SUSTAINABLE STORAGE OF GRAINS
BY IMPLEMENTING A NOVEL PROTECTANT
AND A VERSATILE APPLICATION TECHNOLOGY

D2.3 Data Package for Dissemination and Decision Support System

Work Package 2 contribution to the novIGRain decision-support framework

Report on Formulation Development	
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Issued Date:	**30/06/2026**

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This project has received funding from the European Union's Horizon 2020 research and innovation programme, under grant agreement No 101000663.

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1. Purpose and scope

The **novIGRain** project addresses a practical challenge in the European stored grain sector: maintaining effective protection of stored cereals while regulatory options are becoming more limited and resistance to established insect control measures is increasingly relevant. Within this context, Work Package 2 (WP2) focused on developing and assessing a new plant oil-based ultra-low-volume (ULV) formulation containing S-methoprene as an insect growth regulator (IGR) active substance. The product concept developed in the project, Methograin IGR 30 ULV, is intended for post-harvest indoor treatment of cereals stored in closed grain storage facilities.

This document summarises the WP2 data package in a dissemination-level format and indicates how the information can support the decision-making tool developed in the **novIGRain** project. It is not the "extraction" of the planned regulatory dossier, does not replace the label instructions, and should not be interpreted as a site-specific treatment prescription. Its purpose is to translate the main publicly shareable WP2 findings into structured inputs for stakeholders, including grain store operators, pest management professionals, advisors, farmers, industry representatives and policy-oriented audiences.

2. Product concept and pest management relevance

The selected product concept is a ready-to-use plant oil-based ULV formulation containing 30 g/L S-methoprene and designed for application at 2-4 L per 100 tonnes of grain depending on the required duration of effect. The formulation concept was developed to fit the ULV grain treatment system designed and implemented within WP3, taking into account its intended and realized mode of operation. Its ready-to-use character is an important practical feature: the product does not require dilution before application, thereby avoiding an additional preparation step for the user and supporting easier, more reliable and more user-friendly operation under practical grain storage conditions. The intended use concept is post-harvest indoor treatment of stored cereals. The formulation is designed to provide long-term preventive support against stored grain insect pests, without noticeable odour, and to complement the existing toolbox of grain protection measures.

The main technical principle is insect growth regulation. While conventional adulticidal treatments such as pyrethroid- or organophosphate-based products are primarily intended to control existing adult insects, S-methoprene (IGR) acts at a different point in the pest life cycle by interfering with insect development and reducing the emergence of new adults from treated grain. This makes the approach particularly relevant for preventive pest management, especially where grain is expected to be stored for a

medium or long period and where the goal is to prevent population build-up before damage becomes visible.
An additional practical advantage of the product concept is that Methograin IGR 30 ULV can be used in parallel with an adulticidal product where the pest management situation requires both preventive and curative elements. The active substance and the formulation were selected and developed in a way that allows the S-methoprene-based IGR treatment to complement adulticidal control. In such an integrated application concept, the IGR effect supports the inhibition of insect development and reduction of adult emergence, while the adulticidal product can provide a killing effect against crop infested adult insects and its mobile or feeding larval stages, depending on the authorised use of the selected adulticide.
This parallel-use concept is also supported by the ULV application equipment developed in WP3. The dual-head ULV system allows Methograin IGR 30 ULV and a selected adulticidal product to be applied from separate tanks and through separate ULV heads. As a result, no tank mix needs to be prepared before application, and the products do not need to be physically mixed before reaching the grain surface. This is particularly relevant from a practical application perspective, as it allows the use of adulticidal products with different formulation bases, including water-based or oil-based products, provided that their authorised use conditions allow such application. The separate dosing and application channels support operational flexibility and make it possible to combine the preventive IGR-based approach with adult control where an integrated pest management strategy is needed.
The relevance of this approach is strengthened by the wider project context. Current stored grain protection practices are often based on adulticidal treatments and fumigation-based methods. Resistance data generated in WP1 in the project indicate that resistance is a real concern for several important stored grain pest species. A larvicidal mode of action can therefore contribute to anti-resistance strategies by broadening the available pest management toolbox and reducing overreliance on conventional adulticide-centred approaches.

3. WP2 data generation and formulation development

WP2 followed a stepwise development pathway. The work started with the definition of practical and safety-related requirements for a ULV grain protectant. Candidate formulation components were assessed on the basis of chemical composition, compatibility, preliminary hazard information and practical feasibility. Plant oil-based carriers were selected because they are renewable, accessible and compatible with the formulation concept. Several prototype formulations were prepared and assessed, and

the final formulation was selected after considering formulation stability, active substance content, preliminary efficacy and manufacturing feasibility.
The WP2 work programme also included physico-chemical testing, analytical method development and validation, residue and metabolism studies, toxicological and ecotoxicological studies, exposure estimation, risk assessment inputs and efficacy testing under laboratory, simulated-use and practical conditions.

4. Summary of publicly shareable evidence

The completed and ongoing phisico-chemical-, (eco) toxicological- and metabolism studies generated a broad evidence base to support the scientific assessment of the product. Physico-chemical properties were determined, and analytical methods were validated to support testing in different matrices, including the formulation itself, environmental matrices, plant materials and animal-related matrices where relevant. These data are important because they make it possible to reliably measure S-methoprene, residues and impurities in the studies required for future assessment.
The toxicological and ecotoxicological programme generated key hazard-related inputs. The available public summary data indicate a favourable acute mammalian toxicity profile, with an oral LD50 in rats above 5050 mg/kg body weight. Aquatic toxicity endpoints were also established, including an acute fish LC50 for Danio rerio of 4.26 mg/L over 96 hours and an acute Daphnia magna EC50 of 0.22 mg/L over 48 hours. No endocrine-disrupting, immunotoxicological or neurotoxic effects were observed at the highest tested dose. These figures are risk assessment inputs and do not replace the complete regulatory evaluation.
Residue, metabolism and environmental fate studies provide further support for understanding the behaviour of the active substance and its residues after use. Some metabolism and residue-related studies remain ongoing or dependent on the outcome of earlier steps; however, the data generated so far provide a suitable basis to support the scientific and regulatory assessment of the active substance and the product concept for the intended use. These data contribute to evaluating residue behaviour, consumer exposure, human health aspects and environmental risks, and therefore support the demonstration of safe and responsible use under the proposed conditions. For dissemination, the most appropriate message is that WP2 has generated and organised the data needed to support future assessment of consumer exposure, environmental exposure and responsible use conditions.

5. Efficacy findings and practical interpretation

The efficacy programme provides the most direct input for pest management decision-making. Because S-methoprene (IGR) is an insect growth regulator, the most relevant effect is not immediate adult mortality but suppression of development and reduction of adult emergence from treated grain. This distinction is essential for the decision-support logic and for stakeholder communication.

Laboratory efficacy studies with Methograin IGR 30 ULV showed strong preventive activity against key stored grain pest species. These studies demonstrated a high level of inhibition of adult emergence from treated grain, with values generally in the range of approximately 96-99.9% against lesser grain borer (*Rhyzopertha dominica*), red flour beetle (*Tribolium castaneum*) and saw-toothed grain beetle (*Oryzaephilus surinamensis*) under the tested storage conditions. This means that the formulation effectively interfered with the development of the target insect populations and strongly reduced the number of new adults emerging from the treated grain. The dose range studies confirmed the same mode of action, showing a consistently high reduction of adult emergence under the tested conditions. These results are directly relevant for practical stored grain protection, as they show that the product concept can help prevent the build-up of pest populations during storage and support long-term protection of the commodity. On this basis, the product concept can be considered a valuable preventive option in pest management strategies for stored grain, particularly where the aim is to reduce reliance on purely curative adulticidal treatments and to strengthen protection before visible infestation develops.

The interpretation for users must remain balanced. The product concept should not be presented as a universal stand-alone solution for every pest situation. Where an active infestation with adult insects is already present, an adulticidal or other curative intervention may still be needed. The main value of the S-methoprene approach is long-term prevention and population suppression, either as a single preventive measure under appropriate conditions or as part of an integrated strategy where adult control and prevention are combined.

6. WP2 data inputs for the decision-support system

The online novIGRain decision-support tool is the final user-oriented output that translates project knowledge into practical support for stored grain pest management decisions. The WP2 contribution to this tool is not a transfer of the full confidential regulatory dossier, but the transfer of public, decision-relevant information generated during product development and testing. These WP2 data allow the tool to explain when the Methograin IGR 30 ULV product concept may be relevant, what type of pest

management role it fulfils, and which limitations and responsible-use considerations must be taken into account.

The first WP2 input is the product concept itself. The tool can use the WP2 formulation data to identify Methograin IGR 30 ULV as a ready-to-use, plant oil-based ULV formulation containing S-methoprene as an insect growth regulator. This information supports the tool in distinguishing the product from conventional adulticidal products and in presenting it as a preventive larvicidal option designed for post-harvest indoor treatment of stored grain. The ready-to-use character and the compatibility with the ULV grain treatment system developed in WP3 are also relevant decision inputs, because they help determine whether the approach is technically suitable for a specific storage and grain-handling situation.

The second WP2 input is the intended use pattern. WP2 generated the product concept and application information needed by the tool to describe the proposed treatment scenario: indoor post-harvest treatment of cereals in closed grain storage facilities, using a ULV application rate of 2-4 L per 100 tonnes of grain, depending on the required duration of protection. This allows the tool to connect user-defined storage conditions, such as expected storage duration and preventive protection needs, with an appropriate product concept. It also supports the tool in making clear that the approach is intended for stored grain protection and not for unrelated field or outdoor uses.

The third WP2 input is the mode of action. Because S-methoprene interferes with insect development and reduces adult emergence, the tool can use this information to separate preventive insect growth regulator-based strategies from curative adult-control strategies. This is a central decision point. If the user indicates clean grain, suspected hidden infestation, low initial pest pressure or long storage duration, the tool can identify a preventive IGR-based approach as relevant. If the user indicates an already visible adult infestation, the tool can indicate that adult control or an integrated strategy may need to be considered first, because the main WP2 efficacy endpoint is inhibition of adult emergence rather than immediate adult mortality.

The fourth WP2 input is the efficacy dataset. WP2 efficacy studies showed a high level of inhibition of adult emergence from treated grain against key stored grain pests, including lesser grain borer (*Rhyzopertha dominica*), red flour beetle (*Tribolium castaneum*) and saw-toothed grain beetle (*Oryzaephilus surinamensis*), under the tested storage conditions. These data support the decision logic that Methograin IGR 30 ULV can be considered where the practical objective is to prevent the build-up of pest populations during storage and to support long-term protection of the commodity. In the tool, this information can be used to explain why a preventive larvicidal treatment may be selected before visible infestation develops, especially when grain is expected to remain in storage for a longer period.

The fifth WP2 input is the distinction between target-pest relevance and practical pest diagnosis. The WP2 efficacy results provide species-specific evidence for key stored grain pests. When the tool asks the user to identify the pest species or likely pest group, the WP2 data help determine whether the generated efficacy evidence is directly relevant to the pest situation selected by the user. Where the pest is unknown, this supports a recommendation for sampling and correct pest identification before selecting a treatment strategy.

The sixth WP2 input is the toxicological, ecotoxicological and environmental fate information. These data support the human health and environmental risk assessment for the active substance and final formulation. In the tool, this information can be translated into practical guidance that the product concept must be used only under authorised conditions, with appropriate operator, worker and environmental risk mitigation measures where required. This helps ensure that the tool does not only support efficacy-based decisions, but also responsible and risk-aware pest management choices.

Finally, WP2 data provide an important link to resistance management. By generating evidence for a product concept with a different mode of action from conventional adulticidal treatments, WP2 supports the tool in identifying situations where broadening the pest management toolbox may be beneficial. When combined with WP1 resistance information and WP4 SWOT outputs, the WP2 inputs allow the online tool to provide more specific indicative recommendations, such as: preventive IGR-based treatment may be relevant for long storage and low or hidden pest pressure; adult control should be considered where active adult infestation is confirmed; sampling and pest identification are recommended where the pest situation is uncertain; and an integrated strategy may be appropriate where resistance risk, pest pressure or storage duration justify combining complementary control measures.

7. Public data elements proposed for the tool

The following WP2 data elements are suitable for public dissemination and integration into the decision-support system:

Data element	Public summary
Product concept	Ready-to-use plant oil-based ULV formulation containing S-methoprene as an insect growth regulator (IGR). This identifies the intervention considered by the tool and distinguishes it from conventional adulticidal treatments.
Product name	Methograin IGR 30 ULV.

Data element	Public summary
Active substance concentration	30 g/L S-methoprene.
Intended use scenario	Post-harvest indoor treatment of cereals in closed grain storage facilities. This helps the tool connect the product concept with stored grain protection scenarios rather than unrelated field or outdoor uses.
Indicative application rate	2-4 L/100 tonnes of grain, depending on the required duration of protection and based on the product concept tested in the project.
Application feasibility input	Ready-to-use formulation compatible with the ULV grain treatment system developed in WP3. No dilution is required before application, supporting practical use and helping the tool consider whether the site and equipment are suitable. The dual-head ULV system also supports parallel application with an appropriate adulticidal product from separate tanks and through separate ULV heads, avoiding the need for tank mixing and supporting practical integrated use where both preventive IGR-based treatment and adult control are needed.
Mode of action	IGR: Insect growth regulation; interference with insect development and reduction of adult emergence from treated grain. This enables the tool to separate preventive IGR-based strategies from curative adult-control strategies.
Main pest management role	Preventive treatment and long-term population suppression in stored grain, especially where grain is expected to remain in storage and the aim is to prevent pest population build-up.
Target-pest relevance	Efficacy evidence was generated for key stored grain pests, including lesser grain borer (*Rhyzopertha dominica*), red flour beetle (*Tribolium castaneum*) and saw-toothed grain beetle (*Oryzaephilus surinamensis*). This supports pest-specific guidance and the recommendation to identify the pest situation before selecting a strategy.
Efficacy input	Laboratory and semi-field studies showed a high reduction of adult emergence under tested conditions. This supports tool outputs indicating when preventive larvicidal treatment may be relevant before visible infestation develops.

Data element	Public summary
Residue and metabolism input	Analytical, residue and metabolism data support the assessment of residue behaviour and consumer exposure considerations. In the tool, this supports responsible-use messages and links the use scenario with the need for authorisation-compliant conditions.
Human health and environmental input	Toxicological, ecotoxicological and environmental fate information support human health and environmental risk assessment considerations. The tool can translate this into guidance on authorised conditions, risk mitigation, operator/worker safety and environmental protection.
Resistance-management relevance	A different mode of action from conventional adulticidal treatments allows the tool to combine WP2 product information with WP1 resistance data and WP4 SWOT outputs, supporting indicative recommendations on preventive, curative or integrated strategies.
Limitations of interpretation	The public data package does not replace the confidential regulatory dossier, product authorisation, label instructions or professional site-specific assessment. Tool outputs should therefore be indicative and decision-supportive rather than prescriptive.

8. Key considerations for responsible dissemination

The public communication should emphasise that Methograin IGR 30 ULV is part of integrated stored grain protection. The product concept should be positioned as a preventive larvicidal tool within integrated stored grain protection, not as a replacement for all existing methods or as an immediate curative solution for all adult infestations. Public communication should therefore emphasise monitoring and sampling, correct pest identification, use of preventive measures before pest populations increase, integration with adult control where necessary, and strict compliance with authorised use conditions. Claims that the product is risk-free, universally applicable or suitable without consideration of the storage situation, pest pressure and application conditions should be avoided.

9. Conclusion

The WP2 data package provides a practical bridge between the scientific work carried out in the project and the user-oriented decision-support framework. It summarises the

development of a new plant oil-based ULV insect growth regulator formulation, the selection of the Methograin IGR 30 ULV product concept, the generation of efficacy evidence, and the analytical, residue, toxicological and ecotoxicological information needed to support responsible assessment.

The main value of the WP2 contribution is that it introduces a **preventive larvicidal approach** into stored grain protection. This approach can complement existing adulticidal and fumigation-based methods and may **support resistance management** by broadening the available toolbox.