. The risk of yield loss is reduced and the share of quality 1 class apples rather increases. Fungicide residues in the final product can be slightly or moderately reduced. If robust varieties are grown under organic conditions, they can be strongly reduced (expert 1). The price of class 1 apples would not increase, as there is no label to valorize robust apple varieties on the market. One expert states that there is no increase in costs and therefore no need for a premium.

The number of different fungicide products used will slightly or moderately decrease. The use of non-synthetic fungicides does not change, unless the farm grows the robust varieties under organic conditions (expert 1). Expert 1 states that growing robust varieties should always happen under organic conditions due to marketing considerations. The number of treatments will slightly or moderately decrease, unless the robust varieties are grown under organic conditions, then the number of treatments will not change (expert 1: The combination of organic and robust varieties keeps the number of treatments level with the number of treatments used in a conventionally managed orchard. If non-robust varieties are used (e.g. Gala), the number of treatments in an organically managed orchard are double the number of treatments in a conventionally managed orchard, i.e. about 40 treatments). The share of treatments with organic fungicides will not increase (unless organic strategy is followed; expert 1), but the share of treatments with synthetic fungicides will decrease (more treatments with only non-synthetic products). The costs for fungicides will decrease. The costs for mechanisation and workforce will decrease at least slightly due to the lower number of treatments needed (unless the system is organically managed). There is no requirement for additional agricultural equipment. With the use of more non-synthetic fungicides spray nozzles may break down more quickly, though, as the products are coarser. There is a rather high requirement for research. The resilience against extreme weather events may increase. Since 2024, farmers who grow 'listed' resistant apple varieties receive financial contributions within the 'structural improvement contributions'. The current share of resistant apple varieties in terms of area cultivated is at least 10 to 15% in the conventional sector. Experts agree that within 5 to 10 years time, this share will grow to 30% and appraoch the current share of resistant apple varieties in the organic sector (which is at least 30% according to experts' opinion). According to one expert, the share should further raise to at least 50%, if Swiss apple growers really want to be less dependent on synthetic fungicides.

Agronomic intervention 2: Low residue strategy

The implementation of a low residue strategy in Swiss apple orchards is considered to be rather difficult by the majority of the experts. Depending on the variety grown and the weather, it may be more or less difficult, but wet weather conditions in spring are perceived as one of the major obstacles to the implementation of the low residue strategy. Spring is the main infection phase, and if it rains a lot, the use of organic fungicides is trickier, as for the application of organic fungicides a window of four hours without rain is needed. Over the summer, the use of organic fungicides is much less problematic. Another major obstacle is the increased likelihood of storage diseases as well as losses of class 1 apples. Experts argue that it is very difficult to avoid chemical agents before harvest, as they are crucial for the storability of the apples. Food waste in storage is unacceptable. Concerns are also raised about increased labour requirements and increased number of passes with chemical treatments. Experts also emphasize that such a strategy is more knowledge intensive and requires better monitoring. In addition, experts mention the bad reputation of copper and the lack of sufficient subsidies as barriers. One expert states, that farms are or were able to obtain 0.06CHF per kg for following the low residue strategy, but that farms should receive at least 0.20CHF per kg to be compensated for the additional risks and costs. Despite these challenges, experts argue that the strategy can be viable for farms transitioning to organic practices. It is also recognised that hot water treatment prior to storage, which is already practised in organic farming, can mitigate storage disease problems. However, hot water treatment is very costly and energy intensive.

Currently there is one private initiative from the swiss fruit association running (the program 'Nachhaltigkeit Früchte') which supports the implementation of the low residue strategy (Schweizer Obstverband, 2022). From the side of the government there is the resource efficiency program as well as the 'production system contributions' for permanent crops which incentivize a low residue strategy. The latter can also be collected for partial areas. However, the experts mention that the financial support by the government is rather too low and that private initiatives like the one mentioned above are needed. An important driver for the implementation of the low residue strategy is the development of alternatives for copper.

Table 22 shows the experts' assessment of indicators:

Table 22: Impacts of agronomic intervention 2 in apple orchards, Switzerland: Low Residue Strategy.

Criteria	Indicator	Ex1	Ex2	Ex3	Ex4
Production value	Average yield (tons/ha/season) - normal year	-	--	-	nc
	Risk of yield loss due to fungus diseases (Scale)	++	++	++	(+)

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					Rather high
	Share of quality class 1 (%)	-- 30	-	(-)	(-) 55
	Fungicide residues in final product (Scale)	---	--/-- -	--	(-) Rather low
	Price of class 1 (CHF/kg)	nc	nc	nc	+ 1.30
Fungicide application	Number of different fungicide products used (#/season)	(-)	- 4 to 5	(-)	(-) 7 to 11
	Of which organic (%)	(+)	(+)	(+)	(+) 66
	Number of treatments with fungicides (#/season)	(+)	(+)	++	(+) 22
	Of which with organic fungicides (%)	(+)	(+)	(+)	(+) 66
	Of which with synthetic fungicides (%)	(-)	(-) <50	(-)	(-)
Variable costs	Costs for fungicides (CHF/ha/season)	(-)	(-)	(+)	++
	Costs for mechanisation (machine costs) (CHF/ha/season) - only related to fungus disease	+	nc/+	++	+
	Costs for labour/ workforce (EUR/ha/season) - only related to fungus disease	+	nc/+	(+)	++
Fixed costs	Requirement for additional agricultural equipment/ infrastructure	Yes	No	No	No
Research costs	Requirement for research	No	NA	NA	Yes
Resilience	Resilience against extreme weather events	nc	(-)	nc	nc
Subsidies	Subsidies provided for agronomic intervention	Yes	Yes	Yes	Yes
Current share of apple orchard surface following this practice	Current share of apple orchard surface following this practice (%).	0	0	1	10
Future share of apple orchard surface following this practice	Future share of apple orchard surface following this practice (5 to 10 years) (%)	10	0	1	25

Ex1 to Ex4: Expert 1 to expert 4.

Scale: ++++ = very strong increase of 80% or more; +++ = strong increase of 50 to 70%; ++ = moderate increase of 30 to 40%; + = slight increase of 10 to 20%; nc = no change; - = slight decrease of 10 to 20%; -- = moderate decrease of 30 to 40%; --- = strong decrease of 50 to 70%; ---- = very strong decrease of 80% or more. A minus in brackets, (-) means decrease, a plus in brackets (+) means increase, without specifying the amount of decrease or increase. NA means the expert did not give an answer.

The assessment with experts shows:

The adoption of a low residue strategy very likely leads to a slight or moderate decrease in yield. The risk of yield loss due to fungus disease is moderately increased. One expert specifies that this is mainly due to losses in storage and only holds if no hot water treatment can be used before storage. The share of quality class 1 apples decreases from 70 to 55% or even less. One expert states that apples would have a shorter shelf life and are more likely to get spots. Another expert specifies that the loss would be mainly due to losses of class 1 apples in storage due to storage disease. The fungicide residues in the final product decrease moderately or strongly. The price of class 1 apples does not increase, as there is no label (ex1, ex2, ex3), but it should increase from 1.10 to about 1.30CHF/kg (premium of 0.20CHF/kg) to compensate farmers for the additional costs and risks. The number of different fungicide products used decreases. One expert specifies from 7 to 8 different fungicide products to 4 to 5 different products. Another specifies from 10 to 14 different fungicide products to 7 to 11 different products (expert 4). The number of different organic fungicide products used will increase. The number of treatments with fungicides will slightly (from 18 to 22) or moderately increase. The share of treatments including organic fungicides will increase and the share of treatments including synthetic fungicides will decrease. It is not clear if the total costs for fungicides will decrease or increase. Two experts argue for a decrease and two for an increase. Experts agree that the costs for mechanisation and labour will increase due to the increased number of required treatments (as products are more frequently washed off) as well as due to a greater machine wear with an increased use of organic fungicides (which are coarser). In terms of additional agricultural equipment needed, one expert points out the need for a machine to do the hot water treatment. According to one expert, the requirement for research is rather high, particularly in the area of storage disease. The resilience of the farm whould not change. The practice receives financial support from the government (resource efficiency program and production system contributions for permanent crops). According to one expert, this subsidy is too low and further private initiatives are needed to make the practice attractive to farmers (e.g. the 'Nachhaltigkeit Früchte' program from the Swiss fruit association). The current share of apple orchards who follow this practice in Switzerland (excluding organic farms!) is very low and at maximum 10%. Experts expect no increase or an increase by 10 (from 0 to 10%) to 15% (from 10 to 25%).

Agronomic intervention 3: Foil coverage

Experts agree that it is very difficult to implement foil coverage in Swiss apple orchards. The main obstacles are the exorbitant investment costs for infrastructure (for foil coverage and irrigation), no govermental support, additional labour costs, and the considerable additional space required, which makes it impractical for smaller orchards. Challenges also arise from the promotion of unwanted insects (e.g. aphids and mites) and dry rot fungi due to increased temperatures (and lack of rain that washes insects off) under the foil, the inhibition of fruit ripening and colouring due to reduced light, and the additional need for irrigation (in some parts of Switzerland, irrigation is not a standard in apple orchards). Foil coverage may, according to the experts, help against scab, apple blotch (Marssonina), and potentially also against storage diseases. However, according to the experts, the costs and challenges associated with the installation and management of foil coverage outweigh its potential benefits. The potential benefits may be higher for organic farms, as they are not allowed to use synthetic fungicides. In addition, organic farms already know the practice of using covers and may therefore be more likely to adopt. Farms with an own water source may also be more likely to adopt. In nature reserves or certain areas, there are restrictions based on spatial laws that do not allow covering or only to a limited extent (e.g. only during the actual production phase). Snow fall at higher altitudes further complicates the implementation of foil cover (foil tears apart with snow on it).

Table 23 shows the experts' assessment of indicators:

Table 23: Impacts of agronomic intervention 3 in apple orchards, Switzerland: Foil coverage.

Criteria	**Indicator**	**Ex1**	**Ex2**	**Ex 3**	**Ex4**
Production value	Average yield (tons/ha/season) - normal year	nc	nc	nc	nc
	Risk of yield loss due to fungus diseases (Scale)	---	--/---	---	(-) Very low
	Share of quality class 1 (%)	+	+	nc	(-) 55
	Fungicide residues in final product (Scale)	--	--	---	nc
	Price of class 1 (CHF/kg)	nc	nc	nc	(+)
Fungicide application	Number of different fungicide products used (#/season)	-	-/--	---	(-) 7 to 11
	Of which organic (%)	nc	nc	NA	nc
	Number of treatments with fungicides (#/season)	---	-/--	---	(-) 12 to 13
	Of which with organic fungicides (%)	nc	nc	NA	nc
	Of which with synthetic fungicides (%)	nc	nc	NA	(-)
Variable costs	Costs for fungicides (CHF/ha/season)	--	-	---	--
	Costs for mechanisation (machine costs) (CHF/ha/season) - only related to fungus disease	nc	-	--	++
	Costs for labour/ workforce (EUR/ha/season) - only related to fungus disease	+++	+/++	--	++
Fixed costs	Requirement for additional agricultural equipment/ infrastructure	Yes	Yes	Yes	Yes
Research costs	Requirement for research	Yes	NA	NA	Yes
Resilience	Resilience against extreme weather events	+++	nc	++	++/+++
Subsidies	Subsidies provided for agronomic intervention	No	No	No	No

Current share of apple orchard surface following this practice	Current share of apple orchard surface following this practice (%).	0	0	0	Max 5
Future share of apple orchard surface following this practice	Future share of apple orchard surface following this practice (5 to 10 years) (%)	10	<1	<1	10

Ex1 to Ex4: Expert 1 to expert 4.

Scale: ++++ = very strong increase of 80% or more; +++ = strong increase of 50 to 70%; ++ = moderate increase of 30 to 40%; + = slight increase of 10 to 20%; nc = no change; - = slight decrease of 10 to 20%; -- = moderate decrease of 30 to 40%; --- = strong decrease of 50 to 70%; ---- = very strong decrease of 80% or more. A minus in brackets, (-) means decrease, a plus in brackets (+) means increase, without specifying the amount of decrease or increase. NA means the expert did not give an answer.

The assessment with experts shows:

The adoption of foil coverage in apple orchards will not affect the yield in a normal year. Some experts mention the elimination of potential yield increases – due to less fungus disease – by more insect pressure. The risk of yield loss due to fungus disease will moderately or strongly decrease if the foil cover can be applied timely. The share of class 1 apples will slightly increase (expert 1 and expert 2), if the increase is not eliminated by the increased insect pressure (expert 2) and if the foil will not deprive the trees from too much light, as this negatively effects ripening and colouring. The latter is particularly important in the case of two- or multi-coloured apples. The fungicide residues in the final product will very likely decrease, at least moderately. The price of class 1 apples will not increase, but should increase due to higher investment costs for foil coverage and irrigation. The number of different fungicide products will decrease. The share of different organic fungicide products used will not change. The number of treatments will moderately or strongly decrease. The share of treatments including organic or synthetic fungicides will remain unchanged. The costs for fungicides will decrease at least slightly but rather moderately. It is not clear if the costs for mechanisation will increase, decrease or remain unchanged. The costs for labour would rather increase. One expert states that the opening and closing of the foil is done manually and labour intensive. There is a clear requirement for additional agricultural equipment, including the infrastructure for the foil cover and for irrigation. Due to the lack of practical experience, there is a need for research. The adoption of a foil cover will very likely make the farm more resilient, at least moderately. There are no subsidies for this intervention. The current share of Swiss apple orchards using a foil cover is very low or zero and at maximum 5%. Experts expect an increase to a maximum share of 10%.

4.4 Potato production in the Netherlands

4.4.1 Current agronomic practices

In the farm survey, 15 potato producing farms were interviewed in the Netherlands, 7 organic farms, 3 IPM, and 5 conventional (not IPM) farms. Most of them grow seed potatoes, except for 2 farms (1 IPM and 1 conventional), who do not grow seed potatoes but ware or starch potatoes (F10 and F14). All farms surveyed are located in the North of Holland (Groningen and Friesland).

According to CBS (Central Bureau of Statistics Netherlands) figures from the year 2021, the province of Groningen counts around 800 farms who cultivate potatoes on 26'700 hectares of land (area cultivated and area harvested), of which 9'500 hectares are used to grow seed potatoes (by 280 farms). They achieve a gross yield of 39 tons of potatoes per hectare or 35 tons of seed potatoes per hectare. The province of Friesland counts around 300 farms who cultivate potatoes on 9'000 hectares of land (area cultivated and area harvested), of which almost the whole area (7'500 hectares) is used to grow seed potatoes (by 240 farms). They achieve a gross yield of 35 tons of potatoes per hectare or 33 tons of seed potatoes per hectare. The share of organic farms is quite low in the Netherlands (4% of area cultivated was organic in 2021 (Willer et al., 2023)). This also holds for (seed) potato production.

Table A 11 of Appendix K shows for each farm the reported total number of chemical treatments (fungicides, herbicides and insecticides) separated by farming system (IPM and conventional). Table A 12 of Appendix L shows the number of times a farm applied a fungicide product, separated by farming system (IPM and conventional), and type of product (organic or synthetic). Table A 13 of Appendix M shows for each growing stage (BBCH) and treatment number the number of times an IPM or conventional farm applied a synthetic and/or organic fungicide. Table A 14 of Appendix N shows the quantity of active ingredients each farm applied in grams per hectar, separated by farming system (IPM and conventional), and type of active (organic or synthetic). Organic farms are excluded from these tables, as they did not indicate any chemical treatments.

IPM farms reported 5, 11, and 17 chemical treatments and the conventional farms 8 to 11 or 16 chemical treatments. The farms who reported 16 and 17 chemical treatments, are farms who grow potatoes for consumption (not seeds) (Farm F10 and F14). Seed potatoes are typically harvested earlier (in June/ July instead of August/ September) and therefore require fewer chemical treatments than potatoes for consumption. IPM farms applied 3 to 5 different synthetic fungicide products and no organic fungicide products. In total, IPM farms reported 3, 10, and 14 fungicide product applications. The farm with 14 fungicide product applications grows potatoes for consumption. The conventional farms applied 3 to 6 different synthetic fungicides and no organic fungicide products. In total, each conventional farm reported 7 to 15, and 17 fungicide product applications. The farm with 17 product applications grows potatoes for consumption. The IPM farm started applying fungicides in growing stages 5, 9, and 55 (BBCH). This difference seems to be due to the kind of potato they produce. Seed potato growing IPM farms start applying fungicides earlier and stop earlier than non-seed potato growing IPM farms – except for one late treatment in some cases, probably to prevent storage diseases. The conventional farms started applying synthetic fungicides between the growing stages 5 and 19 (BBCH). In contrast to the non-seed potato growing IPM farm, the non-seed potato growing conventional farm starts very early with the application of fungicides, in fact the earliest (BBCH 5). The last synthetic fungicide application the IPM farms made was in growing stages 59, 89, and 99 (BBCH). The last synthetic fungicide application the conventional farms made was in growing stages 59, 70, 89, and 91 (BBCH).

4.4.2 Ranking of current agronomic practices

Data on crop rotation is only available for one single non-organic farm in the sample and costs for pesticide products are missing. The ranking could therefore only be performed for the environmental and health impacts and damage costs taken from the Sprint deliverable D6.1 (Fantke et al., 2023).

As organic farms did not indicate any chemical treatments, their environmental and human health impact and damage cost levels were not computed. Table 24 shoes the farms with the highest impacts and damage costs are the two farms (one conventional, one IPM; F10 and F14) that grow potatoes for consumption (not for seeds). The conventional farm has significantly higher impacts and damage costs than the IPM farm. When it comes to seed potato growing farms, the ones with a conventional farming system tend to have higher impacts and damage costs on average than those with an IPM system. Whereas IPM and conventional seed potato growing farms can have very similar impacts and damage costs, the highest levels are reached by two conventional farms. As potatoes for consumption are harvested later in the year (August/ September) than seed potatoes (June/ July), growing the former involves considerably more treatments (16 to 17 as opposed to 5 to 11). The two IPM seed potato farms use 5 and 11 treatments, 3 and 4 different fungicide products and 3 and 4 different active ingredients, respectively. The four conventional seed potato farms use 8 to 11 treatments, 3 to 5 fungicide products, and 4 to 5 different active ingredients.

Table 24: Ranking of (seed) potato producing farms by environmental and human health impacts and damage costs.

Farm	Farming system	Human Health Damage costs (EUR/ha)	Ecosystem Damage Costs (EUR/ha)	Resource damage costs (EUR/ha)	Human Health Impacts (µDALY/ha)	Ecosystem Quality (PDF.m2.yr/ha)	Resources (MJ/ha)	Treatments count	Fungicide count	F.AI count	Rank
F12	IPM	237.49	25.30	0.11	3209.36	180.70	26.46	5	3	3	1
F16	Conventional	251.26	27.23	0.12	3395.34	194.46	28.35	11	4	5	2
F08	Conventional	449.26	41.57	0.19	6071.03	296.95	43.47	8	5	5	3
F11	IPM	545.24	61.28	0.27	7368.12	437.70	63.81	11	4	4	4
F13	Conventional	612.40	67.97	0.30	8275.63	485.48	70.79	10	3	4	5
F15	Conventional	679.66	82.58	0.37	9184.53	589.86	86.10	9	4	5	6
F10	IPM	755.60	86.47	0.39	10210.84	617.65	90.10	17	5	5	7

F14	Conventional	1227.11	140.27	0.63	16582.55	1001.93	146.20	16	6	7	8

Note: damage costs are associated with environmental impacts that are not included in the market prices of agricultural production and are therefore costs that are 'external' to the product market.

4.4.3 Impacts of agronomic interventions

To assess the impacts of three agronomic interventions to reduce the reliance on synthetic fungicides in seed potato cultivation in the Netherlands, we conducted two expert interviews with a former seed potato farmer and a researcher, both located in North Holland (Groningen and Friesland). Both experts stated to be knowledgeable in seed potato cultivation in the Netherlands. The former seed potato farmer used to have a conventional farm but undertook a lot of measures to strengthen the soil biology and reduce chemical and nitrogen inputs with the main goal of producing good quality seed potatoes. The researcher is knowledgeable in both conventional and organic systems. Both experts were male. Both interviews were conducted in December 2023 using the online platform Zoom.

The interview was divided into four sections: general information; description of advisory service provided (if any); agronomic interventions to reduce the reliance on synthetic fungicides in seed potato cultivation in the Netherlands; and assessment of ease and impacts of implementation of three selected agronomic interventions.

The following three agronomic interventions were assessed:

1. Robust varieties: reference varieties: Alouette and Jacky (resistant against Phytophtera infestans (phytin))
2. Wider crop rotation (1:4, 1:5, 1:6 instead of 1:3)
3. Changing to organic

The results of the interviews are presented in the following sub sections.

4.4.3.1 Advisory on fungus disease control in potato cultivation

Neither expert is currently working as farm advisor. However, one of the experts mentions that he has a lot of exchange with farmers on practices and experiences through the demonstration farm at his research station.

In terms of relevant fungal diseases, the experts mainly mentioned downy mildew, late blight (Phytophtera infestans – short: phytin), and Rizoptonia which is a soil disease that infects the tuber. One expert specifies that potato blight is the greatest risk of poor harvests in (seed) potatoes.

4.4.3.2 Agronomic interventions to reduce the reliance on synthetic fungicides in potato cultivation

The experts highlight various innovative practices to increase soil quality and biology and plant health, such as the use of manure, green cover (cover crops), wider crop rotations (1:4, 1:5, 1:6 instead of 1:3), and – during the growing season – the use of azotobacter bacteria. The latter can help to generate nitrogen in a natural way, so that no additional nitrogen is needed. Other measures to improve soil quality include the use of mycorrhizal fungi and chitin.

One expert highlights the importance of working with nature and not against it and to consider the whole system, including surrounding farms and ecosystems.

4.4.3.3 Impacts of three proposed agronomic interventions

Based on the agronomic data collected in 2021, the baseline farming system was defined as shown in Table 25:

Table 25: Baseline farming system for seed potato production, Netherlands.

System description baseline, seed potato production, Netherlands (year 2021)	
Region:	North Holland (Groningen, Friesland)
Crop:	Seed potato
Production system:	Conventional
Average farm size:	90 to 100ha – one third used for seed potato cultivation
Family farm:	Yes
Crop rotation width:	1:3
Other crops in crop rotation:	Barley, wheat, sugar beet or onions
Most important fungus diseases:	Downy mildew, late blight (Phytophtera infestans – short: phytin), and Rizoptonia (soil disease).
Fungicide application:	About 8 to 10 treatments with 3 to 5 synthetic fungicide products. No non-synthetic fungicides used.
Buyer:	Large traders
Yield:	30 to 40 tons/ha

Experts state that seed potato farms are growing in size. The smallest farms are about 5ha in size, the largest farms between 400 and 500ha. Smalls farms usually lease their land to larger farms in the year when seed potatoes are grown. One expert states a yield of 36 tons/ha, the other a yield of 40 tons/ha. According to CBS, seed potato yields in Groningen and Friesland range between 33 to 38 tons/ha over a period of 5 years.

Table 26 shows the indicators which were used for the qualitative multicriteria assessment and associated values for the baseline, which are based on the Sprint Farm Survey (FS), literature (Lit), and experts' opinion (Ex).

Table 26: Impact assessment indicators and baseline values for seed potato production, Netherlands.

Criteria	Indicator	Value	Ex	FS	Lit
Production value	Average Yield (normal year) (tons/ha)	30 to 40	x		x[1]
	Risk of yield loss due to fungus disease (normal year)	Low	x		
	Share of good quality seed potatoes that can be sold to traders (normal year) (%)	90 (80 sold to traders, 10 for own use)	x		
	Farm gate price (EUR cents/kg)	0.50 to 0.70	x		x[2]

Fungicide application	Total number of treatments with synthetic fungicides (normal year)	8 to 10 (max 13)	x	x	
	Total number of synthetic fungicide products applied (normal year)	3 to 5	x	x	
Labour	Fungus disease related labour	NA	NA	NA	NA
Fixed costs	Requirement for agricultural equipment for fungus disease control	NA	NA	NA	NA
Resilience	Resilience against extreme weather events	Rather low	x		
Incentives	Subsidies	No	x		
Current share (in terms of surface)	Current share (%)	Very high (>90%)	x		x[3]
Future share (in terms of surface)	Future share (5 to 10 years) (%)	NA	NA	NA	NA
Environmental and health impacts[3]	Human health impacts (µDALY/ha)	3'395 to 9'185			x[4]
	Ecosystem quality impacts (PDF.m2.yr/ha)	194 to 590			x[4]
	Resource use (MJ/ha)	28 to 86			x[4]
Environmental and health damage costs[3]	Human health damage costs (EUR/ha)	251 to 680			x[4]
	Ecosystem damage costs (EUR/ha)	27 to 83			x[4]
	Resource use damage costs (EUR/ha)	0.12 to 0.37			x[4]

Ex: expert opinion; FS: Sprint Farm Survey; Lit: from [1]CBS: Central Bureau of Statistics Netherlands; (Van der Burgt et al., 2021); [3]Willer et al., 2023; [4]Fantke et al., 2023.

Note: The indicators for environmental and health impacts and damage costs were not assessed by experts.

Agronomic intervention 1: Robust varieties

In current seed potato production practices, a single variety is typically grown for 3 to 8 years. Seed potato growers always grow several varieties (8 to 10 or more) at the same time in varying quantitites. Which and for how long a variety is grown very much depends on the offer and demand on the side of seed potato traders with whom seed potato growers have contracts. For instance, at HZPC (https://www.hzpc.com/), a potato wholesale trader, there are around 60 varieties available and farms are asked to grow a new variety about every 3 years. All together, seed potato farms grow about 200 potato varieties. Three varieties which are currently grown in large quantities are Agria, Fontane, and Spunta.

Hence, market forces, particularly influential trading companies such as HZPC, AGRICO and AVERIS, have substantial control over the choice of potato varieties grown. Variety selection is strongly determined by market demand, with these large trading companies playing a crucial role. According to the experts, about 80% of the seed potatoes produced in the Netherlands get exported to international markets, underlining the enormous influence of export markets in determining the range of potato varieties grown. The majority of these potatoes are intended for industrial production, which means that the industry must be persuaded to adopt new potato varieties. The dominance of trading companies in variety selection, coupled with concerns about resistance breakdown, presents the two main obstacles to the adoption of robust varieties mentioned by the experts. In addition, investment in knowledge is proving to be a key factor, as each variety has a unique growth behaviour that requires a nuanced understanding for successful cultivation.

Asked for robust varieties, the experts mention Alouette and Jacky. Whereas the farmer knows Alouette and Jacky only by name, the researcher does have experience with the cultivation of Alouette and Jacky.

Table 27 shows the experts' assessment of indicators:

Table 27: Impacts of agronomic intervention 1 in seed potato production, Netherlands: Robust varieties (reference varieties: Alouette and Jacky).

Criteria	**Indicator**	**Ex1**	**Ex2**
Production value	Average Yield (normal year) (tons/ha)	nc	nc
	Risk of yield loss due to fungus disease (normal year)	nc (but lower chemical input)	nc
	Share of good quality seed potatoes that can be sold to traders (normal year) (%)	nc	nc
	Farm gate price (EUR cents/kg)	nc	nc
Pesticide application	Total number of treatments with synthetic fungicides (normal year)	(-)	-
	Total number of synthetic fungicide products applied (normal year)	nc	nc
Labour	Fungus disease related labour	nc	nc
Fixed costs	Requirement for additional agricultural equipment for fungus disease control	No	NA
Resilience	Resilience against extreme weather events	nc	nc
Incentives	Subsidies	No	No
Current share (in terms of surface)	Current share (%)	2 to 5 (small share)	5
Future share (in terms of surface)	Future share (5 to 10 years) (%)	>2 to 5	NA

Ex1 to Ex2: Expert 1 to expert 2.

Scale: ++++ = very strong increase of 80% or more; +++ = strong increase of 50 to 70%; ++ = moderate increase of 30 to 40%; + = slight increase of 10 to 20%; nc = no change; - = slight decrease of 10 to 20%; -- = moderate decrease of 30 to 40%; --- = strong decrease of 50 to 70%; ---- = very strong decrease of 80% or more. A minus in brackets, (-) means decrease, a plus in brackets (+) means increase, without specifying the amount of decrease or increase. NA means the expert did not give an answer.

The assessment with experts shows:

The adoption of robust seed potato varieties will not affect the yield. Also, the risk of yield loss due to fungus disease, the share of good quality seed potatoes, and the farm gate price remain unchanged. One expert specifies that the price for seed potatoes is determined by the market for consumption potatoes that are grown from the seed potatoes. There, other issues, such as peel quality and internal quality, play a greater role than disease resistance. The number of treatments with synthetic fungicides will be reduced only slightly. One expert specifies: In spite of varieties resistant to potato blight, there is an ongoing discussion about continuing the chemical protection of these varieties, to prevent or postpone the resistance breakthrough. The number of different synthetic fungicides used will remain unchanged. Fungus disease related labour will not be affected. The farm's resilience will not change. One expert specifies that a farm's resilience first and foremost depends on the farm's soil biology. There are no governmental subsidies for growing robust varieties. Currently, about 2 to 5% of the area cultivated with seed potatoes can be attributed to the growth of robust varieties. One expert expects this share to increase. Apparently, breeding stations are working hard to develop more resistant potato varieties, but this will take years.

Agronomic intervention 2: Wider crop rotation

According to the experts, expanding crop rotation is a challenge without an economically competitive crop, as seed potatoes are extremely profitable in comparison. One expert highlights that seed potatoes make up to 75% to 80% of a farm's income. The other highlights that the income from seed potatoes is at least 4 to 6 times higher than the income from wheat. The expert specifies that a 1:5 crop rotation would be best, but the economic impact would be dramatic.

In addition, according to the experts, a wider crop rotation can be effective against soil desease (Rizoptonia) but not necessarily against late blight of potato (phytophtera infestans).

Experts only see a potential for a wider crop rotation in the case of organic farms or if regulations from the government demand a wider crop rotation. In the latter case, however, farms would have to be compensated for the economic loss incurred.

Table 28 shows the experts' assessment of indicators:

Table 28: Impacts of agronomic intervention 2 in seed potato production, Netherlands: Wider crop rotation.

Criteria	Indicator	Ex1	Ex2
Production value	Average Yield (normal year) (tons/ha)	+ 5 to 10%	nc
	Risk of yield loss due to fungus disease (normal year)	nc	nc

	Share of good quality seed potatoes that can be sold to traders (normal year) (%)	nc	nc
	Farm gate price (EUR cents/kg)	nc	nc
Pesticide application	Total number of treatments with synthetic fungicides (normal year)	nc	nc
	Total number of synthetic fungicide products applied (normal year)	nc	nc
Labour	Fungus disease related labour	nc	nc
Fixed costs	Requirement for additional agricultural equipment for fungus disease control	No	NA
Resilience	Resilience against extreme weather events	nc	nc
Incentives	Subsidies	No	No
Current share (in terms of surface)	Current share (%)	Small share	15
Future share (in terms of surface)	Future share (5 to 10 years) (%)	>small share	NA

Ex1 to Ex2: Expert 1 to expert 2.

Scale: ++++ = very strong increase of 80% or more; +++ = strong increase of 50 to 70%; ++ = moderate increase of 30 to 40%; + = slight increase of 10 to 20%; nc = no change; - = slight decrease of 10 to 20%; -- = moderate decrease of 30 to 40%; --- = strong decrease of 50 to 70%; ---- = very strong decrease of 80% or more. A minus in brackets, (-) means decrease, a plus in brackets (+) means increase, without specifying the amount of decrease or increase. NA means the expert did not give an answer.

The assessment with experts shows:

The adoption of a wider crop rotation may have a positive impact on yield, as the soil can rest and therefore has the potential to produce a higher yield. The risk of yield loss due to fungus disease, the share of good quality seed potatoes, as well as the farm gate price will not be affected by the intervention. Both, the number of treatments and fungicide products used will remain unchanged. One expert specifies that a wider crop rotation may be effective against fungus disease in the soil but not against potato blight, which is the greatest risk of poor harvests in seed potato cultivation. Fungus disease control related labour will stay the same. The intervention does not require additional agricultural equipment. It also does not affect the farm's resilience, unless there is a positive effect on soil biology, but a good soil biology can also be achieved with a 1:3 crop rotation, as one expert emphasizes. There are no governmental subsidies for a wider crop rotation. One expert specifies that the government currently intervenes with a regulation that requires a crop rotation with a minimum width of 1:3. The current share of seed potato farms using a crop rotation width above 1:3 is small, possibly about 15% in area cultivated, including organic farms who use a 1:6 crop rotation and conventional farms who use a 1:4 crop rotation. One expert expects the share of wider crop rotations to increase, if restrictions on the use of chemicals become stricter (even though crop rotation is not expected to be effective against the main fungus disease in seed potato farming, which is potato blight).

Disclaimer: This report is part of a project that has received funding by the European Union's Horizon 2020 research and innovation program under grant agreement number 862568.

One expert emphasizes that there is too little objective experience with the effect of increasing crop rotation on fungal diseases. Research on this is considered very complex.

Agronomic intervention 3: Changing to organic

According to the experts, a conversion to organic production faces challenges such as increased weeding, increased labour requirements, and decrease in yield (by 15 to 20 tons/ha). In addition, the incentive for conventional seed potato farms to convert to organic is low, as the business of conventional seed potatoes is so profitable, the demand for organic seed potatoes low (small market and possibility for organic potato producers to use conventional seed potatoes), and the conversion costs borne by the farm itself. Hence, to motivate farmers to convert, experts suggest the following measures: financial support for conversion; higher market price for organic seed potatoes; no tax on organic crops; and phasing out the derogation for the use of organic seeds.

Table 29 shows the experts' assessment of indicators:

Table 29: Impacts of agronomic intervention 3 in seed potato production, Netherlands: Changing to organic.

Criteria	Indicator	Ex1	Ex2
Production value	Average Yield (normal year) (tons/ha)	-- 30 tons/ha	--
	Risk of yield loss due to fungus disease (normal year)	+++	(+)
	Share of good quality seed potatoes that can be sold to traders (normal year) (%)	-/-- 60 to 70%	-
	Farm gate price (EUR cents/kg)	++ 0.40 to 0.50 EUR/kg	++ 0.50 to 0.60 EUR/kg
Pesticide application	Total number of treatments with synthetic fungicides (normal year)	---- None	---- None
	Total number of synthetic fungicide products applied (normal year)	---- None	---- None
Labour	Fungus disease related labour	nc	nc
Fixed costs	Requirement for agricultural equipment for fungus disease control	No	NA
Resilience	Resilience against extreme weather events	(+)	+
Incentives	Subsidies	Yes	Yes
Current share (in terms of surface)	Current share (%)	Small share	<2%
Future share (in terms of surface)	Future share (5 to 10 years) (%)	>small share	NA

Ex1 to Ex2: Expert 1 to expert 2.

Scale: ++++ = very strong increase of 80% or more; +++ = strong increase of 50 to 70%; ++ = moderate increase of 30 to 40%; + = slight increase of 10 to 20%; nc = no change; - = slight decrease of 10 to 20%; --

= moderate decrease of 30 to 40%; --- = strong decrease of 50 to 70%; ---- = very strong decrease of 80% or more. A minus in brackets, (-) means decrease, a plus in brackets (+) means increase, without specifying the amount of decrease or increase. NA means the expert did not give an answer.

The assessment with experts shows:

The conversion to organic will lead to a moderate decrease in yield. According to one expert, the growth of seed potatoes is stopped earlier (by burning the leaves) to prevent that the potato blight disease gets into the tuber. The same expert also states that under organic conditions the yield stability is lower and can go down to 25 tons/ha in a wet season. The risk of yield loss due to fungus disease will increase. The share of good quality seed potatoes will slightly or moderately decrease, from 90% to about 60 to 70%. The farm gate price for organic seed potatoes is moderately higher (premium of 0.10 to 0.20 EUR/kg). Fungus disease related labour will not change. One expert specifies that spraying with modern machines is generally not labour intensive. However, experts indicate that total labour is higher on an organic farm. One expert states: "With an organic farm you work day and night to get a balanced soil biology". The other expert explains that organic cultivation is based on creating resistance of the crop against diseases and pests, considering the entire cultivation system, i.e. the entire crop rotation, by taking measures for a healthy and balanced soil. According to one expert there is no additional agricultural equipment needed for fungus disease control related works. Additional agricultural equipment is needed for weed control. The farm's resilience against extreme weather events is expected to increase if the soil biology is in a good state. An organic farm usually has a higher share of organic matter in its soil and a better root system and is therefore more resilient against dry and wet weather. Subsidies for organic farming are provided from the state, but not during conversion. The current share of organic seed potato farms – in terms of area cultivated – is small, lower than 2%. One expert expects this share to increase, is not entirely sure though how fast the share will increase, due to ongoing discussions about the Green Deal. The expert emphasizes that political decisions have a lot of influence.

4.5 Conclusion

As the case of **Slovenia** shows, **product substitution** can be a very effective way to reduce environmental and health impacts at no additional farm-level cost. However, for product substitution to be successful, a respective policy is needed to create demand and supply for the substitute products. The Kopop program can serve as an example for other countries to encourage product substitution and the adoption of other practices to reduce the reliance on synthetic pesticides. The case of Slovenia also suggests, that **access to new machinery** is very important to reduce the reliance on synthetic herbicides in weed control on arable farms. As the experience in other countries shows, mechanical weeding is an economically viable option with the right machinery and the right incentives (e.g. for organic farming). As the full reliance on mechanical weeding comes with a stronger weather dependence and therefore higher (perceived) production risk, Slovenian farms should implement the intervention gradually and with the support of technical assistance to reduce the risk of yield loss. Furthermore, a the market for low-residue, pesticide-free

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or organic products has to be strengthened. A combination of mechanical weeding and a **wider crop rotation** is a promising strategy to keep perennial weeds under control. A combination of financial incentives and stricter rules regarding animal heads per hectar could help smaller farms to widen their crop rotation.

The case of **France** and **robust grape varieties** provides a good example for a typical lock-in situation. In spite of higher expected yields, lower production risk, and less expected costs for fungus disease control, the adoption of robust grape varieties is very low. The lack of historical roots, which complicates their adoption by AOC (controlled designation of origin) certified farms, the lack of market demand, the high initial investment costs for 'renewing' the vineyard, and the risk of resistance breakdown makes them very unattractive to farmers. A more feasible strategy for grapevine growers to reduce the reliance on synthetic fungicides is the **low residue strategy**. According to experts, a considerable share of grapevine growing farms has already adopted a low residue strategy and the share is expected to increase. For the adoption of **foil coverage** to protect vinyards from rain and prevent mildew the barriers are very high, in spite of its potential to at least moderately decrease the use of synthetic fungicides. High initial investment costs, additional labour costs related to installing, opening and closing the foil, landscape disruption, doubts regarding long term effectiveness, lack of practical experience, increase of oidium pressure (due to temperature increase under the foil), and incompatibility with AOC specifications were mentioned as barriers. **Converting to organic** leads to an increase in costs and a decrease in yields on grapevine growing farms, as shown by the 'Référentiel Economique du Vigneron 2021' (Chambre d'Agriculture de la Gironde, 2022). In addition, a conversion to organic requires additional agricultural equipment, skills, and knowledge and also means stronger weather dependence. Depending on the farm, a conversion can be easier or more difficult to implement.

In **Switzerland**, there are also considerable barriers to the adoption of **robust varieties**, in this case in apple production, but they seem to be lower than in France for grapes. In spite of an expected decrease in the risk of yield loss, an increase in the share of class 1 (high quality) apples, no additional variable costs, and the potential to reduce the number of treatments with synthetic fungicides, the share of robust apple varieties grown is still low in conventional farming. Lack of market demand, practical experience, and risk of resistance breakdown are the main reasons for their low adoption. Currently, growing robust apple varieties is seen as an economically viable strategy for organic farms who can sell them directly to consumers. An increase in the adoption of robust varieties by conventional farms, can be expected, though, due to the financial contributions provided by the government for 'listed' robust varieties since 2024. In contrast to grapes in France, the adoption of the **low residue strategy** for apples in Switzerland is currently not perceived as feasible. A high (perceived) risk of considerable storage losses in class 1 apples, high investment costs for hot water treatment (to prevent storage losses without chemical treatments), low subsidies, and a bad reputation of copper make the intervention strategy rather unattractive. As for grapes in France, the adoption of **foil coverage** to protect apples from rain and prevent mildew is perceived as very difficult. Investment costs are perceived as exorbitant, including fixed costs for foil coverage and irrigation installation. In addition, it is argued, that labour costs would considerably increase. The foil would lead to an increase in temperature, leading to an increase in unwanted insects, mainly aphids and mites, and dry rot funghi. It would also deprive the trees from light, leading to a delay in fruit ripening and lack in colouring. Furthermore, the installation of covers is restricted in some areas. However, there is little practical experience with foil coverage to protect apples from rain. Its effects need to be further studied. The intervention's potential to reduce the use of synthetic fungicides is promising.

In the **Netherlands**, the adoption of **robust varieties**, in this case in the cultivation of seed potatoes, mainly depends on market demand, both home and export markets (80% is exported). Seed potato farms are used to growing new and different varieties at the same time and they receive technical assistance from the seed potato trading companies if needed. The adoption of a **wider crop rotation** is neither perceived as very effective against fungus disease not economically viable. Growing seed potatoes is considerably more profitable than growing other crops. **Converting to organic** is currently not very attractive to seed potato producers. The business of conventional seed potatoes is very profitable and the demand for organic seed potatoes very low. In addition, additional costs during the conversion phase are borne by the farm itself. However, converting to organic is perceived to lead to a higher farm resilience.

The agronomic interventions were assessed individually. In many cases a combination of interventions is meaningful. For example, the combination of robust varieties with organic conversion or the combination of mechanical weeding and wieder crop rotation including more grass. In addition, foil coverage may be more attrative to organic farms or farms intending to convert.

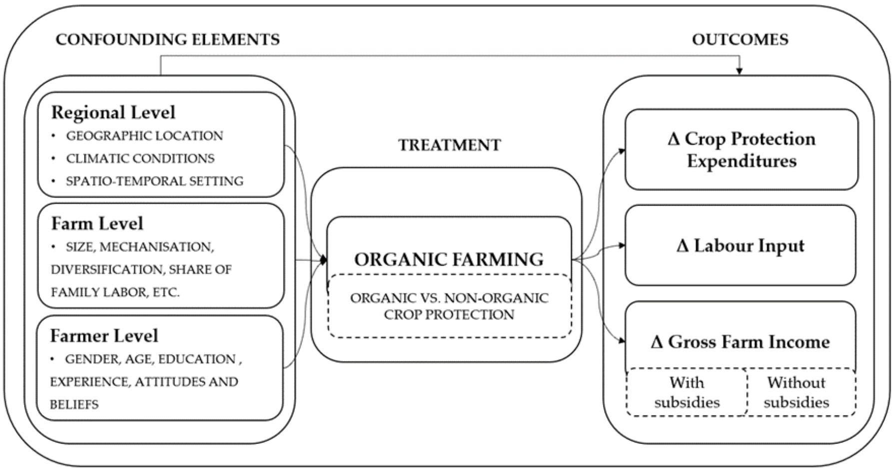
5 Comparative Analysis

Building on the prior analysis, we examined the economic performance of a specific plant protection reduction strategy—organic crop protection—in the European Union (EU) through an extensive cross-country dataset. Our emphasis lies on scrutinizing crop protection expenditures, returns on these expenditures, and correlated indicators like labor and gross farm income. Encompassing seven distinct farm types across 16 EU countries, our study employs an unbalanced panel featuring 151,560 non-organic and 10,531 organic farms from the European Farm Accountancy Data Network.

5.1 Conceptual and Empirical Framework

To undertake a sound comparative analysis of the economics of organic crop protection, we build our conceptual framework based on previous literature describing organic crop protection (Deguine & Penvern, 2014) and the large number of studies that addressed the productivity and profitability of organic farming (Ponisio et al., 2015; Seufert & Ramankutty, 2017; Uematsu & Mishra, 2012). Figure 8 provides an overview of the factors influencing the economics of organic and non-organic crop protection.

Figure 8: Visualising the economics of organic crop protection.



The main goal of our analysis is to quantify the effect of implementing organic farming, our treatment variable, on crop protection expenditures and other economic performance indicators linked to crop protection. To do so, we use empirical farm level data from a large sample of farms reflecting agronomic realities across the EU over the period 2013-2019. To ensure the reliability of our findings and mitigate the impact of endogeneity, such as selection bias, our study is designed to address these concerns and establish comparability between organic and non-organic producers. We consider the risk of selection bias arising from observable characteristics. For instance, it is important to consider that larger farms may be more inclined to adopt organic practices, but they also tend to have higher profitability in general. Therefore, a straightforward comparison between organic and non-organic farms could be biased due to this confounding factor. We here use the inverse probability weighted regression adjustment estimator to account for such potential bias, and to compute the Average Treatment Effect for the Population (ATE) for each outcome variable. The ATE allows us to estimate the effects for the entire population of farms and thus extends our understanding of the impacts of adopting organic farming to all farms represented by our sample. The outcome variables include crop protection expenditures (€/ha), returns on crop protection expenditures (€/ha), total labor inputs (AWU/ha), total family labor input (AWU/ha), gross farm income with and without subsidies (€/ha). Among the explanatory variables, structural farm characteristics include farm size in hectares of agricultural land, size of the agricultural land that is rented, total farm assets per hectare, diversification level, share of family labor, irrigation, crop insurance presence, and share of income from other gainful activities. Soil and climatic conditions are captured through geographic variables such as the NUTS2 region and altitude. We run the regressions separately for each farming type (see Table 30 for the farming type definitions), to ensure a higher degree of comparability between organic and non-organic farms, since cost and revenue structures are more likely similar within the same farming types.

Table 30: Farming types definition.

Principal Farming type [a]	**Description (according to Commission Regulation (EC) No 1242/2008)**
Specialist Arable	General cropping i.e. cereals, dried pulses and protein crops for the production of grain, oilseeds, potatoes, sugar beet, industrial plants, arable land seed and seedlings, other arable land, fallow land and forage for sale > 2/3 of standard output.
Specialist Horticulture	Fresh vegetables, melons and strawberries — market gardening and under glass, flowers and ornamental plants — outdoor and under glass, mushrooms and nurseries > 2/3 of standard output.
Specialist Vineyards	Vineyards > 2/3 of standard output.
Specialist Fruit Farms	Fruit and berries and citrus fruit > 2/3 of standard output.
Specialist Olive Farms	Olives > 2/3 of standard output.
Permanent Crops Mixed	Holdings in class 3 "Specialist Permanent Crops", excluding those in classes 35, 36 and 37
All Crops Mixed	General cropping and horticulture and permanent crops > 2/3 but {general cropping ≤ 2/3 and horticulture ≤ 2/3 and permanent crops ≤ 2/3}

Source: Commission Regulation (EC) No 1242/2008 of 8 December 2008 establishing a Community typology for agricultural holdings. [a] In this classification system, farms are assigned to a type based on the share of standard output generated by a certain crop type. For instance, when 2/3 of the standard output stems from cereal production, the farm is considered a "Specialist cereals, oilseeds and protein crops" farm. We rely on this classification and not a more detailed one, to ensure adequate sample sizes for both treatment and control group.

Disclaimer: This report is part of a project that has received funding by the European Union's Horizon 2020 research and innovation program under grant agreement number 862568.

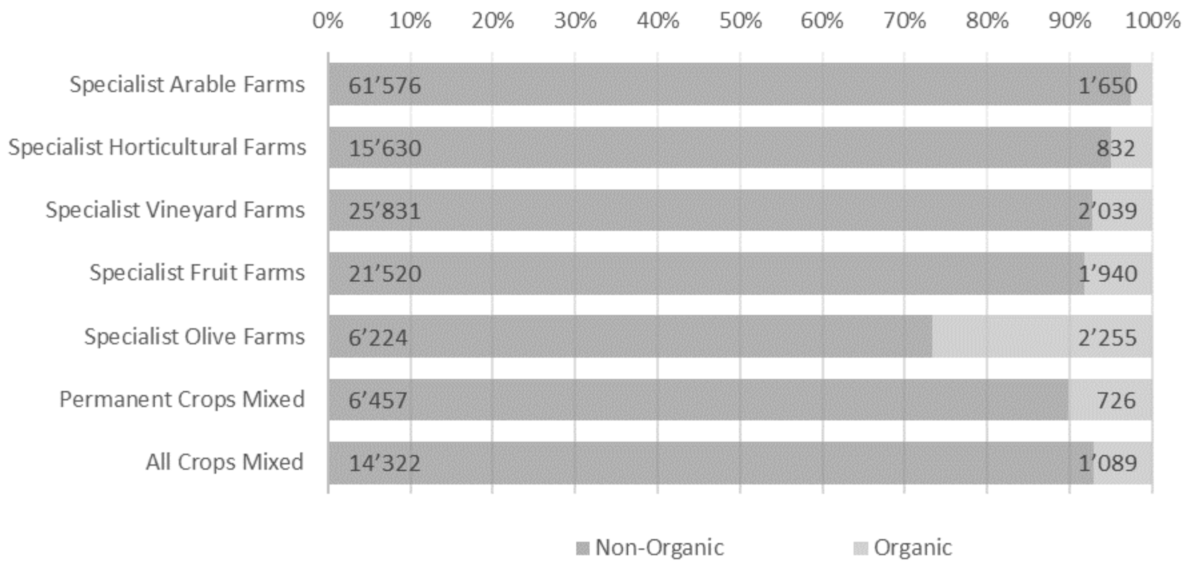
SPRINT SUSTAINABLE PLANT PROTECTION TRANSITION

5.2 Data

We use part of the FADN dataset, collected by the European Commission to undertake a comparative analysis of the economics of crop protection between organic and non-organic farms. This dataset has been increasingly used by researchers to analyze important dynamics and policy impacts within the European agricultural sector (Dabkiene et al., 2021; Grovermann et al., 2021; Slijper et al., 2022), thanks to the availability of detailed farm-level structural and economic information. Our sub-dataset covers a period of seven years (2013 – 2019). This time frame was selected due to the consistency of available data during this period. Additionally, 2019 represents the most recent year for which data was accessible at the time of the data request. By incorporating a seven-year span, we aimed to mitigate potential spikes or anomalies resulting from singular events, such as specific climatic conditions in a given year.

We excluded from the analysis farms under conversion and farmers having only some fields or crops under organic standards as these farms have different yield and price dynamics compared to fully certified organic farms. To identify and discard multivariate outlying observations that could lead to biased results, we used the Bacon approach, which is particularly suitable to identify outliers in large multivariate datasets (Billor et al., 2000). We used all continuous outcome and control variables of our regression to identify outliers in the Bacon approach. We undertook the identification of outliers separately for each farming type, given that the types of crops or cropping systems grown on a farm, determine the distribution of certain economic variables. As a result, within each farming type, we discarded among one up to three percent of observations. Our final sample includes 10,531 organic farms and a total of 151,560 non-organic farms. As shown in Figure 9, the highest share of organic farms is found on agricultural holdings specialized in olive production, while the lowest share is on arable farms.

Figure 9: Sample size of organic and non-organic farms for each farming type. After discarding outliers based on the Bacon approach, the dataset we used in our analysis includes a total sample N of 162'091 farms.



5.3 Estimation Results

The results provide an overview on the effects of adopting and implementing organic farming on a set of economic performance indicators linked with the different crop protection strategies on both organic and non-organic farms. In section 4.3.1 we briefly outline the first stage estimation results. In section 4.3.2 we report the main estimation results of the inverse probability weighted regression adjustment estimator. These are displayed for each performance indicator for the seven farming types included in the analysis. For each outcome variable, we report the ATE in the form of a percent change, the respective robust clustered standard errors (SE), and the absolute changes (obtained by multiplying the percent change by the geometric mean of the weighted untreated group).

5.3.1 First stage estimation results

The first stage estimation results in an inverse probability weighted regression provide valuable insights into the relationship between the treatment assignment and the covariates. These results allow us to assess the extent to which the treatment assignment is influenced by the observed covariates used in the weighting procedure. In our study, various observed factors significantly impact the treatment assignment (i.e. the decision to adopt organic farming) across the different farming types (see Table 31). Notably, altitude and the share of income from other gainful activities consistently emerge as influential factors explaining the selection into treatment across all farming types. The influence of the other covariates (farm size, rented land, and the share of family labor) on the selection into treatment, slightly differs between farming types. By conducting an inverse probability weighted regression analysis, we account for the observed covariates

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and their impact on the treatment assignment, resulting in more reliable estimates of the treatment effect.

Table 31: First stage estimation results

Variable	**Specialist Arable**	**Specialist Hortic.**	**Specialist Vineyard**	**Specialist Fruit**	**Specialist Olive**	**Mixed Perm.**	**Mixed All.**
Sample size (N)	63'226	16'462	27'870	23'460	8'479	7'183	15'411
Farm Size	1.000 (0.000)	1.006* (0.003)	0.989*** (0.002)	1.011*** (0.001)	1.008*** (0.001)	1.001 (0.002)	1.000 (0.001)
Size of Rented area	0.999** (0.000)	0.992* (0.004)	1.005** (0.002)	0.996* (0.002)	0.999 (0.003)	1.004 (0.003)	1.000 (0.001)
Share of Family Labor	0.656*** (0.078)	1.118 (0.123)	0.249*** (0.021)	1.837*** (0.161)	0.711** (0.075)	0.417*** (0.066)	0.606*** (0.075)
Altitude	1.469*** (0.049)	0.654*** (0.052)	0.912* (0.038)	1.162*** (0.043)	0.802*** (0.029)	0.805*** (0.052)	1.160** (0.0539
Share of income other gainful activities	1.756*** (0.100)	1.866*** (0.176)	1.156* (0.077)	1.422*** (0.103)	1.184* (0.096)	1.494*** (0.139)	2.187*** (0.133)

Notes: All coefficients are exponentiated. Notes. Significance levels: *** = $p < 0.001$, ** = $p < 0.01$, * = $p < 0.05$. Standard errors are reported into brackets.

5.3.2 Effects on outcome variables

We find organic farming to decrease crop protection expenditures. More specifically, when controlling for selection bias and ensuring the comparability between organic and non-organic farms, our results show a significant decrease in crop protection expenditures (€/ha) on organic farms for all farming types (see Table 32). The ATE ranges between -44% on vineyard farms up to -97% on arable farms. This translates into absolute cost savings on crop protection expenditures (€/ha) ranging between approximately -22 €/ha on olive farms up to -380 €/ha on horticultural farms. Returns on crop protection expenditures estimates are significantly higher on organic farms, with percent increases ranging from a minimum of +90% on olive farms up to +2'210%% on arable farms. The absolute change for this indicator ranges between +22 €/ha on organic vineyard farms, up to +296 €/ha on organic arable farms.

We find organic farming to not lead to higher labor demand. More specifically, differences between organic and non-organic farms in terms of labor requirements are generally ambiguous and more heterogenous across farming types. For most farming types we see slightly lower total labor inputs, with changes in the ATE ranging between +1% on horticultural farms and -15% on mixed permanent crop farms. Only in the latter case the coefficient is statistically significant ($p < 0.01$). On vineyard farms, labor requirements are slightly higher on organic farms. However, this difference is not statistically significant. The effects on family labor inputs similar as for the total labor inputs, for all farming types.

We find organic farming to increase farm income. More specifically, we find that on all farming types organic farming determined an increase in the gross farm income (incl. subsidies). The estimation of the ATE, shows statistically significant coefficients for arable and vineyard farms. The percent increase ranges between +2% on mixed permanent farms up to +24% on arable farms. This translates into a minimum absolute increase of +34 €/ha on olive farms up to +1'464 €/ha on horticultural farms. When subtracting subsidies to the gross farm income, the picture substantially changes. Except on specialist vineyard and horticultural farms, on all other farming types, gross farm income without subsidies is up to 13% lower. Such results however, are significant only in the case of mixed permanent farms.

Table 32: Average Treatment Effect (ATE) of organic farming on outcome variables, by farming type

	Farming type						
	Specialist Arable	**Specialist Horticulture**	**Specialist Vineyard**	**Specialist Fruit**	**Specialist Olive**	**Mixed Permanent Crops**	**Mixed Crops All**
Crop Protection Expenditures							
ATE (% change)	**-97%*****	**-80%*****	**-44%*****	**-83%*****	**-54%*****	**-67%*****	**-90%*****
SE	0.00	0.05	0.04	0.03	0.08	0.04	0.01
POM (€/ha)	64.60	473.58	254.10	270.26	41.61	93.48	88.68
SE	4.49	72.46	36.61	26.81	7.43	14.18	8.81
Absolute change (€/ha)	-62.66	-380.29	-112.82	-222.96	-22.63	-62.72	-79.99
Returns Crop Protection Expenditures							
ATE (% change)	**2'210%*****	**458%*****	**101%*****	**363%*****	**90%*****	**129%*****	**654%*****
SE	3.07	1.35	0.15	0.66	0.24	0.24	1.05
POM (€/ha)	13.43	48.63	21.92	18.13	40.54	27.51	22.68
SE	0.67	4.94	1.15	1.26	6.26	2.12	1.35
Absolute change (€/ha)	296.87	222.72	22.22	65.75	36.29	35.41	148.27
Total Labor Inputs							
ATE (% change)	**-12%***	-6%	1%	**-14%****	-5%	**-15%****	**-11%***
SE	0.048	0.071	0.044	0.047	0.053	0.051	0.053
POM (AWU/ha)	0.019	0.551	0.14	0.181	0.092	0.117	0.076
SE	0.001	0.067	0.014	0.011	0.013	0.009	0.007
Absolute change (AWU/ha)	-0.002	-0.031	0.002	-0.025	-0.005	-0.018	-0.009
Total Family Labor Inputs							
ATE (% change)	**-12%****	-5%	0%	**-13%***	-3%	**-14%***	**-13%****
SE	0.038	0.078	0.043	0.051	0.05	0.054	0.048
POM (AWU/ha)	0.017	0.245	0.09	0.102	0.061	0.085	0.056
SE	0.001	0.027	0.01	0.007	0.012	0.008	0.006
Absolute change (AWU/ha)	-0.002	-0.012	0.000	-0.013	-0.002	-0.012	-0.007
Gross Farm Income							
ATE (% change)	**24%****	12%	**13%***	5%	10%	2%	5%

SE	0.08	0.08	0.06	0.06	0.09	0.06	0.06
POM (€/ha)	530.50	12'332.58	3'807.96	3'458.22	1'629.44	2'039.05	1'371.89
SE	19.45	1'718.27	444.98	260.63	148.84	204.44	103.73
Absolute change (€/ha)	128.91	1'479.91	502.65	179.83	158.06	34.66	74.08
Gross Farm Income without Subsidies							
ATE (% change)	-2%	12%	7%	-2%	-6%	**-13%***	-9%
SE	0.07	0.08	0.06	0.06	0.08	0.05	0.05
POM (€/ha)	507.96	12'136.83	3'727.40	3'248.08	1'575.52	1'954.21	1'313.30
SE	18.53	1'663.48	440.62	237.62	149.14	203.50	99.40
Absolute change (€/ha)	-7.62	1456.42	246.01	-55.22	-97.68	-259.91	-122.14

Notes. Significance levels: *** = p < 0.001, ** = p < 0.01, * = p < 0.05. SE = Standard Error. POM = Potential Outcome Mean.

5.4 Discussion and Conclusion

The results indicate a significant decrease in crop protection expenditures across all farming types for organic farms. Specifically, when considering arable farms, organic practices result in minimal spending on crop protection. This can be attributed to the prevalent use of mechanical control methods as alternatives to plant protection products. It is worth noting that the costs associated with these practices, such as fuel expenses, may not be fully captured by the analyzed crop protection expenditure indicator. Additionally, it is important to acknowledge that implementing organic plant protection strategies incurs additional costs, such as transitioning to a new production system (i.e. knowledge acquisition) or certification expenses. Unfortunately, these costs are not reflected in the recorded crop protection expenditures. As a result, the unaccounted costs may potentially reduce or alter the magnitude and significance of the observed effects. Nevertheless, our findings challenge the assumption that organic farms experience higher input costs due to elevated prices of plant protection products or increased frequency of sprayings (Bolda et al., 2019). Moreover, the lower costs observed in organic farming may indirectly suggest a reduction in pesticide usage and associated risks. However, caution should be exercised in drawing definitive conclusions, as pesticide costs do not consistently serve as reliable indicators of pesticide risk for the environment and human health (Möhring et al., 2019; Uthes et al., 2019). Moreover, the returns on crop protection expenditures consistently prove higher on organic farms across all farming types. This outcome arises primarily from the reduced crop protection expenditures, as crop revenues (yield multiplied by price) on non-organic farms are higher on some of the farming types. Disentangling the specific contributions of yields and price premiums to this variable is challenging due to limitations in the available data. It is essential to interpret the notably high returns on crop protection expenditures while considering the specific dataset used.

Despite the existing heterogeneity in previous literature regarding labor requirements differences between organic and non-organic farming, it is commonly believed that organic farming generally involves increased labor demands and costs. Our results, based on a comprehensive analysis of a large sample of farms across the EU, counter this widely held belief. Our results indicate that the disparity in total farm labor between organic and non-organic farms is, in fact, minimal. Depending on the farming type, slight increases or even decreases are observed both when looking at total labor inputs as well as when looking specifically at family labor inputs. Such heterogeneity is reflected in the findings of previous studies (e.g.(Orsini et al., 2018). Because of the nature of the data, which provides us with an aggregated figure of labor (i.e. not disaggregated by farming activity) we are left with the following possible explanations of the results regarding the amount of labor required to implement organic crop protection strategies: i) the labor requirements associated with organic crop protection strategies are not higher on organic farms, ii) the higher crop protection labor requirements are compensated by lower labor requirements on other activities and iii) the higher labor requirements are satisfied through alternative forms of unpaid labor, such as apprentices or volunteers, not covered by the data collection. Unfortunately, due to data limitations we are unable to make a more in-depth analysis focusing on differences related to labor activities specific to crop protection. Finally, our results do not back up the hypothesis that organic farming would be beneficial to increase the amount of on-farm job opportunities in rural areas of the EU, as suggested by a previous study in other regions (Finley et al., 2018). Nevertheless, the creation of employment might occur at other levels of the value chain.

On the revenue side, organic farming leads to higher gross farm incomes when accounting for subsidies. This positive effect is evident across all seven farming types examined, with a particularly notable impact on arable farms. However, after subtracting the subsidies from gross farm income, organic production appears to result in slightly less profitability for four of the farming types. Although these effects are not statistically significant, they highlight the significant role that subsidies play in ensuring a positive economic performance on organic farms. Therefore, in order to promote organic farming as an economically viable alternative under the Farm to Fork strategy, it is crucial to maintain appropriate levels of subsidies. Specifically, subsidies under the second pillar that promote production quality are recommended to encourage the adoption of greening measures, which are associated with reduced pesticide use (Aubert & Enjolras, 2018). Investments by governments to support the transition to organic farming will likely pay off in the long run by avoiding environmental and health impacts and associated costs for society.

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Appendix

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A Slovenia: Agronomic practices of the surveyed silage maize farms.

Table A 1: Agronomic practices of silage maize farms in Slovenia.

CSS_ ID	Sequence	Type_of_activity	Machinery	Rented or owned?	Details	BBCH scale	Weather	Date_of _activity	Month_of_ activity	Farming system
F02	1	Previous crop	NA	NA	cereals (barley, triticale)	NA	NA	NA	2020	IPM
F02	2	Tillage	Plough	own	NA	NA	NA	20.11.2020	November 2020	IPM
F02	3	Fertilizer amendment	Slurry tanks (volume 15m3)	own	fertiliser: cow slurry (30m3/ha)	NA	NA	10.05.2021	May 2021	IPM
F02	4	Seed bed preparation	rotary harrow	own	NA	NA	NA	20.05.2021	May 2021	IPM
F02	5	Sowing (including fertilizer amendment)	Seeder-fertiliser	own	seed variety: PIONEER 9911 (75'000 seeds/ha) fertiliser: ENTEC 26N - at sowing	0	dry	22.05.2021	May 2021	IPM
F02	6	Spraying	Sprayer	own	herbicide: MONSOON Bayer 1,7 L/ha	17 (7-8 leaves)	dry	05.06.2021	June 2021	IPM
F02	7	Harvest	Silage harvester	rented	kernel content soft, about 45% dry matter	83	dry	15.09.2021	September 2021	IPM
F02	8	Groundcover management	NA	NA	none; bare	NA	NA	NA	2021/2022	IPM
F03	1	Previous crop	NA	NA	grass-clover mixture	NA	NA	NA	2020	Organic
F03	2	Fertilizer amendment	Slurry tank	own	fertiliser: cow slurry	NA	NA	19.05.2021	May 2021	Organic

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F03	3	Tillage	Plough	own	NA	NA	dry (wet soil from previous days)	20.05.2021	May 2021	Organic
F03	4	Seed bed preparation	Rotary harrow	own	NA	NA	dry	20.05.2021	May 2021	Organic
F03	5	Sowing	Seeder	rented	seed variety: Saatbau Danubio; 90'000 seeds/ha, 9 seedes/m2	0	dry	21.05.2021	May 2021	Organic
F03	6	Mechanical weeding	Hoeing machine	own	weeds: Cirsium vulgare, Amaranthus retroflexus, Setaria viridis, Convolvulus arvensis	13	dry	14.06.2021	June 2021	Organic
F03	7	Mechanical weeding	Hoeing machine	own	weeds: Cirsium vulgare, Amaranthus retroflexus, Setaria viridis, Convolvulus arvensis	17	dry	20.06.2021	June 2021	Organic
F03	8	Fertilizer amendment	Fertiliser spreader	own	ILSA FERTIL N8%	30	dry	25.06.2021	June 2021	Organic
F03	9	Harvest	Harvester	rented	NA	83	dry	16.09.2021	September 2021	Organic
F03	10	Groundcover management	NA	NA	cover crops; green manure	NA	NA	NA	2021/2022	Organic

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F04	1	Previous crop	NA	NA	maize, grass-clover mixture	NA	NA	NA	2020	IPM
F04	2	Tillage	Plough	own	NA	NA	dry	25.05.2021	May 2021	IPM
F04	3	Fertilizer amendment	Slurry tank	own	cow slurry	NA	dry	25.05.2021	May 2021	IPM
F04	4	seed bed preparation	Preeseeder-rotary harrow	own	NA	NA	dry	01.06.2021	June 2021	IPM
F04	5	Sowing (including fertilizer amendment)	Seeding machine +mineral fertiliser	own	mineral fertiliser (NPK 220kg/ha 8:26:26); seed variety: SAATBAU TORRANO (80'000 seeds/ha, 8 seeds/m2)	0	dry	01.06.2021	June 2021	IPM
F04	6	Spraying	Sprayer	own	herbicide: Adengo Weeds: Sorghum halepense, Rumex obtusifolius, Cirsium vulgare, Amaranthus retroflexus, Setaria viridis, Convolvulus arvensis	13 (4-6 leaves)	dry	20.06.2021	June 2021	IPM
F04	7	Mechanical weeding including fertilizer amendment	Mineral fetiliser spreader+hoeing machine	own	fertiliser: 200kg KAN 27%N	17 (6-8 leaves)	dry	30.06.2021	June 2021	IPM
F04	8	Harvest	Silage harvester	rented	kernel content soft, about 45% dry matter	83	dry	28.09.2021	September 2021	IPM

F04	9	Groundcover management	NA	NA	cover crops (winter barley for green manure)	NA	NA	NA	2021/2022	IPM
F06	1	Previous crop	NA	NA	Grass-clover mix (red clover, ryegrass, alfalfa)	NA	NA	NA	2020	IPM
F06	2	Fertilizer amendment	Slurry machine	rented	cow slurry (urine and feces)	NA	dry	04.05.2021	May 2021	IPM
F06	3	Tillage	Subsoiler/ripper	own	NA	NA	dry	05.05.2021	May 2021	IPM
F06	4	seed bed preparation	Rotary harrow	own	NA	NA	dry	06.05.2021	May 2021	IPM
F06	5	Sowing (including fertilizer amendment)	Corn sower	rented	seed variety: Agrosaat LG377 (75'000 seedes/ha, 7.5 seed/m2) Fertiliser: Mineral Ferzilizer N GOOO 32N +30SO3; 32% Nitrogen +sulphur (90day) (200kg/ha)	NA	dry	21.05.2021	May 2021	IPM
F06	6	Spraying	Three point sprayer	own	Herbicide: Adengo Weeds: Setaria viridis, Convolvulus arvensis, Echinochloa crus-galli	15 (4-6 leaves)	dry	10.06.2021	June 2021	IPM

F06	7	Harvest	Harvester	rented	kernel content soft, about 45% dry matter	83	dry	20.09.2021	September 2021	IPM
F06	8	Groundcover management	NA	NA	always covered	NA	NA	NA	2021/2022	IPM
F08	1	Previous crop	NA	NA	oilseed rape, winter wheat	NA	NA	NA	2020	IPM
F08	2	Fertilizer amendment	Slurry tank	own	cow stable manure, 35t/ha, beffe manure (kg of 105N:90P:210K in 35tonnes)	NA	dry	20.03.2021	March 2021	IPM
F08	3	Tillage	Plough	own	NA	NA	dry	15.04.2021	April 2021	IPM
F08	4	seed bed preparation	Preeseeder cultivater	own	NA	NA	dry	20.04.2021	April 2021	IPM
F08	5	Sowing (including fertilizer amendment)	?	own	variety: LGEN - LG 41930 in SEED - Glumanda, 83'000 seeds/ha; 8.3 seed/m2 fertilizer: NPK 8:24:24	0	dry	23.04.2021	April 2021	IPM
F08	7	Fertilizer amendment	Mmineral fertiliser spreader	own	UREA (46%)	17 (6-8 leaves)	dry	19.06.2021	June 2021	IPM

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F08	6	Spraying	Sprayer	own	herbicide: MONSOON active +HERBOCID XL; weeds: Sorghum halepense, Rumex obtusifolius, Cirsium vulgare, Amaranthus retroflexus, Setaria viridis, Convolvulus arvensis	13 (3 leaves)	dry	08.06.2021	June 2021	IPM
F08	8	Harvest	Silage harvester	rented	kernel content soft, about 45% dry matter	83	dry	09.09.2021	September 2021	IPM
F08	9	Groundcover management	NA	NA	Cover crops	NA	NA	NA	2021/2022	IPM
F10	1	Previous crop	NA	NA	cereals (barley, triticale)	NA	NA	NA	2020	IPM
F10	2	Fertilizer amendment	Slurry tank	own	cow slurry 30m3/ha	NA	dry	15.04.2021	April 2021	IPM
F10	3	seed bed preparation	Rotary harrow	own	NA	NA	?	20.04.2021	April 2021	IPM
F10	4	Sowing (including fertilizer amendment)	Seeder-fertiliser	rented	variety: PIONEER P9363; 75'000 seeds/ha, 7.5 seeds/m2 fertiliser: 250 kg/ha NPK (8:20:30)	0	dry	22.04.2021	April 2021	IPM

F10	5	Spraying	Sprayer	own	herbicide: LUMAX 3 L/ha; weeds: Sorghum halepense, Rumex obtusifolius, Cirsium vulgare, Amaranthus retroflexus, Setaria viridis, Convolvulus arvensis	12 (2 leaves)	dry	20.05.2021	May 2021	IPM
F10	6	Fertilizer amendment	Mineral fertiliser spreader	own	Mineral fertilizer NGOOO (40%) (220 kg/ha)	15 (4-6 leaves)	dry	22.05.2021	May 2021	IPM
F10	7	Harvest	Harvester	rented	kernel content soft, about 45% dry matter	83	dry	18.09.2021	September 2021	IPM
F10	8	Groundcover management	NA	NA	Cover crops	NA	NA	NA	2021/2022	IPM
F12	1	Previous crop	NA	NA	Grass-clover mix (red clover, ryegrass, alfalfa)	NA	NA	NA	2020	IPM
F12	2	Fertilizer amendment	Slurry tank	own	cow slurry 30 m3/ha	NA	dry	13.04.2023	April 2021	IPM
F12	3	Tillage	Plough	own	NA	NA	dry	15.04.2021	April 2021	IPM
F12	4	seed bed preparation& mechanical weeding	Rotary harrow	own	before sowing - with rotarry harrow to eliminate weeds	NA	dry	16.04.2021	April 2021	IPM

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F12	5	Mechanical weeding	Rotary harrow	own	before sowing - with rotarry harrow to eliminate weeds weeds: Setaria viridis, Convolvulus arvensis	NA	dry	25.04.2021	April 2021	IPM
F12	6	Sowing (including fertilizer amendment)	Seeder-fertiliser	own	variety: PIONEER MAXIM LUMIGEN STANDARD P9911, 80'000 seeds/ha; 8 seed/m2; fertiliser: NPK 15:15:15, (300kg) - at sowing	0	dry	25.04.2021	April 2021	IPM
F12	7	Spraying	Sprayer	own	LUMAX, Setaria viridis	13 (3+leaves)	dry	15.05.2021	May 2021	IPM
F12	8	Fertilizer amendment	?	own	UREA 46% 300kg	30	dry	20.06.2021	June 2021	IPM
F12	9	Harvest	Harvester	own	kernel content soft, about 45% dry matter	83	dry	15.09.2021	September 2021	IPM
F12	10	Groundcover management	NA	NA	always covered (cover crops - red clover)	NA	NA	NA	2021/2022	IPM
F13	1	Previous crop	NA	NA	Barley	NA	NA	NA	Jul 05	IPM
F13	2	Fertilizer amendment	Manure spreader	own	manure; 25 t/ha manure	NA	dry	14.05.2021	May 2021	IPM
F13	3	Tillage	Plough	own	NA	NA	dry	15.05.2021	May 2021	IPM

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F13	4	Fertilizer amendment	Manure spreader	own	LITOCINK 6-12-26 + Zn	NA	dry	17.05.2021	May 2021	IPM
F13	5	Seed bed preparation	Rotary harrow	own	NA	NA	dry	18.05.2021	May 2021	IPM
F13	6	Fertilizer amendment	Manure spreader	own	Mineral fertilizer N GOOO 32N +30SO3; 32% Nitrogen +sulphur (90day) (300kg/ha)	NA	dry	21.05.2021	May 2021	IPM
F13	7	Sowing	Corn sower	rented	variety: oseva Cefran, LG 30.308, seeds/ha: 83'000 seeds/ha	NA	NA	23.05.2021	May 2021	IPM
F13	8	Spraying	Three point sprayer (1200L)	own	Herbicide: LUMAX + PEAK	15 (4-6 leaves)	NA	07.06.2021	June 2021	IPM
F13	9	Harvest	Harvester	rented	NA	83	dry	15.09.2021	Sep 21	IPM
F13	10	Groundcover management	NA	NA	Always covered	NA	NA	NA	2021/2022	IPM
F14	1	Previous crop	NA	NA	Barley, Grass clover	NA	NA	NA	2020	IPM
F14	2	Tillage	Plough	own	NA	NA	dry	20.05.2021	May 2021	IPM
F14	3	Seed bed preparation	Rotary harrow	own	NA	NA	dry	20.05.2021	May 2021	IPM
F14	4	Fertilizer amendment	Manure spreader	own	Urea (200kg/ha), Manure (100'000kg/ha)	NA	dry	20.05.2021	May 2021	IPM

F14	5	Sowing (including fertilizer amendment)	Corn sower	own	variety: KWS Kashmir, seeds/ha: 90'000 seeds/ha, fertilizer: 280kg/ha NPK (16-27-7)	NA	dry	20.05.2021	May 2021	IPM
F14	6	Spraying	Three point sprayer (800L)	own	Herbicide: Adengo, Banvel 480	12	NA	07.06.2021	June 2021	IPM
F14	7	Harvest	Harvester	rented	Early dough: kernel content soft, about 45% dry matter	83	dry	20.09.2021	Sep 21	IPM
F14	8	Groundcover management	NA	NA	Always covered	NA	NA	NA	2021/2022	IPM
F15	1	Previous crop	NA	NA	Maize	NA	NA	NA	2020	IPM
F15	2	Fertilizer amendment	Manure spreader	own	Manure (30m3/ha), Slurry (200kg/ha)	NA	dry	04.05.2021	May 2021	In transition to organic
F15	3	Tillage	Plough	own	NA	NA	dry	05.05.2021	May 2021	In transition to organic
F15	4	Seed bed preparation	Rotary harrow	own	NA	NA	dry	05.05.2021	May 2021	In transition to organic
F15	5	Sowing	Corn sower	own	variety: CVS kasmir, Sadbau absoluto FAO 410, seeds/ha: 85'000 seeds/ha	NA	NA	06.05.2021	May 2021	In transition to organic
F15	6	Fertilizer amendment	Manure spreader	own	Urea (100kg/ha)	NA	NA	20.06.2021	June 2021	In transition to organic

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F15	7	Spraying	Three point sprayer (1200L)	own	Herbicides: LUMAX	16 (5-7 leaves)	NA	07.06.2021	June 2021	In transition to organic
F15	8	Harvest	Harvester	rented	Early dough: kernel content soft, about 45% dry matter	83	dry	18.09.2021	Sep 21	In transition to organic
F15	9	Groundcover management	NA	NA	Always covered (Grass clover mix)	NA	NA	NA	2021/2022	In transition to organic
F16	1	Previous crop	NA	NA	Maize	NA	NA	NA	2020	IPM
F16	2	Fertilizer amendment	Manure spreader	own	Manure (30t/ha)	NA	dry	05.04.2021	Apr 21	IPM
F16	3	Tillage	Plough	own	18cm deep	NA	dry	NA	May 2021	IPM
F16	4	Seed bed preparation	Rotary harrow	own	NA	NA	dry	25.04.2021	Apr 21	IPM
F16	5	Sowing	Corn sower	own	variety: faraonix, LG 34 90, seeds/ha: 80'000 seeds/ha	NA	dry	26.04.2021	Apr 21	IPM
F16	6	Fertilizer amendment	?	own	Urea (100kg/ha)	NA	NA	17.05.2021	May 2021	IPM
F16	7	Fertilizer amendment	?	own	NPK (300kg/ha)	NA	NA	21.05.2021	May 2021	IPM
F16	8	Spraying	three point sprayer (1200L)	own	Herbicide: Temsa SC + ADENGO	15 (4-6 leaves)	NA	31.05.2021	May 2021	IPM
F16	9	Harvest	Harvester	rented	Early dough: kernel content soft, about 45% dry matter	83	dry	20.09.2021	Sep 21	IPM
F16	10	Groundcover management	NA	NA	Always covered (Winter wheat)	NA	NA	NA	2021/2022	IPM

F17	1	Previous crop	NA	NA	Maize, grass mix	NA	NA	NA	2020	IPM
F17	2	Tillage	Plough	own	18cm deep	NA	dry	10.05.2021	May 2021	IPM
F17	3	Seed bed preparation	NA	rented	NA	NA	dry	15.05.2021	May 2021	IPM
F17	4	Fertilizer amendment	NA	own	Mineral fertilizer (300kg/ha)	NA	dry	15.05.2021	May 2021	IPM
F17	5	Sowing (including fertilizer amendment)	Corn sower	rented	variety: Pioneer 400, seeds/ha: 83'000 seeds/ha, fertiliser: NPK 8-24-24 (300kg/ha) - at sowing	NA	NA	17.05.2021	May 2021	IPM
F17	6	Fertilizer amendment	NA	own	Manure (40'000kg/ha)	NA	dry	20.05.2021	May 2021	IPM
F17	7	Spraying	Three point sprayer (800L)	rented	Herbicide: LUMA + PEAK	15 (4-6 leaves)	NA	25.05.2021	May 2021	IPM
F17	8	Fertilizer amendment	NA	own	KAN (300kg)	7	NA	10.06.2021	June 2021	IPM
F17	9	Harvest	Harvester	rented	Early dough: kernel content soft, about 45% dry matter	83	dry	15.09.2021	Sep 21	IPM
F17	10	Groundcover management	NA	NA	Always covered (grass mix)	NA	NA	NA	2021/2022	IPM
F18	1	Previous crop	NA	NA	Clover	NA	NA	NA	2020	IPM
F18	2	Fertilizer amendment	Manure spreader	rented	Manure (50'000kg/ha) + PRP fix	NA	dry	20.10.2020	October 2020	IPM
F18	3	Tillage	Plough	rented	18cm deep	NA	dry	25.10.2020	October 2020	IPM
F18	4	Seed bed preparation	Rotary harrow	rented	NA	NA	dry	25.04.2021	Apr 21	IPM

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F18	5	Sowing	Corn sower	rented	variety: BC hybrids Zagreb, Pioneer, Agrosaat mix, seeds/ha: 80'000 seeds/ha	NA	NA	04.05.2021	May 2021	IPM
F18	6	Spraying	Three point sprayer (600L)	rented	Herbicide: ADENGO	7	NA	10.05.2021	May 2021	IPM
F18	7	Fertilizer amendment	NA	rented	KAN (300kg)	19	NA	10.06.2021	June 2021	IPM
F18	8	Harvest	Harvester	rented	Early dough: kernel content soft, about 45% dry matter	83	dry	25.09.2021	Sep 21	IPM
F18	9	Groundcover management	NA	NA	Bare	NA	NA	NA	2021/2022	IPM
F19	1	Previous crop	NA	NA	Barley	NA	NA	NA	2020	IPM
F19	2	Fertilizer amendment	Manure spreader	own	Manure (25t/ha)	NA	dry	25.03.2021	March 2021	IPM
F19	3	Tillage	Plough	own	18cm deep	NA	dry	26.03.2021	March 2021	IPM
F19	4	Fertilizer amendment	Manure spreader	own	Manure 30'000kg/ha	NA	NA	20.04.2021	Apr 21	IPM
F19	5	Seed bed preparation	Rotary harrow	own	NA	NA	dry	02.05.2021	May 2021	IPM
F19	6	Sowing (including fertilizer amendment)	Corn sower	rented	variety: oseva Cefran, LG 30.308, seeds/ha: 83'000 seeds/ha, fertilizer: 350kg/ha NPK (7-20-30)	NA	NA	03.05.2021	May 2021	IPM

F19	7	Spraying	Three point sprayer (1200L)	own	Herbicide: ADENGO	15 (4-6 leaves)	NA	15.05.2021	May 2021	IPM
F19	8	Fertilizer amendment	NA	own	KAN (200kg), Urea (150kg/ha)	NA	NA	10.06.2021	June 2021	IPM
F19	9	Harvest	Harvester	rented	NA	83	NA	15.10.2021	October 2021	IPM
F19	10	Groundcover management	NA	NA	Always covered (grass, clover)	NA	NA	NA	2021/2022	IPM
F20	1	Previous crop	NA	NA	Clover	NA	NA	NA	2020	IPM
F20	2	Tillage	Plough	own	23cm deep	NA	dry	16.09.2020	Sep 20	IPM
F20	3	Fertilizer amendment	Manure spreader	own	Manure (40'000kg/ha), Urea (250kg/ha)	NA	dry	NA	April/May 2021	IPM
F20	4	Seed bed preparation	Rotary harrow	own	NA	NA	dry	NA	April/May 2021	IPM
F20	5	Sowing	Corn sower	rented	variety: P9911 pioneer, cevaha, seeds/ha: 80'000 seeds/ha	NA	NA	05.05.2021	May 2021	IPM
F20	6	Spraying	Three point sprayer (250L)	own	Herbicide: LUMAX	7	NA	08.05.2021	May 2021	IPM
F20	7	Fertilizer amendment	Manure spreader	own	Urea (250kg/ha), Okopalnik	NA	NA	15.06.2021	June 2021	IPM
F20	8	Harvest	Harvester	rented	Early dough: kernel content soft, about 37% dry matter	83	dry	05.10.2021	October 2021	IPM
F20	9	Groundcover management	NA	NA	Always covered (clover)	NA	NA	NA	2021/2022	IPM

F21	1	Previous crop	NA	NA	?	NA	NA	NA	2020	IPM
F21	2	Tillage	Plough	own	18cm deep	NA	dry	15.05.2021	May 2021	IPM
F21	3	Seed bed preparation	Rotary harrow	rented	NA	NA	dry	16.05.2021	May 2021	IPM
F21	4	Fertilizer amendment	Manure spreader	own	Manure (25'000kg/ha)	NA	dry	16.05.2021	May 2021	IPM
F21	5	Sowing	Corn sower	rented	variety: Draxter, seeds/ha: 90'000 seeds/ha	NA	dry	25.05.2021	May 2021	IPM
F21	6	Fertilizer amendment	NA	own	Mineral fertilizer N GOOO 32N (300kg/ha)	11	dry	05.06.2021	June 2021	IPM
F21	7	Spraying	Three point sprayer (1200L)	own	Herbicide: Nicosh + Dicash	14	NA	15.06.2021	June 2021	IPM
F21	8	Harvest	Harvester	rented	Early dough: kernel content soft, about 45% dry matter	83	dry	05.10.2021	October 2021	IPM
F21	9	Groundcover management	NA	NA	Always covered (grass)	NA	NA	NA	2021/2022	IPM
F22	1	Previous crop	NA	NA	?	NA	NA	NA	2020	IPM
F22	2	Tillage	Plough	own	20cm deep	NA	dry	25.10.2020	October 2020	IPM
F22	3	Fertilizer amendment	Manure spreader	own	Manure (30t/ha)	NA	dry	28.04.2021	Apr 21	IPM
F22	4	Seed bed preparation	Rotary harrow	own	NA	NA	dry	30.04.2021	Apr 21	IPM
F22	5	Sowing	Corn sower	own	variety: Pioneer, P99.11 FAO 410, seed/ha: 85'000 seeds/ha	NA	NA	01.05.2021	May 2021	IPM

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F22	6	Spraying	Three point sprayer (1200L)	own	Herbicides: Laudis	14 (4-6 leaves)	NA	30.05.2021	May 2021	IPM
F22	7	Fertilizer amendment	NA	own	KAN (350kg/ha)	31	NA	20.06.2021	June 2021	IPM
F22		Harvest	Harvester	rented	Early dough: kernel content soft, about 45% dry matter	83	dry	15.10.2021	October 2021	IPM
F22	8	Groundcover management	NA	NA	Bare	NA	NA	NA	2021/2022	IPM
F23	1	Previous crop	NA	NA	?	NA	NA	NA	2020	IPM
	2	Fertilizer amendment	NA	own	Urea (200kg/ha)	NA	NA	20.04.2021	Apr 21	IPM
F23	3	Tillage	Grubbing	own	18cm deep	NA	dry	10.05.2021	May 2021	IPM
F23	4	Sowing	Direct sower	own	variety: LG 24-90, 47-17, seeds/ha: 90'000 seeds/ha	NA	NA	11.05.2021	May 2021	IPM
F23	5	Fertilizer amendment	Manure spreader	own	Urea	NA	NA	11.05.2021	May 2021	IPM
F23	6	?	Trailed 24m	own	NA	12 (2-3 leaves)	NA	20.05.2021	May 2021	IPM
F23	7	Fertilizer amendment	NA	own	Manure (28'000kg/ha)	NA	NA	10.06.2021	June 2021	IPM
F23	8	Spraying	sprayer	own	Herbicide: ADENGO	15 (4-6 leaves)	NA	?	June 2021	IPM
F23	9	Harvest	harvester	own	Early dough: kernel content soft, about 45% dry matter	83	dry	25.09.2021	Sep 21	IPM

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F23	10	Groundcover management	NA	NA	Always covered	NA	NA	NA	2021/2022	IPM
F24	1	Previous crop	NA	NA	Maize	NA	NA	NA	2020	IPM
F24	2	Fertilizer amendment	Manure spreader	own	Manure (34t/ha)	NA	dry	24.05.2021	May 2021	IPM
F24	3	Tillage	Plough	own	12cm deep	NA	dry	29.05.2021	May 2021	IPM
F24	4	Seed bed preparation	Rotary harrow	own	NA	NA	dry	02.06.2021	June 2021	IPM
F24	5	Sowing (including fertilizer amendment)	Corn sower	own	variety: Pioneer 9486, 9610, 9610 (340-360 FAO), seeds/ha: 86'000 seeds/ha, fertiliser: NPK 15-15-15 (200kg/ha) - at sowing	NA	NA	02.06.2021	June 2021	IPM
F24	6	Spraying	Three point sprayer (1200L)		Herbicide: ADENGO	13 (3 leaves)	NA	16.06.2021	June 2021	IPM
F24	7	Fertilizer amendment	NA	own	Mineral fertilizer N GOOO 40N (200 kg/ha)	NA	NA	25.06.2021	June 2021	IPM
F24	8	Harvest	harvester	rented	Early dough: kernel content soft, about 45% dry matter	83	dry	02.10.2021	October 2021	IPM
F24	9	Groundcover management	NA	NA	Always covered	NA	NA	NA	2021/2022	IPM
F25	1	Previous crop	NA	NA	Grass clover mix	NA	NA	NA	2020	IPM
F25	2	Fertilizer amendment	NA	own	Compost (20t/ha)	NA	dry	10.05.2021	May 2021	IPM
F25	3	Tillage	Plough	own	18cm deep	NA	dry	12.05.2021	May 2021	IPM
F25	4	Fertilizer amendment	NA	own	Urea (100kg/ha)	NA	dry	17.05.2021	May 2021	IPM

F25	5	Seed bed preparation	Rotary harrow	own	NA	NA	dry	13.05.2021	May 2021	IPM
F25	6	Sowing	Corn sower	rented	variety: LG 30.311, seeds/ha: 93'000 seeds/ha	NA	NA	16.05.2021	May 2021	IPM
F25	7	Spraying	Three point sprayer (400L)	rented	Herbicides: ADENGO + Universal BIO	13 (3 leaves)	NA	09.06.2021	June 2021	IPM
F25	8	Harvest	Harvester	rented	Early dough: kernel content soft, about 45% dry matter	83		19.09.2021	Sep 21	IPM
F25	9	Groundcover management	NA	NA	Always covered (grass clover mix)	NA	NA	NA	2021/2022	IPM
F26	1	Previous crop	NA	NA	Patato	NA	NA	NA	2020	IPM
F26	2	Fertilizer amendment	Manure spreader	own	Manure (25t/ha)	NA	dry	04.05.2021	May 2021	IPM
F26	3	Tillage	Plough	own	18cm deep	NA	dry	05.05.2021	May 2021	IPM
F26	4	Seed bed preparation	Rotary harrow	rented	NA	NA	dry	05.05.2021	May 2021	IPM
F26	5	Sowing (including fertilizer amendment)	Corn sower	rented	variety: Deklat 4717, LG 3290, seeds/ha: 80'000 seeds/ha, fertiliser: NPK 2-20-30 (200kg/ha) - at sowing	NA	NA	07.05.2021	May 2021	IPM
F26	6	Spraying	Three point sprayer (1200L)	rented	Herbicides: ADENGO	NA	NA	12.05.2021	May 2021	IPM
F26	7	Fertilizer amendment	NA	own	KAN (200kg/ha)	9 (0 leaves)	NA	20.06.2021	June 2021	IPM

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F26	8	Harvest	Harvester	rented	Early dough: kernel content soft, about 45% dry matter	83	dry	24.09.2021	Sep 21	IPM
F26	9	Groundcover management	NA	NA	?	NA	NA	NA	2021/2022	IPM
F27	1	Previous crop	NA	NA	Grass	NA	NA	NA	2020	IPM
F27	2	Fertilizer amendment	Manure spreader	own	Manure (25t/ha)	NA	dry	12.05.2021	May 2021	IPM
F27	3	Tillage	Plough	own	18cm deep	NA	dry	14.05.2021	May 2021	IPM
F27	4	Seed bed preparation	Rotary harrow	own	NA	NA	dry	14.05.2021	May 2021	IPM
F27	5	Sowing (including fertilizer amendment)	Corn sower	own	variety: ferrarix, seeds/ha: 78'000 seeds/ha, fertiliser: NPK 8 -24 - 24 (250kg/ha) - at sowing	NA	NA	15.05.2021	May 2021	IPM
F27	6	Spraying	Three point sprayer (400K)	own	Herbicides: LUMAX	9 (0 leaves)	NA	19.05.2021	May 2021	IPM
F27	7	Fertilizer amendment	NA	own	Mineral fertilizer N GOOO 32N (300kg/ha)	NA	NA	14.06.2021	June 2021	IPM
F27	8	Harvest	Harvester	rented	Early dough: kernel content soft, about 45% dry matter	83	dry	03.10.2021	October 2021	IPM
F27	9	Groundcover management	NA	NA	Always covered (grass)	NA	NA	NA	2021/2022	IPM

CSS_ID: farm number; sequence: sequence number for agronomic practice.

B France: Agronomic practices of the surveyed grapevine farms.

Table A 2: Agronomic practices of one exemplary conventional and one exemplary organic grapevine farm surveyed in France.

Farm_ID	Type_of_activity	Date_of_activity	Month_of_activity	Farming_system
EF02	Pruning	01.11.2020	November 2020	Conventional
EF02	Pruning	15.11.2020	November 2020	Conventional
EF02	Woods fallen	Missing	after pruning	Conventional
EF02	Shredding of vine shoots	Missing	after pruning	Conventional
EF02	Flacking	Missing	Missing	Conventional
EF02	Folding	Missing	Missing	Conventional
EF02	Soil work: decompacting	Missing	March	Conventional
EF02	Soil work: decompacting	Missing	Missing	Conventional
EF02	Soil work with rotary harrow	Missing	April	Conventional
EF02	mowing between rows and interceps	Missing	April	Conventional
EF02	Feed suckering mechanical	Missing	May	Conventional
EF02	Head desuckering manual	Missing	June	Conventional
EF02	Mechanical weeding 1 row out of 2	Missing	July	Conventional
EF02	mowing between rows and interceps	Missing	August	Conventional
EF02	first lifting	Missing	beg June	Conventional
EF02	second lifting	Missing	End June	Conventional
EF02	mowing	02.06.2021	June 2021	Conventional
EF02	cropping	Missing	End June	Conventional
EF02	mowing	01.07.2021	July 2021	Conventional
EF02	cropping	Missing	July	Conventional
EF02	cropping	Missing	July	Conventional
EF02	mowing	01.08.2021	August 2021	Conventional

EF02	portcullis	Missing	end august	Conventional
EF02	mechanical harvest	25.09.2021	September 2021	Conventional
EF10	green manure	Missing	Missing	Organic
EF10	Pruning	01.12.2020	December 2020	Organic
EF10	Pruning	Missing	January	Organic
EF10	maintenance of the trellising	Missing	january	Organic
EF10	stripping	01.03.2021	March 2021	Organic
EF10	green manure destruction	Missing	March	Organic
EF10	grass mowing	Missing	May	Organic
EF10	1st desuckering	15.05.2021	May 2021	Organic
EF10	topping	15.06.2021	June 2021	Organic
EF10	2nd desuckering	15.07.2021	July 2021	Organic
EF10	cropping	15.07.2021	July 2021	Organic
EF10	cropping	01.08.2021	August 2021	Organic
EF10	cropping	15.08.2021	August 2021	Organic

C France: Total reported number of chemical treatments (fungicides, herbicides and insecticides) for each farm

Table A 3: Total reported number of chemical treatments (fungicides, herbicides and insecticides) for each grapevine farm in France (Bordeaux) divided by the farming system.

Max of Treatment Count										
	Conventional farms					Organic farms				
	EF02	EF03	EF04	EF06	EF07	EF08	EF09	EF10	EF15	EF16
Conventional	15	16	10	11	9					
Organic						16	20	15	16	16
Total value	**15**	**16**	**10**	**11**	**9**	**16**	**20**	**15**	**16**	**16**

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D France: Number of times each farm applied a particular fungicide product by farming system and type of product.

Table A 4: Number of times each viticulture farm in France applied a particular organic or synthetic fungicide.

Sum of Product Count											
	Conventional Farms					Organic Farms					Total value
	EF02	EF03	EF04	EF06	EF07	EF08	EF09	EF10	EF15	EF16	
Fungicide											
Organic fungicide											
Auditorium®							1				1
BB EQAL DG				4					6		10
BB MACCLESFIELD 80®		3		2							5
BB MANICA					1	7			1		9
Bouillie Bordelaise RSR DISPERSS	5	3	6		4	2	12	8	2	16	58
CHAMP FLO AMPLI	4						12	16	4		36
Citrothiol DG								14			14
Cuproxyde®							1				1
Eqal DG								7			7
Funguran			1			4					5
Heliocuivre		4			5	4			2		15
HELIOSOUFRE S		3	6					10	4	9	32
Kocide									2		2
KUMULUS DF		2	6		5					5	18
Microthiol special disperss									7		7
Nordox® 75 WG						5	9	4			18
Prev Am							2	3			5
SOUFREBE DG	4					8					12
SULBARI DF	1					4					5

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Sulfojet® DF	2						6				8
Thiovit Jet						3	4				7
Synthetic fungicide											
ALGEBRE	1										1
AMALINE FLOW				1							1
CHAOLINE	1										1
CONCORDE				2							2
CYFLODIUM	1										1
CYMSUN				1							1
Dynali			1	1							2
ECRIN PRO		1			1						2
Electis Bleu		1		1	1						3
ENERVIN			2								2
ETONAN	3										3
Flint		1			1						2
Forum top					2						2
Grip Top		1									1
LBG		4			6						10
LIDAL	1										1
LUNA SENTATION	1										1
LUTIRAM				1							1
NATCHEZ				2							2
OPTIX Disperss		1	4	3							8
POLYRAM			2								2
Profiler		1	1	1							3
REDELI	1			1							2
RESPLEND	1										1
REVOLUXIO				1							1

ROCCA				1							1
Score	2										2
Sillage					1						1
TEBAIDE	1										1
VIVANDO				1	1						2
YSAYO	1										1
ZORVEC				1							1
Total value	**30**	**25**	**29**	**24**	**28**	**37**	**47**	**62**	**28**	**30**	**340**

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E France: Number of fungicides applied by farm, growing stage, and type of fungicide.

Table A 5: Number of fungicides applied by farm, growing stage, and type of fungicide.

Sum of Product Count	Conventional Farms					Organic Farms					Total value
	EF02	EF03	EF04	EF06	EF07	EF08	EF09	EF10	EF15	EF16	
BBCH 13											
Organic pesticide						2					**2**
BBCH 14											
Organic pesticide							2	3	2		**7**
BBCH 15											
Organic pesticide	2	1		1	2						**6**
Synthetic pesticide		1		1							**2**
BBCH 16											
Organic pesticide			3	1	1	6	5	7	5	4	**32**
Synthetic pesticide	2		2	1	1						**6**
BBCH 51											
Organic pesticide		1	3				1	4	2	2	**13**
Synthetic pesticide		1	1								**2**
BBCH 52											
Organic pesticide							2				**2**
BBCH 53											
Organic pesticide						2					**2**
Synthetic pesticide	2				3						**5**
BBCH 55											

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Organic pesticide		1	3			2	2	4	2	2	**16**
Synthetic pesticide	2		2	3							**7**
BBCH 56											
Organic pesticide				1					2		**3**
Synthetic pesticide				2							**2**
BBCH 57											
Organic pesticide					2	2					**4**
Synthetic pesticide					2						**2**
BBCH 59											
Organic pesticide							1	4		2	**7**
BBCH 61											
Organic pesticide	1		2			3	2	4	3		**15**
Synthetic pesticide	2	2	1								**5**
BBCH 63											
Organic pesticide									1		**1**
BBCH 64											
Synthetic pesticide				3							**3**
BBCH 65											
Organic pesticide							3				**3**
BBCH 70											
Organic pesticide						3				2	**5**
BBCH 71											
Organic pesticide		2	1		2		4	7	3	4	**23**
Synthetic pesticide	2	2	2		1						**7**
BBCH 72											
Organic pesticide						3		3	2	3	**11**

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BBCH 73											
Organic pesticide	2				2	3	2	6	1	2	**18**
Synthetic pesticide	1			2	2						**5**
BBCH 74											
Organic pesticide										2	**2**
BBCH 76											
Organic pesticide	3	3	2	1	3	5	8	10	2	4	**41**
Synthetic pesticide	3	2	1	2	3						**11**
BBCH 77											
Organic pesticide	2		3			2	5		1		**13**
Synthetic pesticide			1	4							**5**
BBCH 78											
Organic pesticide	2	6			3	2	3	4	1	2	**23**
Synthetic pesticide		2			1						**3**
BBCH 79											
Organic pesticide				1					1		**2**
BBCH 80											
Organic pesticide	4	1	1			2	5	4		1	**18**
BBCH 81											
Organic pesticide							2	2			**4**
BBCH 82											
Organic pesticide				1							**1**
BBCH 86											
Organic pesticide			1								**1**
Total value	**30**	**25**	**29**	**24**	**28**	**37**	**47**	**62**	**28**	**30**	**340**

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F France: Active ingredient quantity for each farm separated by farming system and active ingredient type

Table A 6: Quantity of the active ingredients per farm divided by the farming system and active ingredient type.

Sum of total ai applied per ha in grams													
	Conventional Farms					Organic Farms							Total value
	EF02	EF03	EF04	EF06	EF07	EF08	EF09	EF10	EF11	EF15	EF16	EF17	
Organic active ingredient													
Copper	1734	1545	1510	2170	1200	2082	1445	1896	1896	2020	4810	4810	27117.8
Copper hydroxyde	1478	1200	420		1000	1878	1680	2008.8	2008.8	1656			13329.76
Copper oxide				999		517.5	1113.8	412.5	412.5				3455.25
Copper sulfate		800		2045									2844.89
Orange oil							144	185.4	185.4				514.8
Sulfur	22699	10400	17992		21600	33112	39050	28744	28744	21600	16000	16000	255941.2
Sulfur hydroxyde		7700	4620					11858	11858	4900	19460	19460	79856
Synthetic active ingredient													
Aluminiumfosetyl		4000	6167	5600									15766.965
Ametoctradin	133.8		558										691.8
Cyazofamid	109.4												109.4
Cyflufenamid	23.85		14.1	30									67.95
Cymoxanil				99.9									99.9
Difenoconazole			28.2	60									88.2
Dimethomorph	100.4	225											325.35
Disodium Phosphonate	2229			1085									3314
Fenbuconazole		37.5			37.5								75
Fluopicolide	90.13	133.2	131	133.2									487.512
Fluopyram	36.5												36.5
Mandipropamid				125									125
Metiram	1103	1100	3635	1400									7238.402

Metrafenone	97.5			100	100								297.5
Oxathiapiprolin				20									20
Potassium phosphonate	6327	9060			12458								27844.41
Tetraconazole	24.8			52									76.8
Trifloxystrobin	36.5			82.5									119
Zoxamide		112		322.8									434.8
Total value	**36223**	**36313**	**35075**	**14325**	**36395**	**37590**	**43433**	**45105**	**45105**	**30176**	**40270**	**40270**	**440278.189**

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G Switzerland: Total reported number of chemical treatments (fungicides, herbicides and insecticides) by farm and farming system.

Table A 7: Total reported number of chemical treatments (fungicides, herbicides and insecticides) by farm and farming system.

Max of Treatment Count	Farm	ID	
	F10	F22	F25
IPM	22		
Organic		25	25
Gesamtergebnis	**22**	**25**	**25**

H Switzerland: Number of times each farm applied a particular fungicide product by farming system and type of product.

Table A 8: Number of times each farm applied a particular fungicide product by farming system and type of product.

	IPM	Organic		Total value
	F10	F22	F25	
Fungicide				
Organic pesticide				
Airone WG		1		1
Armicarb	6			6
Curatio		5		5
Kocide Opti	1			1
Myco-Sin		13	12	25
Netzschwefel Stulln WG		12	8	20
Vacciplant	2			2
Vitisan			10	10
Synthetic pesticide				
Atollan	4			4
Captan 80 Wdg	9			9
Cyflamid	2			2
Slick	4			4
Stamina S	2			2
Total	**30**	**31**	**30**	**91**

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SUSTAINABLE PLANT PROTECTION TRANSITION

I Switzerland: Number of fungicides applied by farm, growing stage, and type of fungicide.

Table A 9: Number of fungicides applied by farm, growing stage, and type of fungicide.

Sum of Product Count				
	IPM Farms	Organic Farms		Total
	F10	F22	F25	
BBCH 53				
Organic pesticide	1		1	2
BBCH 56				
Organic pesticide	1	5	2	8
Synthetic pesticide	1			1
BBCH 57				
Organic pesticide	1	2		3
Synthetic pesticide	1			1
BBCH 61				
Organic pesticide		2	2	4
Synthetic pesticide	2			2
BBCH 65				
Organic pesticide		1	4	5
Synthetic pesticide	2			2
BBCH 67				

Organic pesticide		2	2	4
Synthetic pesticide	2			2
BBCH 69				
Organic pesticide		3	4	7
Synthetic pesticide	2			2
BBCH 71				
Organic pesticide	1	1	1	3
BBCH 74				
Organic pesticide	1	2	2	5
Synthetic pesticide	2			2
BBCH 77				
Organic pesticide	4	12	10	26
Synthetic pesticide	9			9
BBCH 89				
Organic pesticide		1	2	3
Total	**30**	**31**	**30**	**91**

J Switzerland: Active ingredient quantity for each farm separated by farming system and activity type

Table A 10: Active ingredient quantity for each farm separated by farming system and activity type

Sum of total ai applied per ha in grams	IPM Farms F10	Organic Farms F22	F25	Total value
Fungicide				
Organic pesticide				
Aluminium Sulfate		67600	54275	121875
Calciumpolysulfid		1900		1900
Copper		1008		1008
Copper hydroxyde	450			450
Laminarin	90			90
Potassium bicarbonate	17680		39342	57022
Sulfur		29760	24800	54560
Synthetic pesticide				
Captan	16640			16640
Cyflufenamid	106.4			106.4
Difenoconazole	1000			1000
Dithianon	1792			1792
Potassium phosphonate	1510			1510
Total value	**39268.4**	**100268**	**118417**	**257953.4**

K Netherlands: Total reported number of chemical treatments (fungicides, herbicides and insecticides) by farm and farming system.

Table A 11: Total reported number of chemical treatments (fungicides, herbicides and insecticides) by farm and farming system.

Max of Treatment Count	F08	F10	F11	F12	F13	F14	F15	F16	Total value
Conventional	8				10	16	9	11	16
IPM		17	11	5					17
Total value	**8**	**17**	**11**	**5**	**10**	**16**	**9**	**11**	**17**

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L Netherlands: Number of times each farm applied a particular fungicide product by farming system and type of product.

Table A 12: Number of times each farm applied a particular fungicide product by farming system and type of product.

Sum of Product Count	Conventional Farms					IPM Farms			Total value
	F08	F13	F14	F15	F16	F10	F11	F12	
Fungicide									
Synthetic pesticide									
Amistar			1				1		2
Canvas			1						1
Carial Star	2								2
Curzate Partner- Curzate 60WG	1		2	2	1	2	2		10
Infinito		4	6	6		2			18
Mirador	1							1	2
Nautile DG				1					1
Proxanil						4			4
Ranman Top	1	2	2	2	3	5	6	1	22
Revus	2	4	5		5			1	17
Sacron WG						1			1
Tridex DG							1		1
Zorvec endavia					6				6
Total value	**7**	**10**	**17**	**11**	**15**	**14**	**10**	**3**	**87**

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M Netherlands: Number of fungicides applied by farm, growing stage, and type of fungicide.

Table A 13: Number of fungicides applied by farm, growing stage, and type of fungicide.

Summe von Count									
	Conventional Farms					**IPM Farms**			**Total**
	F08	**F13**	**F14**	**F15**	**F16**	**F10**	**F11**	**F12**	
BBCH 5									
Synthetic pesticide			1					1	2
BBCH 9									
Synthetic pesticide							1		1
BBCH 12									
Synthetic pesticide	1				1			1	3
BBCH 15									
Synthetic pesticide		1			1				2
BBCH 19									
Synthetic pesticide			1	1	1				3
BBCH 40									
Synthetic pesticide		1	1		1		1		4
BBCH 45									
Synthetic pesticide	1	1	1		1		1		5
BBCH 49									
Synthetic pesticide	1	1	1	3	3		1		10
BBCH 55									
Synthetic pesticide	2	2	2	2	2	3	1		14
BBCH 57									
Synthetic pesticide	1	2	3	3	2	3	2		16
BBCH 59									
Synthetic pesticide	1	1	2	1	2	3	2	1	13
BBCH 70									

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Synthetic pesticide			1		1	3			5
BBCH 89									
Synthetic pesticide			3	1			1		5
BBCH 91									
Synthetic pesticide		1	1			1			3
BBCH 99									
Synthetic pesticide						1			1
Total	**7**	**10**	**17**	**11**	**15**	**14**	**10**	**3**	**87**

N Netherland: Active ingredient quantity for each farm separated by farming system and activity type

Table A 14: Active ingredient quantity for each farm separated by farming system and activity type

Sum of total ai applied per ha in grams									
	Conventional Farms					IPM Farms			Total value
	F08	F13	F14	F15	F16	F10	F11	F12	
Fungicide									
Synthetic pesticide									
Amisulbrom			100						100
Azoxystrobin	750		750				625	750	2875
Benthiavalicarb					84				84
Cyazofamid	80	160	112	144	240	384	480	96	1696
Cymoxanil	120		240	300	120	527	240		1547
Difenoconazole	100								100
Fluopicolide		163	238	231		87.5			718.75
Mancozeb				1224			810		2034
Mandipropamid	325	500	675		600			150	2250
Oxathiapiprolin					36				36
Propamocarb						1600			1600
Propamocarb hydrochloride		1625	2375	2313		875			7187.5
Total value	**1375**	**2448**	**4490**	**4212**	**1080**	**3474**	**2155**	**996**	**20228.25**

O List of alternatives to PPPs

Table A 15: List of alternatives classified by IPM codes: 1.1: Chemical control by broad spectrum chemicals, 1.2: chemical control by selective chemicals, 2.1: non chemical control by PPPs, 2.2 non-chemical control by biocontrol, 2.3: non-chemical control by biotechnology, 2.4 non-chemical control by physical control, 3 decision support systems, 4 preventive measures like resistant varieties, cropping technics, seed quality, plant protection services.

Alternative	IPM code	Manufacturer	Active ingredient	Mode of action	Type	Crop	Target organism
Microsal 40S	2.1	Agrocampo	copper sulfate				
Amoeba	2.1	Amoéba	amoeba lysate	Stimulates plant defences and inhibits germination of pathogen spores	Biofungicide	Grapes, vegetables, potatoes, tomatoes, banana, cereals, soybean	Downy mildew, powdery mildew, late blight, rost, septoria, fusarium
Bb-protec	2.1	Andermatt	Beauveria bassiana strain R444	Internal tissue destruction	Bio insecticide	Many crops	Spider mite, whitefly
FLiPPER	2.1	Bayer	extra virgin olive oil	Multi-site	Bio insecticide	Fruit, vegetables	
Sitotroga eggs	2.1	Biocare	Sitotroga eggs				
Trichosafe	2.1	Biocare	Trichogramma brassicae	Parasites	Bio insecticide	Corn	corn borer

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Attracap	2.1	Biocare	CO_2 and entomopathogenic fungus	Mimics aplant releasing CO_2	Bio insecticide	Potato and asparagus	Wireworms
Garnet	2.1	Bioconsortia			Bio fungicide post harvest	Fruits, vegetables	Post harvest diseases
N-Power	2.1	Bioconsortia			seed treatment		
Nemguard SC	2.1	Ecospray	Garlic polysulfids (granul or liquid)		Nematicide	Potatoes, sugar beet	Diamond black moth (larvae)
Vigilance	2.1	Gopro	Geraniol		Bio Nematicide	Grapes, almonds, tomatoes, peppers, strawberries, potatoes	nematodes
Wrath	2.1	Gopro	Geraniol, Peppermint oil, cotton seed oil, rosemary oil	coats soft body causing suffocation, GABA disruption, destroying eggs, nymphs,	Insecticide	Strawberry, grapevine, almonds, potatoes, bluberries, broccoli, tomatoes, citrus, lettuce	insects
Reckoning	2.1	Gopro	Thyme oil		Bio fungicide	many crops	Botrytis
Zayin	2.1	Gopro	Geraniol	Contact kill, preventive action	Bio fungicide	Many crops	Mildew
Stomp	2.1	Gopro	Garlic oil	Contact, salivary gland	Bio insecticide	Many crops	Slug, snails

				and mucus formation			
Kitae	2.1	GreenImpulse	Chitosan chlorhydrate		Fungicide	Cabbage, vegetables, grapevine, cereals	large spectrum
Mycotec	2.1	Evologic technologies	Fungal fermentation				
Bioshield	2.1	Evologic technologies	Bacteria gram -				
	2.1		Saponin				
	2.1	INRAE	Trichogramma				Tree moth
Trehalose SG	2.1	Nagase	Trehalose	none	Adjuvant	none	none
Bio yield ST	2.1	LiveMicrobe	Pantoea agglomerans 3BB1		Microbial product	Corn and soybean	
Toothpick company	2.1	Kichawi Kill	Rice substrate+ Fusarium oxysporum powder		Biological	Maize, sorghum, millet, sugar cane, rice	Striga hermonthica
Antoferine	2.1	Antofénol			Biopesticide, biocontrol	Grapevine, Apple	Mildew

	2.1	BTU Center Ukraine	Microbial polysaccharides				
Liposam	2.1					Corn	Fusarium
RNA interference	2.1	Exponent International					
Rizoderma	2.1		Trichoderma		Biocontrol, Seed treatment	Wheat, soybean, rice	Broad spectrum
Neem tea bag	2.1						
Quartzo		FMC				Sugarcane	Nematodes
AgRHEA	2		Bacillus strains			Wheat	Fusarium Head Blight

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Botector	2	SAM Agrow	Aureobasidium pullulans	Vulnerable plant surface sites like microstraches are colonized by A. pullulans, pathogens dies due to lack of nutrients and space		Tomatoes, cucumber, melon, Brassicaceae, fruit bearing, bushes, strawberry, grapevine	Botrytis and Sclerotinia
KiplantALLGRIP	2	Asfertglobal	Bacterial consortium		Biofertilizer	Tomatoes	none
KiplantiNmass	2	Asfertglobal	Bacterial consortium		Biofertilizer	Potatoes	none
Microil	2	Asfertglobal	Vegetable oils			Most crops	Thrips
Eckosil	2	Asfertglobal	Orthosilicic Acid	Accumulation of silicon in the walls of the plant cells		Pears	
KiplantVS-04	2	Asfertglobal	Chitosan based solution		Fungicide, bactericide	Cucumber	
KiplantEssence	2	Asfertglobal	Terpenic compunds			Tomatoes	Several insects, whiteflies

Cuperdem	2	Asfertglobal	Copper Heptagluconate			Olives	
Derisom EC	2.1	Agri Life	Karanjin Extract	Insect growth regulator	Bioacaricide, Bio insecticide	not specified	Mites, thrips, scales, jassids, white flies, fall army worm, sucking insects

Anosom	2.1	Agri Life	Annona squamosa extract	Insect growth regulator	Bio insecticide	not specified	Helicoverpa, spodoptera, fall army worm, other caterpillar pests

MargoSom EC	2.1	Agri Life	Azadirachtin (Neem tree)	Insect growth regulator	Bio insecticide		sucking insets, fall army worm, chewing insects
MargoSom NF	2.1	Agri Life	Azadirachtin (Neem tree)	Physical barrier to mycelial penetration	Bio fungicide		Fungal pathoge ns

Lipel	2.1	Agri Life	Bacillus thuringiensis var. Kurstaki (MCC0089)	parasits insectsPhysical barrier to mycelial penetration paralyzes and destroys the cells of the insect's gut wall	Bio insecticide		Diamond back moth Helicoverpa, Spodoptera, fall army worm, and other caterpillar pests; Lepidoptera (moths and butterflies) like fruit borer / pod borers, fall army worm, Diamond back moth, Diptera (flies and mosquitoes), Coleoptera (beetles) , Hymenoptera (wasps, bees, ants and sawflies

Racer	2.1	Agri Life	Beauveria bassiana strain MCC0044	Conidial penetration: The microscopic conidial spores of the *Beauveria bassiana* on coming in contact with the body of the insect host start germinating and penetrate into the cuticle and grow inside the insect body thereby killing the insect within a few days. Once the fungus has killed its host, it grows back out through the softer portions of the cuticle, covering the insect with a layer of white mold (hence the name white muscadine disease). This downy mold produces millions of new infective spores that are released to the environment. Enzyme production: Beauveria bassiana secret	Bio insecticide		Helicoverpa, leaf folder, fall army worm, other caterpillar pests

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				es enzymes which attack and dissolve the cuticle, penetrate the skin and grow into the insect body. Beauveria bassiana produces a toxin called beauvericin that weakens the host's immune system. After the insect dies, an antibiotic - oosporein, is produced that enables the fungus to outcompete intestinal bacteria. Beauveria bassiana mycelia also produce an octacyclodepsipeptide toxin called bassianolide that consists of of fourmolecules each of Dhydroxyisovaleric acid and L-N methylleucine which have insecticidal properties.Gro			

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				wth: Once inside, Beauveria bassiana replicates and consumes the insects' internal organs and blood-like fluid, the hemolymph.Beauveria bassiana has the ability to live in the vascular tissue of certain corn cultivars as an endophyte. Beauveria bassiana infects the insect on contact and does not need to be consumed by the host to cause infection. A white mold emerges from the insects' dead body after a few days and produces new spores.			

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Pacer	2.1	Agri Life	Metarhizium anisopliae MCC0051	Insect parasits	Bio insecticide, bio termiticide		Ants that spread mealy bugs, termites, root grubs, fall army worm and other soil insects
Mealikil	2.1	Agri Life	Verticillium lecanii		Bio insecticide		mealy bugs, sucking insects and mites
Paecilo	2.1	Agri Life	Paceliomyces lilacinus		Bio Nematicide		nematod es
Somstar-Ha	2.1	Agri Life	HaNPV		Bio insecticide		helicover pa Sp
Somstar-Sl	2.1	Agri Life	SINPV		Bio insecticide		spodopte ra Sp

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SomGuard	2.1	Agri Life	Nano Silver, Nano Copper, Universal anti viral and microbial disinfectant		Biopesticide		universal disinfectant against pathogenic fungi, bacteria, virus, algae and protozoa, Plants debris and farm equipment and tools infected by pathogen to be treated so that infection does not spread. Animal sheds can also be sprayed
SheathGuard	2.1	Agri Life	Pseudomonas Fluorescens		Bio fungicide, Bio nematicide		Sheath blight, collar rot, stemrot, nematodes

BioNemaGon	2.1	Agri Life			Bio Nematicide		Nematodes
Ecosom-TV	2.1	Agri Life	Trichoderma viride		Bio fungicide		Soil and seed borne fungal diseases, root rot, collar rot
Ecosom-TH	2.1	Agri Life	Trichoderma Harzianum		Bio fungicide, Bio nematicide		fruit rot, botrytis, nematodes
Seed Guard	2.1	Agri Life			Plant growth, biofertilizer, biofungicide		suppresses a wide range of soil pathogens that can cause wilts, damping off, root rot, collar rot, rhizome rot
Powderycare	2.1	Agri Life	Ampelomyces quisqualis		Biopesticide		Powdery mildew
Downycare	2.1	Agri Life	Fusarium proliferatum		Biopesticide		Downy mildew

Growgib	2.1	Agri Life	Fusarium moniliformis		Biopesticide		Stimulates production of gibberlines in plant
Biotilis	2.1	Agri Life	Bacillus subtilis		Biopesticide		fungal diseases
Dieback Care	2.1	Agri Life			Biopesticide		die Back, decline, wilt compex of orchard plants
Biomycin	2.1	Agri Life			Biopesticide		imparts resistance to plants to fight bacterial diseases
Biofit	2.1	Agri Life	Microbial consortium		Biopesticide		fungal diseases
Biokuprum	2.1	Agri Life	Cheatomium cupreum		Biopesticide		fungal diseases
Borer Guard	2.1	Agri Life	Bio complex		Biopesticide		control of all shoot borers

Vectoguard	2.1	Agri Life	Bacillus thuringiensis var. Israelensis 5%		Biological lavicide		biolarvicide for control of anopheles, culex and aedes mosquitos
Quitto	2.1	Agri Life	Herbal Mosquito Repellent		Repellent		effective against all kind of mosquito vectors that spread
Nitrofix	2.1	Agri Life	Nitrogen fixing bacteria		Biofertilizer		none
P sol B	2.1	Agri Life	Phosphobacteria		Biofertilizer		none
K sol B	2.1	Agri Life	Potash mobilizing bacteria		Biofertilizer		none
Zn sol B	2.1	Agri Life	zinc mobilizing bacteria		Biofertilizer		none
Fe Sol B	2.1	Agri Life	ferrous mobilizing bacteria		Biofertilizer		none
S Sol B	2.1	Agri Life	sulphur mobilizing bacteria		Biofertilizer		none
Mn Sol B	2.1	Agri Life	manganese mobilizing bacteria		Biofertilizer		none
Si Sol B	2.1	Agri Life	silicate solubilizing bacteria		Biofertilizer		none
Mycrorhizha	2.1	Agri Life	mycorrhiza		Biofertilizer		none
Silrich	2.1	Agri Life	Biomass		Biofertilizer		none
Kohinoor	2.1	Agri Life	Unique soil health restorer		Biofertilizer		none
RootamBio	2.1	Agri Life	plant probiotics, vitamins, pre-biotics		Biofertilizer		none
BioHume SL	2.1	Agri Life	Bio active humic and fulvic substances from vermi compost		Biostimulants		none
BioHume GR	2.1	Agri Life	Bio active humic and fulvic substances from vermi compost		Biostimulants		none
BioHume SP	2.1	Agri Life	Bio active humic and fulvic substances from vermi compost		Biostimulants		none

SomZyme SL	2.1	Agri Life	liquid seaweed		Biostimulants		none
SomZyme GR	2.1	Agri Life	granule seaweed		Biostimulants		none
SomeZym SP	2.1	Agri Life	fermented Seaweed		Biostimulants		none
Agriboom	2.1	Agri Life	liquid organic manure		Biostimulants		none
Aminocid SL	2.1	Agri Life	protein hydrolysates liquid of vegetative origin		Biostimulants		none
Aminocid Gr	2.1	Agri Life	protein hydrolysates liquid of vegetative origin		Biostimulants		none
Aminocid SP	2.1	Agri Life	protein hydrolysates liquid of vegetative origin		Biostimulants		none
BioKit	2.1	Agri Life			Biostimulants		none
Biosulf	2.1	Agri Life	Liquid sulfur		Biostimulants		none
Biocopp	2.1	Agri Life	liquid nano copper		Biostimulants		none
Lesino	2.1	Agri Life	biostimulant		Biostimulants		none
Bindu	2.1	Agri Life	silicon liquid		Biostimulants		none
Stoma	2.1	Agri Life	triacontanol		Biostimulants		none
Stimula	2.1	Agri Life	o		Biostimulants		none
U-Min	2.1	Agri Life	Neem coating agent for urea		Biostimulants		none
Oxyrich	2.1	Agri Life	oxygen liberator		Biostimulants		none
Oxyrich-N	2.1	Agri Life	soil aerator complex		Biostimulants		none
Madex	2.1	Andermatt	Cydia pomonella granulovirus		Bio insecticide	Apple, pear, walnut, quince and others	Colding moth

Mdex Twin	2.1	Andermatt	Cydia pomonella granulovirus		Bio insecticide	Peach, nectarine, apple, pear, quince, apricot, almond, cherry, plum, walnut	Colding moth, oriental fruit moth
Capex	2.1	Andermatt	Adoxophyes orana granulovirus (AoGV)		Bio insecticide	apple, pear, rose, plum, cherry, apricot, peach, currant, gooseberry	Summer fruuit tortrix Adoxophyes orana
Cryptex	2.1	Andermatt	Cryptophlebia leucotreata granulovirus (CrleGV)		Bio insecticide	Citrus, avocado, pomegranate, bean, cotton, grape, macadamia, corn, pepper, stone fruit, tea	false colding moth Thaumatotibia leucotreata

Helicovex	2.1	Andermatt	Helicoverpa armigera nucleopolyhedrovirus (HearNPV)		Bio insecticide	Soybean, sorghum, corn, cotton, tomato, lettuce, green beans	Cotton bollworm Helicoverpa armigera, corn earworm helicoverpa Zea, other helicoverpa species
Spexit	2.1	Andermatt	Spodoptera exigua multicapsid nucleopolyhedrovirus (SeMNPV)		Bio insecticide	vegetables	Beet armyworm Spodoptera exigua
Tutavir	2.1	Andermatt	Phthorimaea operculella granulovirus (PhopGV)		Bio insecticide	tomatoes	Tomato leafminer
Plutex	2.1	Andermatt	Plutella xylostella granulovirus (PlxyGV)		Bio insecticide	cabbage, broccoli, canola	Diamond back moth Plutella xylostella
Littovir	2.1	Andermatt	Spodoptera littoralis nucleopolyhedrovirus (SpliNPV)		Bio insecticide	row crops, corn, soybean, vegetables	African cotton leafworm spodoptera littoralis, fall armyworm spodoptera frugiperda

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Spodovir Plus	2.1	Andermatt	spodoptera frugiperda multicapsid nucleopolyhedrovirus (SfMNPV)		Bio insecticide	corn, sorghum, rice, sybean	fall armyworm spodoptera frugiperda
Loopovir	2.1	Andermatt	Chrysodeixis includens nucleopolyhedrovirus (ChinNPV)		Bio insecticide	soybean, tomato	Soybean looper Chrysodeixis includens
Loopex	2.1	Andermatt	autographa californica nucleopolyhedrovirus (AcMNPV)		Bio insecticide	Cabbage looper	brassica crops, tomato, lettuice, pea, potato
Nomu-Protec	2.1	Andermatt	Metarhizium rileyi strain PHP1705		Bio insecticide	wide range of crops	Helicoverpa
SilicoSec	2.1	Andermatt	silicon dioxide Kieselguhr		Bio insecticide	all crawling insects in grain, moth larvae, weevils	stord grain, empty storage rooms
Abietiv	2.1	Andermatt	Neodiprion abietis nucleopolyhedrovirus (NeabNPV)		Bio insecticide	Balsam fir sawfly	christmas tree, forest
Lymantria dispar MNPV	2.1	Andermatt	Lymantria dispar multicapsid nucleopolyhedrovirus (LdMNPV)		Bio insecticide		Gypsy moth
AmyProtec 42	2.1	Andermatt	Bacillus velezensis FZB42		Bio fungicide	induction of systemic resistance	seed treatments

T-77	2.1	Andermatt	Trichoderma atroviride strain 77B		Bio fungicide	grape, tomato, onion, strawberry, nectarine, soybean	botrytis, trunk diseases, Monilinia
VitiSan	2.1	Andermatt	Potassium bicarbonate		Bio fungicide	Powdery mildew, scab, botrytis, gloesporium, monilia	grape, pome fruit, stone fruit, tomato, berries
Curatio	2.1	Andermatt	Calcium polysulphide		Bio fungicide	pome fruit, stone fruit, grapes	cab, powdery mildew
T-Gro	2.1	Andermatt	trichoderma asperellum strain kd		Biostimulants, bioinoculants		wide range of crops
Microbials for seedtreatments and coatings	2.1	Andermatt					
VIRANTRA	1	Syngenta Crop Protection	Plinazolin	IRAC Group 30		wide range of crops	wide range of pests
Serenade	2.1	Bayer	Bacillus amyloliquefaciens		Bio fungicide	grapes, vegetables, strawberries	Botrytis, sclerotinia, alternaria, mildew
Fox Supra	1	Bayer	Protioconazol +Impirfluxam		Fungicide	rust	Soybeans
Iblon	1	Bayer	Isoflucypram	SDHI new class	Fungicide		

Xivana	1	Bayer	Fluoxapiprolin		Fungicide	grapes	downy mildew
BeCrop trials	3		none	none	Predictive tool	potatoes	
Semios	2.4		none, trap catches		DSS		Colding moth
UVBoosting (robotics)	2.4	UV Boosting	UV Boosting - Stimulation des défenses naturelles des plantes par flashs UV	none	robotics	Vine strawberries	
Prédiction des vols de ravageurs	3	Terres Inovia	predictive tool https://www.terresinovia.fr/en/web/guest/-/terres-inovia-met-en-ligne-le-premier-outil-de-prediction-des-vols-de-charancon-de-la-tige-du-colza	none	Predictive tool	rapeseed	weevil flights