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In dit rapport presenteren we een analyse van de gevolgen van het Europese toelatingsbeleid van gewasbeschermingsmiddelen binnen de context van de implementatie van de Farm to Fork Strategie voor de Nederlandse Glastuinbouw. We analyseren het Europese en Nederlandse Gewasbeschermingsmiddelenbeleid, en verkennen de gevolgen van de verwachte afname in het aantal goedgekeurde gewasbeschermingsmiddelen voor vijf gewassen: tomaat, komkommer, gerbera, chrysant en Phalaenopsis. Op basis van deze cases maken we een analyse voor de gehele glastuinbouw. Vervolgens geven we een overzicht van de huidige en toekomstige ontwikkelingen in duurzame gewasbeschermingsmethoden. Ten slotte presenteren we voorwaarden die aan overheid, toeleveranciers, afnemers, onderzoekers en adviseurs, en de glastuinbouw zelf gesteld kunnen worden, die bijdragen aan een setting waarin glastuinders in staat zijn om de gewasbescherming te blijven verduurzamen op een bedrijfseconomisch verantwoorde wijze.

In this report, we present an analysis of the consequences of the European authorization policy for plant protection products within the context of the implementation of the Farm to Fork Strategy for Dutch greenhouse horticulture. We analyse European and Dutch crop protection policy and explore the consequences of the expected decrease in the number of approved plant protection products for five crops: tomato, cucumber, gerbera, chrysanthemum and Phalaenopsis. Based on these cases, we make an analysis for the entire greenhouse horticulture sector. Afterwards, we provide an overview of current and future developments in sustainable crop protection methods. Finally, we present conditions that can be imposed on the government, suppliers, buyers, researchers and advisers, and the greenhouse horticulture sector itself, which contribute to a setting in which greenhouse growers are able to continue to make crop protection more sustainable in an economically responsible manner.

Key words: impact assessment, sustainability, crop protection, plant protection products, integrated pest management, greenhouse horticulture

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Preface

Sustainable crop production is increasingly the focus of European policy. The Farm to Fork and Biodiversity strategies are at the heart of the European Green Deal Roadmap aiming to make food systems fair, healthy and environmentally-friendly. Both strategies contain clear new targets to be met by 2030 which should contribute to a sustainable food system. These targets need to be met in a period in which we expect that the number of available plant protection products will reduce due to the high number of active ingredients that will pass the expiration date in the coming four years and the stricter criteria for (re)approval of active ingredients under Regulation (EC) No 1107/2009. The purpose of this Regulation is to ensure a high level of protection of both human and animal health and the environment and at the same time to safeguard the competitiveness of Community agriculture.

The Dutch branch organisation for greenhouse horticulture Glastuinbouw Nederland has requested us to analyse the consequences of a reduction in the number of available plant protection products for the greenhouse horticulture in the Netherlands. This analysis has been executed by a team from Wageningen Research. The research team wants to thank all greenhouse growers and experts who have contributed by giving interviews, providing farm visits and participating in the workshop. Furthermore, we thank the colleagues from both outside and inside Wageningen University and Research for reviewing the results. We thank the representatives of Glastuinbouw Nederland and other stakeholders who have guided the project and commented on the output of this study. Finally, we want to thank Kyra Broeders from Glastuinbouw Nederland for the open and involved way she supervised this project.

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Summary

S.1 Introduction

For decades, the Dutch greenhouse horticulture sector has been working on sustainable production. The sector is confident that it will be able to produce more sustainably over a period of 20 years, in accordance with the then applicable requirements for production. As such, the Sustainable Use of Pesticides Regulation implementing the objectives for crop protection of the Farm to Fork Strategy can serve as a helping hand for the sector to achieve sustainable crop protection. The bottleneck, however, is bridging this period of 20 years. The greenhouse horticulture sector needs sufficient crop protection methods to bridge the gap to a sustainable future. Plant protection products (PPPs)[1] are also needed in the longer term to be able to effectively control diseases and pests in integrated cultivation. This report explains and elaborates the conditions for making crop protection more sustainable, and which scope is needed in policy, legislation, and regulations to make this possible.

S.2 Main findings

The following conclusions can be drawn:

1. We expect that in 2030, greenhouse growers have less plant protection products available to control pests and diseases. Many plant protection products that are allowed to be applied in the greenhouse horticulture (as well as in open field production) pass the expiration data before 2030, which implies that reassessment of the plant protection product of the effects on human health and the environment and the efficacy will take place, if requested by the registration holder. Based on analysis of data available in the EU Pesticides Database, it can be expected that the number of chemical and microbial active ingredients that are allowed to be used may reduce with approximately 25 to 30% until 2027. The effect on yield is difficult to assess, but losses up to 20% in vegetable production are possible, with higher fluctuations. In ornamental production the losses can be even larger due to the zero-tolerance policy for pests and pathogens present in the product, which will make export almost impossible. It is likely that the product prices will increase. Greenhouses horticulture is highly capital intensive, which makes it more vulnerable for yield fluctuations than horticulture in the open field.
2. The expected reduction in the availability of chemical plant protection products forces greenhouse horticulture to search for alternative, sustainable crop protection methods. However, on the other hand, continuing to make crop protection more sustainable becomes difficult for the following reasons:
   a. The application of biocontrol is at risk, when specific chemical plant protection products that can be applied in combination with biocontrol will lose their approval, and broad spectrum plant protection products will be applied. The application of biocontrol requires a careful IPM strategy for two reasons. First of all, the application of biocontrol agents limits the number of chemical plant protection products that can be applied, since a large number of plant protection products can have negative effects on biocontrol agents. Secondly, the population of especially macro-organisms need to be built up to reach a level with maximum efficacy. This could also be the case for microbes in substrates. By consequence, decision making about crop protection needs to be taken at strategic (multiple cultivation cycles) and tactical level (before a cultivation cycle), which has consequences for daily decisions about crop protection. A careful crop protection strategy has to be developed to control all pests and diseases, while safeguarding the applied biocontrol agents, to maintain their efficacy level. If no sufficient selective chemical plant protection products remain available that can be applied in combination with biocontrol, the application of more green plant protection products will be hampered.
   b. Limitation of the number of plant protection products leads to an increased risk on resistance of pests and diseases against specific products. A criterion that is applied in the comparative assessment of

[1] A Glossary and abbreviations are presented in Appendix 1.

Candidates for Substitution is that at least 5 modes of action to control a pest or disease need to be available to prevent resistance development. The expected reduction in the availability of chemical active ingredients, and consequently increased risks on resistance development, combined with the limitations of the use of chemical plant protection products such as maximum number of sprayings in combination with biocontrol agents will lead to more bottlenecks in crop protection in greenhouse horticulture. It is therefore important that sufficient modes of action remain available to control pests and diseases.

c. The set of pests and diseases that need to be controlled in greenhouse crops is not static over time. New pests and diseases can enter the greenhouses due to climate change and international trade in plants and plant products. Pests and pathogens that were in the past not considered as important pests can cause more damage, since broad spectrum crop protection products have lost registration. Greenhouse growers should be aware of and prepared for the entrance of new pests and diseases. The dynamics in disease and pest pressure forces the greenhouse growers to continuous adjustment of the crop protection strategy. Both development and registration of targeted solutions are time-consuming and costly, which stresses the need to continue the development of resilient plants and cultivation systems.

S.3 Recommendations

We recommend:

1. Policy makers to take into account the consequences of a reduction in the number of available active ingredients for the continuous development of sustainable crop protection in greenhouse horticulture, the reduced production, higher prices and increased imports.
2. To accelerate development and market introduction of alternative sustainable crop protection methods and low risk active ingredients.
3. Greenhouse growers to accelerate the adoption of currently available techniques by greenhouse growers in order to reduce the use and risk of plant protection products. Early adopters need to be awarded, and cooperation between greenhouse growers supported to share best practices. This can be done by encouragement of participation in study groups, encouragement of participation in certification systems such as MPS and cooperation of Glastuinbouw Nederland with independent advisors. Furthermore, research is necessary to detect bottlenecks in the decision making about adoption of sustainable crop protection techniques.
4. To intensify research on resilient cultivation systems, plant resilience and soil suppression of diseases.
5. To intensify development and application of prevention systems, monitoring, biological control as described in the Sustainable Use of Pesticides Regulation (SUR), precision spraying and monitoring technologies, cultural control methods and low risk and biological control PPPs in the short and mid-term.
6. National Authorization boards to reduce the lead times and simplify procedures where possible for registration of biological control and (low risk) PPPs and no waiting times for registration for these products.
7. Legislators to enable temporary options for emergency use by greenhouse growers of plant protection products that lost registration under the condition the greenhouse horticulture contributes significantly to reduction of overall use and risk of PPPs and emissions of plant protection products to the environment with specific attention for the surface water. Evaluate to what extent the existing options for derogation and provisional authorisation as described in Regulation (EC) No 1107/2009 can fulfil this need in order to maintain at least five modes of action to control pests and diseases. Furthermore, monitor and evaluate to what extent emergency options contribute to producing more sustainably in the greenhouse horticulture, or will lead to stagnation of producing more sustainably.
8. To investigate to what extent more advanced indicators such as the environmental Indicator Crop Protection measuring environmental impacts can be applied that serve the ultimate goals for reducing plant protection product use and risk on the one hand, but allows more options to intervene for greenhouse growers on the other hand.

Furthermore we recommend the European Commission to investigate to what extent the realization of the crop protection targets of the Farm to Fork Strategy will be realized by the reduction of the availability of plant protection products on the one hand and the implementation of the SUR on the other hand.

S.4 Methodology

The impact assessment starts with a policy analysis, in which we analyse the existing European and Dutch legislation on crop protection. Furthermore, we analyse the Farm to Fork Strategy and the proposed implementation of the targets for reduction of pesticide use and risk by the Sustainable Use Regulation as presented in the summer of 2022, which need to be elaborated in national action plans by the Member States.

The basis for the impact assessment of the Farm to Fork strategy has been provided by an in-depth analysis of the crop protection of five case crops: tomato and cucumber are representatives of the vegetables, gerbera and chrysanthemum as representatives of the cut flowers, cultivated in the soil and on substrate and *Phalaenopsis* as representative of the pot plants. We present the pests and diseases that need to be controlled by the greenhouse growers for each crops, the existing crop protection means: chemical plant protection products, biocontrol, both microbes and macro-organisms and other cultural control methods. Furthermore, we explore the future availability of the plant protection products based on their expiration dates. On the basis of these data we explore the bottlenecks in the near future.

We have made use of public data about plant protection products as available on the website of the Ctgb and Eurostat, data provided by suppliers of plant protection products in the greenhouse horticulture. Furthermore interviews with crop advisers and greenhouse growers have been executed. A workshop with growers, advisers, suppliers, representatives of the value chain and researchers has been organised to discuss intermediate findings.

Samenvatting

S.1 Inleiding

Al decennialang werkt de Nederlandse glastuinbouwsector aan duurzame productie. De sector heeft er vertrouwen in dat zij over een periode van 20 jaar duurzamer kan produceren, conform de dan geldende productie-eisen. Zo kan de Verordening Duurzaam Gebruik Gewasbeschermingsmiddelen (SUR) waarmee de doelen van de Farm to Fork Strategie voor gewasbescherming geïmplementeerd worden een handreiking zijn voor de sector om te komen tot duurzame gewasbescherming. Het knelpunt is echter het overbruggen van deze periode van 20 jaar. De glastuinbouwsector heeft voldoende gewasbeschermingsmiddelen nodig om de kloof naar een duurzame toekomst te overbruggen. Gewasbeschermingsmiddelen zijn ook op langere termijn nodig om ziekten en plagen effectief te kunnen bestrijden in de geïntegreerde teelt. Dit rapport verantwoordt en werkt de voorwaarden uit voor verduurzaming van de gewasbescherming en welke ruimte nodig is in beleid, wet- en regelgeving om dit mogelijk te maken.

S.2 Belangrijkste bevindingen

De volgende conclusies kunnen worden getrokken:

1. We verwachten dat glastuinders in 2030 minder gewasbeschermingsmiddelen beschikbaar hebben om ziekten en plagen te bestrijden. Veel gewasbeschermingsmiddelen die in de glastuinbouw (maar ook in vollegrondsteelt) mogen worden toegepast, passeren de expiratiedatum voor 2030, wat impliceert dat herbeoordeling van het gewasbeschermingsmiddel op de effecten op de menselijke gezondheid en het milieu en de werkzaamheid zal plaatsvinden, op verzoek van de registratiehouder. Gebaseerd op data uit de EU Pesticiden Database mag verwacht worden dat het aantal chemische en microbiële werkzame stoffen dat gebruikt mag worden tot 2027 met circa 25 tot 30% kan afnemen. Het effect op de opbrengst is moeilijk te beoordelen, maar opbrengstverliezen tot 20% in de groenteproductie zijn mogelijk, met grotere schommelingen. In de sierteelt kunnen de verliezen nog veel groter zijn door het nultolerantiebeleid voor in het product aanwezige plagen en ziekteverwekkers, waardoor export nagenoeg onmogelijk wordt. De glastuinbouw is zeer kapitaalintensief en daardoor kwetsbaarder voor opbrengstfluctuaties dan de vollegrondstuinbouw.
2. De verwachte afname van de beschikbaarheid van chemische gewasbeschermingsmiddelen dwingt de glastuinbouw tot het zoeken naar alternatieve, duurzame gewasbeschermingsmiddelen. Aan de andere kant wordt het verder verduurzamen van gewasbescherming lastig om de volgende redenen:
   a. De toepassing van biologische bestrijding komt in gevaar wanneer bepaalde chemische gewasbeschermingsmiddelen die in combinatie met biologische bestrijding kunnen worden toegepast hun goedkeuring verliezen en breedwerkende gewasbeschermingsmiddelen worden toegepast. De toepassing van biologische bestrijding vereist om twee redenen een zorgvuldige IPM-strategie. Ten eerste beperkt de toepassing van biologische bestrijdingsmiddelen het aantal chemische gewasbeschermingsmiddelen dat kan worden toegepast, aangezien een groot aantal gewasbeschermingsmiddelen een negatief effect kan hebben op biologische bestrijdingsmiddelen. Ten tweede moet de populatie van met name macro-organismen worden opgebouwd om een niveau met maximale werkzaamheid te bereiken. Dit zou ook het geval kunnen zijn voor microben in substraten. Beslissingen over gewasbescherming moeten daarom op strategisch (meerdere teeltcycli) en tactisch niveau (vóór een teeltcyclus) worden genomen, wat gevolgen heeft voor de dagelijkse beslissingen over gewasbescherming. Er moet een zorgvuldige gewasbeschermingsstrategie worden ontwikkeld om alle ziekten en plagen te bestrijden en tegelijkertijd de toegepaste biologische bestrijders te vrijwaren om hun werkzaamheid op peil te houden. Als er onvoldoende selectieve chemische gewasbeschermingsmiddelen beschikbaar blijven die in combinatie met biologische bestrijding kunnen worden toegepast, wordt de toepassing van meer groene gewasbeschermingsmiddelen belemmerd.

b. Beperking van het aantal gewasbeschermingsmiddelen leidt tot een verhoogd risico op resistentie van ziekten en plagen tegen specifieke middelen. Een criterium dat wordt gehanteerd bij de vergelijkende beoordeling van Candidates for Substitution is dat er minimaal 5 werkingsmechanismen (modes of action) aanwezig moeten zijn om een plaag of ziekte te bestrijden om resistentieontwikkeling te voorkomen. De verwachte afname van de beschikbaarheid van chemische werkzame stoffen, en daarmee verhoogde risico's op resistentieontwikkeling, in combinatie met de beperkingen van het gebruik van chemische gewasbeschermingsmiddelen zoals het maximaal aantal bespuitingen in combinatie met biologische bestrijdingsmiddelen, zullen leiden tot meer knelpunten in de gewasbescherming in de glastuinbouw. Het is daarom van belang dat er voldoende werkingsmechanismen (modes of action) beschikbaar blijven om ziekten en plagen te bestrijden. Voor elk van de onderzochte gewassen worden meerdere knelpunten in de bestaande en nabije toekomst geïdentificeerd. Voorbeelden zijn de bestrijding van ziekten in de wortelzone zoals pythium, het insect *Nesidiocoris tenuis* in tomaat, bladluis in komkommer en chrysant en potwormen in *Phalaenopsis*. Als deze knelpunten niet kunnen worden opgelost, zijn aanzienlijke opbrengstverliezen te verwachten, met de grootste risico's voor snijbloemen en potplanten vanwege de nultolerantie voor de aanwezigheid van plagen en ziekteverwekkers.
c. De reeks plagen en ziekten die in kasgewassen moeten worden bestreden, is niet statisch in de tijd. Door klimaatverandering en internationale handel in planten en plantaardige producten kunnen nieuwe ziekten en plagen de kassen binnendringen. Plagen en ziekteverwekkers die in het verleden niet als belangrijk ongedierte werden beschouwd, kunnen meer schade aanrichten, wanneer breedwerkende gewasbeschermingsmiddelen de registratie hebben verloren. Glastuinbouwers moeten zich bewust zijn van en voorbereid zijn op de komst van nieuwe plagen en ziekten. De dynamiek in ziekte- en plaagdruk dwingt de glastuinders tot continue bijstelling van de gewasbeschermingsstrategie. Zowel de ontwikkeling als de registratie van gerichte oplossingen is tijdrovend en kostbaar, wat de noodzaak benadrukt om door te gaan met de ontwikkeling van weerbare planten en teeltsystemen.

S.3 Aanbevelingen

Wij adviseren:

1. Beleidsmakers rekening te houden met de gevolgen van een vermindering van het aantal beschikbare werkzame stoffen voor de continue ontwikkeling van duurzame gewasbescherming in de glastuinbouw, de verminderde productie, hogere prijzen en toegenomen import.
2. De ontwikkeling en marktintroductie van alternatieve duurzame gewasbeschermingsmiddelen en laag-risico werkzame stoffen te versnellen.
3. De glastuinbouw de adoptie van de huidige beschikbare technieken door glastuinders te versnellen om het gebruik en risico van gewasbeschermingsmiddelen te verminderen. Early adopters moeten worden beloond en samenwerking tussen glastuinders moet worden ondersteund om best practices te delen. Dit kan door stimulering van deelname aan studiegroepen, stimulering van deelname aan certificatiesystemen zoals MPS en samenwerking van Glastuinbouw Nederland met onafhankelijke adviseurs. Verder is onderzoek nodig om knelpunten in de besluitvorming over adoptie van duurzame gewasbeschermingstechnieken op te sporen.
4. Het intensiveren van onderzoek naar veerkrachtige teeltsystemen, plantweerbaarheid en bodemonderdrukking van ziekten.
5. Op korte en middellange termijn intensivering van het ontwikkelen en toepassen van preventie en monitoring, toepassing van biologische bestrijding zoals beschreven in de SUR, toepassing van precisiespuit- en monitoringtechnieken, fysieke methoden, laag risico en biologische gewasbeschermingsmiddelen.
6. Toelatingsautoriteiten waar mogelijk de doorlooptijden verkorten en procedures vereenvoudigen voor registratie van biologische bestrijdingsmiddelen en (laag risico) gewasbeschermingsmiddelen, en geen wachttijden voor registratie voor deze producten.
7. Wetgevers om tijdelijk mogelijkheden te maken voor noodgebruik van gewasbeschermingsmiddelen die de registratie hebben verloren onder de voorwaarde dat de glastuinbouw een significante bijdrage levert aan vermindering van het totale gebruik en risico van gewasbeschermingsmiddelen, met bijzondere aandacht voor het oppervlaktewater. Evalueer in hoeverre de bestaande opties voor afwijking en

voorlopige toelating zoals beschreven in Verordening (EG) nr. 1107/2009 kunnen voldoen aan deze behoefte om ten minste vijf middelen en methoden voor de bestrijding van ziekten en plagen te behouden. Verder monitoren en evalueren in hoeverre noodopties bijdragen aan duurzamer produceren in de glastuinbouw, of zullen leiden tot stagnatie van duurzamere productie.
8. Te onderzoeken in welke mate meer geavanceerde indicatoren zoals de milieuindicator gewasbescherming die de milieueffecten meten kunnen worden toegepast die enerzijds de uiteindelijke doelen dienen voor het verminderen van gewasbeschermingsmiddelengebruik en risico's, maar anderzijds meer interventiemogelijkheden bieden voor glastuinders.

Verder bevelen wij de Europese Commissie aan om te onderzoeken in hoeverre de realisatie van de gewasbeschermingsdoelstellingen van de Farm to Fork Strategie wordt gerealiseerd door enerzijds het verminderen van de beschikbaarheid van gewasbeschermingsmiddelen en anderzijds het implementeren van de SUR.

S.4 Methodologie

De impact assessment start met een beleidsanalyse, waarin we de bestaande Europese en Nederlandse wetgeving op het gebied van gewasbescherming analyseren. Verder analyseren we de Farm to Fork-strategie en de voorgestelde implementatie van de doelstellingen voor vermindering van het gebruik en de risico's van gewasbeschermingsmiddelen en door de verordening inzake duurzaam gebruik, zoals gepresenteerd in de zomer van 2022, die door de lidstaten moeten worden uitgewerkt in nationale actieplannen.

De basis voor de effectbeoordeling van de Farm to Fork-strategie is gevormd door een diepgaande analyse van de gewasbescherming van vijf case gewassen: tomaat en komkommer als vertegenwoordigers van de groenten, gerbera en chrysant als vertegenwoordigers van de snijbloemen, geteeld in de grond en op substraat en *Phalaenopsis* als vertegenwoordiger van de potplanten. Per gewas presenteren wij de ziekten en plagen die door de glastuinders bestreden dienen te worden, de bestaande gewasbeschermingsmiddelen: chemische gewasbeschermingsmiddelen, biologische bestrijdingsmiddelen, zowel micro- als macro-organismen en andere gewasbeschermingsmethoden. Verder verkennen we de toekomstige beschikbaarheid van de gewasbeschermingsmiddelen op basis van de expiratiedata van de gewasbeschermingsmiddelen. Op basis van deze gegevens verkennen we de knelpunten in de nabije toekomst.

Wij hebben gebruik gemaakt van openbare gegevens over gewasbeschermingsmiddelen zoals beschikbaar op de website van het Ctgb en Eurostat en gegevens aangeleverd door leveranciers van gewasbeschermingsmiddelen in de glastuinbouw. Verder zijn er interviews gehouden met teeltadviseurs en glastuinders. Er is een workshop georganiseerd met telers, adviseurs, leveranciers, vertegenwoordigers van de waardeketen en onderzoekers om tussentijdse bevindingen te bespreken.

1 Introduction

Policy context

The *European Green Deal* (GD) was launched by the European Commission in December 2019. Its main goal being to make Europe the first climate-neutral continent by 2050. It maps a new, sustainable and inclusive growth strategy to boost the economy, improve people's health and quality of life, care for nature, and leave no one behind. At the heart of the GD is the *Farm to Fork* (F2F) *Strategy*, which was launched by the European Commission in May 2020 in order to achieve a fair, healthy and environmentally-friendly food system by 2030. According to the F2F Strategy, there is a need to reduce dependency on plant protection products and antimicrobials, reduce excess fertilisation, increase organic area under farming, improve animal welfare and reverse biodiversity loss. The Commission will ensure that the strategy is implemented in close coherence with the other elements of the GD, amongst others the *Biodiversity (BD) Strategy* for 2030, launched simultaneously with the Farm to Fork Strategy. Many targets in the BD overlap with the F2F Strategy.

As outlined in the F2F Strategy, the Commission will table a legislative proposal for a framework for a sustainable food system by the end of 2023 to accelerate and facilitate this transition and ensure that all foods placed on the EU market become increasingly sustainable. This will promote policy coherence at EU and national levels, mainstream sustainability in all food-related policies and strengthen the resilience of food systems. Following a broad consultation and impact assessment, the Commission will work on common definitions and general principles and requirements for sustainable food systems and foods.

The use of plant protection products in agriculture and horticulture may contribute to soil-, water- and air-pollution, biodiversity loss and can harm non-target plants, insects, birds, mammals and amphibians (EASAC, 2015; Jansen and van Rijn, 2021; Desneux et al, 2007; Yamamuro et al., 2019). The Commission has already established two Harmonised Risk Indicators (HRI) to quantify the progress in reducing the use and risks linked to pesticides.[2] The latest Commission publication, according to Harmonised Risk Indicator 1 demonstrates a 21% decrease in the use and risks from plant protection products since the period 2011-2013 (Eurostat, 2021). The Commission will take additional action to reduce the overall use and risk of chemical pesticides by 50% and the use of more hazardous pesticides[3] by 50% by 2030 compared to the reference period 2015-2017.

The Dutch greenhouse horticulture sector has been working for decades on sustainable production. On 95% of the greenhouse area biological control is applied (CBS, 2022a). The sector is confident that it will be able to produce more sustainably over a period of 20 years, in accordance with the then applicable requirements for production. As such, the Sustainable Use of Pesticides Regulation (SUR) can serve as a helping hand for the sector to achieve sustainable crop protection. The bottleneck, however, is the bridging period of 20 years. The greenhouse horticulture sector needs sufficient (plant protection) products to be able to bridge the gap to this future. Plant protection products are also needed in the longer term to be able to effectively combat diseases and pests in integrated cultivation to maintain the ecosystem in the greenhouse, and to prevent resistance. This research is intended to define the conditions for making crop protection more sustainable, and what scope is needed in policy, legislation and regulations to make this possible.

[2] Harmonised Risk Indicators are defined in the Directive 2009/128/EC establishing a framework for Community action to achieve the sustainable use of plant protection products (the Sustainable Use Directive). These indicators are needed to measure progress in the reduction of risks from pesticide use for human health and the environment. The European Commission calculates them for the EU, and Member States should calculate the Harmonised Risk Indicators at a national level. The data to be used for the calculations shall be statistical data collected in accordance with Union legislation concerning statistics on plant protection products, i.e. Regulation (EC) No 1185/2009 on pesticide statistics, and other relevant data.

[3] These are plant protection products containing active substances that meet the cut-off criteria as set out in points 3.6.2. to 3.6.5 and 3.8.2 of Annex II to Regulation (EC) No 1107/2009 or are identified as candidates for substitution in accordance with the criteria in point 4 of that Annex.

Objective
The objective is to provide a basis for policy, legislation and regulations, national and European, that support greenhouse horticulture to take the step towards a sustainable future and to safeguard the competitiveness of the European agriculture acting in a global market.

The scope of the project is crop protection in Dutch plant production. The focus is on greenhouse horticulture. The analyses focus on 2030 (the time horizon of the F2F strategy) and 2040 (a year in which the sustainability ambitions of greenhouse horticulture can be realised, taking into account the investment rhythm in greenhouse horticulture.

Reading guide
This report is structured as follows. In Chapter 2 we describe and analyse the legal framework and ongoing political developments. In Chapter 3 we present in-depth analyses for five case crops (tomato, cucumber, gerbera, chrysanthemum and *Phalaenopsis*). In Chapter 4 we explore future pathways for making crop protection sustainable in the mid- and long term, and the conditions necessary to realise those pathways. The report ends with discussion, conclusions and recommendations in Chapter 5.

2 Developments in policy and legislation

2.1 Introduction

Crop protection is applied to keep the crops healthy to guarantee a high level of yield per ha of high-quality products. High levels of yield contribute to food security and sufficient income for the farmer. Since it became apparent that the use of chemical plant protection products caused harm to the environment and human health, and the market mechanism was not able to regulate this properly, legislation has been developed to protect both the environment and human health.

In this chapter we briefly describe the legal framework in the EU and the Netherlands dealing with crop protection and ongoing developments that shape future directions. In Section 2.2 we discuss the existing EU legal framework and ongoing developments in crop protection policy, with major attention to the Farm to Fork Strategy (F2F). Furthermore, we pay attention to legislation about biocontrol and phytosanitary policy. In Section 2.3, we discuss the Dutch crop protection legislation and policy. Finally, we conclude in Section 2.4 with the implications for the greenhouse horticulture.

2.2 EU legislation and Policy

The EU legal Framework for crop protection

The core of the European legal framework regulating crop protection in the EU consists of two regulations and one directive:

1. Regulation (EC) No 1107/2009 contains the principles and guidelines for placement in the market of Plant Protection Products (PPPs). This regards both chemical plant protection products, and plant protection products from natural origin and microbes. The objective of this regulation is to protect humans, animals, and the environment against negative side effects of PPPs use and to safeguard the competitiveness of the European agriculture acting in a global market. The evaluation of PPPs is both hazard-based and risk-based. The hazard-based approach implies that the product should not have any of the following criteria (Annex II, art. 3.6 and 3.7):
    a. Persistent organic pollutants
    b. PBTs (Persistent, Bioaccumulative and Toxic)
    c. vPvB (very Persistent and very Bioaccumulative)
    d. CMR category 1 and 2 (can be carcogenetic, mutagenetic, or risks for Reproduction)
    e. Endocrine disruptors.

    If an active ingredient fulfils any of these five criteria, the evaluation procedure will terminate. If an active ingredient does not comply to any of these criteria, it will be subject to a risk assessment. Active ingredients that comply to the criteria of the risk assessment will be admitted. The decision about the approval of active ingredients is delegated by the EC to the Standing Committee on Plants, Animals, Food and Feed (SCoPAFF).

    Regulation (EC) No. 1107/2009 contains the option to classify active ingredients as Candidate for Substitution (CfS). CfSs are approved under this regulation and are considered to be safe. However, these substances have certain properties that indicate a relatively high risk for environment and human health. The criteria used to classify an active substance as a candidate for substitution are defined in Annex II (4) of this Regulation. Applications for products containing an active substance that has been classified as Candidate for substitution will be subject to a comparative assessment.
    The website of the Dutch Board for the Authorisation of Plant Protection Products and Biocidal Products (Ctgb) contains the following descriptions:

> ‘The aim of “comparative assessment and substitution” is to reduce risks by gradually replacing products containing substances that are appointed as candidates for substitution, by methods and products with a lower risk in order to benefit the protection of human or animal health and the environment. A comparative assessment with the alternative shall be performed to demonstrate whether it can be used with similar effect on the target organism and without significant economic and practical disadvantages to the user or not.
>
> [...]
> Alternatives can consist of other chemical products, but also of non-chemical agricultural practices. The Netherlands Food and Consumer Product Safety Authority (NVWA) advises the Ctgb on agricultural practices. If alternatives do exist, the corresponding use will no longer be authorized or renewed. A CfS will lose registration if at least five alternative products with different Mode of Actions (chemical and non-chemical methods) are available. Multiple modes of action are necessary to prevent the emergence of resistance of pests and diseases against plant protection products. Because the available products and agricultural practices can vary between countries, comparative assessment always takes place at the national level.’

If the outcome of a comparative assessment is that an alternative product or method (substitute) with an at least comparable efficacy is available for the product or one of its uses, then this substitution takes place after 3 years, unless the authorisation period of the corresponding active ingredient expires before this date. The comparative assessment does not include potential limitations in the use of potential alternative that may occur due to the Integrated Pest Management (IPM) applied or adverse effects on biocontrol agents applied.

The original list of CfSs (2015) contains 77 active ingredients. Until now, none of the comparative assessments has resulted in the replacement or ban of a CfSs. This implies that all CfSs are still approved in the Netherlands, with the exception of some active ingredients that have lost registration due the fact that they passed the expiration date and/or did not comply with the criteria of the risk assessment.

Active ingredients in general can lose their approval due to the following causes:

a. They passed the expiration date and no request for re-registration has been submitted by the manufacturer or wholesaler.
b. They did not comply with the criteria of the risk assessment. The risk assessment framework is continuously subject to adaptation on the basis of state of the art scientific information and data. Risk assessment criteria can be adjusted in the following ways:
   - New protection goals have been added
   - The protection goals have been adjusted.
   - New data on the characteristics of the substance have become available
c. In the case of renewal, the plant protection product doesn’t meet the actual criteria.

The approval procedure contains different tier levels. At lower tier levels the data requirements for approval of active ingredients are limited, but the criteria are conservative. If the active substance does not meet the criteria at the lowest tier level, additional data are required for assessment at higher tier level, which requires the applicant to do additional tests, increasing the costs and the lead time. The continuous adaptation of the risk framework forces more active ingredients to be assessed at higher tier levels.

2. Regulation (EC) No 396/2005 contains the procedure for definition of the Maximum Residue Levels (MRL) of plant protection products that are allowed on or in plants and animals and products from plant and animal origin to safeguard the health of humans that consume those products. The MRL of a plant protection product can be adjusted if there is reason to do so.

Furthermore Directive 2009/128/EC (Sustainable Use of pesticides Directive, (SUD)) provides guidelines for Member States of the EU to support the sustainable use of plant protection products. From 1 January 2014, farmers are obliged to apply the principles of IPM in accordance with the European Directive 2009/128 on the sustainable use of pesticides. Member States have implemented these guidelines in national action programmes.

Both regulations and the SUD have been recently evaluated. With respect to the Regulations 1107/2009 and 396/2005, the Commission reported to the European Parliament that stakeholders share the opinion that those regulations are among the strictest in the world. Both regulations are effective, but efficiency can be improved. Application of prescribed processes are delayed due to lack of sufficient capacity in the Member States. Improvement of these processes will contribute to the effectiveness and contribute to the realisation of the objectives of the Farm to Fork Strategy and Biodiversity Strategy by banning plant protection products that do not comply with the existing criteria for registration and by stimulating the use of low-risk plant protection products and non-chemical crop protection methods.

The evaluation of the Sustainable Use Directive (SUD) executed on behalf of the European Commission has resulted in the conclusion that both the effectiveness and the efficiency cannot be easily assessed due to lack of data and indicators measuring the relationship between measures and targets.

Farm to Fork Strategy
A new trend has been set by the European Green Deal that has been presented in 2020 to prevent climate change and environmental pollution and reduction of its impact. The sustainability of the food system has been elaborated in the Farm to Fork Strategy. This strategy contains objectives for crop protection: 50% reduction of the use and risk of chemical pesticides in 2030, and 50% reduction of the use of more hazardous pesticides (Candidates for Substitution) by 2030. The reduction of use and risk of plant protection products will be monitored at Member State (MS) level by the EU using the Harmonized Risk Indicator I. Harmonised Risk Indicators are defined in the Directive 2009/128/EC establishing a framework for Community action to achieve the sustainable use of plant protection products (the Sustainable Use Directive). These indicators are needed to measure progress in the reduction of the use and risk of pesticides for human health and the environment. The European Commission calculates these statistics for the EU, while MSs are expected to calculate the Harmonised Risk Indicators at national level. The data to be used for the calculations shall be statistical data collected in accordance with EU legislation concerning statistics on plant protection products, i.e. Regulation (EC) No 1185/2009 on plant protection product statistics, and other relevant data. The Harmonised Risk Indicator I divides plant protection products into the following four categories:

a. Group 1
   Low risk active ingredients which are approved or deemed to be approved under Article 22 of Regulation (EC) No 1107/2009, and which are listed in part D of the Annex to Regulation (EU) No 540/2011. Plant protection products in this category have a weighting factor of 1.
b. Group 2
   Active ingredients which are approved or deemed to be approved under Regulation (EC) No 1107/2009, and not falling in other categories and which are listed in part A and B of the Annex to Regulation (EU) No 540/2011. Plant protection products in this category have a weighting factor of 8.
c. Group 3
   Active ingredients which are approved or deemed to be approved under Article 24 of Regulation (EC) No 1107/2009, which are candidates for substitution and which are listed in part E of the Annex to Regulation (EU) No 540/2011. Plant protection products in this category have a weighting factor of 16.
d. Group 4
   Active ingredients which are not approved under Regulation (EC) No 1107/2009, and therefore are not listed in the Annex to Regulation (EU) No 540/2011. Plant protection products in this category have a weighting factor of 64.

The value of the Harmonised Risk Indicator can be calculated by summing up the volume in kg of the active ingredients of the plant protection products placed on the market.

In June 2022, a proposal of the Sustainable Use of pesticides Regulation (Regulation (EU) 2021/2115, (SUR)) has been presented by the European Commission. This Regulation is the successor of the SUD, but serves also as the legal instrument to implement the targets of the Farm to Fork Strategy. The SUR contains binding prescriptions for Member States. Under conditions, Member States can deviate from the prescribed reduction of 50%, but at EU level, the 50% reduction must be realised. Therefore, the European Commission has proposed reduction percentages for each Member States. The percentages have been based on the average weight of active ingredients applied per ha and the average reduction realised in the period 2011-2017. Since the Dutch agriculture is characterised by a high intensity (high yields per ha) and cash crops with a high value per ha, the plant protection product use per ha is relatively high. This is especially true for greenhouse horticulture, where production year-round takes place. Furthermore, the SUR proposed to ban the use of plant protection products in sensitive areas. The proposal is to forbid the use of pesticides in a buffer zone of 3 meters alongside surface water. However, the definition of sensitive areas is not clear. In more stringent interpretations, the Netherlands as a whole can be considered as a sensitive area. Currently, the proposed SUR is discussed in parliaments of the Member States and in the Council of the European Union. The Dutch Minister of Agriculture frequently informs the Dutch Parliament about the progress and the content of the debate about the SUR.

Availability of Plant Protection Products

The description of the crop protection policy and legislation does not indicate to what extent plant protection products will be available in the future. The European Pesticides Database contains the status of the pesticides since 2014. When we analyse the data it becomes apparent that 70% of the chemical active ingredients currently approved will pass the expiration date before 1 January 2027 (see Appendix 2). Since 2018, 82 chemical active ingredients lost approval. For 65% of those active ingredients that lost approval, renewal has not been requested; 35% did not meet the approval criteria. 38 chemical active ingredients have been renewed which is 32% of the expired chemical active ingredients. 11 chemical active ingredients have been approved for the first time in that period. 38 chemical active ingredients have the status pending, which means that the dossier is valid, but approval still needs to take place. On the basis of these data, it is likely that the number of available chemical active ingredients will reduce with 37 to 48%, in the coming 4 years, dependent on the extent to which active ingredients will be approved and the approval of new chemical active ingredients will take place, and provided that no delay in the reassessment will take place. Assumed that 75% of the reassessed micro-organisms will be renewed and all 26 pending micro-organisms will be approved, it is likely that the number of registered organisms will increase from 74 to 90 in the coming period. Although the number of new registrations of micro-organisms is higher than of chemical active ingredients, it is not sufficient to compensate the reduction in the total number of active ingredients that will be available towards 2030, so a reduction of 25 to 30% in the available active ingredients in the coming 4 years is expected.

Biological control

The following definition is used in the SUR for 'biological control'. 'Biological control' means the control of organisms harmful to plants or plant products using natural means of biological origin or substances identical to them, such as micro-organisms, semiochemicals, extracts from plant products as defined in Article 3(6) of Regulation (EC) No 1107/2009, or invertebrate macro-organisms.

We have to distinguish between micro-organisms such as fungi and bacteria, semiochemicals, extracts from plant products and macro-organisms such as insects, mites and nematodes as they have different regulations.

The approval of micro-organisms as a plant protection product is subject to the same procedure as chemical plant protection products (Köhl, et al, 2019), which has led to very lengthy procedures (Frederiks and Wesseler, 2019). As such a need has been identified to update the regulatory scientific assessment procedure for microbials (Merten et al., 2020). In addition to its application as a plant protection product, micro-organisms can also be used for other claims which are regulated by other legislation. These micro-organisms are not plant protection products, but biostimulants. Legally, they have a separate position placed under fertilisers legislation.

Thus, recently, the EU adopted four new regulations, which take into account the specific characteristics of living agents in the approval procedure. The intention is to apply a procedure that is more fit-for-purpose and flexible. This legislation came into force on 22 November 2022, so it is too early to assess whether these intentions have been realised.

Furthermore, the shorter procedure implies that only relevant data are addressed, which requires less testing and shorter lead times. As a consequence the adjusted legislation will likely result in a shorter registration procedure if correctly implemented, and more targeted procedure for the approval of micro-organisms as biocontrol agent.

However, microbes are also classified in the HRI system, predominantly in risk category 2. Other microbes are classified in risk category 1 (low risk active substances). As microbes may need to be added on a regular basis as they act preventive to disease and the average dose of microbes is higher than of chemical plant protection products, this may increase the volume used and thus the amount of products used resulting in higher HRI I score. Some micro-organisms can also stimulate plant growth by reducing abiotic stress. These micro-organisms are not plant protection products, but biostimulants. Legally, they have a separate position within the fertilisers legislation.

The permission to apply macro-organisms is regulated at member state level. Macro-organisms that are listed in the annexes 8 and 9 of the Dutch Regulation Nature Conservation are free to use, both in protected cultivation and cultivation in the open field. For all other organisms, dispensation for use needs to be requested from the government. Only organisms that are not risky for plants and animals in nature and of which the likelihood that they will emerge as a pest is assessed to be minimal (RVO, n.d.). Such a risk assessment is especially important for exotic organisms, which can become invasive, once introduced.

Phytosanitary policy
Phytosanitary policy has been developed to prevent the introduction of exotic plant pests, diseases and weeds, which can have devastating consequences if the new environment contains host plants and environmental conditions that favour the establishment and spread of the organisms. The European Plant Health Law regulates the measures to prevent the introduction of quarantine organisms. Phytosanitary policy and management is important for greenhouse horticulture to prevent the emergence of new pests and diseases. However, zero-tolerance is an important phytosanitary principle. This implies that plants and plant products that are exported need to be free from pests, diseases and other organisms, such as biological control. This principle is at odds with the principles of biocontrol, which implies a balance between the pest and disease pressure on the one hand, and biological control on the other hand at a level that damage does not lead to economic losses. By consequence plants and plant products can contain low concentrations of pests, pathogens and biological control.

2.3 The Dutch Framework

In 2019, the Ministry of Agriculture has published her future vision on sustainable crop protection, towards resilient plants and cultivation systems, which has been developed in cooperation with the Ministry of Infrastructure and Water Management, Water Authorities, relevant private stakeholders and NGOs. The strategic objectives are:

1. Planting and cultivation systems are resilient
2. Agriculture, horticulture and nature are connected
3. Almost no emissions to the environment and almost no residues on products

On the basis of this vision, an execution programme has been elaborated in cooperation with involved stakeholders to realise these objectives. It contains a long list of activities to be undertaken by the stakeholders. It does not include quantitative targets with respect to plant protection product use and risk reduction which need to be achieved in 2030. It contains quantitative targets to reduce exceedance of plant protection product standards in surface water.

In line with Regulation (EC) No 1107/2009, the central government has adjusted the Law on Plant protection products and Biocides, containing guidelines for the registration of plant protection products, and the Authority of the Dutch Board for the Authorization of Plant Protection Products and Biocides to apply procedures. This law is currently under revision to make the legislation also applicable for private persons and to extend the legal basis for professional use of Plant Protection Products outside agriculture. However, one of the amendments made to the proposed adjustment, which has been accepted by the majority of the

Dutch Parliament, is to include limitations to the use of Candidates for Substitution: a reduction of 50% realised in 2025 and 95% in 2030 compared to the reference period 2015 – 2017 as applied in the Farm to Fork Strategy. These targets are more advanced than the Farm to Fork Strategy targets. The Dutch Minister of Agriculture is currently considering this amendment, and will soon come with a response on how to proceed.

2.4 Implications for Greenhouse Horticulture

The greenhouse horticulture is characterised by a high intensity cultivation on a limited area which can take place year-round due to the climate control in the greenhouse. This makes the request for registration of plant protection products for greenhouse crops less attractive compared to arable crops, which are cultivated at a larger scale, since the high costs for registration have to be compensated by sales with a lower volume. By consequence, less active ingredients are available for application in greenhouse horticulture. Since integrated pest management (IPM) is common practice in greenhouse horticulture, the application of plant protection products needs careful decision making to prevent disturbance of the balance in the crop protection strategy by biological control with macro-organisms and micro-organisms. This requires that sufficient selective active ingredients need to be registered for application in greenhouse horticulture crops to maintain the common practice of IPM. The analysis of the availability of active ingredients in the near future points at a significant reduction in the availability of chemical plant protection products in greenhouse horticulture due to more stringent criteria. The number of new introduction declines due to the application of those criteria, which results in longer lead times and higher registration costs. This reduction can partly be compensated by the increase in availability of low-risk active ingredients and biocontrol agents. However, since the efficacy of low risk products and biocontrol agents can be lower than of chemical plant protection products, the efficacy of all available modes of action might decrease.

Active ingredients need to be alternated to prevent resistance development and chemical and non-chemical plant protection products need to be applied in an integrated manner. Furthermore, if few modes of actions (both chemical plant protection products and non-chemical measures) are available, the risk of resistance development by the pest and pathogens is too high (Hawkins et al., 2019). In addition, costs of application of biocontrol agents (macro-organisms) is relatively high. Greenhouse growers will only be prepared to pay these costs if selective corrective chemical plant protection products are available to intervene if the efficacy of biocontrol is too low. If these corrective plant protection products will not be available, they are reluctant to apply biocontrol.

It can be expected that the greenhouse horticulture will be requested to contribute to the reduction of plant protection product use. This need to be realised by reducing the volume and replacement of active ingredients with active ingredients of a lower risk category, also because the high volume used per ha in greenhouse horticulture. The CBS reports more than 75 kg active ingredients per ha in Chrysanthemum and 40 kg per ha in Gerbera (CBS, 2022b).

In summary, the future perspective is that the number of available active ingredients will decline, that Dutch legislation will ban CfSs and that alternative crop protection methods will have to be used such as biocontrol, precision techniques and cultural control methods such as insect screens.

However, these methods take time to come to market. Furthermore, existing alternative plant protection products often have a lower efficacy, which can result in an increase of the applied volume of low risk or biological plant protection products. This increases the tension between the Farm to Fork Strategy objectives for crop protection, and the practical options for greenhouse growers to apply sustainable crop protection options.

3 Existing crop protection strategies in greenhouse horticulture

3.1 Introduction

The greenhouse horticulture deviates from cultivation in the open fields amongst others on the following aspects:

1. The cultivation space inside the greenhouse is physically separated from the outside environment. The greenhouse acts as a physical barriers against pests and diseases present in the outside environment.
2. The climate inside the greenhouse can be controlled on elements such as temperature, light and humidity, resulting in year-round production.

On the one hand, the greenhouse is a physical barrier for the entrance of pests and diseases. On the other hand, pests and diseases can survive inside the greenhouse, that would not survive outside. Cultivation on soilless growing media reduces the occurrence of soil bound pests and diseases. Finally, the controlled greenhouse climate and the physical barrier create favourable environmental conditions for crop protection options such as biocontrol with natural enemies. This provides the greenhouse growers with more options to protect plants against pests and diseases. The greenhouse horticulture has served as the nursery for the development and application of biological control. Biocontrol is currently commonplace in greenhouse horticulture. The application of biocontrol requires a careful crop protection strategy that needs to be elaborated sometimes even before the cultivation cycle starts, taking into account pests and diseases that need to be controlled. The application of biocontrol needs to start in time in order to get the desired balance between the biocontrol density and the pest and disease pressure. Furthermore, the grower has to consider the potential negative effects of plant protection products that will be applied to control other pests and diseases. In order to mitigate negative effects, the grower will reduce the application of chemical plant protection products as much as possible, according to the principles of integrated pest management.[4]

The basis for the impact assessment of the Farm to Fork Strategy has been provided by an in depth analysis of the crop protection of five case crops: tomato and cucumber are representatives of the vegetables, chrysanthemum and gerbera as representatives of the cut flowers, respectively cultivated in the soil and on substrate and *Phalaenopsis* as representative of the pot plants. In this chapter we will present the analyses for each of the case studies separately. Afterwards we will present the meta-analysis for the entire greenhouse horticulture in the Netherlands, taking into account the specific position of small crops.

The methodology applied for data collection is as follows. PPPs used for pest and diseases were identified via the farms participating in the Farm Accountancy Data Network (FADN). Furthermore, spraying advice lists of PPP suppliers Van Ieperen and Royal Brinkman have been used as well as feedback of experts. The number of active ingredients were identified by grouping the PPPs by active ingredients per pest and disease. The effects on biological control agents were identified by the information on spraying advice cards, as well as the digital databases of Koppert and Biobest. The analyses for each of the crops have been discussed with specialised advisors and with greenhouse growers during firm visits. Draft results have been discussed in a workshop with growers, advisors, researchers, representatives of branch organisations and suppliers.

The analysis of each of the case crops is structured as follows:

1. We start with an overview of the most important pests and diseases that need to be controlled for the crop, classified in taxonomic groups. If these pests and diseases cannot be controlled, economic damage in terms of yield and/or quality loss will occur. The overview presents the common names, the scientific names, the type of damage and the consequences such as yield loss, quality loss or mortality of the plants.
2. Afterwards, we analyse the availability of the plant protection products in the period towards 2030 based on information of the EU Pesticides database. For each of the pests and diseases, we list the number of

[4] https://food.ec.europa.eu/plants/pesticides/sustainable-use-pesticides/integrated-pest-management-ipm_en

available plant protection products that can be applied until 2027 based on the expiration date. An overview of all available active ingredients and plant protection products per pest and disease for each of the case crops is provided in Appendix 3.
3. In this overview, we also present the number of available plant protection products without adverse effects on biocontrol. If less than 5 plant protection products will be available, the figures are presented in Italics. The number of 5 is based on the criteria applied by the Ctgb in the comparative assessment of Candidates for Substitution to assess whether the CfS can be replaced. On the basis of this overview, an analysis is made which new bottlenecks can be expected in the near future.
4. Next, an overview is presented of alternative, non-chemical methods that can be applied for all pests and diseases.
5. In the next section, we discuss the existing and near future bottlenecks: the pests and diseases that are difficult to control because of the limited efficacious plant protection products and non-chemical crop protection methods that are allowed to apply.
6. We conclude the analysis with a final conclusion taking into account the existing and future availability of plant protection products and the existing availabilities of alternative crop protection measures taking into account their efficacy.

The analysis per crop is limited to conventional cultivation systems. Organic greenhouse horticulture is not included.

3.2 Tomato

3.2.1 Overview of existing pests and diseases in tomato

In the Netherlands, tomatoes are produced all year round in the greenhouses for the fresh market. It is a differentiated product and covers e.g. vine tomatoes, snack tomatoes and beef tomatoes. Tomatoes are cultivated in greenhouses on substrate, such as rockwool. The water is recirculated. Greenhouses are heated and large parts of the production receives artificial lighting.

Currently, the production of tomatoes in greenhouses can be affected by the pests and diseases of which an overview is presented in Table 3.1.

Table 3.1 *Most important pest and diseases in tomatoes*

Common name	Scientific name	Type of damage	Consequences
Aphids (mainly potato aphid)	*Macrosiphum euphorbiae; Myzus*	Honeydew on fruits; damage of leaves	Quality loss, yield loss
Obscure mealybug	*Pseudococcus viburni*	Honeydew on fruits; damage of leaves	Quality loss, yield loss
Leaf miners	*Liriomyza* spp.	Damage of leaves	Yield loss
golden twin-spot moth	*Chrysodeixis chalcites*	Damage of leaves and fruits	Yield loss
Spider mites	*Tetranychus urticae*	Damage of leaves	Yield loss
Tomato russet mite	*Aculops lycopersici*	Damage of leaves, stems and fruits	Yield loss, quality loss
South American tomato pinworm	*Tuta absoluta*	Damage of leaves and fruits	Yield loss
whiteflies: greenhouse whitefly & tobacco whitefly	*Trialeurodes vaporariorum; Bemisia tabaci*	Damage to leaves, honeydew on leaves and fruits, vector of viruses	Yield loss, quality loss
tomato bug	*Nesidiocorus tenuis*	Damage stems, flowers and fruits	Yield loss, quality loss
Gray mould	*Botrytis cinerea*	Damage, flower, fruits, leaves and stems	Yield loss, quality loss, plant mortality
Powdery Mildew	*Oidium neolycopersici; leveilula Taurica*	Damage of leaves	Yield loss
Late blight	*Phytophthora infestans*	Root rot and rot of stem, leaves and fruits	Yield loss, plant mortality
Pythium Damping-off	*Pythium aphanidermatum; Pythium ultimum; P. Irregulare*	Root rot and stem rot	Yield loss, plant mortality
crazy roots, hairy roots	*Agrobacterium rhizogenes*	Extensive root growth	yield loss, when roots block water supply also mortality
Bacterial wilt and canker of tomato	*Clavibacter michiganensis subsp. Michiganensis*	Damage of leaves, stems and fruits	Yield loss, the infected plant(s) needs to be destroyed (regulated non-quarantine pest in Europe)
Fusarium wilt	*Fusarium oxysporum; Fusarium solani*	Root rot, yellow leaves, mortality	Yield loss and mortality
Downy mildew	*Peronosporaceae spp.*	Damage flowers, leaves and fruits	Yield loss and mortality
Verticillium wilt	*Verticillium dahliae; Verticillium albo-atrum*	damage of leaves	Yield loss and mortality
viruses	*Tomato brown rugose fruit virus (*ToBRFV); Pepino mosaic virus (PepMV), Tomato leaf curl virus (TYLVC), Tomato chlorosis virus (ToCV), Tomato torrado virus (ToTV), Tomato spotted wilt virus (TSWV)	Damage of leaves and fruits	Yield losses and fruit quality, plant mortality

3.2.2 Overview of existing and near future potential availability of active ingredients registered for use in tomato production

In Table 3.2 and overview is presented of the number of active ingredients that will be available in the coming years to control pests and diseases in tomato production based on the expiration date. This table does not include the expected number of renewals or new introduction of active ingredients or micro-organisms. The number in brackets are active ingredients without a known effect on biological control agents. Numbers in italics indicate that less than five active ingredients (AI) are available when the registration is not renewed. This number is used as a critical number of modes of action to prevent resistance development. The table shows that most active ingredients will pass the expiration date before 2027.

Table 3.2 *Number of active ingredients currently registered that can be applied to control the listed pests and diseases in tomato production*

	2023	2024	2025	2026	2027>
Aphids and mealybugs	8(0)	6(0)	*4(0)*	*3(0)*	*1(0)*
Leaf miners	8(2)	7(2)	5(1)	*4(1)*	*4(1)*
golden twin-spot moth	8(4)	7(3)	5(2)	*2 (2)*	*2 (2)*
Spider mites	11(5)	9(5)	6(2)	*2(1)*	*1(0)*
Tomato russet mite	5(1)	5(1)	*4(1)*	*3(0)*	*2(0)*
South American tomato pinworm	6(3)	5(2)	*3(1)*	*1(1)*	*1(1)*
whiteflies: greenhouse whitefly & tobacco whitefly	14(7)	12(7)	7(3)	5(2)	*3(2)*
tomato bug	*4(0)*	*4(0)*	*4(4)*	*2(0)*	*0*
Gray mould	12(12)	8 (8)	*4 (4)*	*4 (4)*	*4 (4)*
Powdery Mildew	17(17)	16(16)	8(8)	*3(3)*	*3(3)*
Late blight	6 (6)	5 (5)	*2 (2)*	*2 (2)*	*2 (2)*
Pythium Damping-off	5 (5)	*4 (4)*	*1 (1)*	*1 (1)*	*1 (1)*
crazy roots, hairy roots	*1(1)*	*1(1)*	*0*	*0*	*0*
Bacterial wilt and canker of tomato	*0*	*0*	*0*	*0*	*0*
Fusarium wilt	*1(1)*	*1(1)*	*1(1)*	*1(1)*	*1(1)*
Downy mildew	*1(1)*	*1(1)*	*0*	*0*	*0*
Verticillium wilt	*0*	*0*	*0*	*0*	*0*
Pepino Mozaic virus	*2(2)*	*2(2)*	*2(2)*	*2(2)*	*2(2)*

3.2.3 Overview of biological control agents and alternative methods used against pests and plant diseases in tomato

In Table 3.3 an overview is presented of the biological control agents that can be applied to control the pests and diseases listed in Table 3.1. Since micro-organisms are registered under Regulation 1107/2009/EC, overlap exists between both tables. This has been visualised by presenting the microbial PPPs boldly.

Table 3.3 *Biological control agents and alternative methods in tomato plants. Bold biological control agents indicate that they are registered as microbial PPP*

	Biological control agents	Alternative methods specific for pest
potato aphid	B02 *Aphidius ervi* B03 *Aphidoletes aphidimyza* *Macrolophus pygmaeus* *Praon volucre* *Aphelinus abdominalus*	
Obscure mealybug	*Cryptolaemus montrouzieri* *Leptomastix epona* *Acerophagus maculipennis*	
Leaf miners	*Diglyphus isaea* ***Bacillus thuringiensis subsp. Kurstaki***	
Golden twin-spot moth	*Macrolophus pygmaeus* *Trichogramma achaeae* *Steinernema feltiae* ***Bacillus thuringiensis ssp. Kurstaki SA-11*** ***Bacillus thuringiensis subsp. Aizawai*** ***Bacillus thuringiensis subsp. Kurstaki***	Physical traps
Spider mites	A07 *Phytoseiulus persimilis* ***Beauveria bassiana ATCC74040***	
Tomato russet mite	***Beauveria bassiana ATCC74040***	

	Biological control agents	Alternative methods specific for pest
South American tomato pinworm	*Macrolophus pygmaeus* ***Bacillus thuringiensis subsp. Kurstaki***	Physical traps mass trapping with sex pheromones
whiteflies: greenhouse whitefly & tobacco whitefly	B05 *Encarsia formosa* (against greenhouse whitefly) B06 *Eretmocerus eremicus* (against tobacco whitefly) C02 *Macrolophus pygmaeus* ***Beauveria bassiana strain PPRI5339*** ***Beauveria bassiana ATCC74040*** ***Beauveria bassiana strain GHA*** ***Isaria fumosorosea Apopka strain 97*** ***Lecanicillium muscarium strain Ve6***	Physical traps
tomato bug		Tomato bug can be blown away from tops of tomato plant
Gray mould	***Bacillus amyloliquefaciens strain QST 713*** ***Bacillus amyloliquefaciens strain MBI 600*** ***Clonostachys rosea J1446*** ***Trichoderma atroviride strain SC1***	Decision Support System for Botrytis Less susceptible cultivars
Powdery Mildew	***Ampelomyces quisqualis strain AQ 10*** ***Bacillus amyloliquefaciens strain FZB42*** ***Bacillus amyloliquefaciens strain QST 713*** ***Bacillus amyloliquefaciens strain MBI 600*** ***Bacillus amyloliquefaciens subsp. Plantarum D747*** ***Bacillus pumilus QST 2808***	Partially resistent cultivars UV_C
Late blight	***Bacillus amyloliquefaciens strain FZB42*** ***Clonostachys rosea J1446***	
Pythium Damping-off	***Bacillus amyloliquefaciens strain QST 713*** ***Clonostachys rosea J1446*** ***Trichoderma asperellum strain T34***	
crazy roots, hairy roots	***Bacillus amyloliquefaciens strain QST 713***	hygiene/ cleaning during change of crops
Bacterial wilt and canker of tomato		Prevention by using tested and disinfected seeds and applyng strict hygiene measures in the greenhouse; remove infected plants.
Fusarium wilt	***Clonostachys rosea J1446***	Partially resistant cultivars/rootstocks
Downy mildew		
Verticillium wilt		Partially resistant cultivars and rootstocks
Viruses		Resistant cultivars (not available for all viruses) Partially resistant rootstocks (not available for all viruses) hygiene/ cleaning during change of crops Use skimmed milk to prevent virus spread in greenhouse crops preventive measures against white fly (and trips) (Vectors of some virus)

3.2.4 Current and near-future potential bottlenecks in tomato crop protection

On the basis of the overviews of tables 3.2 and 3.3, an analysis of existing and expected bottlenecks have conducted. The following pests and diseases are difficult to control:

- Tomato russet mite. Plant protection products based on five active ingredients are currently available. Four of them affect biological control agents. Spiromesifen and abamectin are allowed to be used respectively four or three times a year. The predatory mite *Pronematus ubiquitous* is currently tested for controlling tomato russet mite. It has recently been found that this tiny predator also reduces powdery mildew through direct consumption and probably induced plant defenses (Pijnakker et al., 2022). The efficacy needs further evaluation in large scale greenhouse trials.
- Bug *Nesidiocorus tenuis*. Only four active ingredients are currently available. All PPPs available can affect biological control agents including the predatory bug *Macrolophus pygmaeus,* which is used against whitefly, eggs and caterpillars of different moths, spider mites, aphids and leafminer larvae (polyphagous predator). Pre-establishment by other mirid bugs, such as *Dicyphus errans*, reduces the establishment of *N. tenuis (Mouratidis et al., 2022),* but further studies are needed to develop application in practice.
- No PPP are available for Bacterial wilt and canker of tomatoes. Preventive measures, such as clean and tested seeds are needed for diseases prevention.
- Few PPP available for diseases in rootzone:
  - For Pythium control there are only 5 active ingredients of which there are three microbes. The other two products both contain propamocarb as active ingredient, but also other active ingredients.
  - Phytophthora seems to have still 6 active ingredients available, of which 2 are microbials, but problems will occur since Aaterra is not registered to be used.
  - One PPP on the market against *Agrobacterium rhizogenes*
  - Fusarium: only Prestop (containing active ingredient: *Clonostachys rosea* J1446) currently approved.
  - Verticillium no treatments available
  - One PPP is registered to be used against Downy mildew.

When we analyse near Future potential problems, we identify the following worst-case scenarios:

- From 2025 onwards, there are less than five active ingredients left to treat pests without effect on biological control agents if the expiring active ingredients are not renewed.
- From 2026, there may only be few active ingredients left to be used against insects as Aphids and mealybugs, Leaf miners, golden twin-spot moth, Spider mites, Tomato russet mite, South American tomato pinworm if expiring active ingredients are not renewed.
- Currently, there is a temporary release of the use of the product Verimark® (active ingredient: cyantraniliprole) as other products to treat whiteflies also affect biological control agents in the greenhouse.[5] If this product is not renewed than there may be a problem for an integrated growing system after 2027.
- Botrytis might be a larger problem in the forthcoming years due to increased humidity and lower temperatures as a consequence of high energy costs if active ingredients are not renewed. One PPP, Switch is used when Botrytis is a real problem in the greenhouse, but has as expiration date 31-10-2023 and is a Candidate for Substitution. This will likely not be renewed.

3.3 Cucumber

3.3.1 Overview of existing pests and diseases in Cucumber

Cucumbers are all year round cultivated in greenhouses on substrate such as rockwool and in eco-cultivation in soil. The water is recirculated. Greenhouses are heated and artificial lightning is applied on part of the cultivated area. Currently, the production of cucumbers in greenhouses can be affected by the pests and diseases of which an overview is presented in Table 3.4.

[5] https://zoek.officielebekendmakingen.nl/stcrt-2022-15966.html, CTGB: https://toelatingen.ctgb.nl/nl/authorisations/15424

Table 3.4 *Most important pest and diseases in Cucumber plants*

Common name	**Scientific name**	**Type of damage**	**Consequences**
Aphids (mainly cotton aphid)	*Aphidoidea* *Aphis gossypii*	Honeydew on fruits, vector CABYV	Quality loss, yield loss
Leaf miners	*Liriomyza spp*	Damage of leaves	Yield loss
Caterpillar	*Lepidoptera*	Damage of leaves, stems, flowers and fruits	Quality- and yield loss
Whitefly	*Trialeurodes vaporariorum, Bemisia tabaci*	Damage of leaves, honeydew on leaves, vector diseases	Quality- and yield loss
Thrips, western flower thrips, onion thrips	*Thysanoptera,* *Frankliniella occidentalis* *Thrips tabaci* *Echinothrips americanus*	Damage of leaves and fruits, vector diseases	Quality- and yield loss
Spider mite	*Tetranychus urticae*	Damage of leaves	Quality- and yield loss
Plant bug (wants)	*Nezara viridula, Lygus rugulipennis, Lygoris pabulinus, Liocoris tripustulatris*	Damage on fruits, leaves and stems	Quality and yield loss
Gummy stem blight, Mycosphaerella	*Didymella bryoniae*	Damage of leaves, fruits and stems, malformations of fruits	Quality- and yield loss
Grey mould	*Botrytis cinerea*	Damage of fruits, stems, leaves and flowers	Quality- and yield loss
Fusarium wilt	*Fusarium oxysporum*	Damage of leaves, fruits, stems and flowers	Quality- and yield loss
Powdery mildew	*Sphaerotheca spp, Erysiphe spp.*	Damage of leavesand stems	Quality- and yield loss
Downy mildew	*Pseudoperonospora cubensis*	Damage of leaves, mortality	Yield loss
Damping-off	*Pythium spp.*	Root- and stem rot, mortality	Yield loss
Crazy (hairy) roots disease	*Rhizobium rhizogenes (formerly Agrobacterium)*	Extensive root growth, oxygen shortage	Yield loss, sometimes quality loss
Belly rot	Rhizoctonia solani	Damage of fruits, leaves, roots and stems	Quality- and yield loss
Phytophthora blight	*Phytophtera capsici*	Rot of fruits, leaves, stems, roots and calyx, mortality	Quality- and yield loss
Viruses	*CABYV, CGMMV, BPYV, CMV, ZYMV, TNV, MNSV, CPFVd**	Mortality	Yield and quality loss

* CABYV Cucurbit Aphid-Borne Yellow Virus, CGMMV Cucumber Green Mottle Mosaic Virus, BPYV Beet Pseudo Yellow Virus, CMV Cucumber Mosaic Virus, ZYMV Zucchini Yellow Mosaic Virus, TNV Tobacco Necrosis Virus, MNSV Melon Necrotic Spot Virus, CPFVd Cucumber Pale Fruits Viroid.

3.3.2 Overview of existing and near future potential availability of active ingredients registered for use in cucumber production

In Table 3.5 and overview is presented of the number of active ingredients that will be available in the coming years to control pests and diseases in cucumber production based on the expiration date. This table does not include the expected number of renewals or new introduction of active ingredients or micro-organisms. The number in brackets are active ingredients without a known effect on biological control agents. Numbers in italics indicate that less than five active ingredients (AI) are available when the registration is not renewed. The table shows that most active ingredients will pass the expiration date before 2027.

Table 3.5 *Number of active ingredients currently registered that can be applied to control the listed pests and diseases in cucumber production*

	2023	2024	2025	2026	2027>
Aphids	10 (7)	7 (5)	*4 (3)*	*3 (2)*	*1 (0)*
Leaf miner	5 (3)	*4 (2)*	*4 (2)*	*3 (1)*	*3 (1)*
Caterpillar	10 (5)	9 (4)	7 (3)	*2 (0)*	*2 (0)*
Spider mite	9 (3)	7 (2)	5 (1)	*3 (1)*	*1 (1)*
Whitefly	17 (7)	14 (5)	8 (3)	6 (2)	*3 (0)*
Thrips	11 (8)	10 (7)	6 (4)	*4 (2)*	*2 (1)*
Plant bug	5 (4)	*4 (3)*	*4 (3)*	*2 (2)*	*0 (0)*
Grey mould	8 (8)	5 (5)	*2 (2)*	*1 (1)*	*1 (1)*
Powdery Mildew	19 (19)	18 (18)	9 (9)	*4 (4)*	*4 (4)*
Gummy stem blight, Mycosphaerella	7 (7)	6 (6)	*3 (3)*	*2 (2)*	*2 (2)*
Damping off	7 (7)	6 (6)	*2 (2)*	*1 (1)*	*1 (1)*
Fusarium wilt	*4 (4)*	4 (4)	*1 (1)*	*1 (1)*	*1 (1)*
Downy Mildew	*2 (2)*	*2 (2)*	*0 (0)*	*0 (0)*	*0 (0)*
Belly rot (Rhizoctonia)	*1 (1)*	*1 (1)*	*1 (1)*	*1 (1)*	*1 (1)*
Phytophthora blight	*1 (1)*	*1 (1)*	*1 (1)*	*1 (1)*	*1 (1)*
Crazy (hairy) roots disease	*1(1)*	*1(1)*	*0 (0)*	*0 (0)*	*0 (0)*

3.3.3 Overview of biological control agents and alternative methods used against plant diseases in cucumber

In Table 3.6 an overview is presented of the Biological control agents that can be applied to control the pests and diseases listed in Table 3.4. Since micro-organisms are registered under Regulation 1107/2009/EC, overlap exists between both tables. This has been visualised by presenting the microbial PPPs boldly.

Table 3.6 *Biological control agents and alternative non-chemical methods for pest and diseases in Cucumber. Bold biological control agents indicate that are registered as microbial PPP*

Common name	Biological control agents	Alternative methods specific for pest
aphids	*B01 Aphidius colemani* *B03 Aphidoletes aphidimyza* Ladybugs *Orius majusculus* *Micromus angulatus* *Adalia bipunctata* *Propylea quatuordecimpunctata* *Episyrphus balteatus* *Eupeodes corollae* *Sphaerophoria rueppellii* *Chrysoperla carnea*	
Leaf miners	*B04 Diglyphus isaea*	
Caterpillar, including golden twin-spot moth	*Trichogramma achaeae* *Orius majusculus* *Steinernema feltiae* ***Bacillus thuringiensis subsp. Kurstaki*** ***Bacillus thuringiensis subsp. Aizawai***	Physical traps mass trapping with sex pheromones
Whitefly	*A01 Amblydromalus limonicus* *A03 Amblyseius swirskii* *A09 Transeius montdorensis* *B05 Encarsia formosa (against Trialeurodes vaporariorum)* *B06 Eretmocerus eremicus (against Bemisia tabaci)* *C01 Delphastus pusillus* *Macrolophus pygmaeus Mirical* ***Beauveria bassiana strain GHA***	reset at plant change silicon polymers (Protac SF) Physical traps

Common name	Biological control agents	Alternative methods specific for pest
	Beauveria bassiana PPRI 5339 ***Lecanicillium muscarium strain Ve6*** ***Beauveria bassiana ATCC74040*** ***Isaria fumosorosea Apopka strain 97***	
Thrips	*A01 Amblydromalus limonicus* *A03 Amblyseius swirskii* *A04 Macrocheles robustulus (only in soil)* *A08 Stratiolaelaps scimitus (only in soil)* *A09 Transeius montdorensis* *C03 Orius majusculus* *Franklinothrips vespiformis (against Echinothrips)* *Neoseiulus cucumeris* ***Beauveria bassiana strain GHA*** ***Beauveria bassiana PPRI 5339***	reset at plant change
Spider mite	*A05 Neoseiulus californicus* *A07 Phytoseiulus persimilis* *B07 Feltiella acarisuga* ***Beauveria bassiana ATCC74040***	reset at plant change
Plant bug (wants)	*Trissolcus basalis (egg parasitoid of Nezara viridula)*	insect screens light traps against *Lygus rugulipennis*
Gummy stem blight, Mycosphaerella	***Trichoderma asperellum st. T34*** ***Clonostachys rosea J1446***	prevention high humidity
Grey mould	***Clonostachys rosea J1446*** ***Bacillus amyloliquefaciens strain QST 713*** ***Bacillus amyloliquefaciens subsp. Plantarum strain D747*** ***Pythium oligandrum strain M1***	prevention high humidity
Fusarium wilt	***Trichoderma asperellum st. T34*** ***Bacillus amyloliquefaciens strain QST 713*** ***Clonostachys rosea J1446*** ***Streptomyces K61***	
Powdery mildew	***Bacillus amyloliquefaciens subsp. Plantarum strain D747*** ***Ampelomyces quisqualis strain AQ10*** ***Bacillus pumilus QST*** ***Bacillus amyloliquefaciens strain FZB42*** ***Pythium oligandrum strain M1***	resistant cultivars UV-C
Downy mildew		prevention of high humidity
Damping-off	***Trichoderma asperellum st. T34*** ***Clonostachys rosea J1446*** ***Bacillus amyloliquefaciens strain QST 713*** ***Streptomyces K61*** ***Trichoderma harianum Rafai strain T-22***	Prevention of high temperatures of the irrigation water
Crazy (hairy) roots disease	***Bacillus amyloliquefaciens strain QST 713***	hygiene/ cleaning during change of crops
Belly rot	***Clonostachys rosea J1446***	
Phytophthora blight	***Clonostachys rosea J1446***	
Viruses		partial resistant cultivars hygiene/ cleaning during change of crops Use skimmed milk to prevent spread in greenhouse of viruses that are mechanically transferable preventive measures against aphids, whiteflies and thrips (Vectors of several viruses)

3.3.4 Current and near-future potential bottlenecks in cucumber crop protection

On the basis of the overviews of Tables 3.5 and 3.6, an analysis of existing and expected bottlenecks have conducted. The following pests and diseases are difficult to control:

1. Current bottlenecks, specific pests or diseases
    a. Aphids. The current active ingredients pirimicarb and flonicamid have resistance problems and the effect of the treatment has reduced effect on Myzus persicae. Especially the cotton Aphid has an exponential development that biological predators can’t keep up with and virus infected aphids can quickly infects plants, which can be an infection source for other aphids. A virus infection (e.g. CABYV) has a destructive impact on plants. The crop protection product Verimark, with active ingredient cyantraniliprole, is by exemption allowed in 2022 till 2027 for aphid extermination. The active ingredient has limited negative impact on biological predators. Limitations of maximum use per year and a different application method then prescribed of a crop protection products, effects a complete removal of the aphids. The most of the active ingredients have negative impacts on the lifestyle of biological predators.
    b. Caterpillar. Insect mesh works well against the entry of moths, but it is a considerable investment and reduces the ventilation capacity of the greenhouse. If moths and butterflies are in the glasshouse, combatting them is difficult. Problems with moths and caterpillars occur mostly in summer and autumn.
    c. Mycosphaerella, Botrytis. Because of the increasing costs of fossil energy, the climate becomes more moisture and diseases like Mycosphaerella appear easily. Mycosphaerella infected cucumbers are not always detected at processing and slip into the supply chain.
    d. Fusarium wilt, Downy Mildew, belly rot, Phytophthora blight and Crazy (hairy) are root diseases. Less than 5 active ingredients are available from 2023 onwards.

When we analyse near Future potential problems, we identify the following worst-case scenarios:

a. For Leaf miner and plant bugs from 2024 less than 5 active ingredients available if all expiring active ingredients are not renewed. For aphids, Botrytis, Mycospaerella and Pythium less than 5 active ingredients are available from 2025 onwards when registration of active ingredients are not renewed.
b. Four active ingredients are classified as Candidates for Substitution, fludioxonil, cyprodinil, difenoconazole in 2023 and pirimicarb in 2024. No renewal of these substances is expected after expiration. Expiration of products causes less availability of active ingredients besides Candidates for Substitutions.
c. Active ingredients have restrictions in maximum use per year, with reducing active ingredients, more pressure on existing ingredients with increasing risks for resistance.
d. Efficacy of low risk/biological PPPs is mostly lower than traditional chemical products, more applications are needed for effective pest control. The same effect as from chemical. In registration applications of wider effective crop protection products are registered for other pests then present. These alternative registrations cause an incorrect view on used crop protection products and present pests.

3.4 Gerbera

3.4.1 Overview of existing pests and diseases in Gerbera

Gerberas are grown in greenhouses on substrate such as rockwool and mainly applied in bouquets. Greenhouses are heated and artificial lightning is applied. The water is recirculated. A cultivation cycle takes two or three years. The production of gerberas in greenhouses can be affected by the pests and diseases of which an overview is presented in Table 3.7.

Table 3.7 *Overview of important pests and diseases in Gerbera*

Common name	**Scientific name**	**Type of damage**	**Consequences**
Whiteflies	*Trialeurodes vaporariorum; Bemisia tabaci*	Damage to leaves, honeydew on leaves	Yield loss
Thrips	*Frankliniella occidentalis; Echinothrips americanus*	Flower damage (western flower thrips) leaf damage	Quality loss, yield loss
Aphids	*Aphidoidea*	Honeydew on plant; damage of leaves	Quality loss, yield loss
Leaf miners	*Liriomyza* spp.	Damage of leaves	Quality loss, yield loss
Caterpillars including golden twin-spot moth	*Chrysodeixis chalcites* *Duponchelia fovealis* *Clepsis spectrana* *Cacoecimorpha pronubana*	Damage of leaves, roots and flowers	Quality loss, yield loss
Spider mites	*Tetranychus urticae; Tetranychus cinnabarinus*	Damage of leaves	Quality loss, yield loss
Thread-footed mites (Tarsonemid mites)	*Tarsonemidae spp*	Damage leaves and flowers	Quality loss, yield loss
Non-native earwig	Euborellia annulipes	Damage flowers	Quality loss, yield loss
Fungus gnats	*Sciaridae spp.*	Wilting of plants, growth problems, mortality	Quality loss, yield loss, mortality
Slugs	*Gastropoda spp.*	Damage of roots and leaves	Quality- and yield loss
Gray mould	*Botrytis cinerea*	Damage to flower	Quality- and yield loss
Powdery Mildew	*Spaerotheca fusca*	Damage of leaves	Yield loss
Late blight	*Phytophthora cryptogea*	Root rot and crown rot	Yield loss, plant mortality
Pythium Damping-off	*Pythium ultimum*	Root rot and stem rot	Yield loss, plant mortality
Rhizoctonia root rot	*Rhizoctonia solani*	Wilting of plants and mortaility	Yield loss, plant mortality
Fusarium wilt	*Fusarium oxysporum, Fusarium solani, Fusarium proloferatum*	Root rot, Yellow leaves, mortality	Yield loss and mortality
Downy mildew	*Peronosporaceae spp.*	Damage flowers, leaves and fruits	Yield loss and mortality
Rust	*Puccinia spp.*	Damage leaves	Yield loss
White mould	*Sclerotinia sclerotiorum*	Stem rot	Yield loss

3.4.2 Overview of existing and near future potential availability of active ingredients registered for use in Gerbera

Table 3.8 presents an overview of the number of active ingredients that will be available in the coming years to control pests and diseases in production of gerberas based on the expiration date. This table does not include the expected number of renewals or new introduction of active ingredients or micro-organisms. The number in brackets are active ingredients without a known effect on biological control agents. Numbers in italics indicate that less than five active ingredients (AI) are available when the registration is not renewed. The table shows that most active ingredients will pass the expiration date before 2027.

Table 3.8 *Number of active (combined) substances currently registered that can be applied to control the listed pests and diseases in Gerbera*

	2023	2024	2025	2026	2027>
Whitefly	20(8)	16(8)	8(4)	5(3)	*2(2)*
thrips	14(6)	11(6)	8(5)	5(4)	*3(3)*
Aphids	16(5)	12(4)	6(2)	*3(1)*	*0(0)*
leaf miner	7(2)	5(2)	*3(2)*	*1(1)*	*1(1)*
Caterpillars including golden twin-spot moth	10(7)	8(7)	5(5)	*2(2)*	*2(2)*
Spider mite	14(7)	10(5)	7(3)	*2(2)*	*0(0)*
Thread-Footed Mites	12(5)	9(4)	6(3)	*2(2)*	*0(0)*
non-native earwig	0	0	0	0	*0*
Fungus gnats	0	0	0	0	*0*
slugs	*2(2)*	*2(2)*	*1(1)*	*1(1)*	*1(1)*
Gray mould	8(8)	5(5)	*3(3)*	*2(2)*	*2(2)*
Powdery Mildew	16(15)	15(14)	9(8)	5(4)	5(4)
Late Blight	7(7)	*4(4)*	*0*	*0*	*0*
Pythium Damping-off	7(7)	5(5)	1(1)	*0*	*0*
Rhizoctonia root rot	*4(4)*	*4(4)*	1(1)	0	*0*
Fusarium wilt	*4(4)*	*4(4)*	1(1)	0	*0*
Downy mildew	*2(2)*	*2(2)*	*0*	*0*	*0*
Rust	*2(2)*	*2(2)*	*0*	*0*	*0*
White mould	*4(4)*	*3(3)*	*1(1)*	1(1)	*1(1)*

3.4.3 Overview of biological control agents and alternative methods used against plant diseases in Gerbera

In Table 3.9 an overview is presented of the Biological control agents that can be applied to control the pests and diseases listed in Table 3.7. Since micro-organisms are registered under Regulation 1107/2009/EC, overlap exists between both tables. This has been visualised by presenting the microbial PPPs boldly.

Table 3.9 *Biological control agents and alternative methods in Gerbera plants. Bold biological control agents indicate that they are registered as microbial PPP*

Common name	Biological control agents	Alternative non-chemical methods
Whiteflies	*A01 Amblydromalus limonicus* *A03 Amblyseius swirskii* *A09 Transeius montdorensis* *B05 Encarsia formosa* *B06 Eretmocerus eremicus* *C01 Delphastus pusillus* ***Beauvaria bassiana strain PPRI5339*** ***Beauveria bassiana ATCC74040*** ***Beauveria bassiana strain GHA*** ***Isaria fumosorosea Apopka strain 97*** ***Lecanicillium muscarium strain Ve6***	
thrips	*A01 Amblydromalus limonicus* *A03 Amblyseius swirskii* *A04 Macrocheles robustulus* *A06 Neioseiulus cucumeris* *A08 Stratiolaelaps scimitus* *A09 Transeius montdorensis* *C03 Orius laevigatus* *D02 Steinernema feltiae* *Orius majusculus* *Franklinothrips vespiformis (only against Echinothrips)(* ***Beauveria bassiana strain PPRI5339*** ***Lecanicillium muscarium strain Ve6***	

Common name	Biological control agents	Alternative non-chemical methods
Aphids	*B01 Aphidius colemani* *B02 Aphidius ervi* *B03 Aphidoletes aphidimyza* *Orius majusculus* *Micromus angulatus* *Adalia bipunctata* *Propylea quatuordecimpunctata* *Episyrphus balteatus* *Eupeodes corollae* *Sphaerophoria rueppellii* *Praon volucre* *Aphelinus abdominalus* *Chrysoperla carnea*	
Leaf miners	B04 Diglyphus isaea	
Caterpillars including golden twin-spot moth	*D01 Steinernema carpocapsae* *Trichogramma achaeae (against Chrysodeixis chalcites)* *Orius majusculus* *A08 Stratiolaelaps scimitus (against Duponchelia)* ***Bacillus thuringiensis ssp. Kurstaki SA-11*** ***Bacillus thuringiensis subsp. Aizawai*** ***Bacillus thuringiensis subsp. Kurstaki***	light traps insect screens
Spider mites	*A07 Phytoseiulus persimilis* *B07 Feltiella acarisuga* *Neoseiulus californicus* ***Beauveria bassiana strain GHA***	
Thread-footed mites (weekhuidmijt)	*Phytoseiid predatory mites* ***Beauveria bassiana strain GHA***	
non-native earwig		Dry root environment
Fungus gnats	*Dalotia coriaria (previous name: Atheta coriaria)* *Stratiolaelaps scimitus (old name: Hypoaspis miles)* *Steinernema feltiea* *Macrocheles robustulus*	
slugs		
Gray mould	***Bacillus amyloliquefaciens*** ***Bacillus pumilus QST 2808***	
Powdery mildew	***Bacillus amyloliquefaciens*** ***Bacillus amyloliquefaciens strain QST 713*** ***Bacillus pumilus QST 2808***	UV_B (Leiss et al., 2022), UV-C
Late blight		
Pythium Damping-off	***Bacillus amyloliquefaciens strain QST 713*** ***Streptomyces K61 (previous name: S. griseoviridis)*** ***Trichoderma Asperellum strain T34*** ***Trichoderma harzianum Rifai strain T-22***	
Rhizoctonia root rot	***Bacillus amyloliquefaciens strain QST 713*** ***Trichoderma harzianum Rifai strain T-22***	
Fusarium wilt	***Trichoderma Asperellum strain T34*** ***Streptomyces K61 (formerly S. griseoviridis)*** ***Bacillus amyloliquefaciens strain QST 713*** ***Trichoderma harzianum Rifai strain T-22***	
Downy mildew		
Rust		
white mould	***Bacillus amyloliquefaciens***	

3.4.4 Current and near-future potential bottlenecks in plant protection

On the basis of the overviews of Tables 3.8 and 3.9, an analysis of existing and expected bottlenecks have conducted. The following pests and diseases are difficult to control:

- Non-native earwig has no curative treatment available and no biological control agents. A dried root environment can be used preventive.
- Sciarid flies can only be treated by biological control agents. So there is no curative treatment available.
- Chemical PPP against whiteflies also kills biological control agents when these are used as a reset of whiteflies.
- There are only 4 active ingredients registered to treat Sclerotinia. One of these active ingredients (difenoconazole) is a candidate of substitution that will expire in 2023.
- There are only 4 active ingredients registered to treat Fusarium and these are all microbials. There are no chemical PPP left for a curative treatment.
- There are only 4 active ingredients registered to treat Rhizoctonia of which 2 are microbial PPP and 2 are chemical PPP.
- Puccinia can be treated with 2 active ingredients.
- Downy Mildew can be treated with 2 active ingredients.
- Leaf miners, Aphids, and thread-footed mites, there are currently only 5 active ingredients without effects on biological control agents.

When we analyse near future potential problems, we identify the following worst-case scenarios:

- From 2025, there are less than five active ingredients left to treat pests without effect on biological control agents if the expiring active ingredients are not renewed.
- From 2026, there may only be few active ingredients left to be used against insects as whiteflies, thrips, aphids, spider mites, thread-footed mites, leaf miners, and caterpillars if expiring active ingredients are not renewed.
- three active ingredients are left in 2025 to treat Botrytis if expiring active ingredients are not renewed. The expiring PPP Switch (2 active ingredients: cyprodinil, fludioxonil) is a Candidate of Substitution that will expire in 2023.
- In 2024 only 4 active ingredients are left to treat Phytophthora if expiring active ingredients are not renewed. In addition, the frequency of application is rather low.
- In 2025 only 1 active ingredient (*Trichoderma harzianum* Rifai strain T-22) is left to treat Pythium when expiring active ingredients are not renewed.
- For Caterpillars, there are only 2 active ingredients left in 2026 if expiring active ingredients are not renewed. Two of the expiring active ingredients (one in 2023 and one in 2024) are a candidate of substitution and will likely not be renewed (AS are respectively Esfenvalerate and Methoxyfenozide).

3.5 Chrysanthemum

Contrary to gerberas, chrysanthemums are grown in the soil. A cultivation cycle takes approximately ten weeks. Each week part of the flowers are harvested and young plants planted. By consequence each stadium of the flowers is always present in the greenhouse. The greenhouses are heated and artificial lightning is applied. The production of chrysanthemums can be affected by the pests and diseases of which an overview is presented in Table 3.10.

3.5.1 Overview of existing pests and diseases in Chrysanthemum

Table 3.10 *Pest and diseases in Chrysanthemum*

Common name	Scientific name	Type of damage	Consequences
Aphids	*Aphis gossypii., Myzus persicae, Macrosiphum euphorbiae, Aulcortum solani, Macrosiphoniella sanborni, Brachycaudus helichrysi*	Honeydew on leaves, damage growth points and flowers	Quality loss, yield loss
Leaf miners	*Liromyza trifolii, Liriomyza huidobrensis, Chromatomyia syngenesiae*	Damage of leaves and flowers	Quality- and yield loss
Caterpillar	*Noctuidae, Geometridae, Totricidae*	Damage of leaves, stems and flowers	Quality- and yield loss
Whitefly	*Trialeurodes vaporariorum*	Honeydew on leaves	Quality- and yield loss
Thrips, western flower thrips, onion thrips	*Thysanoptera Frankliniella occidentalis Thrips tabaci*	Malformations and scars, silver spots, flower damage, transmission of TSWV	Quality- and yield loss
Spider mite	*Tetranychus urticae*	Spider webs, yellow-silver spots	Quality- and yield loss
True bugs	*Lygus rugulipennis, Lygoris pabulinus, Liocoris tripustulatris*	Damage of leaves and flowers, malformations	Yield loss
Slug and snails	*Gastropoda*	Damage of roots and leaves	Quality- and yield loss
Nematodes (e.g. root knot nematodes, root lesion nematodes)	*Pratylenchus spp., Radopholus similis, Aphelenchoides ritzemabosi, Meloidogyne spp.*	Root damage, leaves damage	Quality- and yield loss
Rust	*Puccinia spp.*	Damage of leaves	Yield loss
Root rot	*Pythium spp.*	Root and stem rot	Quality- en yield loss
Late Blight	*Phytophthora infestans*	Root and stem rot, mortality	Yield loss
Basal stem rot	*Rhizoctonia solani*	Root rot, mortality	Quality- and yield loss
Wilt and stem rot	*Fusarium oxysporum, Fusarium solani*	Root rot, mortality	Yield loss
Verticillium wilt	*Verticillium dahliae,*	Inhibited growth	Quality- and yield loss
Powdery mildew	*Sphaerotheca spp.*	White spots, leaves fall	Yield loss
Grey mould	*Botrytis fuckeliana*	Damage of flowers and leaves	Quality- and yield loss
Stem and crown rot	*Sclerotinia sclerotiorum*	Mortality	Yield loss
Bacteria	*Pseudomas cichorii, erwinia carotovora erwiia chrysanthemi, Agrobacterium tumefaciens*	Necrosis, mortality	Quality- and yield loss
Virus diseases	*CMV, INSV, TSWV, CCMVd, CSVd, CSNV, TAV, CVB**	Mortality	Yield loss

* CMV Cucumber Mosaic Virus, INSV Impatiens Necrotic Spot virus, TSVW Tomato Spotted Wilt Virus, CCMVd Chrysanthemum Chlorotic Mottle Viroid, CSVd Chrysanthemum Stunt Viroid, CSNV Chrysanthemum Stem Necrosis Virus, INSV Impatiens Necrotic Spot Virus, TAV Tomato Aspermy Virus, CVB Chrysanthemum Virus B.

3.5.2 Overview of existing and near future potential availability of active ingredients registered for use in Chrysanthemum production

In Table 3.11 an overview is presented of the number of active ingredients that will be available in the coming years to control pests and diseases in the production of Chrysanthemum based on the expiration date. This table does not include the expected number of renewals or new introduction of active ingredients or micro-organisms. The number in brackets are active ingredients without a known effect on biological control agents. Numbers in italics indicate that fewer than five active ingredients (AI) are available when the registration is not renewed. The table shows that most active ingredients will pass the expiration date before 2027.

Table 3.11 *Number of (combined) active ingredients currently registered that can be applied to control the listed pests and diseases in chrysanthemum production*

	2023	2024	2025	2026	2027>
Aphids	10 (1)	7 (1)	*5 (1)*	*2 (1)*	*0*
Leaf miner	9 (0)	6 (0)	*4 (0)*	*1 (0)*	*1 (0)*
Caterpillar	13 (5)	10 (5)	6 (3)	*1 (1)*	*1 (1)*
Spider mite	15 (6)	11 (5)	8 (4)	*3 (3)*	*1(1)*
Thrips	14 (4)	11 (4)	8 (3)	*3 (3)*	*2 (2)*
True bugs	7 (1)	*4 (1)*	*4 (1)*	*2 (0)*	*0*
Slugs and snails	*2 (2)*	*2 (2)*	*1 (1)*	*1 (1)*	*1 (1)*
Nematodes	*2 (0)*	*1 (0)*	*0*	*0*	*0*
Root rot	10 (9)	9 (9)	*3 (3)*	*1 (1)*	*1 (1)*
Rust	9 (9)	8 (8)	*3 (3)*	*2 (2)*	*1 (1)*
Late Blight	8 (7)	7 (7)	*2 (2)*	*1 (1)*	*1 (1)*
Basal Stem rot	6 (6)	6 (6)	*3 (3)*	*1 (1)*	*1 (1)*
Powdery Mildew	14 (14)	13 (13)	6 (6)	*4 (4)*	*4 (4)*
Grey Mould	11 (11)	7 (7)	*4 (4)*	*3 (3)*	*3 (3)*
Stem and crown rot	*1 (1)*	*1 (1)*	*0*	*0*	*0*
Verticillium wilt	*0*	*0*	*0*	*0*	*0*
Growth regulation	*1 (1)*	*1 (1)*	*0*	*0*	*0*

3.5.3 Overview of biological control agents and alternative methods used against pests and plant diseases in Chrysanthemum

In Table 3.12 an overview is presented of the Biological control agents that can be applied to control the pests and diseases listed in Table 3.10. Since micro-organisms are registered under Regulation 1107/2009/EC, overlap exists between both tables. This has been visualised by presenting the microbial PPPs boldly.

Table 3.12 *Overview of biological control agents and alternative methods available against pest and diseases in Chrysanthemum. Bold biological control agents indicate that they are registered as microbial PPP*

Common name	biological control agents	alternative methods
Aphids	*B03 Aphidoletes aphidimyza* *B01 Aphidius colemani* *Chrysoperla carnea* *Orius laevigatus* *Orius majusculus*	insect screens, steaming soil with remaining affected plant material with Aphids.
Leaf miners	*B04 Diglyphus isaea*	
Caterpillar	*D01 Steinernema carpocapsae* *D02 Steinernema feltiae* ***Bacillus thuringiensis subsp. Kurstaki*** ***Bacillus thuringiensis subsp. Aizawai***	insect screens
Whitefly	*A01 Amblydromalus limonicus,* *A03 Amblyseius swirskii,* *A09 Transeius montdorensis,* *B05 Encarsia formosa,* ***Beauvaria bassianna strain PPRI5339*** ***Beauveria bassiana ATCC74040*** ***Beauveria bassiana strain GHA*** ***Isaria fumosorosea Apopka strain 97*** ***Lecanicillium muscarium strain Ve6***	
Thrips	*A01 Amblydromalus limonicus* *A03 Amblyseius swirskii* *A04 Macrocheles robustulus* *A06 Neoseiulus cucumeris,* *A08 Stratiolaelaps scimitus* *A09 Transeius montdorensis*	steaming

Common name	biological control agents	alternative methods
	C03 Orius laevigatus *D02 Steinernema feltiae* ***Beauvaria bassiana GHA*** ***Beauvaria bassianna strain PPRI5339***	
Spider mite	*A05 Neioseiulus californicus* *A07 Phytoseiulus persimilis* *Neoseiulus cucumeris* ***Beauvaria bassianna strain PPRI5339***	Steaming soil with remaining affected plant material with Aphids
True bugs (wants)		insect screens
Slug and snails	*Phasmarhabditis californica (Nemaslug)*	Steaming soil with remaining affected plant material with Aphids
Nematodes		steaming
Rust	***Bacillus subtilis strain QST***	steaming
Root rot	***Trichoderma asperellum strain T34*** ***Streptomyces K61*** ***Bacillus subtilis strain QST*** ***Bacillus amyloliquefaciens strain FZB24*** ***Trichoderma harzianum Rifai strain T-22***	amino acids and peptides steaming
Late Blight	***Bacillus subtilis strain QST*** ***Bacillus amyloliquefaciens strain FZB24*** ***Trichoderma harzianum Rifai strain T-22***	amino acids and peptides steaming
Basal stem rot	***Bacillus amyloliquefaciens strain QST 713*** ***Bacillus amyloliquefaciens strain FZB24*** ***Trichoderma harzianum Rifai strain T-22***	steaming
Wilt and stem rot	***Streptomyces K61*** ***Trichoderma harzianum Rifai strain T-22***	steaming resistant cultivar
Verticillium wilt		steaming
Powdery mildew	***Bacillus amyloliquefaciens strain QST 713*** ***Bacillus amyloliquefaciens strain FZB24*** ***Bacillus pumilus QST 2808***	Steaming, UV_C
Grey mould	***Bacillus amyloliquefaciens strain QST 713*** ***Bacillus amyloliquefaciens strain FZB24*** ***Bacillus pumilus QST*** ***Trichoderma atroviride strain SC1***	
Stem and crown rot		steaming
Bacteria		
Virus diseases		

3.5.4 Current and near-future potential bottlenecks in plant protection

On the basis of the overviews of Tables 3.11 and 3.12, an analysis of existing and expected bottlenecks have conducted. The following pests and diseases are difficult to control:

a. Aphids. The current active ingredients have resistance problems with reduced effect for *Myzus persicae*. There are legal limitations to the maximum number of sprayings per year and most ingredients have possible impacts on lifestyle biological predators.
b. True bugs. Intervention with most active ingredients most likely also affects beneficial bugs such as Orius spp.
c. Slugs and snails. The origin of the pest is not clear, so prevention is difficult. Intervention with nematodes is possible but nematodes are not always available and have a lower efficacy. To reduce the number of slugs and snails requires a lot of granules with active ingredients. There are limitations on maximum use per year of the use of granules.
d. From 2025 the availability of active ingredients for control pests and diseases are limited if crop protection products are not renewed, less than 5 active ingredient per pest/disease per 2026 (yellow). For snails-slugs, nematodes Stem-crown rot and Verticillium wilt fewer than 5 active ingredients are available in 2023. There are 3 Candidates of Substitution which expire in 2023-2024 but alternatives are then still available. In registration applications of wider effective crop protection products are registered for other pests then present. These alternative registrations cause an incorrect view on used crop protection products and present pests.

When we analyse near future potential problems, we identify the following worst-case scenarios:

a. Active ingredients have restrictions in maximum use per year, from 2026 9 active ingredients have a maximum of 4 applications per year. With reducing active ingredients, more pressure on existing ingredients.
b. Control of nematodes The current crop protection product Vydate is a Candidate of Substitution and expire in 2024 and will not be renewed. Physical methods (e.g. steaming) is also possible, but often not enough.
c. Growth regulation is used to control the length and shape of Chrysanthemum, from 2025 the active ingredient is no longer available if not renewed.
d. Steam between crop cycles to control soil pathogens and thrips. Steaming with increasing costs of gas consumption besides disinfection and cleaning a planting area. Steaming also kills beneficial microbes in the soil and can form a window of opportunity for pathogens to establish if present in another corner in the greenhouse. Steaming will also most likely lead to an increased leaching of plant protection products to ground- and surface water due to a decreased degradation as degrading micro-organisms are killed.
e. LED instead of SON-T with less warming and de-humification with investments for diseases finds more presence, growers relay on chemicals for preventing diseases when crops becomes wet.
f. Weed control outside the glasshouse for preventing infection from direct surroundings.

3.6 *Phalaenopsis*

3.6.1 Overview of existing pests and diseases in *Phalaenopsis*

Phalaenopsis is a pot plant with a relative long cultivation cycle. The plants are grown on roller tables in transparent pots with bark as substrate. The water is recirculated. Greenhouses are heated and artificial lightning is applied. Currently, the production of *Phalaenopsis* in greenhouses can be affected by the pests and diseases of which an overview is presented in Table 3.13.

Table 3.13 *Pests and diseases in Phalaenopsis*

Common name	Scientific name	Type of damage	Consequences
Fungus gnats	Lyprauta spp.	Feeding damage	Yield loss
Mealy bug	*Planococcus citri* *Pseudococcus longispini*	Flower and leaf damage	Reduced ornamental value
Mite	*Tetranychidae, Tenuipalpus*	Feeding damage leaves and flowers	Quality and yield loss
Sciara flies	*Sciaridae*	Feeding damage	Quality and yield loss
Thrips	*Dichromothrips corbetti, Frankliniella occidentalis, Echinotrips americanus*	Deformity of buds, flowers and leaves	Quality and yield loss
Slugs	*Gastropoda*	Feeding damage	Quality and yield loss
Caterpillar	*Duponchelia, Noctuidae*	Feeding damage	Quality and yield loss
Grey mould	*Botrytis cinerea*	Spot on flowers	Quality and yield loss
Fusarium rot	*Fusarium oxysporum, Fusarium solani, Fusarium proliferatun*	Yellowing leaves	Quality and yield loss
Rhizoctonia	*Rhizoctonia solani*	Root damage	Quality and yield loss
Phytophthora rot	*Phytophthora cactorum*	Root rot and witling of young plants	Quality, yield loss and mortality
Pythium rot	*Pythium ultimum, Pythium debaryanum, Pythium splendens*	Root rot and witling of young plants	Quality, yield loss and mortality
Bacteria	*Acidovorax cattleyae*, Erwinia spp	Brown spots and soft rot	Loss of plants, yield loss
Virus diseases	Cymbidium Mosaic virus (CymMV) Odontoglossum Ringspot Virus (ORSV) Tomato Spotted Wilt Virus (TSWV), Impatiens Necrotic Spot Virus (INSV)	Mortality	Loss of plants, yield loss

3.6.2 Overview of existing and near future potential availability of active ingredients registered for use in *Phalaenopsis*

In Table 3.14 and overview is presented of the number of active ingredients that will be available in the coming years to control pests and diseases in *Phalaenopsis* production based on the expiration date. This table does not include the expected number of renewals or new introduction of active ingredients or micro-organisms. The number in brackets are active ingredients without a known effect on biological control agents. Numbers in italics indicate that less than five active ingredients (AI) are available when the registration is not renewed. The table shows that most active ingredients will pass the expiration date before 2027.

Table 3.14 *Number of active (combined) substances currently registered that can be applied to control the listed pests and diseases in Phalaenopsis*

	2023	**2024**	**2025**	**2026**	**2027>**
Mealy bug	6 (2)	*4 (2)*	*2 (1)*	*1 (1)*	*0 (0)*
Gnat larvae	*0*	*0*	*0*	*0*	*0*
Sciara flies	*2 (1)*	*0 (0)*	*0 (0)*	*0 (0)*	*0 (0)*
Mite	12 (5)	7 (3)	*4 (2)*	*1 (1)*	*0 (0)*
Thrips	14 (6)	11 (6)	8 (5)	6 (4)	*4 (3)*
Snails and slugs	*2 (1)*	*2 (1)*	*1 (1)*	*1 (1)*	*1 (1)*
Botrytis	8 (8)	*4 (4)*	*1 (1)*	*1 (1)*	*1 (1)*
Fusarium rot	*3 (3)*	*3 (3)*	*1 (1)*	*1 (1)*	*1 (1)*
Rhizoctonia	5 (5)	5 (5)	*2 (2)*	*1 (1)*	*1 (1)*
Phytophthora rot	7 (6)	5 (5)	*1 (1)*	*1 (1)*	*1 (1)*
Bacteria	*0*	*0*	*0*	*0*	*0*
Growth regulation	*4 (4)*	*2 (2)*	*1 (1)*	*1 (1)*	*0 (0)*
Pythium rot	6 (5)	5 (5)	*0*	*0*	*0*

3.6.3 Overview of biological control agents and alternative methods used against plant diseases in *Phalaenopsis*

In Table 3.15 an overview is presented of the Biological control agents that can be applied to control the pests and diseases listed in Table 3.13. Since micro-organisms are registered under Regulation 1107/2009/EC, overlap exists between both tables. This has been visualised by presenting the microbial PPPs boldly.

Table 3.15 *Overview of biological control agents and alternative methods against plant diseases in Phalaenopsis. Bold biological control agents indicate that they are registered as microbial PPP*

Common name	biological control agents	alternative methods
Gnat larvae (Pot worm)		dry root environment insect sheets
Mealy bugs	*Cryptolaemus montrouzieri (against mealy bugs)* *Anagyrus pseudococci* *Leptomastix dactylopii*	
Sciara flies	*A04 Macrocheles robustulus* *A08 Stratiolaelaps scimitus* *Steinernema feltiae* (Nemasys F) *Phasmarhabditis californica* (Nemaslug 2.0) ***Bacillus thuringiensis subs. Israelensis***	
Vanda thrips	***Beauveria bassiana strain GHA*** ***Beauveria bassiana strain PPRI5339***	
Slugs	*Phasmarhabditis californica* (Nemaslug 2.0)	
Grey mould	***Gliocladium catenalatum st. J1446*** ***Pythium oligandrum strain M1***	
Fusarium rot	***Bacillus amyloquefaciens str. QST 713*** ***Gliocladium catenalatum st. J1446*** ***Trichoderma asperellum strain T34***	
Rhizoctonia	***Bacillus amyloquefaciens str. QST 713*** ***Gliocladium catenalatum st. J1446*** ***Trichoderma harianum Rifai T-22***	
Phytophthora rot	***Bacillus amyloquefaciens str. QST 713*** ***Gliocladium catenalatum st. J1446***	
Pythium rot	***Gliocladium catenulatum strain J1446*** ***Bacillus amyloquefaciens str. QST 713***	
Bacteria		remove infested plant

3.6.4 Current and near-future potential bottlenecks in plant protection

On the basis of the overviews of Tables 3.14 and 3.15, an analysis of existing and expected bottlenecks have conducted. The following pests and diseases are difficult to control:

a. Gnat larvae. There is no crop protection product available for control.
b. Sciara flies. There are no crop protection products available.
c. Thrips. Predators have difficulties to survive in *Phalaenopsis* and are released several times.
d. Mealybugs. Several species of natural enemies are they are not always effective. Mealy bugs hide away in the plants and with their natural cover they are difficult to combat.
e. Rhizoctonia and bacteria are bottlenecks with low availability of crop protection products. Fusarium lost an important crop protection product Topsin-m-Ultra in 2021, cultivation measures and remaining crop protection products combat Fusarium.
f. Increasing costs of fossil use results in suboptimal climate.
g. There are restrictions on maximum use, although *Phalaenopsis* is not a very intensively treated crop for pests and diseases (if treatable). Because of possible measures (biological and prevention), restrictions of maximum use have little impact.
h. In 2023 9 crop protection products expire and in 2024 4 crop protection products.
i. Candidates for Substitution; Expiration dates of 5 CfS is in 2023 and 4 CfS are in 2024, there is no renewal expected.

When we analyse near future potential problems, we identify the following conditions to prevent worst-case scenarios:

a. Compartmentalisation and monitoring relative humidity during cultivation is essential because the availability of successful curative crop protection methods is low.
b. The use of insect screens can be used locally on potted plants (panties) or containers (mosquito nets) to prevent infection but has impact on light transmittance and microclimate.

c. Focus on irrigation and relative humidity in cultivation with LED (instead of SON-T) to prevent diseases in case of low availability of crop protection products and reduced heating because of higher costs of fossil energy.
d. Labour in separated compartments. In cultivation spaces no personnel admitted to prevent contamination, admittance only for maintenance and specific crop tasks.

3.7 Analysis

In this section we analyse the existing and near future potential crop protection options for the greenhouse horticulture based on the results of the analysis of the existing and future crop protection options for the five crops as presented in Sections 3.2 to 3.6.

When we analyse the results of the five case studies we can draw the following conclusions:

1. Many plant protection products that are allowed to be applied in greenhouse horticulture pass the expiration data before 2030, which implies that reassessment of the plant protection product on the effects on human health and the environment and the efficacy will take place, if requested by the registration holder. (Approximately 70% of all registered active ingredients will expire before the beginning of 2027)[6].
   In Tables 3.2, 3.5, 3.8, 3.11 and 3.14 containing overviews of the number of available active ingredients per crop, only plant protection products are included that are currently registered. The availability of plant protection products per crop (including micro-organisms) in 2030 will be determined by three categories:
   a. Plant protection products with an expiration date after 2030
   b. Plant protection products for which renewals will be required and approved
   c. New active ingredients.
   We have analysed the approval of renewals (see section 2.2). From the 120 chemical active ingredients that have passed the expiration date in the period 2018-2022 only 32% has been renewed.[7] In the years 2023 to 2026 248 chemical active ingredients have to be reassessed. Since the number of new active ingredients that have the status 'pending' is much lower (64), it can be expected that the number of chemical and microbial active ingredients that are allowed to be used will reduce with approximately 25 to 30% until 2027. The status 'pending' implies that the dossier for assessment is valid, but decision-making has yet to take place.
2. The application of biocontrol agents against pests is common in greenhouse horticulture. Statistic Netherlands (CBS) reports that biocontrol against pests is applied on 95% of the greenhouse area (CBS, 2022a). In the cultivation of tomatoes and cucumbers it is even 100%.
3. The application of biocontrol requires a careful IPM strategy for two reasons. First of all, the application of biocontrol agents limits the number of plant protection products that can be applied, since a large number of plant protection products can have significant negative effects on biocontrol agents. Secondly, the population of especially macro-organisms need to be build up to reach a level with maximum efficacy. By consequence, decision making about crop protection needs to be taken at strategic and tactical level, which has consequences for daily decisions about crop protection. A careful crop protection strategy has to be developed to control all pests and diseases, while safeguarding the applied biocontrol agents.
4. Some pests and diseases have a quarantine or regulated non-quarantine pest status. For these organisms a zero tolerance policy is applied. This requires a very high efficacy of the applied plant protection products, because those pests and diseases need to be totally eradicated. An example is *Clavibacter michiganensis* in tomato production.
5. Few plant protection products are available to control diseases in the rootzone such as phytophthora, which can cause high yield losses.
6. Limitation of the number of plant protection products leads to an increased risk on resistance of pests and diseases against specific products. An example is the control of aphids in cucumber and chrysanthemum which can currently be controlled by 10 active ingredients of which 9 pass the expiration date for application in cucumber before 2027 and all ten have to be reassessed in chrysanthemum.

6 https://food.ec.europa.eu/plants/pesticides/eu-pesticides-database_en

Resistance is especially a threat when active ingredients belong to the same resistance group and count for one. Some plant protection products can only be used a limited number of times. This increases the pressure on using plant protection products without this limitation, with increased risk on resistance development as a consequence.

7. This year, greenhouse growers are faced to high energy costs as a consequence of the war in Ukraine. By consequence they search for options to reduce the costs. One of the options is to reduce the temperature. However, temperature reduction leads to higher humidity, which favours the development of diseases, such as Botrytis and Mildew.
8. The reduction in the availability of active ingredients, and consequently increased risks on resistance development, combined with the limitations of the use of chemical plant protection products in combination with biocontrol agents will lead to significant more bottlenecks in crop protection in greenhouse horticulture. In order to make a comparison with other crops, we have listed the available active ingredients for controlling pests, weeds and diseases for potato production (see Appendix 4). This analysis shows that for each of the pests and diseases, slightly more active ingredients are available. The relative share of chemical plant protection products in the available PPPs is higher for potato cultivation than for greenhouse horticulture, see Appendix 4. The relative share of biocontrol agents (micro-organisms) is small. Also for potato production applies that most active ingredients pass the expiration date before 2027. Another difference regards the control of weeds which is of minor importance in greenhouses. (Partially) shifting from herbicides to mechanical weed control is an important pathway to reduce the use of chemical plant protection products.
9. The potential quantitative impact in terms of financial losses due to yield and quality loss of the anticipated bottlenecks can be significant but it is complex to estimate for two reasons:
   a. We have estimated the decline in number of active ingredients, but do not know which of these active ingredients will not be renewed.
   b. Because of the application of biocontrol which can be affected by chemical plant protection products applied to control other pests and diseases, the consequences of the bottlenecks for each of the pests and diseases cannot be assessed in isolation, but are linked to each other.

   However, the organic production can be considered as the bottom line for an impact assessment. Organic production in greenhouses for vegetables such as tomato and cucumber exists. For tomato a yield level for organic production of 80% compared to conventional production is estimated (Ponti et all, 2012). However, cut flowers and pot plants are hardly organically cultivated, since the market for these products is too small. More importantly, all products that will be exported need to be totally free from pests and diseases. Even if the cut flower or pot plant has no symptoms, the presence of pests or pathogens can lead to rejection for export, making them useless for trade. By consequence, these zero-tolerance requirements can lead to much more financial impact than 20% financial losses for cut flowers and pot plants.
10. The set of pests and diseases that need to be controlled in greenhouse crops is not static over time. New pests and diseases can enter the greenhouses due to climate change and international trade in plants and plant products. Pests and pathogens that were in the past not considered as important pests can cause more damage, since broad spectrum crop protection products have lost registration. The dynamics in disease and pest pressure forces the greenhouse growers to continuous adjustment of the crop protection strategy. Both development and registration of targeted solutions are time-consuming.
11. Although the greenhouse horticulture is of significant economic importance in the Netherlands, in terms of the attractiveness for the crop protection industry developing chemical plant protection products, it is of minor importance. The reason is that the greenhouse crops are cultivated on small areas, contrary to e.g. arable farming and that crop protection costs only cover a limited share in the total costs. It would help if the registration policy in the greenhouse would be organised at family level, and not at species level, which would reduce the costs for approval.

4 The future of crop protection in Greenhouse horticulture

4.1 Long-term perspectives on a sustainable greenhouse horticulture

In this section we present developments in making greenhouse horticulture more sustainable, that affect crop protection. We do not provide a complete overview of all developments.

High energy prices, caused by the war in Ukraine, are demanding the utmost from greenhouse horticulture entrepreneurs to adjust their operations. The greenhouse horticulture in The Netherlands is a technologically advanced sector, heavily depending on energy supply. Since the greenhouse horticulture consumes a lot of gas (9% of the total gas use in the Netherlands)(van ‘t Hoog, 2022), energy saving, shifting to sustainable energy sources and the transition to a fossil-free energy supply are important areas of research and development for decades. The greenhouse industry’s ambition is to produce energy neutrally by 2040. The climatic conditions in the greenhouse have consequences for the crop protection strategy. Currently, many greenhouse growers are cultivating their vegetables, cut flowers and pot plants at lower temperatures. However, this leads to higher levels of humidity and an increased risk on longer periods with wet leaves. This increases the disease pressure of especially fungi. These developments trigger greenhouse growers to speed up innovations that makes them less dependent from gas, such as electrification.

Another trend involves closed systems (including vertical farming). The objective is to separate the cultivation entirely from the outside environment to prevent the introduction of pests and diseases in the greenhouse. Important elements are the use of insect screens for the ventilation windows, which also keeps the biocontrol agents (macro-organisms) inside the greenhouse. Furthermore, the Water Framework Directive enforces growers to reach a zero emission of nutrients to surface water in 2027. This objective becomes urgent. After a period of increasing water quality, stagnation took place in 2019 and 2020 and concentrations of plant protection products in the surface water of the water board Delfland are too high. Glastuinbouw Nederland and the water board collaborate in the application of a risk based approach to reduce the emissions. The easiest way to achieve zero emission is that water applied in the greenhouses will be reused completely (Topsector T&U, n.d.). This requires good quality irrigation water, and a robust microbial composition of the water in the rootzone to keep the balance between good and bad organisms. Since 2018, growers have been required to remove 95% of PPPs from the drainage water using purification techniques. Recirculation can be readily achieved for cultivation on substrate, but is more difficult and less efficient for soil grown cultivation. These developments do not solve the bottlenecks in crop protection, but contribute to prevent the negative consequences for the environment.

A new trend is to connect the greenhouse cropping system with the environment and an increasing number of growers is exploring functional biodiversity in and around greenhouses (Messelink et al, 2021). The main benefit is that biodiversity around the greenhouses serve as a habitat for natural enemies that might help to suppress pests and diseases present in the greenhouses. However, this trend is at odds with the development of closed systems.

Another important development is to reduce the use of peat significantly. A number of organisations, including the Dutch Ministry of Agriculture, Nature and Food Quality, the Action Group *TurfVrij*, the Association of Potting Soil and Substrate Manufacturers of the Netherlands (VPN) and Glastuinbouw Nederland, recently signed a covenant to gradually reduce the use of peat in the coming years. One of the ambitions is to have at least 85% of the substrate consists of renewable raw materials for consumer products (Hortidaily, 2022). Further research is necessary to investigate the consequences of the use of renewable materials in substrates for the resilience of the cultivation system.

Al these developments fit into the concept of integrated crop management (ICM) in which all cultivation processes such as water management, nutrient management, crop protection, use of raw materials and energy will be tuned to each other and are interdependent. This requires careful decision making and a long period of getting experienced in application of ICM, in such a way that pollution of the environment is minimised, that human health is served, that renewable resources will be used and the greenhouse grower has a sustainable basis for generating sufficient income and future perspective.

4.2 Pathways towards a sustainable crop protection in Greenhouse horticulture

Greenhouse growers, extension workers, suppliers and researcher intensively and continuously cooperate to make the greenhouse horticulture in general and crop protection in particular sustainable. In this section we discuss the pathways that will contribute to the sustainable crop protection. We will distinguish between the techniques that can contribute in the short and mid-term (until 2030) and afterwards. The first category has a Technological Readiness Level (TRL) of at least 6 (technology demonstrated in relevant environment). The techniques that can contribute in the long term have a TRL of at least 3 (experimental proof of concept), see box 1. The techniques that are presented contribute to basic steps of Integrated Pest Management (IPM) as presented in Directive EU/128/2009 (Sustainable Use Directive), starting with prevention, followed by monitoring, use of sustainable, non-chemical methods and (reduced) use of chemical plant protection products. Pathways are not separate tracks, but are complementary to each other. A comprehensive overview of the most important pathways for horticulture is described in Hengsdijk et al. (2022).

Textbox 1. Overview of technological readiness levels (European Commission, 2014)

TRL 1 – basic principles observed

TRL 2 – technology concept formulated

TRL 3 – experimental proof of concept

TRL 4 – technology validated in lab

TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)

TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)

TRL 7 – system prototype demonstration in operational environment

TRL 8 – system complete and qualified

TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

4.2.1 Pathways applicable before 2030

Prevention is the basis of integrated pest management. It starts with pests and disease free young plants and cultivation materials, preferably applied in closed systems. The greenhouse is cleaned and disinfected before young plants enter the greenhouse. Strict hygiene protocols are developed and applied to prevent the introduction of pests and disease in the packing hall and greenhouse. Examples are insect screens and lock gates. Further, other plants and plant products than produced in the greenhouse are not handled and packed in the packing hall. In addition, measures are taken to prevent the introduction of invasive pests and diseases when importing young plants. This requires the availability of biocides and disinfection agents.

Systematic and regular **monitoring** remains an important next step in application of IPM. Continuous scouting by specialised employees is already common in the greenhouses, supported by colleagues taking care and harvesting the vegetables, flowers and pot plants in the greenhouse and in the packing hall.

However, monitoring can be improved significantly by making use of digital techniques such as scouting cameras and drones. The use of digital techniques makes early warning possible, much earlier than visual scouting. This enables the grower to intervene earlier, which prevents increase of the pest or disease pressure, and reduces the use of plant protection products significantly, because only affected spots need to be treated. Moreover, it may improve the use of biological control (both macro and micro) as intervention can start in an earlier phase.

Biological or biocontrol remains an important pathway contributing to the sustainability of crop protection in the greenhouse horticulture. Biocontrol regards the application of micro-organisms such as fungi and bacteria, as well as macro-organisms such as insects, mites and nematodes, the use of semi-chemicals and extracts from plant products. The search for efficacious species of micro- and macro-organisms that can be applied without the risk that they will become a disease or a pest needs to continue. The new European regulations for registration of micro-organisms can shorten the process for registration of these biocontrol agents. However, this needs to be proven in the future.

Advanced **precision spraying techniques** can contribute to reduce the volume of the plant protection product applied and effective application, which becomes more important with the application of green plant protection products. Examples are data driven spot spraying in combination with early warning systems.

Cultural control methods can be applied to prevent or control pests and diseases. Cultural control practices can be categorised as preventative control measures that can take effect before the pest or pathogen has established in the crop (Katan, 1996). They encompass:

a. practices that are usually applied for general agricultural purposes, but can have a direct or indirect and positive or negative effect on pest incidence (e.g. greenhouse climate control (dehumidification), fertilisation, irrigation, crop density, training and pruning). Furthermore, the use of Led light or optimisation of fertilisation might add to increase plant resilience and UV-C can be used to reduce powdery mildew. In addition, the use of anaerobic disinfection of soil could prevent diseases in ground-bound diseases as Verticillium and Nematodes (Garcia Victoria et al., 2015; Ludeking et al., 2013).
b. practices that are used solely or mainly for pest and disease control (e.g. sanitation, insect screens, use of gauze over the plants or covering the entire pot to prevent the entrance of harmful insects mass trapping, airlocks) and
c. practices that are used for both agricultural as well as pest control purposes (e.g. the choice of crop cultivar and growing medium, grafting, crop rotation and composting).

Finally, the development and registration of **low risk plant protection products** without effects on natural enemies is important to provide greenhouse growers with sufficient modes of action to protect their plants against pests and diseases.

The pathways presented above are available for all growers. To a certain extent they are already applied by greenhouse growers. Therefore, greenhouse growers can take profit of learning from each other. Especially greenhouse growers with a low adoption rate of non-chemical methods and a high use and risk of chemical plant protection products are encouraged to invest in techniques and knowledge to apply those alternative techniques. Research can help to detect the bottlenecks those greenhouse growers experience in adoption of sustainable crop protection methods.

4.2.2 Pathways for the long term

An important objective for the long term is to make the greenhouse horticulture **resilient** against pests and diseases. Instead of focussing on single risks that need to be managed by direct interventions, in a resilient driven model, we focus on enhancing the self-regulating capacity of the growing system with indirect interventions oriented at long term security (Erisman et al., 2016). We differentiate between a resilient cultivation system, plant resilience and soil suppression (in growing media). **Plant resilience** is defined as the ability of the plant to defend itself against attacks by pests and diseases. This can be either constitutive (always present) or induced. In the latter case, the plants immune response can be turned on by a pest or pathogen itself, by the microbial community in the soil or elicitors. The microbial community in the growing medium also provide direct suppression against pathogens, which is called soil suppression. **Soil**

suppression is the ability of the microbial community to prevent establishment and persistence of the pathogen by the microbial community in the soil (Schlatter et al., 2017; Raaijmakers and Mazzola, 2016). Soil suppression can be turned on by the addition of beneficial microbial communities or the stimulation of the natural suppression of pathogens by the microbiome of the growing media via the addition of organic materials, but more research is needed on how to achieve this. Growers are experimenting with resilient growing in soil e.g. in Chrysanthemum (Roelofs, 2022). In contrast, a **resilient cultivation system** involves farming practices that optimise food production and minimising its impact on the natural environment by providing a good balance between farming practices and the exploitation and use of biodiversity, ecosystem services and the natural surroundings (Erisman et al., 2016). This involves a whole array of measures for optimal growth of the plant, such as the choice of LED light, climate, UV-C, growing media, irrigation strategy, design of the greenhouse and greenhouse cover as well as the choice of cultivar, hygiene measures, clean starting materials. In a resilient cultivation system, pests and diseases are as much as possible preventively controlled via the characteristics of the resilient model (Figure 4.1) and the principles of plant resilience and soil suppression are taken into account. In a greenhouse, there is usually no natural diversity of insects as the plants are cultivated indoors, but the control of pests needs the establishment of biocontrol agents. Thereto, optimal conditions for increasing the number and diversity of natural enemies against pests and diseases are important pillars. The diversity of indoor insects can be increased by the use of banker and nectar plants to host natural enemies, the addition of alternative food sources for above and belowground predators and the addition of beneficial microbial communities or to stimulate the natural suppression of pathogens by the microbiome of the growing medium. As such, resilience against pests and diseases involves understanding how to manage plant resilience, soil suppression and the use of a resilient cultivation system. However, further and combined fundamental and applied research are necessary to analyse and understand the underlying processes, to analyse to what extent resilient cultivation systems can contribute to an effective ad sustainable crop protection, to analyse how to prevent diseases and to use this knowledge for the development of applicable solutions.

A technique that contributes to prevention and resilience is **breeding varieties resistant against pests and diseases**. Conventional breeding techniques take on average at least 10 years and up to 30 years to produce new varieties with properties that have added value, such as a better taste, improved storability, different shape of flowers, or new colours. The importance of breeding resistant varieties has gained importance, although still of minor importance in the breeding practice. A severe bottleneck is the current European legislation on Genetic modification (GMO) that prohibits the use of new breeding techniques (NBTs) to prevent the incorporation of genes derived from other species. However, these techniques can also be applied for more targeted breeding making use of genes from the specie itself. Techniques such as CRISPR-Cas can be applied to shorten the breeding process significantly, e.g. from 10 to 5 years.

4.3 Conditions for a successful transition towards a sustainable crop protection

To enable the pathways to contribute optimally to sustainable crop protection in greenhouse horticulture, conditions need to be created by different stakeholders. Relevant stakeholders are (1) the researchers that develop the necessary knowledge for development and application of these pathways; (2) supply chain partners and consumers that create the demand and willingness to pay for sustainable products they require as citizens; (3) suppliers such as the crop protection industry and breeders for development of low risk plant protection products, biocontrol, resistant varieties,(4) Policy makers and legislators that supports options to apply sustainable solutions and (5) advisors, who play an important role in integrating the various components into a systems approach of IPM (Integrated Pest Management) or ICM (Integrated Crop Management) at company level. Finally, we pay attention to the contribution the greenhouse horticulture can deliver to make the crop protection more sustainable.

4.3.1 Research and development

Research and development play an important role in the following pathways:

i. Development of resilient cultivation systems, focussing on the combined effects of biological control options, resilience and technology
ii. Continued search for and selection of biocontrol agents, especially of endemic species
iii. Development of data driven monitoring and spraying techniques
iv. Development of cultural control methods (controlling pests by changing living habits or environments for pests)
v. Fundamental and applied research of plant resilience, soil suppression and resilient cultivation systems (see 4.2.2)
vi. Increasing functional biodiversity to support resilient cultivation systems
vii. Designing resistant cultivars against pest and diseases
viii. Development of cross protection for multiple viruses.

4.3.2 Supply chain partners

Citizens require responsible behaviour of producers, traders, retailers with respect to food supply. However, sustainable requirements can only be met if consumers are prepared to pay a higher price to compensate additional costs. Therefore, supply chain partners need to create and implement mechanisms that enable consumers to pay the true price for the products they buy. This requires differentiation in the supply of plant products based on sustainability or minimum sustainability requirements based on certification of products in the sourcing strategy.

4.3.3 Suppliers

Biological control and low risk plant protection products need to be developed. Since the society and the market ask for sustainable plant protection products, the crop protection industry is motivated to develop them if legislation and long waiting times and admission procedure is not preventing its development. If the demand for resistant varieties increases, breeders are motivated to increase their efforts producing those varieties.

4.3.4 Legislation

Legislators, in this case the European Union and the Dutch government can significant contribute in the following way:

At EU level:

1. To give priority to new biological control and low risk plant protection products in the assessment procedure.
2. Simplification and differentiation of procedures to bring novel biological control products to market quickly and safely.
3. Shorten the lead time for registration of plant protection products, especially of biological control. This will reduce the likelihood that insufficient crop protection modes of action are available.
4. Implementation of suitable legislation framework for the safe use of microbial consortia to create microbial communities that are beneficial to the plant and contribute to the natural suppression of pathogens. This can be achieved when microbiome scientist and legislators are co-developing and evaluating legislation as the field of microbiome science is currently moving faster than the legislation for microbial PPP (Maguin et al., 2022).
5. Prevention of the delay for the development of new biological control. A major change in regulation came with the Convention on Biological Diversity that developed the so-called Nagoya Protocol on access to genetic resources and the sharing of benefits arising from their utilisation. The implementation of this new regulation has complicated the collection and export of new natural enemies for BC research in several countries. A major concern is the strong delay this regulation causes for the development of new BCAs, and in addition, the costs for sharing benefits and regulation of natural enemies may become disproportionally high.

6. To differentiate between open and closed cultivation systems, since closed cultivation systems have more options to mitigate emissions to air, soil and surface water.

At national level:

7. Enlarge the lower limit for registration of active ingredients at species level from 1,000 to 5,000 ha in greenhouse horticulture to increase the attractiveness for providers of plant protection products to request approval.
8. Create an emergency counter for sudden bottlenecks. In those cases quick decision making is required. Current lead times for approval of emergency uses of 3 months are too long.
9. Create options that sufficient plant protection products are allowed to be used in emergency situations to protect the crop under conditions such as limited plant protection product use and zero emission to surface water. Evaluate to what extent the existing option for derogation and provisional authorisations can be applied for this purpose. A derogation as described in article 53 of Regulation (EC) No 1107/2009 (emergency authorisation) can be applied by Member State governments to allow farmers to use a plant protection product under specific conditions for specified crops for at most 120 days. A provisional authorisation regards the use of active ingredients for which the request for authorisation is pending (article 30 of Regulation (EC) No 1107/2009).

4.3.5 Advisors

Invest in elaboration of IPM and ICM systems at firm level. Assist in creation of demonstration projects. Connect growers which have skills to produce sustainable and resilient to each other and to early adopters. Create conditions for win-win situations in cooperations by experiments and sharing experiences, in direct connection with researchers.

4.3.6 The greenhouse horticulture sector

Given the current situation greenhouse growers can contribute significantly to make crop protection more sustainable. The greenhouse horticulture is well-known as an innovative sector. Part of the innovations have been initiated and developed by the growers themselves, whether or not in cooperation with suppliers and researchers. First of all, growers can apply technologies presented in Section 4.2 that are already on the market. Many of those techniques are applied by part of the growers, but can be adopted by more growers. The economic performance of growers of the same product every year shows a large distribution over the firms. The same applies for the amount of chemical crop protection products that are applied. Growers that apply high volumes can learn from growers that apply small volumes. This requires a culture of sharing best practices, willingness to change and to experiment. And of course there will continue to be differences between greenhouse growers, but everyone can always learn to do even better, as the past in greenhouse farming has proven. Research can be done to detect bottlenecks in the decision making about adoption of sustainable crop protection techniques which can be overcome when those greenhouse growers will be stimulated to adopt those techniques. Greenhouse growers also contribute to the research and the development of innovations by providing more budget.

5 Discussion, conclusions and recommendations

5.1 Discussion

Relation between F2F/SUR and registration policy
The reason for commission of this study by Glastuinbouw Nederland is the release of the Farm to Fork Strategy in 2020 and the presentation of the Sustainable Use Regulation in 2022, which contains the proposal for implementing the objectives for reduction of pesticide use and risk of at member state level. The core of this study regards the analysis of the existing and future availability of active ingredients. The registration policy is regulated in Regulation EC (No) 1107/2009, which is currently not in discussion. Therefore, positioning the results of this study should not be framed as consequences of the Farm to Fork Strategy and Sustainable Use Regulation. However, a relation between both policy areas exists. If active ingredients change from risk category due to reassessment or will not be renewed, this will have consequences for realisation of the reduction targets for pesticide use and risk.

Level of detail
In this study, we have analysed the availability of the active ingredients for five representative crops in the greenhouse horticulture at individual pest and disease level. These cases can be elaborated in more detail, by analysing the future perspectives of each active ingredient separately, both the active ingredients which will be subject to reassessment, the active ingredients that have a expiration date after 2030 and the new active ingredients of which the approval is pending. This requires in-depth knowledge about the current criteria for approval on the one hand and scores on these criteria for the active ingredients on the other hand. Another level of detail that can be added regards the label prescriptions, which can contain limitations to the use of plant protection products such as the maximum number of applications.

Furthermore, resistance development is not only dependent on the number of active ingredients that are available, but also on the mutual similarities between the active ingredients. If active ingredients belong to the same group, alternate use does not contribute to the reduction of the risk of resistance development.

No easy solutions
In the analysis of future pathways, a number of future options have been proposed. No easy solutions are available, given the relative short term in which they will become urgent. A transition to a sustainable crop protection is needed, which requires longer lead times, usually twenty-five to thirty years. Given the fact that a broad support in society exists for reduction of the use and risk of plant protection products, there is wide consensus that the use and risk of plant protection products needs to be reduced. The greenhouse industry has to contribute to the reduction of PPP together with the other agricultural sectors including arable farming, grasslands used for animal production and the production of horticulture in the open fields (fruits, vegetables, flower bulbs and nursery stock).

Differences between chemical plant protection products and biocontrol
One of the criteria of approval of an active ingredient regards the efficacy. For chemical plant protection products, a higher efficacy level will be applied than for micro-organisms. The approval guidelines for efficacy of micro-organisms of the Ctgb prescribe that the efficacy of chemical plant protection products must be similar to an approved reference product. For biocontrol agents this level can be lower and should be in trials at least significantly higher than in the untreated control (Ctgb, 2022). In the case the availability of chemical PPPs reduces and can be replaced by biocontrol with a lower efficacy, the total efficacy level can reduce, or more biocontrol agents need to be applied, to maintain the efficacy level. This will also lead to higher costs.

In this study, we have explored the potential development in the number of available chemical and microbial active ingredients. We expect a reduction between 40 and 45% of chemical active ingredients until 2027 and an increase in the available microbial active ingredients leading to an overall decline in the number of active ingredients of 25 to 30% until 2027. However, it should be noted that not all microbial plant protection products have a different mode of action. Groups of microbial active ingredients have the same mode of action and cannot be considered as complementary to each other. Therefore, the developments in the number of mode of actions can be lower than in the number of active ingredients.

The expected decline in the availability of active ingredients is not limited to greenhouse horticulture. We expect that the decline in the open field production will be higher since less biocontrol agents can be applied in the open fields.

Focus on multiple pathways to reduce PPP in Horticulture
The proposed pathways towards a sustainable crop protection in Chapter 4 need to be developed in parallel and applied in combination with each other. They can reinforce each other. An example is the use of precision techniques such as early warning and spot spraying, which reduces the risk for harming biocontrol agents. Furthermore, finding solutions is not only the responsibility of the greenhouse grower, but of the entire supply chain starting at the crop protection industry and ending at the consumer, and of private and public stakeholders.

Implications for minor crops
The crops selected for the different cases are representatives of the vegetables, cut flowers and pot plants in the greenhouse horticulture, but are relatively large crops. If the area (in The Netherlands) of a crop is less than 1,000 ha in the protected cultivation, it can make use of special regulations limiting the costs of registration of active ingredients for these crops. However, the availability of active ingredients will not be better for minor crops in comparison with large crops. They only have an advantage if they are less vulnerable for pests and diseases than other crops.

Position of greenhouse horticulture compared to crops produced in the open field
The main differences between crop protection in greenhouse horticulture and in open field crops are described in Section 3.1. In this study we have not been able to explore the economic consequences of the reduction targets for plant protection product use in detail, as has been conducted for open field crops (Bremmer et al., 2021). In open field crops, the consequences have been assessed of the realisation of the F2F targets for reduction of pesticide use and risk in ten crops. One of the conclusions is that the estimated yield reduction is approximately 10% for annual crops and around 15 to 20% for perennial crops. These results can not directly be extrapolated to the greenhouse horticulture. As has been elaborated in Section 3.7, yield losses up to 20% in vegetable production are possible, and can be higher in cut flower and pot plants due to the zero tolerance policy with respect to the presence of pests and diseases in products produced for export. In the greenhouse horticulture, less chemical plant protection products but more biocontrol agents are registered in comparison with open field production. If for major pests and diseases the number of plant protection products becomes too low to control, significant yield reduction can occur. Furthermore, the willingness to apply biocontrol as a preventive measure can reduce if greenhouse growers do not have alternative methods to intervene curatively in that system. The application of biocontrol methods is expensive compared to chemical methods.

It can be questioned to what extent yield reduction and increased costs will be problematic for the Dutch greenhouse horticulture. The crop protection policy regards the entire European Union. Spanish and Italian growers will be affected as well as Dutch growers, so a level playing field within the EU exists. When assessing the competitive position of the Dutch greenhouse horticulture we need to consider competitors outside the EU. For some cut flowers competition takes place in East-Africa. For vegetables such as tomatoes, competition takes place with producers in North-Africa such as Morocco, although the growing season not fully overlaps. However, it is likely that yield reduction will be at least partially be compensated by higher prices. However, and maybe more importantly, the anticipated increase in bottlenecks in crop protection will not only lead to lower yield levels on average, but also to higher fluctuations in the yield level. Since the greenhouse industry is highly capital intensive, the future perspective on firm continuity will immediately be at risk. Greenhouse growers are more vulnerable for increased risks than producers in the open field.

Therefore, it is important to intensify the research on resilience of plants and cultivation systems, which is also important for open field cultivation, to provide emergency options and to apply other measures as elaborated in Chapter 4, not only for the larger crops, but also for the minor crops.

Efforts of the Greenhouse growers

The emphasis in this report lays on making the crop protection more sustainable in order to reduce the use of chemical plant protection products as much as possible, and thus to reduce residues on products and emissions to the external environment. Besides the use of sustainable crop protection methods, the emissions can be reduced by application of emission reducing measures. In comparison with cultivation in the open field, the greenhouse horticulture has the advantage of cultivation in greenhouses, with limits the emission to the environment. Most emissions take place to the surface water. Despite the progress in reducing the emissions to the surface water, exceedance of the norms still take place, especially in locations where greenhouse horticulture is concentrated. Additional efforts should be made to comply with the standards of the Water Framework Directive in 2027. The technology to purify the discharge water is available.

Indicators measuring impacts

The European Commission applies the Harmonized Risk Indicator I as a measure to differentiate in impact measurement of PPPs application. However, the division of all PPPs, including microbes in four groups is a rather rough approach, which leads to a loss of relevant information about the potential impacts of PPPs. Other indicators which differentiate on the basis of plant protection product properties, mode of application and application of emission reducing technologies are available or will become available soon. An example is the Environmental Indicator Crop Protection that will become available in 2024 (Focks et al., 2023) and is developed consistent with the risk assessment methodology applied in the registration procedure. This is especially relevant for greenhouse horticulture, since the cultivation in greenhouses and on substrate enables the reduction to zero or almost zero with no impact on protection goals such as birds & mammals and soil life.

Realisation of Farm to Fork Strategy objectives on crop protection

In Chapter 2 we have addressed the relationship between the Farm to Fork strategy and the authorisation policy of active ingredients. The emphasis in this report is on the potential consequences of the expected reduction in the availability of plant protection products in greenhouse horticulture as a consequence of the existing authorisation legislation. The question is to what extent will the reduction targets of the Farm to Fork Policy with respect to crop protection will be met by the reduction in the availability of the plant protection products: targets are 50% reduction in the overall use and risk of pesticides and 50% reduction in the use of more hazardous pesticides (Candidates for Substitution). Since the realisation of the first objective is measured by the Harmonized Risk Indicator I, it is likely that the reduction of those targets can be largely or totally be realised by the reduction in the availability of plant protection products. The reason is that if active ingredients will not be renewed, they will be placed in risk category 4 with a weighting factor of 64. They can only be used if derogation is allowed by the member state authority. Therefore, the applied volume will be reduced to zero or almost zero. More importantly, the plant protection product use in the reference period (2015-2017) will be recalculated with the new weighting factors. In that case, substitution of plant protection products with a high weighting factor by plant protection products with a lower weighting factor and reduction of the frequencies of spraying will not be necessary, provided that this is possible. Further research is necessary to assess to what extent these expectations will hold.

Stick and carrot

For a real transition to a resilient system, a stick and a carrot are necessary. The SUR is mainly focused on the stick. The implementation of the SUR is still in development, so carrots can be added to support greenhouse horticulture to realise the transition and to achieve a biological ecosystem in the circular greenhouse. An option is to make a distinction between cultivation in the greenhouses and open field, to allow separate options for both cultivation types. Other options are rewarding sustainable techniques such as application of biocontrol, including technology that reduces the use of plant protection products or emissions such as closed systems in the legislation. Finally, increased capacity for assessment of existing and new plant protection products and giving priority to biocontrol can also contribute to keeping the availability of plant protection products at an acceptable level.

5.2 Conclusions

The following conclusions can be drawn:

1. We expect that in 2030, greenhouse growers have less plant protection products available to control pests and diseases. Many plant protection products that are allowed to be applied in the greenhouse horticulture (as well as in open field production) pass the expiration data before 2030, which implies that reassessment of the plant protection product of the effects on human health and the environment and the efficacy will take place, if requested by the registration holder. Based on analysis of data available in the EU Pesticides Database, it can be expected that the number of chemical and microbial active ingredients that are allowed to be used may reduce with approximately 25 to 30% until 2027. The effect on yield is difficult to assess, but yield losses up to 20% in vegetable production are possible, with higher fluctuations. In ornamental production the losses can be even larger due to the zero-tolerance policy for pests and pathogens present in the product, which will make export almost impossible. It is likely that the product prices will increase. Greenhouses horticulture is highly capital intensive, which makes it more vulnerable for yield fluctuations than horticulture in the open field.
2. The expected reduction in the availability of chemical plant protection products forces greenhouse horticulture to search for alternative, sustainable crop protection methods. However, on the other hand, continuing to make crop protection more sustainable becomes difficult for the following reasons:
    a. The application of biocontrol is at risk, when specific chemical plant protection products that can be applied in combination with biocontrol will lose their approval, and broad spectrum plant protection products will be applied. The application of biocontrol requires a careful IPM strategy for two reasons. First of all, the application of biocontrol agents limits the number of chemical plant protection products that can be applied, since a large number of plant protection products can have negative effects on biocontrol agents. Secondly, the population of especially macro-organisms need to be built up to reach a level with maximum efficacy. This could also be the case for microbes in substrates. By consequence, decision making about crop protection needs to be taken at strategic (multiple cultivation cycles) and tactical level (before a cultivation cycle), which has consequences for daily decisions about crop protection. A careful crop protection strategy has to be developed to control all pests and diseases, while safeguarding the applied biocontrol agents, to maintain their efficacy level. If no sufficient selective chemical plant protection products remain available that can be applied in combination with biocontrol, the application of more green plant protection products will be hampered.
    b. Limitation of the number of plant protection products leads to an increased risk on resistance of pests and diseases against specific products. A criterion that is applied in the comparative assessment of Candidates for Substitution is that at least 5 modes of action to control a pest or disease need to be available to prevent resistance development. The expected reduction in the availability of chemical active ingredients, and consequently increased risks on resistance development, combined with the limitations of the use of chemical plant protection products such as maximum number of sprayings in combination with biocontrol agents will lead to more bottlenecks in crop protection in greenhouse horticulture. It is therefore important that sufficient modes of action remain available to control pests and diseases.
    c. The set of pests and diseases that need to be controlled in greenhouse crops is not static over time. New pests and diseases can enter the greenhouses due to climate change and international trade in plants and plant products. Pests and pathogens that were in the past not considered as important pests can cause more damage, since broad spectrum crop protection products have lost registration. Greenhouse growers should be aware of and prepared for the entrance of new pests and diseases. The dynamics in disease and pest pressure forces the greenhouse growers to continuous adjustment of the crop protection strategy. Both development and registration of targeted solutions are time-consuming and costly, which stresses the need to continue the development of resilient plants and cultivation systems.

5.3 Recommendations

We recommend:

1. Policy makers to take into account the consequences of a reduction in the number of available active ingredients for the continuous development of sustainable crop protection in greenhouse horticulture, the reduced production, higher prices and increased imports.
2. To accelerate development and market introduction of alternative sustainable crop protection methods and low risk active ingredients.
3. Greenhouse growers to accelerate the adoption of currently available techniques by greenhouse growers in order to reduce the use and risk of plant protection products. Early adopters need to be awarded, and cooperation between greenhouse growers supported to share best practices. This can be done by encouragement of participation in study groups, encouragement of participation in certification systems such as MPS and cooperation of Glastuinbouw Nederland with independent advisors. Furthermore, research is necessary to detect bottlenecks in the decision making about adoption of sustainable crop protection techniques.
4. To intensify research on resilient cultivation systems, plant resilience and soil suppression of diseases.
5. To intensify development and application of prevention systems, monitoring, biological control as described in the Sustainable Use of Pesticides Regulation (SUR), precision spraying and monitoring technologies, cultural control methods and low risk and biological control PPPs in the short and mid-term.
6. National Authorization boards to reduce the lead times and simplify procedures where possible for registration of biological control and (low risk) PPPs and no waiting times for registration for these products.
7. Legislators to enable temporary options for emergency use by greenhouse growers of plant protection products that lost registration under the condition the greenhouse horticulture contributes significantly to reduction of overall use and risk of PPPs and emissions of plant protection products to the environment with specific attention for the surface water. Evaluate to what extent the existing options for derogation and provisional authorisation as described in Regulation (EC) No 1107/2009 can fulfil this need in order to maintain at least five modes of action to control pests and diseases. Furthermore, monitor and evaluate to what extent emergency options contribute to producing more sustainably in the greenhouse horticulture, or will lead to stagnation of producing more sustainably.
8. To investigate to what extent more advanced indicators such as the environmental Indicator Crop Protection measuring environmental impacts can be applied that serve the ultimate goals for reducing plant protection product use and risk on the one hand, but allows more options to intervene for greenhouse growers on the other hand.

Furthermore we recommend the European Commission to investigate to what extent the realization of the crop protection targets of the Farm to Fork Strategy will be realized by the reduction of the availability of plant protection products on the one hand and the implementation of the SUR on the other hand.

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Appendix 1 Glossary and abbreviations

Glossary

Active ingredient	Ingredient in the plant protection product that is effective against the harmful organism
Active substance	Synonym for Active ingredient
Biocide	A pesticide intended for use outside agriculture
Biocontrol	Method to control pests, weeds and diseases by other organisms, both beneficial microbes (fungi, bacteria) and arthropods (insects, nematodes)
Integrated Pest Management	Careful consideration of all available plant protection methods and subsequent integration of appropriate measures that discourage the development of populations of harmful organisms and keep the use of plant protection products and other forms of intervention to levels that are economically and ecologically justified and reduce or minimise risks to human health and the environment
Macro-organism	Beneficial arthropods (see definition of biocontrol)
Microbes	Beneficial micro-organisms (see definition of biocontrol
Mode of action	Mechanism how an active ingredient kills a pest or pathogen. Pests, weeds and diseases which are resistant against a plant protection product are also resistant against other plant protection products containing other active ingredients with the same mode of action.
Pesticide	A ‘pesticide’ prevents, destroys, or controls a harmful organism (‘pest’) or disease
Plant Protection Product	A pesticide intended for use in agriculture

Abbreviations

AI	Active Ingredient
AS	Active Substance
BD	Biodiversity Strategy
CfS	Candidate for Substitution
Ctgb	Dutch Board for the Authorisation of Plant Protection Products and Biocidal Products
EC	European Commission
F2F	Farm to Fork Strategy
GD	European Green Deal
HRI I	Harmonized Risk Indicator I
ICM	Integrated Crop Management
IPM	Integrated Pest Management
MRL	Maximum Residue Level
PPP	Plant Protection Product
SUD	Sustainable Use of Pesticides Directive
SUR	Sustainable Use of Pesticides Regulation

Appendix 2 Overview of Status of active ingredients since 2018[8]

	Chemical a.i.	of which CfS	Micro-organisms
Currently approved	355	53	74
of which renewed since 2018	38	9	9
of which first approval since 2018	11	0	16
Expiration before 2027	248	50	40
not approved since 2018	82	38	3
Pending	38	0	26

[8] Based on data of the EU Pesticides database of February 2023.

Appendix 3 Overview of available Plant protection products per crop per pest and disease[9]

A. Tomato

Diseases or Pest	Active Substance	Product name	Expiration date
Aphids	acetamiprid	Gazelle	01-01-2025
Aphids	azadirachtin	NeemAzal-T/S	31-05-2025
Aphids	azadirachtin	Oikos	31-05-2025
Aphids	azadirachtin	BloomAzal	31-05-2025
Aphids	Cyantraniliprole	Verimark	14-09-2027
Aphids	flupyradifuron	Sivanto Prime	09-12-2026
Aphids	imidacloprid	Admire	01-12-2020
Aphids	pirimicarb	Pirimor	01-12-2024
Aphids	pyrethrins	Spyro	31-08-2023
Aphids	spirotetramat	Movento	02-11-2019
Aphids	sulfoxaflor	Closer	18-08-2026
Aphids	sulfoxaflor	Sequoia	18-08-2026
Aphids	thiacloprid	Calypso	03-08-2020
Aphids	fatty acids, potassium salts	FLiPPER Plus	31-08-2023
leaf miner	abamectin	Abamectin	01-05-2025
leaf miner	abamectin	Budget Abamectin 18 EC	01-05-2025
leaf miner	abamectin	Imex-Abamectin 2	01-05-2025
leaf miner	abamectin	Vectine	01-05-2025
leaf miner	abamectin	Vertimec	01-03-2027
leaf miner	azadirachtin	BloomAzal	31-05-2025
leaf miner	azadirachtin	NeemAzal-T/S	31-05-2025
leaf miner	azadirachtin	Oikos	31-05-2025
leaf miner	*Bacillus thuringiensis subsp. kurstaki*	DiPel DF	30-04-2024
leaf miner	chlorantraniliprole	Altacor	01-07-2027
leaf miner	Cyantraniliprole	Verimark	14-09-2027
leaf miner	cyromazine	Trigard 100 sl	31-12-2019
leaf miner	deltamethrin	Decis	31-10-2023
leaf miner	deltamethrin	Deltamethrin	31-10-2023
golden twin-spot moth	azadirachtin	Oikos	31-05-2025
golden twin-spot moth	azadirachtin	NeemAzal-T/S	31-05-2025
golden twin-spot moth	azadirachtin	BloomAzal	31-05-2025
golden twin-spot moth	*Bacillus thuringiensis ssp. kurstaki SA-11*	Delfin	30-04-2023
golden twin-spot moth	*Bacillus thuringiensis subsp. aizawai*	Turex 50 wp	30-04-2024
golden twin-spot moth	*Bacillus thuringiensis subsp. aizawai*	Xen Tari WG	01-05-2025
golden twin-spot moth	*Bacillus thuringiensis subsp. Kurstaki*	CoStar WG	30-04-2024
golden twin-spot moth	*Bacillus thuringiensis subsp. kurstaki*	DiPel DF	30-04-2024
golden twin-spot moth	chlorantraniliprole	Altacor	7-1-2027
golden twin-spot moth	deltamethrin	Decis	31-10-2023
golden twin-spot moth	deltamethrin	Deltamethrin	31-10-2023
golden twin-spot moth	esfenvalerate	Sumicidin super (no registration in tomato)	01-12-2023
golden twin-spot moth	indoxacarb	Steward	19-03-2022
golden twin-spot moth	metaflumizone	Verismo	31-12-2025
golden twin-spot moth	methoxyfenozide	Runner	01-04-2024
golden twin-spot moth	pyridalyl	Nocturn	01-05-2027

[9] Based on data of 2022.

Diseases or Pest	Active Substance	Product name	Expiration date
golden twin-spot moth	spinosad	Tracer	30-4-2024
golden twin-spot moth	teflubenzuron	Nomolt	30-11-2019
golden twin-spot moth	sulfur	Sulfur tablets (no registration in tomato)	01-02-2027
spider mite	abamectin	Abamectin	01-05-2025
spider mite	abamectin	Vectine	01-05-2025
spider mite	abamectin	Vertimec	01-03-2027
spider mite	abamectin	Budget Abamectin 18 EC	01-05-2025
spider mite	abamectin	Imex-Abamectin 2	01-05-2025
spider mite	acequinocyl	Cantack	31-08-2025
spider mite	azadirachtin	NeemAzal-T/S	31-05-2025
spider mite	*Beauveria bassiana ATCC74040*	Naturalis-L	30-04-2024
spider mite	bifenazate	Floramite 240 SC	31-07-2023
spider mite	cyflumetofen	Scelta	01-06-2026
spider mite	hexythiazox	Nissorun fluid	01-06-2025
spider mite	maltodextrin	Eradicoat Max	30-09-2024
spider mite	maltodextrin	ERII	30-09-2024
spider mite	Orange oil	Oroganic	30-04-2025
spider mite	spiromesifen	Oberon	30-09-2023
Tomato russet mite	sulfur	Kumulus s	01-03-2027
Tomato russet mite	*Beauveria bassiana ATCC74040*	Naturalis-L	30-04-2024
Tomato russet mite	spiromesifen	Oberon	30-09-2023
Tomato russet mite	abamectin	Vertimec	01-03-2027
Tomato russet mite	abamectin	Budget Abamectin 18 EC	01-05-2025
Tomato russet mite	abamectin	Imex-Abamectin 2	01-05-2025
South American tomato pinworm	azadirachtin	NeemAzal-T/S	31-05-2025
South American tomato pinworm	azadirachtin	Oikos	31-05-2025
South American tomato pinworm	azadirachtin	BloomAzal	31-05-2025
South American tomato pinworm	*Bacillus thuringiensis subsp. kurstaki*	CoStar WG	30-04-2024
South American tomato pinworm	*Bacillus thuringiensis subsp. kurstaki*	DiPel DF	30-04-2024
South American tomato pinworm	chlorantraniliprole	Altacor	01-07-2027
South American tomato pinworm	indoxacarb	Steward	19-03-2022
South American tomato pinworm	metaflumizone	Verismo	31-12-2025
South American tomato pinworm	spinosad	Tracer	30-04-2024
South American tomato pinworm	(E,Z,Z)-3,8,11-Tetradecatrien-1-yl acetate 720 g/kg en (E,Z)-3,8-Tetradecadien-1-yl acetate 83 g/kg	Isonet T	31-8-2023
South American tomato pinworm	(E,Z,Z)-3,8,11-Tetradecatrien-1-yl acetate 720 g/kg en (E,Z)-3,8-Tetradecadien-1-yl acetate 83 g/kg	Tutatec	31-8-2023
white fly	azadirachtin	Azatin	31-05-2025
white fly	azadirachtin	NeemAzal-T/S	31-05-2025
white fly	azadirachtin	Oikos	31-05-2025
white fly	azadirachtin	BloomAzal	31-05-2025
white fly	*Beauvaria bassiana strain PPRI5339*	Velifer	20-02-2030
white fly	*Beauveria bassiana ATCC74040*	Naturalis-L	30-04-2024
white fly	*Beauveria bassiana strain GHA*	Botanigard wp	31-07-2024
white fly	Cyantraniliprole	Verimark	14-09-2027
white fly	deltamethrin	Decis	31-10-2023

Diseases or Pest	Active Substance	Product name	Expiration date
white fly	deltamethrin	Deltamethrin	31-10-2023
white fly	flupyradifuron	Sivanto Prime	09-12-2026
white fly	*Isaria fumosorosea Apopka strain 97*	PreFeRal	31-12-2031
white fly	*Lecanicillium muscarium strain Ve6*	Mycotal	01-03-2024
white fly	maltodextrin	Eradicoat Max	30-09-2024
white fly	maltodextrin	ERII	30-09-2024
white fly	Sodiumlaurylethersulfate	SB instant	(niet in ctgb database)
white fly	pymetrozine	Plenum 50 WG	30-04-2019
white fly	pyriproxyfen	Admiral	01-04-2024
white fly	pyriproxyfen	Proxyral	01-04-2024
white fly	silicon polymers	Protac SF	(niet in ctgb database)
white fly	Orange oil	Limocide	31-07-2025
white fly	Orange oil	Oroganic	30-04-2025
white fly	spiromesifen	Oberon	30-09-2023
white fly	Sulfoxaflor	Closer	18-08-2026
white fly	Sulfoxaflor	Sequoia	18-08-2026
white fly	thiacloprid+C73	Calypso	03-08-2020
white fly	fatty acids, potassium salts	FLiPPER Plus	31-08-2023
tomato bug	acetamiprid	Gazelle	01-01-2023
tomato bug	azadirachtin	NeemAzal-T/S	31-05-2025
tomato bug	azadirachtin	Oikos	31-05-2025
tomato bug	azadirachtin	BloomAzal	31-05-2025
tomato bug	flupyradifuron	Sivanto Prime	09-12-2026
tomato bug	indoxacarb	Steward	19-03-2022
tomato bug	metaflumizone	Verismo	31-12-2025
tomato bug	Sulfoxaflor	Closer	18-08-2026
tomato bug	Sulfoxaflor	Sequoia	18-08-2026
Gray mould	*Bacillus amyloliquefaciens strain QST 713*	Serenade SC	30-04-2024
Gray mould	*Bacillus amyloliquefaciens strain MBI 600*	Serifel	16-09-2027
Gray mould	Benzoic acid	MENNO Florades (disinfectant)	31-08-2033
Gray mould	boscalid, pyraclostrobin	Signum	31-01-2024
Gray mould	Cerevisane	Romeo	23-04-2031
Gray mould	chloorthalonil	Daconil	20-11-2019
Gray mould	*Clonostachys rosea J1446*	Prestop	31-03-2035
Gray mould	cyprodinil, fludioxonil	Switch	31-10-2023
Gray mould	Fenhexamid	Teldor	01-01-2024
Gray mould	Fenpyrazamin	Prolectus	31-12-2023
Gray mould	fluopyram	Luna Privilege	01-06-2027
Gray mould	iprodion	Rovral aquaflo	01-03-2018
Gray mould	mepanipyrim	Frupica	30-04-2024
Gray mould	n10361 Thiram	Thianosan ultra dispersible	30-01-2019
Gray mould	pyrimethanil	Scala	30-04-2024
Gray mould	*Trichoderma atroviride strain SC1*	Vintec	06-07-2032
Gray mould	trifloxystrobin, fluopyram	Luna Sensation (no registration in tomato)	01-09-2023
Powdery Mildew	*Ampelomyces quisqualis strain AQ 10*	AQ 10	01-08-2024
Powdery Mildew	azoxystrobin	Ortiva	31-12-2025
Powdery Mildew	*Bacillus amyloliquefaciens strain FZB42*	Taegro	06-01-2033
Powdery Mildew	*Bacillus amyloliquefaciens strain QST 713*	Serenade SC	30-04-2024
Powdery Mildew	*Bacillus amyloliquefaciens strain MBI 600*	Serifel	16-09-2027
Powdery Mildew	*Bacillus amyloliquefaciens subsp. plantarum D747*	Amylo-X WG	31-03-2025
Powdery Mildew	*Bacillus pumilus QST 2808*	Sonata	31-08-2025
Powdery Mildew	boscalid, pyraclostrobin	Signum	31-01-2024
Powdery Mildew	bipurimate	Abir	31-05-2025
Powdery Mildew	bipurimate	Nimrod fluid	31-05-2025
Powdery Mildew	COS-OGA	FADO	22-04-2031

Diseases or Pest	Active Substance	Product name	Expiration date
Powdery Mildew	cyflufenamid	Takumi	31-03-2024
Powdery Mildew	fluxapyroxad, difenoconazole	Bifasto	31-12-2023
Powdery Mildew	imazalil	Fungaflash	31-12-2025
Powdery Mildew	isopyrazam	Reflect	08-09-2022
Powdery Mildew	potassium hydrogen carbonate	Karma	31-10-2022
Powdery Mildew	mepanipyrim	Frupica	30-04-2024
Powdery Mildew	metrafenon	Vivando	30-04-2024
Powdery Mildew	penconazole	Topaz	01-09-2024
Powdery Mildew	trifloxystrobin	Flint	01-07-2024
Powdery Mildew	triflumizole	Rocket ec	30-06-2020
Powdery Mildew	sulfur	Pipe sulfur	01-02-2027
Powdery Mildew	sulfur	Spray sulfur	01-02-2027
Powdery Mildew	sulfur	Dust sulfur	01-02-2027
Powdery Mildew	sulfur	AFEPASA GREENHOUSE SULPHUR TABLETS	31-12-2023
Powdery Mildew	sulfur	Sulfur tablets	01-02-2027
Late blight	*Bacillus amyloliquefaciens strain FZB42*	Taegro	06-01-2033
Late blight	Clonostachys rosea J1446	Prestop	31-03-2035
Late blight	cyazofamid	Ranman	8-1-2024
Late blight	cymoxanil, propamocarb hydrochloride	Proplant	31-07-2023
Late blight	etridiazole	AAterra ME	31-05-2021
Late blight	etridiazole	Aaterra fluid	31-05-2021
Late blight	fosetyl, propamocarb	Previcur Energy	30-04-2024
Late blight	mandipropamid	Pergado V	31-07-2024
Pythium Damping-off	*Bacillus amyloliquefaciens strain QST 713*	Serenade SC	30-04-2024
Pythium Damping-off	*Clonostachys rosea J1446*	Prestop	31-03-2035
Pythium Damping-off	cymoxanil, propamocarb hydrochloride	Proplant	31-07-2023
Pythium Damping-off	etridiazole	AAterra ME	31-05-2021
Pythium Damping-off	etridiazole	Aaterra fluid	31-05-2021
Pythium Damping-off	fosetyl, propamocarb	Previcur Energy	30-04-2024
Pythium Damping-off	*T. asperellum strain T34*	Asperello T34	31-05-2024
Crazy roots, Hairy roots	*Bacillus amyloliquefaciens strain QST 713*	Serenade SC (only in nurseries)	30-04-2024
Fusarium wilt	Clonostachys rosea J1446	Prestop	31-03-2035
	benzoic acid	MENNO Florades	31-08-2033
	tebuconazole	Prosaro	31-07-2023
Downey mildew	rapeseed oil, cyazofamid	Ranman Top	01-08-2024
Verticillium wilt			
PepMV	Pepino mosaic virus, strain CH2, isolaat 1906	PMV-01	8-7-2031
PepMV	MILD PEPINO MOSAIC VIRUS ISOLATE VC1; MILD PEPINO MOSAIC VIRUS ISOLATE VX1	V10	29-03-2033
nematodes			
growth stimulation	ethefon	Ethrel-a	31-07-2023
desinfection	benzoic acid	MENNO Florades	31-08-2033
desinfection	pentapotassium bis(peroxymonosulfate)bis(sulfate)	Virkon	01-02-2032

B. Cucumber

Pest/disease	Active ingredient	Name CPP	Expiration date
Aphids	flonicamid	Afinto	01-05-2024
Aphids	azadirachtin	Azatin	31-05-2025
Aphids	spirotetramat	Batavia	30-4-2024
Aphids	azadirachtin	BloomAzal	31-05-2025
Aphids	thiacloprid	Calypso	08-03-2020
Aphids	sulfoxaflor	Closer	18-8-2026
Aphids	deltamethrin	Decis ec	31-10-2023
Aphids	fatty acids, potassium salts	FLiPPER Plus	31-08-2023
Aphids	acetamiprid	Gazelle	01-01-2023
Aphids	flonicamid	Inter Peki	6-3-2023
Aphids	azadirachtin	NeemAzal-T/S	31-05-2025
Aphids	azadirachtin	Oikos	31-5-2025
Aphids	pirimicarb	Pirimor	12-01-2024
Aphids	pymetrozine	Plenum	30-4-2019
Aphids	sulfoxaflor	Sequoia	18-8-2026
Aphids	flupyradifuron	Sivanto Prime	12-09-2026
Aphids	pyethrinen	Spyro	31-8-2023
Aphids	flonicamid	Teppeki	05-01-2024
Aphids	cyantraniliprole	Verimark	14-9-2027
Leaf miner	abamectin	Imex-Abamectin 2	01-05-2025
Leaf miner	chlorantraniliprole	Altacor	01-07-2027
Leaf miner	azadirachtin	Azatin	31-05-2025
Leaf miner	azadirachtin	BloomAzal	31-05-2025
Leaf miner	abamectin	Budget Abamectin 18 EC	01-05-2025
Leaf miner	deltamethrin	Decis ec	31-10-2023
Leaf miner	azadirachtin	NeemAzal-T/S	31-05-2025
Leaf miner	azadirachtin	Oikos	31-5-2025
Leaf miner	abamectin	Vectine Plus	5-1-2025
Leaf miner	cyantraniliprole	Verimark	14-9-2027
Leaf miner	abamectin	Vertimec Gold	03-01-2027
Caterpillar	chlorantraniliprole	Altacor	07-01-2027
Caterpillar	*Bacillus thuringiensis subsp. Kurstaki*	CoStar WG	30-4-2024
Caterpillar	*Bacillus thuringiensis subsp. Kurstaki*	Delfin	30-4-2023
Caterpillar	*Bacillus thuringiensis subsp. Kurstaki*	DiPel DF	30-4-2024
Caterpillar	emamectin benzoate	Proclaim	30-11-2025
Caterpillar	indoxacarb	Steward	19-3-2022
Caterpillar	spinosad	Tracer	30-4-2024
Caterpillar	azadirachtin	Azatin	31-05-2025
Caterpillar	azadirachtin	BloomAzal	31-05-2025
Caterpillar	spinetoram	Exalt	30-6-2025
Caterpillar	azadirachtin	NeemAzal-T/S	31-05-2025
Caterpillar	azadirachtin	Oikos	31-5-2025
Caterpillar	deltamethrin	Decis ec	31-10-2023
Caterpillar	*Bacillus thur. subsp. Aizawai*	Turex	30-4-2024
Caterpillar	cyantraniliprole	Verimark	14-9-2027
Caterpillar	metaflumizone	Verismo	31-12-2025
Caterpillar	*Bacillus thur. subsp. Aizawai*	XenTari	05-01-2025
Spider mite	acequinocyl	Cantack	31-8-2025
Spider mite	abamectin	Budget Abamectin 18 EC	01-05-2025
Spider mite	abamectin	Imex-Abamectin 2	01-05-2025
Spider mite	maltodextrin	ER II	30-9-2024
Spider mite	maltodextrin	Eradicoat Max	30-9-2024
Spider mite	bifenazate	Floramite 240 SC	31-7-2023
Spider mite	*Beauveria bassiana ATCC74040*	Naturalis-L	30-04-2024
Spider mite	hexythiazox	Nissorun vlb	06-01-2025
Spider mite	spiromesifen	Oberon	30-9-2023

Pest/disease	Active ingredient	Name CPP	Expiration date
Spider mite	terpenoid blend QRD	Requiem Prime	08-10-2026
Spider mite	cyflumetofen	Scelta	06-01-2026
Spider mite	abamectin	Vectine Plus	5-1-2025
Spider mite	abamectin	vertimec Gold	03-01-2027
Thrips	azadirachtin	Azatin	31-5-2025
Thrips	*Beauveria bassiana strain GHA*	BotaniGard WP	31-7-2024
Thrips	deltamethrin	Decis ec	31-10-2023
Thrips	maltodextrin	ER II	30-9-2024
Thrips	maltodextrin	Eradicoat Max	30-9-2024
Thrips	spinetoram	Exalt	30-6-2025
Thrips	azadirachtin	NeemAzal-T/S	31-5-2025
Thrips	teflubenzuron	Nomolt	30-11-2019
Thrips	azadirachtin	Oikos	31-5-2025
Thrips	terpenoid blend QRD	Requiem Prime	08-10-2026
Thrips	flupyradifuron	Sivanto Prime	12-09-2026
Thrips	spinosad	Tracer	30-4-2024
Thrips	abamectin	Vectine Plus	5-1-2025
Thrips	*Beauveria bassiana PPRI 5339*	Velifer	20-2-2030
Thrips	abamectin	Budget Abamectin 18 EC	01-05-2025
Thrips	abamectin	Imex-Abamectin 2	01-05-2025
Thrips	azadirachtin	BloomAzal	31-05-2025
Thrips	abamectin	Vertimec Gold	03-01-2027
Thrips	Formetanaat	Winner	31-7-2024
Plant bug	deltamethrin	Decis ec	31-10-2023
Plant bug	sulfoxaflor	Closer	18-8-2026
Plant bug	azadirachtin	Azatin	31-5-2025
Plant bug	azadirachtin	BloomAzal	31-05-2025
Plant bug	azadirachtin	NeemAzal-T/S	31-5-2025
Plant bug	azadirachtin	Oikos	31-5-2025
Plant bug	sulfoxaflor	Sequoia	18-8-2026
Plant bug	indoxacarb	Steward	19-3-2022
Plant bug	metaflumizone	Verismo	31-12-2025
Plant bug	acetamiprid	Gazelle	01-01-2023
Plant bug	flupyradifuron	Sivanto Prime	12-09-2026
Plant bug	deltamethrin	Decis ec	31-10-2023
Plant bug	sulfoxaflor	Closer	18-8-2026
Plant bug	azadirachtin	Azatin	31-5-2025
Plant bug	azadirachtin	BloomAzal	31-05-2025
Plant bug	azadirachtin	NeemAzal-T/S	31-5-2025
Plant bug	azadirachtin	Oikos	31-5-2025
Plant bug	sulfoxaflor	Sequoia	18-8-2026
Plant bug	indoxacarb	Steward	19-3-2022
Plant bug	metaflumizone	Verismo	31-12-2025
Plant bug	acetamiprid	Gazelle	01-01-2023
Plant bug	sulfoxaflor	Sequoia	18-8-2026
Plant bug	flupyradifuron	Sivanto Prime	12-09-2026
Whitefly.	pyriproxyfen	Admiral	04-01-2024
Whitefly	azadirachtin	Azatin	31-5-2025
Whitefly	spirotetramat	Batavia	30-4-2024
Whitefly	*Beauveria bassiana strain GHA*	BotaniGard vlb	31-7-2024
Whitefly	thiacloprid	Calypso	08-03-2020
Whitefly	sulfoxaflor	Closer	18-8-2026
Whitefly	maltodextrin	ER II	30-9-2024
Whitefly	maltodextrin	Eradicoat Max	30-9-2024
Whitefly	Fatty acids, potassium salts	Flipper Plus	31-8-2023
Whitefly	*Lecanicillium muscarium strain Ve6*	Mycotal	01-03-2024
Whitefly	*Beauvaria bassiana strain PPRI5339*	Velifer	20-02-2030
Whitefly	azadirachtin	BloomAzal	31-05-2025

Pest/disease	Active ingredient	Name CPP	Expiration date
Whitefly	deltamethrin	Decis ec	31-10-2023
Whitefly	acetamiprid	Gazelle	01-01-2023
Whitefly	*beauveria bassiana ATCC74040*	Naturalis-L	30-4-2024
Whitefly	azadirachtin	NeemAzal-T/S	31-5-2025
Whitefly	teflubenzuron	Nomolt	30-11-2019
Whitefly	spiromesifen	Oberon	30-9-2023
Whitefly	azadirachtin	Oikos	31-5-2025
Whitefly	Orange oil	Oroganic	30-4-2025
Whitefly	*Isaria fumosorosea Apopka strain 97*	Preferal	31-12-2031
Whitefly	pyriproxyfen	Proxyral EC	04-01-2024
Whitefly	terpenoid blend QRD	Requiem Prime	08-10-2026
Whitefly	sulfoxaflor	Sequoia	18-8-2026
Whitefly	flupyradifuron	Sivanto Prime	12-09-2026
Whitefly	cyantraniliprole	Verimark	14-9-2027
Grey mould	*Clonostachys rosea J1446*	Prestop	31-3-2035
Grey mould	*Bacillus amyloliquefaciens strain QST 713*	Serenade	30-4-2024
Grey mould	pyrimethanil	Scala	30-4-2024
Grey mould	fludioxonil, cyprodinil	Switch	31-10-2023
Grey mould	fenhexamid	Teldor	01-01-2024
Grey mould	*Bacillus amyloliquefaciens subsp. plantarum strain D747*	Amylo-X WG	31-3-2025
Grey mould	*Pythium oligandrum strain M1*	Polyversum	30-4-2024
Grey mould	fenpyrazamine	Prolectus	31-12-2023
Grey mould	thiram	Thianosan ultra	30-1-2019
Powdery mildew	bipurimate	Abir	31-5-2025
Powdery mildew	*Bacillus amyloliquefaciens subsp. plantarum strain D747*	Amylo-X WG	31-3-2025
Powdery mildew	*Ampelomyces quisqualis strain AQ10*	AQ10	08-01-2024
Powdery mildew	difenoconazole, fluxapyroxad	Bifasto	31-12-2023
Powdery mildew	boscalid, kresoxim-methyl	Collis	31-7-2024
Powdery mildew	COS-OGA	Fado	22-4-2031
Powdery mildew	trifloxxystrobin	Flint	07-01-2024
Powdery mildew	mepanipyrim	Frupica SC	30-4-2024
Powdery mildew	imazalil	Fungaflash	31-12-2025
Powdery mildew	potassium hydrogen carbonate	Karma	31-10-2022
Powdery mildew	fluopyram	Luna Privelege	06-01-2027
Powdery mildew	azoxystrobin	Ortiva	31-12-2025
Powdery mildew	*Pythium oligandrum strain M1*	Polyversum	30-4-2024
Powdery mildew	isopyrazam	Reflect	09-08-2022
Powdery mildew	trifluizole	Rocket	30-6-2020
Powdery mildew	Cerevisane	Romeo	23-4-2031
Powdery mildew	Bacillus amyloliquefaciens strain QST 713	Serenade	30-4-2024
Powdery mildew	*Bacillus pumilus QST*	Sonata	31-8-2025
Powdery mildew	*Bacillus amyloliquefaciens strain FZB42*	Taegro	06-01-2033
Powdery mildew	cyflufenamid	Takumi	31-3-2024
Powdery mildew	penconazole	Topaz	09-01-2024
Powdery mildew	metrafenon	Vivando	30-4-2024
Gummy stem Blight	*Trichoderma asperellum st. T34*	Asperello T34 Biocontrol	31-5-2024
Gummy stem Blight	difenoconazole, fluxapyroxad	Bifasto	31-12-2023
Gummy stem Blight	boscalid, kresoxim-methyl	Collis	31-7-2024
Gummy stem Blight	mepanipyrim	Frupica SC	30-4-2024
Gummy stem Blight	imazalil	Fungaflash	31-12-2025
Gummy stem Blight	fluopyram	Luna Privelege	06-01-2027
Gummy stem Blight	*Clonostachys rosea J1446*	Prestop	31-3-2035
Damping-off	etridiazole	Aaterra ME	31-5-2021
Damping-off	*Trichoderma asperellum st. T34*	Asperello T34 Biocontrol	31-5-2024
Damping-off	Streptomyces K61 (formerly S. griseoviridis)	LALSTOP K61 WP	01-07-2024
Damping-off	*Clonostachys rosea J1446*	Prestop	31-3-2035

Pest/disease	Active ingredient	Name CPP	Expiration date
Damping-off	propamocarb, fosetyl	Previcur Energy	30-4-2024
Damping-off	propamocarb hydrochloride	Proplant	31-7-2023
Damping-off	*Bacillus amyloliquefaciens strain QST 713*	Serenade	30-4-2024
Damping-off	*Trichoderma harianum Rafai strain T-22*	Trianum P	12-01-2025
Downy mildew	cyazofamid	Ranman Top	08-01-2024
Downy mildew	propamocarb, fosetyl	Previcur Energy	30-4-2024
Fusarium wilt	*Trichoderma asperellum st. T34*	Asperello T34 Biocontrol	31-5-2024
Fusarium wilt	Streptomyces K61 (formerly S. griseoviridis)	Lalstop K61 WP/Mycostop	07-01-2024
Fusarium wilt	*Bacillus amyloliquefaciens strain QST 713*	Serenade	30-4-2024
Fusarium wilt	*Clonostachys rosea J1446*	Prestop	31-3-2035
Phytophtera, Rhizoctonia	*Clonostachys rosea J1446*	Prestop	31-3-2035

C. Chrysanthemum

Pest/disease	Active ingredient	Name CPP	Expiration date
Aphids	spirotetramat	Batavia	30-04-2025
Aphids	sulfoxaflor	Closer	18-08-2026
Aphids	deltamethrin	Decis vlb	31-10-2023
Aphids	acetamiprid	Gazelle	01-01-2023
Aphids	spirotetramat	Movento	30-04-2025
Aphids	Orange oil	Oroganic	30-4-2025
Aphids	pirimicarb	Pediment	01-12-2024
Aphids	pymetrozine	Plenum	30-4-2019
Aphids	pyrethrins, rapeseed oil	Raptol	31-08-2023
Aphids	sulfoxaflor	Sequoia	18-08-2026
Aphids	flupyradifuron	Sivanto prime	12-9-2026
Aphids	azadirachtin	Azatin	31-05-2025
Aphids	azadirachtin	BloomAzal	31-05-2025
Aphids	fatty acids, potassium salts	FLiPPER Plus	31-08-2023
Aphids	flonicamid	Inter Peki	6-3-2023
Aphids	flonicamid	Teppeki	01-05-2024
Aphids	Terpenoid blend QRD	Requiem Prime	10-08-2026
Aphids	esfenvalerate	Sumicidin super	12-1-2023
Aphids	flonicamid	teppeki	5-1-2024
Leaf miner	deltamethrin	Decis vlb	31-10-2023
Leaf miner	esfenvalerate	Sumicidin super	12-1-2023
Leaf miner	azadirachtin	Azatin	31-05-2025
Leaf miner	azadirachtin	BloomAzal	31-05-2025
Leaf miner	azadirachtin	NeemAzal-T/S	31-05-2025
Leaf miner	azadirachtin	Oikos	31-05-2025
Leaf miner	abamectin	Budget Abamectin 18 EC	01-05-2025
Leaf miner	abamectin	Vertimec Gold	5-1-2025
Leaf miner	abamectin	Vectine plus	5-1-2025
Leaf miner	spinosad	Conserve	30-04-2024
Leaf miner	spinetoram (L)	Exalt	30-06-2025
Leaf miner	abamectin	Imex-Abamectin 2	01-05-2025
Leaf miner	pyrethrins, rapeseed oil	Raptol	31-8-2023
Leaf miner	milbemectin	Milbeknock	31-07-2024
Leaf miner	cyantraniliprole	Mainspring	14-9-2027
Leaf miner	cyromazine	Trigard	31-12-2019
Caterpillar (V)=Mots (L)=Larvea	*Bacillus thuringiensis subsp. Kurstaki (L)*	Costar	30-04-2024
Caterpillar	deltamethrin (V)	Decis vlb	31-10-2023
Caterpillar	*Bacillus thuringiensis subsp. Kurstaki (L)*	Dipel DF	30-04-2024
Caterpillar	spinetoram (L)	Exalt	30-06-2025
Caterpillar	pyridalyl (L)	Nocturn	01-05-2027
Caterpillar	azadirachtin	Azatin	31-05-2025
Caterpillar	azadirachtin	BloomAzal	31-05-2025
Caterpillar	azadirachtin	NeemAzal-T/S	31-05-2025
Caterpillar	azadirachtin	Oikos	31-05-2025
Caterpillar	abamectin	Budget Abamectin 18 EC	01-05-2025
Caterpillar	abamectin	Vertimec Gold	5-1-2025
Caterpillar	spinosad	Conserve	30-04-2024
Caterpillar	spinetoram (L)	Exalt	30-06-2025
Caterpillar	abamectin	Imex-Abamectin 2	01-05-2025
Caterpillar	pyrethrins, rapeseed oil	Raptol	31-8-2023
Caterpillar	milbemectin	Milbeknock	31-07-2024
Caterpillar	teflubenzuron (V)	Nomolt	30-11-2019
Caterpillar	methoxyfenozide (L)	Runner	4-1-2024
Caterpillar	esfenvalerate (V)	Sumicidin super	12-1-2023
Caterpillar	*Bacillus thuringiensis subsp. Aizawai (V)*	Turex 50 WP	10-1-2024
Caterpillar	metaflumizone (L)	Verismo	31-12-2025

Pest/disease	Active ingredient	Name CPP	Expiration date
Caterpillar	*Bacillus thuringiensis subsp. Aizawai (L)*	XenTari WG	5-1-2025
Spider mite	etoxazale	Borneo	2-1-2023
Spider mite	acquinocyl	Cantack	31-08-2025
Spider mite	pyridaben	Carex 10 SC	30-04-2024
Spider mite	spirodiclofen	Envidor	31-7-2020
Spider mite	bifenazate	floramite 240 SC	31-07-2023
Spider mite	abamectin	Budget Abamectin 18 EC	01-05-2025
Spider mite	abamectin	Imex-Abamectin 2	01-05-2025
Spider mite	maltodextrin	ERII	30-09-2024
Spider mite	spirotetramat	Batavia	30-04-2025
Spider mite	milbemectin	Milbeknock	31-07-2024
Spider mite	spirotetramat	Movento	30-04-2025
Spider mite	rapeseed oil, pyrethrins	Raptol	31-08-2023
Spider mite	hexythiazox	Nissorun vlb	6-1-2025
Spider mite	spiromesifen	Oberon	30-09-2023
Spider mite	Orange oil	Oroganic	30-4-2025
Spider mite	Terpenoid blend QRD	Requiem Prime	8-10-2026
Spider mite	cyflumetofen	Scelta	6-1-2026
Spider mite	abamectin	Vectine plus	5-1-2025
Spider mite	beauvaria bassianna strain PPRI5339	Velifer	20-02-2030
Spider mite	abamectin	Vertimec Gold	5-1-2025
Thrips	azadirachtin	Azatin	31-05-2025
Thrips	azadirachtin	BloomAzal	31-05-2025
Thrips	azadirachtin	Oikos	31-05-2025
Thrips	Terpenoid blend QRD	Requiem Prime	8-10-2026
Thrips	spirotetramat	Batavia	30-04-2025
Thrips	abamectin	Budget Abamectin 18 EC	01-05-2025
Thrips	abamectin	Imex-Abamectin 2	01-05-2025
Thrips	*beauvaria bassiana GHA*	BotaniGard WP	31-07-2024
Thrips	spinosad	Conserve	30-04-2024
Thrips	deltamethrin	Decis vlb	31-10-2023
Thrips	spinetoram	Exalt	30-06-2025
Thrips	fatty acids, potassium salts	FLiPPER Plus	31-08-2023
Thrips	lufenuron	Match	31-12-2019
Thrips	spirotetramat	Movento	30-04-2025
Thrips	azadirachtin	NeemAzal-T/S	31-05-2025
Thrips	pyridalyl	Nocturn	5-1-2027
Thrips	Orange oil	Oroganic	30-4-2025
Thrips	pyrethrins, rapeseed oil	Raptol	31-08-2023
Thrips	esfenvalerate	Sumicidin super	12-1-2023
Thrips	abamectin	Vectine plus	5-1-2025
Thrips	*beauvaria bassianna strain PPRI5339*	Velifer	20-02-2030
Thrips	abamectin	Vertimec Gold	5-1-2025
Thrips	formetenaat	Winner	31-07-2024
True bugs	deltamethrin	Decis vlb	31-10-2023
True bugs	sulfoxaflor	Closer	18-08-2026
True bugs	sulfoxaflor	Sequoia	18-08-2026
True bugs	flupyradifuron	Sivanto prime	12-9-2026
True bugs	azadirachtin	Azatin	31-05-2025
True bugs	azadirachtin	BloomAzal	31-05-2025
True bugs	azadirachtin	Oikos	31-05-2025
True bugs	azadirachtin	NeemAzal-T/S	31-05-2025
True bugs	metaflumizone	Verismo	31-12-2025
True bugs	pyrethrins, rapeseed oil	Raptol	31-08-2023
True bugs	esfenvalerate	Sumicidin super	12-1-2023
True bugs	acetamiprid	Gazelle	01-01-2023
Whitefly	azadirachtin	Azatin	31-05-2025
Whitefly	azadirachtin	NeemAzal-T/S	31-05-2025
Whitefly	azadirachtin	Oikos	31-05-2025

Pest/disease	Active ingredient	Name CPP	Expiration date
Whitefly	azadirachtin	BloomAzal	31-05-2025
Whitefly	*beauvaria bassianna strain PPRI5339*	Velifer	20-02-2030
Whitefly	*beauveria bassiana ATCC74040*	Naturalis-L	30-4-2024
Whitefly	*Beauveria bassiana strain GHA*	Botanigard fluid	31-07-2024
Whitefly	buprofezin	Applaud 25SC	31-1-2024
Whitefly	flonicamid	Teppeki	01-05-2024
Whitefly	flonicamid	Inter Peki	6-3-2023
Whitefly	*Isaria fumosorosea Apopka strain 97*	PreFeRal	31-12-2031
Whitefly	*Lecanicillium muscarium strain Ve6*	Mycotal	01-03-2024
Whitefly	maltodextrin	ERII	30-09-2024
Whitefly	pyrethrins, rapeseed oil	Raptol	31-08-2023
Whitefly	pyriproxyfen	Admiral	01-04-2024
Whitefly	Orange oil	Oroganic	30-4-2025
Whitefly	spiromesifen	Oberon	30-09-2023
Whitefly	spirotetramat	Batavia	30-04-2025
Whitefly	spirotetramat	Movento	30-04-2025
Whitefly	sulfoxaflor	Closer	18-08-2026
Whitefly	sulfoxaflor	Sequoia	18-08-2026
Whitefly	teflubenzuron	Nomolt	30-11-2019
Whitefly	Terpenoid blend QRD	Requiem Prime	8-10-2026
Whitefly	thiamethoxam	Actara	30-4-2019
Whitefly	fatty acids, potassium salts	FLiPPER Plus	31-08-2023
Grey mould	chloorthalonil	Daconil	20-11-2019
Grey mould	*Bacillus amyloliquefaciens strain QST 713*	Serenade SC	30-04-2024
Grey mould	boscalid, pyraclostrobin	Signum	31-01-2024
Grey mould	captan	Captosan 500 SC	30-06-2024
Grey mould	fludioxonil	geoxe	31-10-2023
Grey mould	fluopyram	Luna Privilege	01-06-2027
Grey mould	Fenpyrazamine	Prolectus	31-12-2023
Grey mould	fludioxonil	Safir	31-10-2023
Grey mould	*Bacillus amyloliquefaciens strain FZB24*	Taegro	06-01-2033
Grey mould	fenhexamid	Teldor	01-01-2024
Grey mould	*Bacillus pumilus QST*	Sonata	31-08-2025
Grey mould	fludioxonil, cyprodinil	Switch	31-10-2023
Grey mould	fenhexamid	Teldor	01-01-2024
Grey mould	*Trichoderma atroviride strain SC1*	Vintec	06-07-2032
Rust	*Bacillus subtilis strain QST*	Serenade SC	30-04-2024
Rust	azoxystrobin, difoconazole	Alibi flora	31-12-2023
Rust	boscalid, pyraclostrobin	Signum	31-01-2024
Rust	acibenzolar-S-methyl	Insssimo	4-1-2032
Rust	penconazole	Topaz	01-09-2024
Rust	boscalid, kresoxim-methyl	Collis	31-07-2024
Rust	azoxystrobin	Ortiva	31-12-2025
Rust	kresoxim-methyl	Kenbyo FL	8-1-2026
Rust	trifloxystrobin	Flint	7-1-2024
Rust	chloorthalonil	Daconil	20-11-2019
Rust	mancozeb	Mancozeb flowable	7-4-2021
Rust	mancozeb	Penncozeb	7-4-2021
Late Blight	etridiazole	AAterra ME	31-5-2021
Late Blight	fenamidone, fosetyl-aluminium	Fenomenal	14-2-2019
Late Blight	captan	Captosan 500 SC	30-06-2024
Late Blight	metalaxyl-M	Metalaxyl-M SL	01-06-2023
Late Blight	propamocarb fosetyl	Previcur Energy	30-04-2024
Late Blight	propamocarb hydrochloride	Proplant	31-07-2023
Late Blight	Cyazofamid	Ranman Top	08-01-2024
Late Blight	metalaxyl-m	Ridomil Gold	6-1-2023
Late Blight	propamocarb hydrochloride	Rival	31-07-2024
Late Blight	*Bacillus subtilis strain QST*	Serenade SC	30-04-2024
Late Blight	*Bacillus amyloliquefaciens strain FZB24*	Taegro	06-01-2033

Pest/disease	Active ingredient	Name CPP	Expiration date
Late Blight	thiofanaat-methyl	Topsin m vlb	19-4-2021
Late Blight	*Trichoderma harzianum Rifai strain T-22*	Trianum-G	12-1-2025
Late Blight	*Trichoderma harzianum Rifai strain T-22*	Trianum-P	12-1-2025
Root rot	etridiazole	AAterra ME	31-5-2021
Root rot	*Trichoderma asperellum strain T34*	Asperello T34	31-05-2024
Root rot	fenamidone, fosetyl-aluminium	Fenomenal	14-2-2019
Root rot	metalaxyl-M	Metalaxyl-M SL	01-06-2023
Root rot	*Streptomyces K61*	Lalstop K61 WP/Mycostop	07-01-2024
Root rot	azoxystrobin	Ortiva	31-12-2025
Root rot	propamocarb fosetyl	Previcur Energy	30-04-2024
Root rot	propamocarb hydrochloride	Proplant	31-07-2023
Root rot	Cyazofamid	Ranman Top	08-01-2024
Root rot	metalaxyl-m	Ridomil Gold	6-1-2023
Root rot	propamocarb hydrochloride	Rival	31-07-2024
Root rot	*Bacillus subtilis strain QST*	Serenade SC	30-04-2024
Root rot	*Bacillus amyloliquefaciens strain FZB24*	Taegro	06-01-2033
Root rot	thiofanaat-methyl	Topsin m vlb	19-4-2021
Root rot	*Trichoderma harzianum Rifai strain T-22*	Trianum-G	12-1-2025
Root rot	*Trichoderma harzianum Rifai strain T-22*	Trianum-P	12-1-2025
Powdery Mildew	COS-OGA	Fado	22-4-2031
Powdery Mildew	azoxystrobin, difenoconazole	Alibi Flora	31-12-2023
Powdery Mildew	kresoxim-methyl, boscalid	Collis	31-07-2024
Powdery Mildew	trifloxystrobin	Flint	01-07-2024
Powdery Mildew	mepanipyrim	Frupica SC	30-04-2024
Powdery Mildew	fluopyram	Luna Privilege	01-06-2027
Powdery Mildew	azoxystrobin	Ortiva	31-12-2025
Powdery Mildew	*Bacillus amyloliquefaciens strain QST 713*	Serenade SC	30-04-2024
Powdery Mildew	*Bacillus pumilus QST 2808*	Sonata	31-08-2025
Powdery Mildew	boscalid, pyraclostrobin	Signum	31-01-2024
Powdery Mildew	*Bacillus amyloliquefaciens strain FZB24*	Taegro	06-01-2033
Powdery Mildew	*cerevisane*	Romeo	23-4-2031
Powdery Mildew	cyflufenamid	Takumi	31-03-2024
Powdery Mildew	Cyazofamid	Ranman Top	08-01-2024
Stem and crownrot	difenoconazole, fluxapyroxad	Bifasto	31-12-2023
Wilt and stemrot	*Streptomyces K61*	Lalstop K61 WP/Mycostop	07-01-2024
Wilt and stemrot	*Trichoderma harzianum Rifai strain T-22*	Trianum-G	12-1-2025
Wilt and stemrot	*Trichoderma harzianum Rifai strain T-22*	Trianum-P	12-1-2025
Wilt and stemrot	*Bacillus amyloliquefaciens strain QST 713*	Serenade SC	30-04-2024
Basal stem rot	boscalid, pyraclostrobin	Signum	31-01-2024
Basal stem rot	*Bacillus amyloliquefaciens strain FZB24*	Taegro	06-01-2033
Basal stem rot	flutolanil	Monarch	01-11-2025
Basal stem rot	pencycuron	Montego	31-05-2021
Basal stem rot	*Trichoderma harzianum Rifai strain T-22*	Trianum-G	12-1-2025
Basal stem rot	*Trichoderma harzianum Rifai strain T-22*	Trianum-P	12-1-2025
Basal stem rot	tolclos-methyl	Rizolex vlb	7-1-2024
Nematodes	oxamyl	Vydate	31-01-2024
Nematodes	garlic extract	NEMguard DE	9-1-2023
Snails	iron (III) phosphate	Sluxx HP	31-12-2031
Snails	iron (III) phosphate	Ironmax Pro	31-12-2031
Snails	metaldehyde	Metarex inov	31-5-2024
Growth regulators	daminozide	Alar 64 sp (85 SG)	31-10-2023
Growth regulators	daminozide	Imex-Daminozide SG	31-10-2023
Growth regulators	daminozide	Dazide Enhance	31-10-2023
Growth regulators	daminozide	Holland Fytozide	31-10-2023
Growth regulators	gibberellinen	Berelex ga 4/7	10-1-2024
Growth regulators	Sodium silver thiosulfate	Chrysal avb	7-1-2025
Growth regulators	Aluminium sulfate	Florissant	3-1-2025

D. Gerbera

Disease or Pest	Active Substance (AS)	Plant protection product	Expiration date
White fly	acetamiprid	Gazelle	1-1-2025
White fly	azadirachtin	Azatin	31-05-2025
White fly	azadirachtin	NeemAzal-T/S	31-05-2025
White fly	azadirachtin	Oikos	31-05-2025
White fly	*Beauvaria bassiana strain PPRI5339*	Velifer	20-02-2030
White fly	*Beauveria bassiana ATCC74040*	Naturalis-L	30-04-2024
White fly	*Beauveria bassiana strain GHA*	Botanigard fluid	31-07-2024
White fly	buprofezin	Applaud 25 SC	31-01-2024
White fly	deltamethrin	Decis	31-10-2023
White fly	esfenvalerate	Sumicidin super	01-12-2023
White fly	flupyradifuron	Sivanto Prime	09-12-2026
White fly	*Isaria fumosorosea Apopka strain 97*	PreFeRal	31-12-2031
White fly	rapeseed oil, pyrethrins	Raptol	31-08-2023
White fly	*Lecanicillium muscarium strain Ve6*	Mycotal	01-03-2024
White fly	maltodextrin	ERII	30-09-2024
White fly	Sodiumlaurylethersulfate	SB instant	(geen ctgb)
White fly	pymetrozine	Plenum 50 WG	23-2-2018
White fly	pyridaben	Carex	30-04-2024
White fly	pyriproxyfen	Admiral	01-04-2024
White fly	pyriproxyfen	Proxyral	01-04-2024
White fly	Orange oil	Oroganic	30-04-2025
White fly	spiromesifen	Oberon	30-09-2023
White fly	spiroteramat	Batavia	30-04-2025
White fly	Sulfoxaflor	Closer	18-08-2026
White fly	Sulfoxaflor	Sequoia	18-08-2026
White fly	Terpenoid blend QRD 460	Requiem prime	10-08-2026
White fly	thiamethoxam	Actara	30-04-2019
thrips	abamectin	Budget Abamectin 18 EC	01-05-2025
thrips	abamectin	Imex-Abamectin 2	01-05-2025
thrips	abamectin	Vectine	01-05-2025
thrips	abamectin	Vertimec	01-05-2025
thrips	azadirachtin	Azatin	31-05-2025
thrips	azadirachtin	NeemAzal-T/S	31-05-2025
thrips	azadirachtin	Oikos	31-05-2025
thrips	*Beauvaria bassiana strain PPRI5339*	Velifer	20-02-2030
thrips	Cyantraniliprole	Mainspring	14-09-2027
thrips	deltamethrin	Decis	31-10-2023
thrips	esfenvalerate	Sumicidin super	01-12-2023
thrips	flupyradifuron	Sivanto Prime	09-12-2026
thrips	formetanaat	Winner (Gowan)	31-07-2024
thrips	rapeseed oil, pyrethrins	Raptol	31-08-2023
thrips	*Lecanicillium muscarium strain Ve6*	Mycotal	01-03-2024
thrips	lufenuron	Match	31-12-2019
thrips	pyridalyl	Nocturn	01-05-2027
thrips	Orange oil	Oroganic	30-04-2025
thrips	spinosad	Conserve	30-04-2024
thrips	Terpenoid blend QRD 460	Requiem prime	10-08-2026
Aphids	acetamiprid	Gazelle	1-1-2025
Aphids	azadirachtin	Azatin	31-05-2025
Aphids	azadirachtin	NeemAzal-T/S	31-05-2025
Aphids	azadirachtin	Oikos	31-05-2025
Aphids	buprofezin	Applaud 25 SC	31-01-2024
Aphids	chlofentezin	Apollo	31-12-2023
Aphids	deltamethrin	Decis	31-10-2023
Aphids	esfenvalerate	Sumicidin super	01-12-2023
Aphids	flonicamid	Inter Peki	6-3-2023

Disease or Pest	Active Substance (AS)	Plant protection product	Expiration date
Aphids	flonicamid	Teppeki	01-05-2024
Aphids	flupyradifuron	Sivanto Prime	09-12-2026
Aphids	rapeseed oil, pyrethrins	Raptol	31-08-2023
Aphids	maltodextrin	ERII	30-09-2024
Aphids	pirimicarb 10%	Pediment smoke developer	01-12-2024
Aphids	pirimicarb 50%	Pediment	01-12-2024
Aphids	pymetrozine	Plenum 50 WG	23-2-2018
Aphids	Orange oil	Oroganic	30-04-2025
Aphids	spiroteramat	Batavia	30-04-2025
Aphids	Sulfoxaflor	Closer	18-08-2026
Aphids	Sulfoxaflor	Sequoia	18-08-2026
Aphids	Terpenoid blend QRD	Requiem Prime	10-08-2026
Spider mite	abamectin	Budget Abamectin 18 EC	01-05-2025
Spider mite	abamectin	Imex-Abamectin 2	01-05-2025
Spider mite	abamectin	Vectine	01-05-2025
Spider mite	abamectin	Vertimec	01-05-2025
Spider mite	acequinocyl	Cantack	31-08-2025
Spider mite	azadirachtin	NeemAzal-T/S	31-05-2025
Spider mite	*Beauveria bassiana strain GHA*	Botanigard wp	31-07-2024
Spider mite	bifenazate	Floramite 240 SC	31-07-2023
Spider mite	chlofentezin	Apollo	31-12-2023
Spider mite	cyflumetofen	Scelta	01-06-2026
Spider mite	etoxazole	Borneo	01-02-2023
Spider mite	hexythiazox	Nissorun fluid	01-06-2025
Spider mite	milbemectin	Milbeknock	31-07-2024
Spider mite	pyridaben	Carex	30-04-2024
Spider mite	Orange oil	Oroganic	30-04-2025
Spider mite	spiromesifen	Oberon	30-09-2023
Spider mite	Terpenoid blend QRD 460	Requiem prime	10-08-2026
Thread-footed mites	abamectin	Vectine	01-05-2025
Thread-footed mites	abamectin	Vertimec	01-05-2025
Thread-footed mites	acequinocyl	Cantack	31-08-2025
Thread-footed mites	azadirachtin	NeemAzal-T/S	31-05-2025
Thread-footed mites	Beauveria bassiana strain GHA	Botanigard wp	31-07-2024
Thread-footed mites	bifenazate	Floramite 240 SC	31-07-2023
Thread-footed mites	cyflumetofen	Scelta	01-06-2026
Thread-footed mites	etoxazole	Borneo	01-02-2023
Thread-footed mites	milbemectin	Milbeknock	31-07-2024
Thread-footed mites	pyridaben	Carex	30-04-2024
Thread-footed mites	Orange oil	Oroganic	30-04-2025
Thread-footed mites	spiromesifen	Oberon	30-09-2023
Thread-footed mites	Terpenoid blend QRD 460	Requiem prime	10-08-2026
leaf miners	abamectin	Budget Abamectin 18 EC	01-05-2025
leaf miners	abamectin	Imex-Abamectin 2	01-05-2025
leaf miners	abamectin	Vectine	01-05-2025
leaf miners	abamectin	Vertimec	01-05-2025
leaf miners	azadirachtin	NeemAzal-T/S	31-05-2025
leaf miners	azadirachtin	Oikos	31-05-2025
leaf miners	*Bacillus thuringiensis subsp. aizawai*	Turex 50 wp (no registration leaf miner and not on spray advice cadt)	30-04-2024
leaf miners	chlorantraniliprole	Altacor (no registration fro Gerbera and leaf miner)	01-07-2027
leaf miners	Cyantraniliprole	Mainspring	14-09-2027
leaf miners	cyromazine	Trigard 100 sl	31-12-2019
leaf miners	deltamethrin	Decis	31-10-2023
leaf miners	esfenvalerate	Sumicidin super	01-12-2023
leaf miners	milbemectin	Milbeknock	31-07-2024

Disease or Pest	Active Substance (AS)	Plant protection product	Expiration date
leaf miners	spinosad	Conserve	30-04-2024
Caterpillars including golden twin-spot moth	azadirachtin	NeemAzal-T/S	31-05-2025
Caterpillars including golden twin-spot moth	*Bacillus thuringiensis ssp. kurstaki SA-11*	Delfin	30-04-2023
Caterpillars including golden twin-spot moth	Bacillus thuringiensis subsp. aizawai	Turex 50 wp	30-04-2024
Caterpillars including golden twin-spot moth	Bacillus thuringiensis subsp. aizawai	Xen Tari WG	01-05-2025
Caterpillars including golden twin-spot moth	*Bacillus thuringiensis subsp. kurstaki*	CoStar WG	30-04-2024
Caterpillars including golden twin-spot moth	*Bacillus thuringiensis subsp. kurstaki*	DiPel DF	30-04-2024
Caterpillars including golden twin-spot moth	*Bacillus thuringiensis subsp. kurstaki*	Lepinox Plus	30-04-2024
Caterpillars including golden twin-spot moth	Cyantraniliprole	Mainspring	14-09-2027
Caterpillars including golden twin-spot moth	deltamethrin	Decis	31-10-2023
Caterpillars including golden twin-spot moth	esfenvalerate	Sumicidin super	01-12-2023
Caterpillars including golden twin-spot moth	indoxacarb	Steward	19-03-2022
Caterpillars including golden twin-spot moth	metaflumizone	Verismo	31-12-2025
Caterpillars including golden twin-spot moth	methoxyfenozide	Runner	01-04-2024
Caterpillars including golden twin-spot moth	pyridalyl	Nocturn	01-05-2027
Caterpillars including golden twin-spot moth	spinosad	Conserve	30-04-2024
Caterpillars including golden twin-spot moth	teflubenzuron	Nomolt	30-11-2019
Fungus gnats			
Sluggs	iron(III)phosphate	Ironmax Pro	31-12-2031
Sluggs	metaldehyde	Metarex inov	31-05-2024
Sluggs	metaldehyde	Slakkenkorrels	31-05-2024
Sluggs	iron(III)phosphate	Sluxx HP	31-12-2031
non-native earwig			
Powdery Mildew	acibenzolar-S-methyl	Inssimo	01-04-2032
Powdery Mildew	azoxystrobin	Ortiva	31-12-2025
Powdery Mildew	azoxystrobin, difenoconazole	Alibi Flora	31-12-2023
Powdery Mildew	*Bacillus amyloliquefaciens*	Taegro	06-01-2033
Powdery Mildew	*Bacillus amyloliquefaciens strain QST 713*	Serenade SC	30-04-2024
Powdery Mildew	*Bacillus pumilus QST 2808*	Sonata	31-08-2025
Powdery Mildew	bipurimate	Abir	31-05-2025
Powdery Mildew	bipurimate	Nimrod fluid	31-05-2025
Powdery Mildew	COS-OGA	Fado	22-04-2031
Powdery Mildew	cyflufenamid	Takumi	31-03-2024
Powdery Mildew	fenpropidin, penconazole	Solvit	31-12-2020
Powdery Mildew	fluopyram	Luna Privilege	01-06-2027
Powdery Mildew	fluxapyroxad, difenoconazole	Bifasto	31-12-2023
Powdery Mildew	imazalil	Fungaflash	31-12-2025
Powdery Mildew	potassium hydrogen carbonate	Karma	31-10-2022
Powdery Mildew	kresoxim-methyl, boscalid	Collis	31-07-2024
Powdery Mildew	mepanipyrim	Frupica SC	30-04-2024
Powdery Mildew	penconazole	Topaz 100 ec	01-09-2024
Powdery Mildew	propiconazole	Tilt 250 ec	19-06-2019

Disease or Pest	Active Substance (AS)	Plant protection product	Expiration date
Powdery Mildew	trifloxystrobin	Flint	01-07-2024
Powdery Mildew	sulfur	Kumulus s	01-03-2027
Powdery Mildew	sulfur	Pipe sulfur	01-02-2027
Powdery Mildew	sulfur	Spray sulfur	01-02-2027
Powdery Mildew	sulfur	Dust sulfur	01-02-2027
Powdery Mildew	sulfur	Thiovit	01-02-2027
Powdery Mildew	sulfur	Afepasa Greenhouse Sulphur Tablets	31-12-2023
white mould	*Bacillus amyloliquefaciens*	Taegro	06-01-2033
white mould	boscalid, pyraclostrobin	Signum	31-01-2024
white mould	captan	Captosan	30-06-2024
white mould	captan	Merpan Flowable	30-06-2024
white mould	fluxapyroxad, difenoconazole	Bifasto	31-12-2023
Gray mould	*Bacillus amyloliquefaciens*	Taegro	06-01-2033
Gray mould	*Bacillus pumilus QST 2808*	Sonata	31-08-2025
Gray mould	boscalid, pyraclostrobin	Signum	31-01-2024
Gray mould	cyprodinil, fludioxonil	Switch	31-10-2023
Gray mould	fenhexamid	Teldor	01-01-2024
Gray mould	Fenpyrazamine	Prolectus	31-12-2023
Gray mould	fluopyram	Luna Privilege	01-06-2027
Gray mould	mepanipyrim	Frupica SC	30-04-2024
Late blight	captan	Merpan Flowable	30-06-2024
Late blight	cyazofamid	Ranman	31-07-2022
Late blight	cyazofamid	Ranman Top	01-08-2024
Late blight	dimethomorf	Paraat	01-07-2023
Late blight	fosetyl, propamocarb	Previcur Energy	30-04-2024
Late blight	mandipropamid	Pergado V	31-07-2024
Late blight	metalaxyl-M	Ridomil Gold 480 EC	01-06-2023
Late blight	propamocarb hydrochloride	Proplant	31-07-2023
Pythium Damping-off	*Bacillus amyloliquefaciens strain QST 713*	Serenade SC	30-04-2024
Pythium Damping-off	fosetyl, propamocarb	Previcur Energy	30-04-2024
Pythium Damping-off	fosetyl-aluminium, fenamidone	Fenomenal	14-02-2019
Pythium Damping-off	metalaxyl-M	Budget Metalaxyl-M SL	01-06-2023
Pythium Damping-off	metalaxyl-M	Ridomil Gold 480 EC	01-06-2023
Pythium Damping-off	propamocarb hydrochloride	Proplant	31-07-2023
Pythium Damping-off	*Streptomyces K61 (formerly S. griseoviridis)*	Lalstop K61 WP	01-07-2024
Pythium Damping-off	*T. asperellum strain T34*	Asperello T34	31-05-2024
Pythium Damping-off	*Trichoderma harzianum Rifai strain T-22*	Trianum-P	12-01-2025
Fusarium wilt	*T. asperellum strain T34*	Asperello T34	31-05-2024
Fusarium wilt	*Streptomyces K61 (previous name S. griseoviridis)*	LALSTOP K61 WP	01-07-2024
Fusarium wilt	*Bacillus amyloliquefaciens strain QST 713*	Serenade SC	30-04-2024
Fusarium wilt	*Trichoderma harzianum Rifai strain T-22*	Trianum-P	12-01-2025
Rhizoctonia root rot	*Bacillus amyloliquefaciens strain QST 713*	Serenade SC	30-04-2024
Rhizoctonia root rot	boscalid, pyraclostrobin	Signum	31-01-2024
Rhizoctonia root rot	tolclofos-methyl	Rizolex fluid	01-07-2024
Rhizoctonia root rot	*Trichoderma harzianum Rifai strain T-22*	Trianum-P	01-12-2025
Rust	kresoxim-methyl, boscalid	Collis	31-07-2024
Rust	trifloxystrobin	Flint	01-07-2024
Downy mildew	fosetyl, propamocarb	Previcur Energy	30-04-2024
Downy mildew	cyazofamid	Ranman Top	01-08-2024
desinfection	Menno Florades	Benzoic acid	31-08-2033

E. *Phalaenopsis*

Pest/disease	Active ingredient	Name CPP	Expiration date
Aphids	fatty acids, potassium salts	Flipper Plus	31-8-2023
Aphids	pirimicarb	Pediment	12-1-2024
Aphids	deltamethrin	Decis vlb	31-10-2023
Aphids	esfenvalerate	Sumicidin Super	12-1-2023
Aphids	acetamiprid	Gazelle	1-1-2023
Aphids	terpenoid blend QRD	Requiem Prime	8-10-2026
Aphids	sulfoxaflor	Closer	18-8-2026
Aphids	sulfoxaflor	Sequoia	18-8-2026
Aphids	flupyradifuron	Sivanto Prime	12-9-2026
Aphids	spirotetramat	Batavia	30-4-2025
Aphids	flonicamid	Teppeki	5-1-2024
Aphids	azadirachtin	NeemAzal-T/S	31-5-2025
Aphids	pyrethrins, rapeseed oil	Raptol	31-8-2023
Mealybug (wolluis)	terpenoid blend QRD	Requiem Prime	8-10-2026
Mealybug (wolluis)	acetamiprid	Gazelle	1-1-2023
Mealybug (wolluis)	buprofezin	Applaud 25SC	31-1-2024
Mealybug (wolluis)	spirotetramat	Batavia	30-4-2025
Mealybug (wolluis)	maltodextrin	ER II	30-9-2024
Mealybug (wolluis)	pyrethrins, rapeseed oil	Raptol	31-8-2023
Gnat larvae Lyprauta spp (potworm)			
Mite	fatty acids, potassium salts	Flipper Plus	31-8-2023
Mite	pyrethrins, rapeseed oil	Raptol	31-8-2023
Mite	milbemectin	Milbeknock	31-7-2024
Mite	abamectin	Vectine Plus	5-1-2025
Mite	abamectin	Vertimec gold	5-1-2025
Mite	chlofentezin	Apollo	31-12-2023
Mite	hexythiazox	Nissorun	6-1-2025
Mite	etoxazole	Borneo	2-1-2023
Mite	acequinocyl	Cantack	31-8-2025
Mite	bifenazate	Floramite	31-7-2023
Mite	pyradiben	Carex 10Sc	30-4-2024
Mite	spiromesifen	Oberon	30-9-2023
Mite	maltodextrin	Eradicoat Max	30-9-2024
Mite	maltodextrin	ER II	30-9-2024
Mite	cyflumetofen	Scelta	6-1-2026
Thrips Vandatrips, *Dichromothrips corbetti*	terpenoid blend QRD	Requiem Prime	8-10-2026
Thrips	azadirachtin	Azatin	31-5-2025
Thrips	azadirachtin	NeemAzal-T/S	31-5-2025
Thrips	pyridalyl	Nocturn	5-1-2027
Thrips	*Beauveria bassiana strain GHA*	Botanigard WP	31-7-2024
Thrips	*Beauveria bassiana strain PPRI5339*	velifer	20-2-2030
Thrips	formetenaat	Winner	31-7-2024
Thrips	deltamethrin	Decis vlb	31-10-2023
Thrips	esfenvalerate	Sumicidin Super	12-1-2023
Thrips	flupyradifuron	Sivanto Prime	12-9-2026
Thrips	spinosad	Conserve	30-4-2024
Thrips	abamectin	Vectine Plus	5-1-2025
Thrips	abamectin	Vertimec gold	5-1-2025
Thrips	azadirachtin	Oikos	31-5-2025
Thrips	pyrethrins, rapeseed oil	Raptol	31-8-2023
Thrips	*beauveria bassiana PPRI5339*	velifer	20-2-2030
Thrips	cyantraniliprole	Mainspring	14-9-2027
Sciariden (varenrouwmug)	*Bacillus thuringiensis subs. Israelensis*	Gnatrol SC	30-4-2023
Sciariden (varenrouwmug)	deltamethrin	Decis vlb	31-10-2023

Pest/disease	Active ingredient	Name CPP	Expiration date
Sciariden (varenrouwmug)		.	
Nematodes	oxamyl	Vydate 10G	31-1-2024
Snails	metaldehyde	Metarex Inov	31-5-2024
Snails and slugs	iron (III) phosphate	Sluxx slakkenkorrels	31-12-2031
Botrytis	boscalid, pyraclostrobin	Signum	31-1-2024
Botrytis	fludioxonil	Geoxe	31-10-2023
Botrytis	*gliocladium catenalatum st. J1446*	Prestop	31-3-2035
Botrytis	mepanipyrim	Frupica SC	30-4-2024
Botrytis	fludioxonil, cyprodinil	Switch	31-10-2023
Botrytis	*Pythium oligandrum strain M1*	Polyversum	30-4-2024
Botrytis	fenpyrazamine	Prolectus	31-12-2023
Botrytis	fenhexamid	Teldor	1-1-2024
Fusarium	*Bacillus amyloquefaciens str. QST 713*	Serenade	30-4-2024
Fusarium	*gliocladium catenalatum st. J1446*	Prestop	31-3-2035
Fusarium	*Trichoderma asperellum strain T34*	Asperello T34	31-5-2024
Phytophtora	dimethomorph	Paraat	31-7-2024
Phytophtora	propamocarb hydrochloride	Proplant	31-7-2023
Phytophtora	*Bacillus amyloquefaciens str. QST 713*	Serenade	30-4-2024
Phytophtora	propamocarb fosetyl	Previcur Energy	30-4-2024
Phytophtora	*gliocladium catenalatum st. J1446*	Prestop	31-3-2035
Phytophtora	cyazofamid	Ranman Top	8-1-2024
Phytophtora	metalaxyl-m	Ridomil Gold	6-1-2023
Phytophtora	fenamidone, fostyl-aluminium	Fenomenal	14-2-2019
Pythium	*gliocladium catenulatum strain J1446*	Prestop 4B	4-1-2024
Pythium	propamocarb fosetyl	Previcur Energy	30-4-2024
Pythium	propamocarb hydrochloride	Proplant	31-7-2023
Pythium	metalaxyl-m	Ridomil Gold	6-1-2023
Pythium	*Bacillus amyloquefaciens str. QST 713*	Serenade	30-4-2024
Pythium	propamocarb hydrochloride	Rival	31-7-2024
Pythium	cyazofamid	Ranman Top	8-1-2024
Rhizoctonia	*Bacillus amyloquefaciens str. QST 713*	Serenade	30-4-2024
Rhizoctonia	*gliocladium catenalatum st. J1446*	Prestop	31-3-2035
Rhizoctonia	boscalid, pyraclostrobin	Signum	31-1-2024
Rhizoctonia	*Trichoderma harianum Rifai T-22*	Trianum-G	12-1-2025
Rhizoctonia	tolclofos-methyl	Rizolex	7-1-2024
bacteria like Acidovorax en Erwinia			
Growth regulation	daminozide	Dazide Enhance	31-10-2023
Growth regulation	prohexadon calcium	Regalis plus	31-12-2023
Growth regulation	paclobutrazol	Bonzi	12-1-2024
Growth regulation	paclobutrazol	Pirouette	31-5-2024
Growth regulation	chloormequatchloride	UPL CCC 750	6-1-2025
Growth regulation	chloormequatchloride	CeCeCe	4-1-2026
celstrekking	Gibberlic acid	Florgib ST	31-8-2024
Cleaning	didecyldimethyl-ammoniumchloride	Menno ter forte	09-09-999
Cleaning	hydrogen peroxide, peracetic acid	Jet 5	09-09-999
Desinfection	benzoic acid	Menno Florades	31-8-2033
Weed, not in protected cultivation	triclopyr	Genoxone ZX	1-1-2024
	glufosinaat-ammonium	Liberty (Basta)	31-07-2018
	florasulam, fluroxypyr-meptyl	Primstar	31-12-2025
	glyphosate	Roundup ultra	15-07-2020
	MCPA	U 46 m-fluid-500 mcpa	6-1-2025

Appendix 4 Overview of available Plant protection products for potato per pest and disease[10]

Pest / disease	Chemical PPPs Active Ingredient	Product name	Expiration date
Seed weeds			
	aclonifen	Challenge e.a.	31-7-2024
	bentazon	Basagran	31-5-2026
	clethodim	Centurion Plus e.a.	1-3-2024
	clomazone	Centium e.a.	1-10-2023
	cycloxydim	Focus Plus	1-10-2026
	fluazifop-P-butyl	Fusilade Max e.a.	1-3-2023
	metobromuron	Proman e.a.	31-12-2024
	metribuzin	Sencor e.a.	31-7-2024
	pendimethalin	Stomp e.a.	1-1-2024
	propaquizafop	Agil	30-11-2023
	prosulfocarb	Boxer e.a.	1-9-2023
	quizalofop-P-ethyl	Pilot	30-11-2023
	rimsulfuron	Titus	30-4-2024
root weeds			
	glyphosate	Roundup e.a.	15-12-2023
	MCPA	U46 MCPA e.a.	1-6-2025
	2,4-D	Mega 2,4-D e.a.	1-7-2023
	triclopyr	Genoxone ZX e.a.	1-1-2024
nematodes			
	fluopyram	Velum e.a.	31-1-2025
	fosthiazate	Nemathorin	31-10-2023
	oxamyl	Vydate	31-1-2024
aphids			
	deltamethrin	Decis e.a.	31-10-2023
	esfenvalerate	Sumicidin e.a.	1-12-2023
	flonicamid	Teppeki	1-1-2023
	flupyradifon	Sivanto Prime	9-12-2026
	lambda-cyhalothrin	Karate e.a.	1-5-2023
	pirimicarb	Pirimor e.a.	1-2-2024
	spirotetramat	Batavia e.a.	30-4-2024
wireworms			
	fosthiazate	Nemathorin	31-10-2023
	tefluthrin	Force Evo	31-12-2025
Colorado beetle			
	chlorantraniliprole	Coragen	1-6-2027
	cyantraniliprole	Benevia	14-9-2027
	acetamiprid	Gazelle	1-1-2023
	azadirachtine	NeemAzal	31-5-2025
bean spider mite			
	spirotetramat	Batavia e.a.	30-4-2024
Bugs			
	acetamiprid	Gazelle	1-1-2023
	deltamethrin	Decis e.a.	31-10-2023
	esfenvalerate	Sumicidin e.a.	1-12-2023
	lambda-cyhalothrin	Karate e.a.	1-5-2023

[10] Based on data of 2022.

Pest / disease	Chemical PPPs Active Ingredient	Product name	Expiration date
alternaria			
	See scheme below		
phytophthora			
	See scheme below		
rhizoctonia			
	azoxystrobin	Amistar e.a.	31-12-2025
	fludioxonil	Maxim e.a.	1-10-2023
	flutolanil	Monarch e.a.	1-11-2025
	fluxapyroxad	Allstar	31-12-2023
	Bacillus subtilis QST 713	Serenade	30-4-2024
sclerotinia			
	Coniothyrium minitans	Contans	31-7-1933
	boscalid/pyraclostrobin	Signum e.a.	31-1-2024
	fluazinam	Vendetta e.a.	28-2-2024
Snails			
	iron(III)phosphate	Sluxx HP e.a.	31-12-1931
haulm killing			
	carfentrazone-ethyl	Spotlight e.a.	1-8-2024
	pyraflufen-ethyl	Quickdown e.a.	1-6-2023
sprout inhibition			
	maleine hydrazide	Royal MH e.a.	31-10-1933
	1,4-dimethylnaftalene	1,4 Sight	1-7-2025
	Ethylene	Restrain	31-8-2024
	Spearmint oil	Biox M	31-8-2024
	orange oil	Argos	

	alternaria & use	**phytophthora &use**	ametoctradin	amisulbrom	azoxystrobin	benthiavalicarb-isopropyl	cyazofamid	cymoxanil	difenoconazole	dimethomorph	fluazinam	fluopyram	fluopicolide	fluxapyroxad	mandipropamid	oxathiapiproline	propamocarb	propiconazole	zoxamid
Expiration date			**31-7-2024**	**30-6-2025**	**31-12-2025**	**31-7-2024**	**1-8-2024**	**1-9-2025**	**31-12-2023**	**1-11-2025**	**28-2-2024**	**31-7-2023**	**31-5-2024**	**31-12-2023**	**31-7-2024**	**3-3-2028**	**31-5-2024**	**31-7-2023**	**1-1-2024**
Amphore Flex								1							1				
Banjo Forte****										1	1								
Canvas****		j		1															
Carial Star									1						1				
Curzate Partner****								1											
Dagonis SC	j								1					1					
Enervin SC****			1																
Gachinko**		j		1															
Infinito		j											1				1		
Kunshi****								1			1								
Narita	j								1										
Orvego			1							1									
Propulse	j											1						1	
Proxanil***								1									1		
Ranman Top		j					1												
Reboot****								1											1
Revus		j													1				
Vendetta					1						1								
Versilus						1													
Zorvec Endavia		j				1										1			
Zorvec Enicade		j														1			

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