Annex 1 – Project Plan and Project Budget

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PPP proposal title: **Effect of cover crops, weeds and compost as primary inoculum source for foliar pathogens in arable cropping systems**

General information

Applicant/coordinator contact details (i.e. not the research institute)

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The PPP proposal will contribute either to the following mission:

☐ 1. Nature
☑ 2. Sustainable agriculture and horticulture
☐ 3. Vital countryside in a climate-resilient Netherlands
☐ 4. Sustainable valued food which is healthy, accessible and safe
☐ 5. The sustainable and safe use of the North Sea and large bodies of water
☐ 6. Safe deltas

Or the following key technology:

☐ ST1. Smart technologies for the blue-green domain
☐ ST2. Biotechnology and breeding

Or the following:

☐ ST3. Fermentation and bioconversion
☐ Crossover with TKI Life Sciences and Health (KIA Health & Care)
☐ Crossover with TKI Logistics (onderdeel van KIA Energy & Circularity)
☐ Crossover with TKI IT (KIA Digitalisation)

Please note: put an X in one box only

If a mission has been selected, which Innovation Programme and mission does the proposal relate to?

This proposal contributes to mission 2, "Sustainable agriculture and horticulture". More specifically, it addresses challenges defined within innovation programme 2C "Resilient plant production on a vital soil and substrate".

TRL at the start of the project

TRL 3: testing (Proof of principle / Proof of concept). We investigate the applicability of the concept on an experimental basis (experimental proof of concept). We test and validate hypotheses about different components of the concept.

Brief summary of the PPP proposal

Many foliar pathogens of arable crops, like *Alternaria solani* and *Cercospora beticola* can survive saprophytically during the intercropping season on crop residues, defined as the remains of the above-ground biomass of the crop (i.e., dead leaves and stems). Saprophytic growth might also occur in alternative host plants, such as cover crops and weeds, which may be present in the rotation system. Especially cover crops are grown more and more in crop rotation systems. Optimal arable cropping systems can be designed in combination with measures that further limit the survival of the pathogenic populations during fallow. For that, it is necessary to complete the knowledge gap about the population dynamics of pathogenic fungi and the disease epidemiology in crop rotation systems. This project will obtain specific knowledge of which cover crops and weeds can act as a source of disease inoculum. We will investigate the role of cover crops and weeds as source of inoculum of *A. solani*, causal agent of potato early blight and *C. beticola*, causal agent of leaf spot in sugar beet. This research will be performed at residue stage but also, as a novelty, at fresh stage in the field crop. Furthermore the role of compost will be investigated as well. The presence of *A. solani* an *C. beticola* will be measured by visual observations and molecular quantitative detection methods (qPCR assays) not only at their pathogenic stage, but also during their saprophytic development.

The purpose of this project fits with the KIA-LWV mission 2C Duurzame landbouw - Weerbare plantaardige productie op een vitale bodem/substraat, providing essential knowledge to reduce disease pressure before and during cultivation of the host crop. The acquired information on population dynamics of potato and sugar beet pathogens will enable to select cover crops which do not support the occurrence of fungal pathogens during their fresh/residue stage, and to implement management measures to reduce weeds that host fungal pathogens during their fresh/residue stage. This will help arable farmers to develop resilient cultivation systems and become less dependent on the use of chemical fungicides, which are used as the principal strategy to manage the most common fungal diseases in arable crops.

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PPP proposal (max. 10 pages)

1. Objective and expected results

Crop residues, defined as the above-ground biomass of the crop (i.e., dead leaves and stems) including dead weeds and dead cover crops, are left in the field after harvesting. Many foliar pathogens can survive saprophytically on these residues and multiply during the the intercropping season to infect new susceptible crops in the rotation. Additionally, cover crops, used for e.g. Carbon sequestration, Nitrogen fixation, (ground) water quality, etc., and weeds that may be present in the rotation, might act as alternative host plants, where pathogens can survive. Periods in the cropping system where the host plant is not present can be potentially used to reduce populations of plant pathogens. Optimal crop rotation systems can be designed in combination with measures that further limit the survival of the pathogenic populations. For the design of optimal crop rotation systems, it is crucial to have pathogen-specific knowledge of which crop residues, cover crops and weeds can be used by the pathogen and what role they play as a source of disease for subsequent host crops.

In the past decades, this knowledge in a crop rotation context was very limited. In the recent years, two PPS projects LWV19003 Gewasrestenmanagement tegen ziekten and LWV20.167 Rol van gewasresten voor bladpathogenen van suikerbiet in bouwplanverband have obtained first insights on how plant pathogens in arable crops, such as *Alternaria solani*, causal agent of potato early blight and *Cercospora beticola*, causal agent of leaf spot in sugar beet, are able to survive, not only in crop residues of sensitive host plants i.e., potato and sugar beet, but also in residues from other crops, weeds and non-susceptible cover crops within the rotation system. Additionally, the new PPS project LWV23071 'Crop Residues Management 2.0: Breaking the Pathogen Cycle (BreakPaths)' has just started to continue tracking these pathogens in different crop rotation systems and to investigate the ability of different treatments to reduce the pathogen presence in the crop residues. However, more substantial investigation is still missing to address and understand the role of cover crops and weeds as source of inoculum.

This PPS project will build on the work of the above-mentioned PPS projects, obtaining quantitative and qualitative results about the occurrence of *A. solani* and *C. beticola*, two of the most relevant foliar fungal pathogens in potato and sugar beet, in cover crops and weeds. This research will be performed at residue stage but also, as novelty in this new project, at fresh stage in the field crop, to fill the knowledge gap about their population dynamics and disease epidemiology in crop rotation systems. This will help Dutch growers to make the right decisions in terms of cover crop selection or weed management, to decrease the potential risk of pathogen inoculum sources. Another novelty is the role of compost. The results obtained in this new project, together with the results obtained in the previous ones, will complete the needed overview of the role of different residues, cover crops and weeds in the survival of major fungal leaf pathogens in arable cropping systems. This information is essential to help agricultural Dutch systems to become more resilient and less dependent on the use of chemical fungicides.

2. Project appropriate for the KIA and contribution to portfolio

Agricultural food systems have become very dependent on the use of chemical fungicides, which are used as common strategy to manage fungal diseases in arable crops. National and EU-policies aim to reduce the use of, and dependence on these synthetic fungicides. KIA-LWV mission 2C Duurzame landbouw - Weerbare plantaardige productie op een vitale bodem/substraat envisages to achieve agricultural food systems with cost-effective control of diseases, pests and weeds by 2030, with virtually no emissions and residues of crop protection products, safe for local residents and users, and with reduced dependence on chemical crop protection products. This mission is in line with the EU objectives stablished by the Farm to Fork strategy, at the heart of the European Green Deal, aiming at reducing the use and risk of chemical pesticides by 50% in 2030, as well as with the Plant Health action plan from BO Akkerbouw, which aims to implement resilient cultivation systems, reduce the impact on the environment with tailored administration of crop protection, contribute to increasing biodiversity and make environmental performance more transparent for the market. This new scenario will place our Dutch growers in a precarious situation

with a higher disease pressure and lack of suitable crop disease management options. It is of high priority to be ready for this transition towards less use of chemical fungicides and have solid and reliable alternatives to manage diseases. This project aims to contribute to a sustainable solution by providing essential knowledge to manage these diseases and develop resilient cultivation systems.

The current management of the most problematic fungal pathogens in arable crops is dependent on the use of chemical fungicides, some of them containing active substances listed as Candidates for Substitution, such as tebuconazole and difenoconazole. In 2020, the use of these two substances in the Netherlands exceeded 21 tonnes per year. The sectors involved note that the current control strategy will be insufficient and that knowledge about the disease pressure at the start of the growing season, or which inoculum sources are of importance and to what extent is lacking. This complicates the development of targeted management. One strategy to reduce the pressure of fungal diseases in arable crops is to tackle the pathogens survival when the host crop is not present, such as at crop residue, cover crop or even weed level. An adequate management of these stages along the crop rotation system will be translated in less dependency on the use of chemical treatments during the crop season.

This project will continue and complement the successful close collaboration of the PPS projects LWV19003, LWV20.167 and LWV23071, by tracking the development of foliar pathogen populations in cover crops and weeds (at fresh and residue stage) through arable cropping systems. The generated knowledge in this project is necessary for the arable farming sector and for the research institutions involved in developing robust cultivation systems, to design systems with a lower risk of pathogens occurrence. An approach which includes the role that various cover crops and weeds play in pathogen survival along the rotation, together with different crop residue management measures, is highly original and offers new perspectives in arable farming.

3. Impact

The results obtained regarding the role of cover crops, weeds and compost as inoculum sources of fungal leaf pathogens in arable cropping system will benefit Dutch farmers and the arable crop sector, enabling growing crops with lower fungal disease pressure. The specific project results, effects and societal impact are presented in Annex 1.

This project will continue the task started in the previous PPS projects LWV19003, LWV20.167 and LWV23071. The proposed research is innovative because little is known about the survival of pathogens such as *A. solani* and *C. beticola* on cover crops and weeds at fresh and residue stage during fallow. The development of quantitative molecular tests in the PPS projects LWV19003 and LWV20.167 and their large-scale application, enables us to develop targeted research on cover crops and weeds in this current project. During the trials it will become clear what effect the presence of different cover crops and weeds has on the survival and multiplication of these pathogens. This will make available new relevant information on population development of pathogens across these potential disease sources. The obtained results are the basis to implement new/improved sustainable strategies for targeted cover crop and weed management and become less dependent from conventional plant protection products. The generated knowledge will be applied to develop new arable robust systems, aiming at reducing the disease occurrence during the crop rotation. This will help to achieve the long-term societal impact of cost-effective control of diseases with virtually no emissions and residues of crop protection products that is safe for local residents and users, and with reduced dependence on chemical crop protection products.

Dissemination of the obtained results will be one of the main pillars of this project, as detailed in the WP4 description and section 6 of this proposal. Already at the proposal stage preparation, the research questions and approaches have been designed in consultation and agreement with all members of this consortium (which includes end-users) to guarantee that the targeted impact will be reached. During the course of the project, the execution will be done together with all partners. The Arable Farming Branch Organization (BO Akkerbouw) will inform to their affiliated members about the novel results and the knowledge obtained in this project, so Dutch growers, stakeholders and

companies from the arable sector can already become acquainted with the trial design and the results. This will help Dutch growers to have sufficient perspective for action to meet changing demands of the market and society. Additionally, there will be constant contact and exchange of the newest results with the PPS projects LWV23071, LWV23064 Integrated crop management voor de beheersing van ziekten, plagen en onkruiden in akkerbouw op zandgronden (AoZ 2.0) and, specially, LWV22013 Groenbemesters II, where cover crops selection is ameliorate based on preventing nutrient emissions and improving soil structure and carbon sequestration. The network established within these projects will make possible to update and improve their execution. The knowledge will be shared by the partners involved with study groups of farmers and networks of all three projects. Therefore, connection to international scientific and applied research into the transition of agricultural systems is further strengthened during and after the execution of this project.

4. Project approach

In this three-year project, four Work Packages (WP) are foreseen. In this section there is a summary of the activities that will be developed within each WP. Extensive information about the tasks, the timeline followed for the implementation of the tasks, the resulting deliverables and the cooperation with other projects is detailed in Annex 3.

WP1. Tracking the presence of key fungal pathogens in cover crops

Each of the 2 years, two experimental field trials will be located in Valthermond, growing two main crops, potato and sugar beet. After harvesting the main crops, cover crops will be sown. A total of 10 to 15 cover crops will be examined in this project. Four plots (repetitions) will be used per cover crop. One extra treatment will be added as a control, without cover crop presence (fallow).

During the second half of the growing season of potato and sugar beet, early blight and Cercospora leaf spot severity, respectively, will be visually assessed. At the end of the growing season of the main crops, samples of the main crops will be collected to establish quantitively the disease pressure of *A. solani* and C. *beticola* in the debris of the crops, using the already available qPCR assays from the PPS projects LWV19003 and LWV20.167. The cover crops sown after the main crops will be sampled at different times of the season to obtain and analyse fresh and residue material. Samples will be assessed for the presence of *A. solani* and *C. beticola* symptoms, doing visual observations in cover crop plants. In case visual symptoms are found, pictures will be taken to record them and isolations will be performed to confirm the presence of the targeted pathogens. Furthermore, samples will be assessed to quantify the presence of both pathogens, using the qPCR assays mentioned above. Visual observations and DNA quantification are complementary information to unravel the role of the cover crops for *A. solani* and *C. beticola* during not only their pathogenic stage but also during their saprophytic development.

Collected data in both experiments will be analysed and processed to elaborate datasets containing symptom observations and DNA concentration of both pathogens in their host crops, as a control measure, and in the cover crops grown in the succession. The complete datasets will contain data of two years.

WP2. Tracking the presence of key fungal pathogens in weeds

Samples of commonly occurring weed species, both fresh plant material and residues, will be collected in the experimental field trials of WP1, when the *A. solani* and *C. beticola* epidemic is going on, i.e., in the second part of the season. If there is not sufficient weed material to have consistent samplings, other crop fields, including potato and sugar beet in their rotation system, will be examined for the presence of weeds to collect the samples. Samples will be assessed as in WP1. Collected data in both experiments will be analysed and processed as in WP1.

WP3. Tracking the presence of the key fungal pathogens in compost

The potential contribution of compost increasing *A. solani* and *C. beticola* inoculum presence in the field will be also assessed in the two experimental field trials located in Valthermond. The selection of the compost will be discussed with the consortium. The compost will be applied at two different times of the season, in autumn, right after harvesting the main crop (potato or sugar beet) and in spring, following standard agricultural practices. The application of the compost will be combined with one or more cover crops used within this project and the PPS LWV22013, to evaluate their effect together.

WP4. Project management and dissemination of results

Two general meetings per year with all partners and regular meetings within WR groups will be organized to discuss the obtained results, status of the tasks and deliverables, and to decide what the next steps are. Furthermore, there will be communication between this project and the PPS projects LWV23071, LWV23064 and LWV22013, where data and results will be exchanged during yearly meetings. Main findings of this project will be published in Dutch on Crkls (dissemination website where BO Akkerbouw is co-founder of), using up to 2% of the project budget, newsletters of WR, IRS and/ or BO Akkerbouw, farmers' magazines and specialized journals, such as Gewasbescherming. Additionally, results will be published in open access peer-reviewed journals. Communication with growers and stakeholders will be also done by demonstrating the results on open days organized by WUR (e.g. Groenbemesterdag) and IRS. This shared information will allow growers to better develop rotation systems and focus on cover crops weeds as hosts of specific diseases in order to prevent disease outbreaks and make arable cropping systems more resilient.

A decision point will be established at month 12, if DNA of *A. solani* and *C. beticola* is not detected in the collected samples of cover crops during the first experiment. Other cover crops will be included in the second experiment. A decision point will be also established every 6 months during the whole project, if there is not sufficient weed material to have consistent samplings. Other potato and sugar beet fields will be examined for the presence of weeds to collect samples.

5. Organisation

The secretary function (penvoerder) will be in BO Akkerbouw hands. The project will be conducted by Dr. Georgina Elena Jiménez, from WR BioInteractions & Plant Health (BioInt), who has experience in running projects related to epidemiology and biocontrol research on plant pathogens. She has been already involved in the previous PPS projects on crop residues LWV19003 and LWV20.167 and she is coordinating the current PPS LWV23071. Dr. Bert Evenhuis, from WR Field Crops (FC), will provide support with an extensive experience in arable crops and plant diseases. He has been/is also involved in the PPS projects LWV19003, LWV20.167, LWV23071 and LWV23064. Dr. Jürgen Köhl, from WR BioInt, project leader of the former PPS projects LWV19003 and LWV20.167 and also involved in the current PPS project LWV23071, will be advising during the project, due to his extensive career and experience on biocontrol research and track record in the field of fundamental and strategic research on plant pathogens and detection techniques.

The research is being carried out in collaboration between BO Akkerbouw, WR and IRS. The involvement of BO Akkerbouw, with its strong connection to growers and the outreach that it has, guarantees that the generated knowledge can be directly applied in the farmer's business operations. Wageningen Research is responsible for the design and execution of the experiments and the optimization and evaluation of detection methods. IRS will contribute with their expertise on crop protection and sugar beet production. BO Akkerbouw and IRS have been/ are also involved in the PPS projects LWV19003, LWV20.167, LWV23071 and LWV23064.

There will be regular meetings (once per month) within Wageningen partners carrying out the project tasks (BioInt and FC), to fine tune how tasks are performed and to troubleshot in case of drawbacks, or if a second approach is needed. Furthermore, it will be planned in advance two general meetings per year with all partners involved, where an overview of the status of the tasks and deliverables will be discussed, together with preliminary results (when possible) and new objectives will be established for until the next meeting. BO Akkerbouw, together with IRS, make sure that the needs and voice of the arable sector is taken into account. Moreover, there will be communication between this project and the PPS projects LWV23071, LWV23064 and LWV22013, where data and results will be exchanged.

6. Knowledge valorisation and knowledge sharing

The information obtained in this project will benefit farmers and the arable crop sector and it is expected to be used to reduce the disease pressure through cover crop choice, which will encourage their beneficial use, and weed management in arable cropping systems. The research questions and approaches of this project are being defined and co-designed together with all partners already at the proposal stage. Additionally, BO Akkerbouw is willing to actively think about how to strategically set up communication along the different projects. This way, we ensure that this project addresses the societal challenge of helping Dutch growers to face the reduction of pesticides use and the increase of disease pressure in their crops. The obtained results will be already shared with farmers associations, arable companies and their networks. This will make possible a rapid implementation of the acquired knowledge by growers, which will gain insights into whether cover crop choice and weed management will be suitable and relevant for specific crop system-pathogens.

Public dissemination will be promoted by facilitating the access of the project results to farmers, arable companies, scientific community and general public via:

- Publication of the main findings in Dutch on Crkls, a dissemination website co-founded by BO Akkerbouw, using up to 2% of the project budget.
- Publication of main findings in the national journal Gewasbescherming, which stakeholders read.
- Summary of main findings in Newsletters of WR, IRS and/ or BO Akkerbouw and farmers' magazines.
- Scientific publications of the results in open access peer-reviewed journals, to allow other scientist and public to learn from our findings and to build up more knowledge on those data.
- Communication to growers/ stakeholders by demonstrating the results in open days organized by WUR (e.g. Groenbemesterdag) and IRS.
- Knowledge shared with partners involved in the PPS projects LWV23071, LWV23064 and LWV22013.