The Collaborative Research Project

between
Gyeongsangbuk-do Agricultural Research & Extension Services (GBARES) of Republic of Korea

and
Research Institute of Organic Agriculture (FiBL) of Switzerland

Development of Organic Stone Fruit Production Technology

Final report form

1. Project Outline

□ Department / Main Researcher:

- Hans-Jakob Schaerer, Fabian Baumgartner, Helin Bozbeyoglu; Department of Crop Sciences, FiBL Switzerland
- Chung-Sil Kim, Hye-Rin Jeong, Hye-Jeong Jeong, Hye-Min Oh; Organic Farming Unit Uiseong, GBARES Korea

□ Research Period: 2023~ 2025

- Reporting period: January 1st 2023 to December 31st 2025

□ Budgetary plan

Year	Expenditures	Amount (Korean won)	Descriptions
1st year (2023)	Personnel expenses	25,000,000	• Allowance and salary for GBARES researcher during staying in FiBL • Allowance and salary for FiBL scientists
	Research supplies	20,000,000	• Agricultural materials • All kinds of supplies for project
	Research activities	15,000,000	• Farm visits, local trips, and so on • Research work in other places than FiBL
2nd year (2024)	Personnel expenses	25,000,000	• Allowance and salary for GBARES researcher during staying in FiBL • Allowance and salary for FiBL scientists
	Research supplies	20,000,000	• Agricultural materials • All kinds of supplies for project
	Research activities	15,000,000	• Farm visits, local trips, and so on • Research work in other places than FiBL
3rd year (2025)	Personnel expenses	25,000,000	• Allowance and salary for GBARES researcher during staying in FiBL • Allowance and salary for FiBL scientists
	Research supplies	20,000,000	• Agricultural materials • All kinds of supplies for project
	Research activities	15,000,000	• Farm visits, local trips, and so on • Research work in other places than FiBL
Total		180,000,000	

2. Summary

<table>
<tr><td>Purpose & Contents</td><td colspan="5">This report presents the results of a three-year collaborative research project (2023–2025) between Gyeongsangbuk-do Agricultural Research & Extension Services (GBARES) of Republic of Korea and Research Institute of Organic Agriculture (FiBL) of Switzerland aimed at improving organic stone fruit production. The project focused on plum orchards, combining system-based approaches in Switzerland and disease management strategies in Korea.</td></tr>
<tr><td>Results</td><td colspan="5">In Switzerland, results from the first productive year indicate that orchard protection systems did not result in clear differences in overall tree vigor or health, while pest pressure and fruit damage varied among cultivars and between systems. However, these observations are preliminary, as the trees are still in the establishment phase and yield data remain limited. In Korea, disease occurrence and treatment performance also varied between years and were strongly influenced by annual weather conditions and pest presence, highlighting that conclusive assessments cannot yet be made and that longer-term observations are required for some experiments. Nevertheless, Lime sulfure was identified as an effective agent against plum pocket.</td></tr>
<tr><td>Expected Contribution</td><td colspan="5">The project provides practical and scientific evidence supporting organic stone fruit systems and informs growers, advisors, and policymakers on products efficiency, cultivar choice, and orchard design under climate variability.</td></tr>
<tr><td>Keywords</td><td>Organic agriculture</td><td>Stone Fruit</td><td>Plum</td><td>Pest & disease</td><td>Cultivar evaluation</td></tr>
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Ⅰ. Introduction

1. Research Background

Stone fruit production is increasingly affected by climate variability, emerging pest and disease pressures. In temperate and continental regions, irregular precipitation, heat stress, and late frost events challenge orchard stability and productivity. At the same time, climate change is contributing to shifts in pest and pathogen dynamics, increasing uncertainty for growers.

In organic systems, these challenges are amplified by the limited number of approved plant protection products. As a result, organic fruit production relies primarily on preventive and system-based approaches, including orchard design, cultivar selection, physical protection structures, and optimized timing of management interventions, rather than curative control measures.

Against this background, plum orchards were selected as a model system due to their economic relevance and their sensitivity to both pest pressure and climatic conditions. The need for scientifically sound, field-based research is particularly strong for organic systems, where management options are constrained and long-term resilience is a key objective.

2. Project Objectives

The overall objective of this project was to generate applied scientific knowledge to support the development of resilient organic stone fruit production systems. Specific objectives were defined for each project year:

2.1 Objectives in the 1st Year (2023)

- Establishment of experimental plum orchards in Switzerland and Korea under organic management.
- Implementation of orchard protection systems and disease management strategies.
- Development of protocols & knowledge sharing.

2.2 Objectives in the 2nd Year (2024)

- Consolidation of the experimental design and completion of orchard planting.
- Adjustment of management practices based on field conditions.
- Initial observations on tree development, phenology, and pest occurrence.

2.3 Objectives in the 3rd Year (2025)

- Collection of data on phenology, pest and disease occurrence, and early yield.

- Collection of data on products efficiency
- Preparation of a scientific synthesis of results.

3. Project Duration

The project was conducted over a three-year period from 2023 to 2025.

4 Project Activities

4.1 Activities in the 1st Year

- Orchard establishment and infrastructure installation.
- Selection of cultivars
- Selection of experimental treatments.

4.2 Activities in the 2nd Year

- Completion of planting.
- Continued orchard management and monitoring.
- Experiments on disease control

4.3 Activities in the 3rd Year

- Field observations and data collection during the first productive year.
- Analysis and interpretation of preliminary results.
- Preparation of the final report.
- Preparation of grower's guide for plum production in Korea.

Ⅱ. Materials and Methods

1. Field experiment in Switzerland on plum cultivar performance under different orchard systems

1.1 Experimental design, cultivar selection, and protection systems

The Swiss experimental work was conducted at the FiBL research station in Frick, Switzerland, under certified organic management conditions. The site is in a temperate climatic region suitable for organic stone fruit production in Switzerland.

The experimental orchard was established in two planting phases. The first planting phase was carried out in December 2023, followed by a second planting phase in November 2024.

A total of eight plum cultivars were included in the trial. Four cultivars of *Prunus domestica* were planted in December 2023: 'Löhrpflaume', a locally adapted cultivar and Plum of the Year 2022; 'Jubiläum', 'Early Laxton', an early-ripening cultivar; and 'Reineclaude', a widely grown reference cultivar. Four additional cultivars were planted in November 2024: 'Aprimira' *(Prunus domestica*), described as a robust cultivar; 'Black Diamond' (*Prunus salicina*), a Japanese plum cultivar, characterized by its dark skin and red flesh; 'Santa Rosa' (*Prunus salicina*), also present in Korea; and 'Cometa', an interspecific hybrid derived from *Prunus ussuriensis, P. simonii, and P. salicina*. All cultivars were present in both protection systems, namely a system protected with hail netting and a covered system equipped with rain covers (See Figure 1).

Figure 1. Aerial view of the experimental orchard area at the FiBL research station in Frick (Switzerland). (A) Apricot *(Prunus armeniaca)* orchard. (B) Plum (Prunus spp.) orchard under hail net protection. (C) Plum *(Prunus spp.)* orchard under rain protection canopy. (D) Cherry *(Prunus avium)* experimental orchard.

For each cultivar, twelve trees were distributed across the two protection systems. Trees were arranged in two rows of forty-eight trees, with four blocks of three trees per cultivar (Figure 2). All trees were trained according to the Drapeau Marchand system, with the trunk initially planted upright and subsequently bent to an angle of

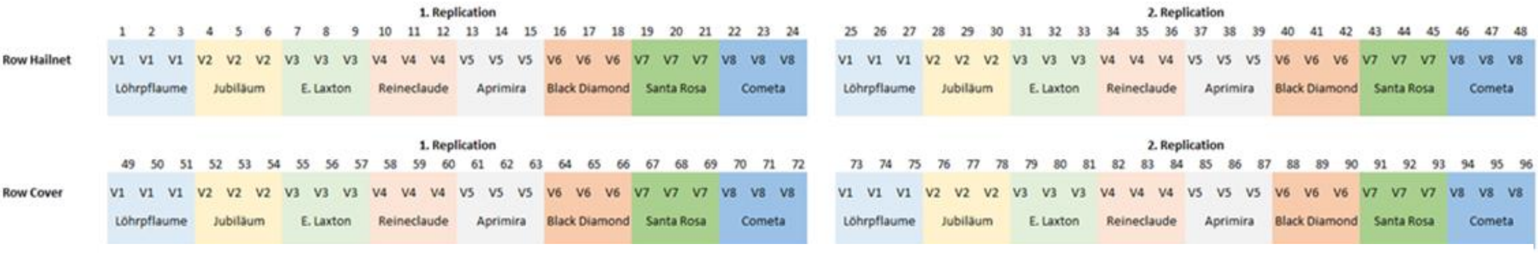

Figure 2. Layout of the plum orchard experiment showing the distribution of the eight cultivars across the two protection systems (hail netting and rain cover). Each system comprised two rows with two replications, resulting in twelve trees per cultivar per system.

Figure 3. First growing year of the plum cultivar 'Black Diamond' trained according to the Drapeau Marchand system, with the trunk initially planted upright and subsequently bent to an angle of approximately 45° and supported by longitudinal wires.

approximately 45°, supported by longitudinal wires (See Figure 3)

1.2 Orchard management, phenological observations and assessments

The experimental orchard in Switzerland was managed in accordance with certified organic production standards throughout the project period (2023–2025). Management practices aimed to ensure uniform tree establishment and system stability during the establishment phase. From March onwards, the tree row area was mechanically weeded using a Ladurner-Hackgerät, while inter-row vegetation was regularly mulched. An organic fertiliser was applied once in March at an approximate rate of 30 kg N ha^{-1}, adjusted to the requirements of young trees.

To control overwintering insect stages, particularly the leaf-curling plum aphid, two applications of mineral oil were applied in March. No fungicide treatments were applied during the growing seasons. In the rain protection treatment, the plastic cover was installed in early March; from this point onwards, the irrigation system was activated to compensate for the exclusion of natural precipitation. The hail net system was managed according to standard organic orchard practices, without specific irrigation adjustments. Formative pruning and shoot pinching were carried out in May to promote the development of future structural axes along the main shoot, in accordance with the Drapeau Marchand training system.

Phenological observations were conducted during the growing season. Tree vigour and tree health were assessed using visual rating scales. Pest occurrence was assessed on trees at defined time points, focusing on aphid species, winter moth, and plum moth. Early yield observations were carried out during the 2025 growing season. All data are considered indicative only for the early age of the trees.

2. Field experiments in the Republic of Korea on plum disease management under field conditions

2.1 Plum pocket disease experiment (Taphrina pruni)

The plum pocket disease experiment was conducted in Uiseong (Republic of Korea) under natural infection conditions at the GBARES research station. The trial aimed to evaluate disease management strategies compatible with organic production systems. The experiment was carried out over two consecutive growing seasons on the locally cultivated plum cultivar 'Oishiwase'. Trees were trained according to a Y-training system (See Figure 4) and managed uniformly across treatments, except for the disease control measures under evaluation. During the first experimental year (2024), the study compared two fungicide-based disease management strategies. Three treatment

Figure 4. Plum orchard in the Republic of Korea illustrating the planting layout and training system used in the field trials. The image shows the orchard structure and row arrangement (left) and the Y-training system applied to individual trees from front (right)

variants were evaluated: (1) a copper-based fungicide (Bordeaux mixture) applied twice, (2) lime sulphur applied twice, and (3) an untreated control (UTC). The untreated control consisted of a central untreated row positioned between treated rows to limit spray interference. Based on the outcomes of the 2024 experiment, the second experimental year (2025) focused on optimizing the lime sulphur application strategy.

Three treatment variants were evaluated: (1) lime sulphur applied once, (2) lime sulphur applied twice, and (3) an untreated control (See Figure 5).

In both years, the first spray application was performed in late February at the onset of bud break. When applicable, the second application was carried out two weeks after the first spray. No additional disease management practices were applied after the final spray in either year.

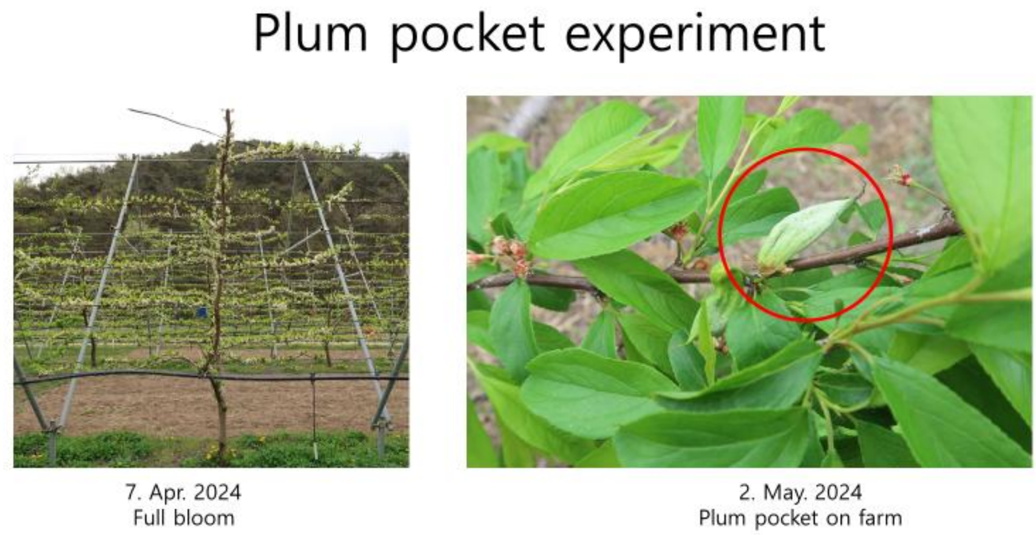

Figure 6. Plum pocket experiment conducted in 2024. Left: plum trees at full bloom (7 April 2024). Right: characteristic plum pocket symptoms observed in the orchard on 2 May 2024 (circled).

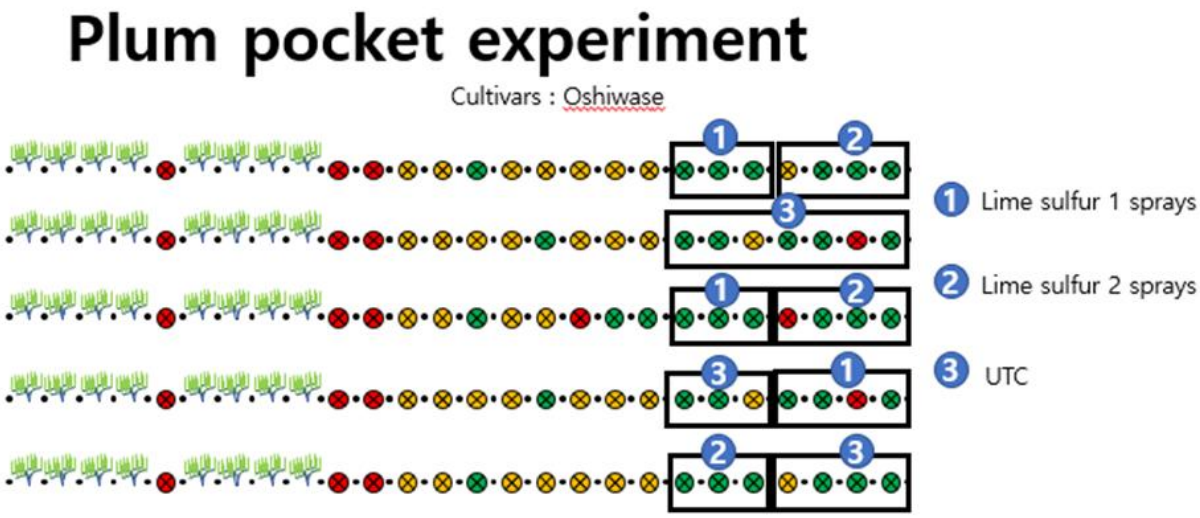

Figure 5. Experimental design of the plum pocket disease trial conducted in 2025 on the cultivar 'Oishiwase'. The layout illustrates the spatial distribution of the three treatment variants evaluated under natural infection conditions: (1) lime sulphur, one spray application; (2) lime sulphur, two spray applications; and (3) untreated control (UTC). Treatments were arranged in replicated blocks within the same orchard.

Plum pocket disease incidence was assessed in spring by visually inspecting all fruits on each experimental tree (See Figure 6). The total number of fruits and the number of symptomatic fruits were recorded. Disease incidence was expressed as the percentage of infected fruits per tree.

2.2 Bacterial shot hole disease experiment (Xanthomonas arboricola)

The bacterial shot hole disease experiment was conducted in Uiseong (Republic of Korea) under natural infection conditions in a commercial plum orchard managed according to standard on-farm practices. The trial aimed to evaluate disease management strategies compatible with organic production systems for the control of bacterial shot hole disease caused by *Xanthomonas arboricola*.

The experiment was carried out on the plum cultivar 'Formosa'. The field trial followed a randomized block design and included three treatment variants: (1) a microbial-based product containing Bacillus subtilis strain QST713, (2) a copper-based treatment (Bordeaux mixture), and (3) an untreated control (UTC).

Treatments were randomly distributed within blocks to account for spatial variability within the orchard (See Figure 7). Each treatment received three spray applications during the growing season. No additional plant protection measures were applied beyond the planned experimental treatments.

Spray applications were initiated on 2 May and repeated at 10-day intervals, resulting in a total of three applications per treatment. Applications targeted both foliage and developing fruits. No curative treatments were applied outside the defined spray

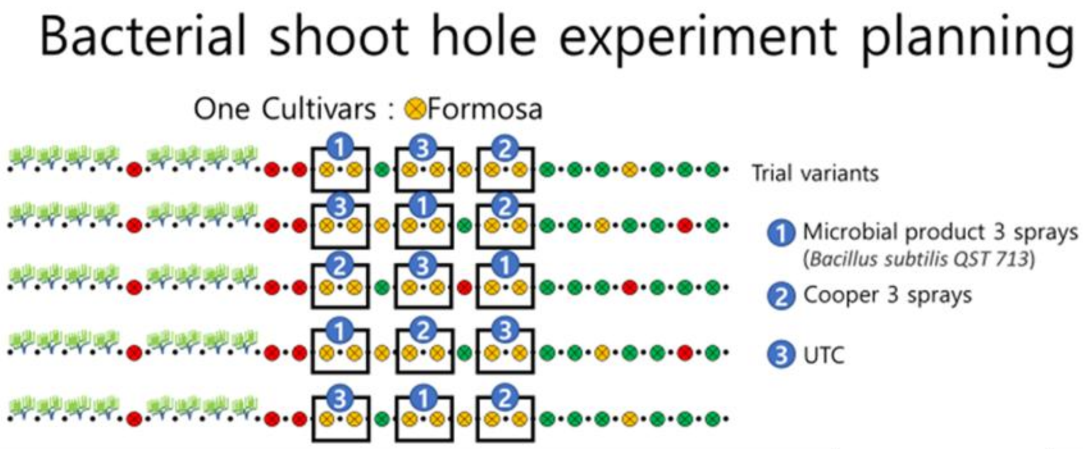

Figure 7. Experimental layout of the bacterial shot hole disease trial conducted on the plum cultivar 'Formosa' in Uiseong (Republic of Korea). The layout illustrates the spatial distribution of the three treatment variants evaluated under natural infection conditions: (1) microbial-based product containing Bacillus subtilis strain QST713 applied three times, (2) copper-based treatment (Bordeaux mixture) applied three times, and (3) untreated control (UTC).

schedule.

Disease development was monitored throughout the growing season by visually inspecting leaves and fruits for symptoms consistent with bacterial shot hole disease. Observations focused on the presence and distribution of necrotic lesions on leaves and fruits.

Ⅲ. Results and discussions

1.1 Swiss field experiments

Tree vigour and health

Across the 2024 and 2025 growing seasons, no major differences in tree vigour or overall tree health were observed between the hail net and rain protection systems. Visual assessments indicated comparable tree size, branch structure, and shoot orientation across both production systems. Similarly, indicators of tree health, including leaf colour, general canopy appearance, and the absence of severe physiological disorders, were largely consistent between treatments (See Figure 8). In 2024, data were not available for four cultivars that had been planted in the same year; these cultivars generally exhibited lower vigour in 2025, which was attributed to their younger.

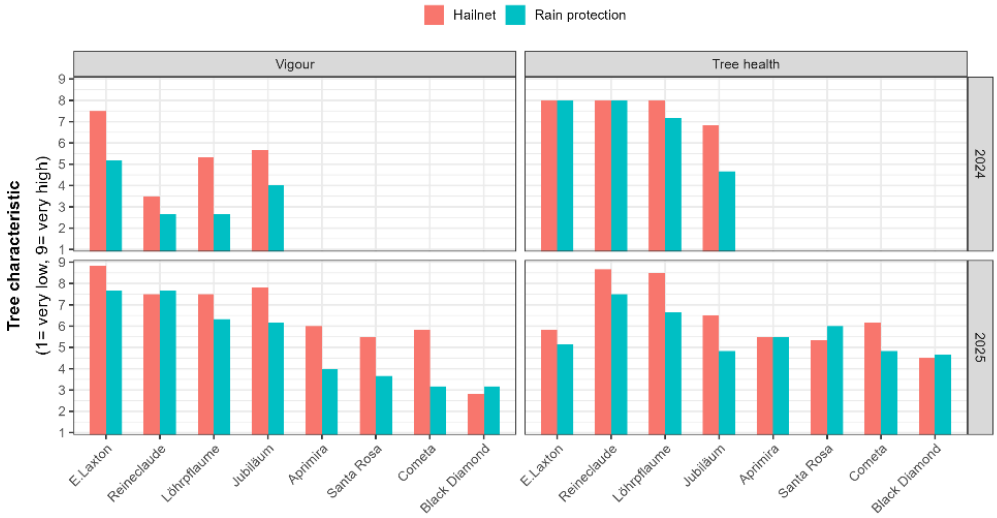

Figure 8. Tree vigour and health scores under hail net and rain protection systems in 2024 and 2025. Scores were assessed on a visual scale from 1 (very low) to 9 (very high) and represent mean values per cultivar.

Pest incidence

Overall pest pressure remained low to moderate during the observation period. Most aphid species, including the leaf-curling plum aphid *(Brachycaudus helichrysi*) and the black peach aphid (*Brachycaudus persicae*), occurred at low incidence levels, with no consistent differences observed between hail net and rain protection systems (See Figure 9). The winter moth (*Operophtera brumata*) was recorded in both systems; however, infestation levels were comparable and remained within a moderate range throughout the monitoring period. The winter moth (*Operophtera brumata*) was recorded in both systems. Infestation levels remained within a moderate range overall but tended to be slightly higher under the hail net system during the monitoring period.

In contrast, the incidence of the mealy plum aphid (*Hyalopterus pruni*) was clearly higher under the rain protection system, particularly in 2024. This pattern is consistent with previously reported effects of rain protection structures, which can create a more favourable microclimate for aphid development by limiting rainfall-induced wash-off and promoting more stable temperature and humidity conditions.

Flowering intensity and early yield

In 2025, no flowering or yield data were recorded for the four cultivars planted in 2024 ('Aprimira', 'Cometa', 'Black Diamond', and 'Santa Rosa'), as these trees were deliberately pruned to promote vegetative establishment and structural development. Consequently, no meaningful conclusions can be drawn for these cultivars at this stage.

Yield and flowering intensity were assessed for 'E. Laxton', 'Jubilaum', 'Löhrpflaume', and 'Reine Claude', revealing pronounced cultivar-dependent differences. 'Jubilaum' showed the highest yields, reaching 1.2 kg per tree under hailnet protection and 2.2 kg per tree under rain protection, whereas 'E. Laxton' produced lower yields despite comparable or higher flowering intensity (See Figure 10 & Figure 11). This discrepancy indicates that higher flowering intensity did not translate directly into higher yield and suggests a higher level of natural fruit drop in 'E. Laxton' compared to 'Jubilaum'. 'Löhrpflaume' and 'Reine Claude' exhibited low flowering intensity and minimal yields, consistent with the juvenile stage of the trees. Overall, rain protection was associated with higher flowering intensity. However, given the very limited number of fruits observed on the trees, it is too early to draw conclusions regarding yield or to assess the relationship between flowering intensity and fruit production. At this stage, any potential link between flowering and yield remains uncertain and is likely to depend on cultivar-specific fruit set and fruit retention in subsequent seasons.

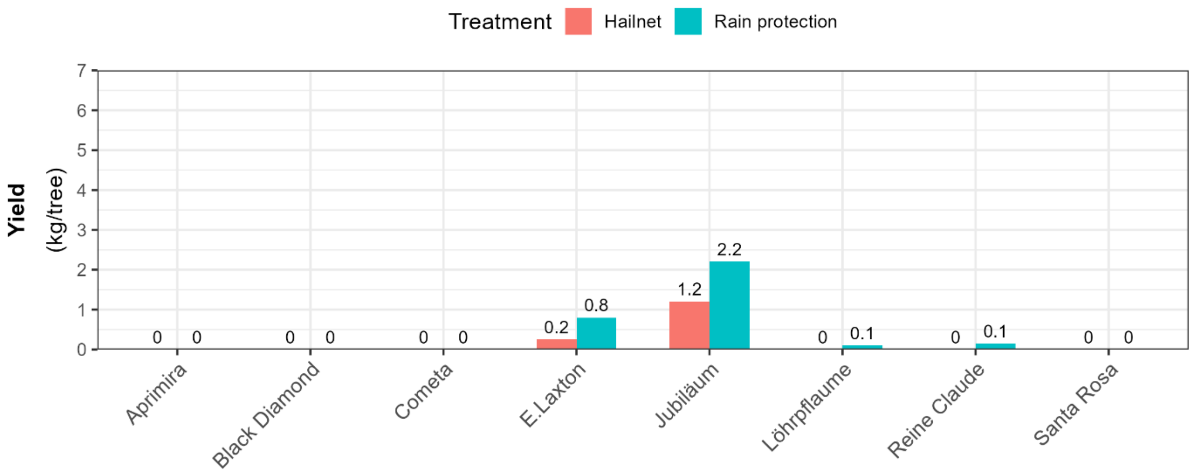

Figure 10. Yield (kg per tree) of eight plum cultivars assessed in 2025 under two protection systems: hailnet and rain protection.

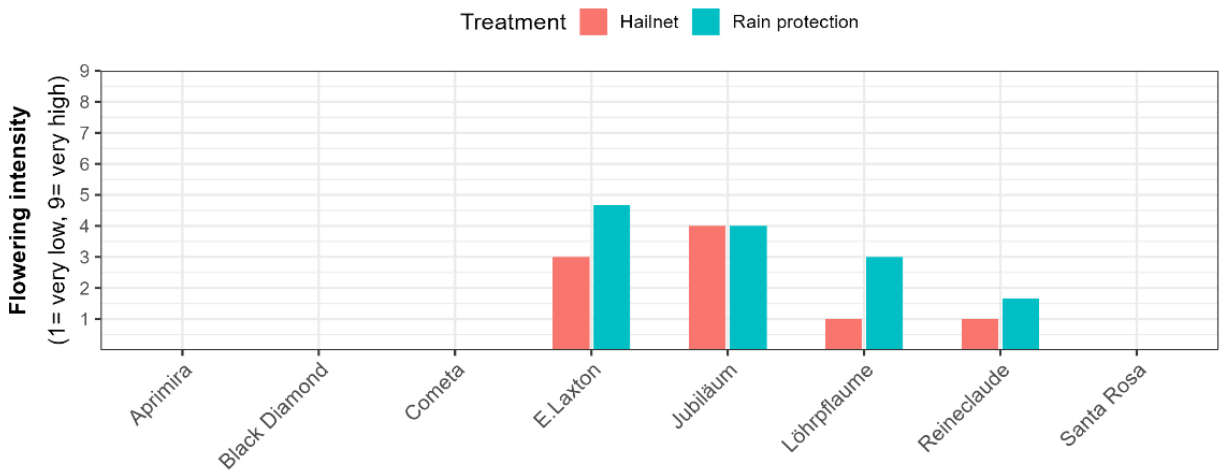

Figure 11**.** Flowering intensity of eight plum cultivars assessed in 2025 under two protection systems: hailnet and rain protection. Flowering intensity was scored on a semi-quantitative scale from 1 (very low) to 9 (very high).

Plum moth damage

Plum moth damage was assessed only for cultivars that produced fruits, as cultivars without fruit set could not be evaluated (See Figure 12). In 2025, strong cultivar-dependent differences in plum moth damage caused by *Grapholita funebrana* were observed. 'Jubiläum' was by far the most affected cultivar, with approximately 40% of fruits damaged under rain protection and about 25% under hailnet protection.

'Löhrpflaume' and 'Reine Claude' also exhibited noticeable damage, but only under the rain protection system and at substantially lower levels.

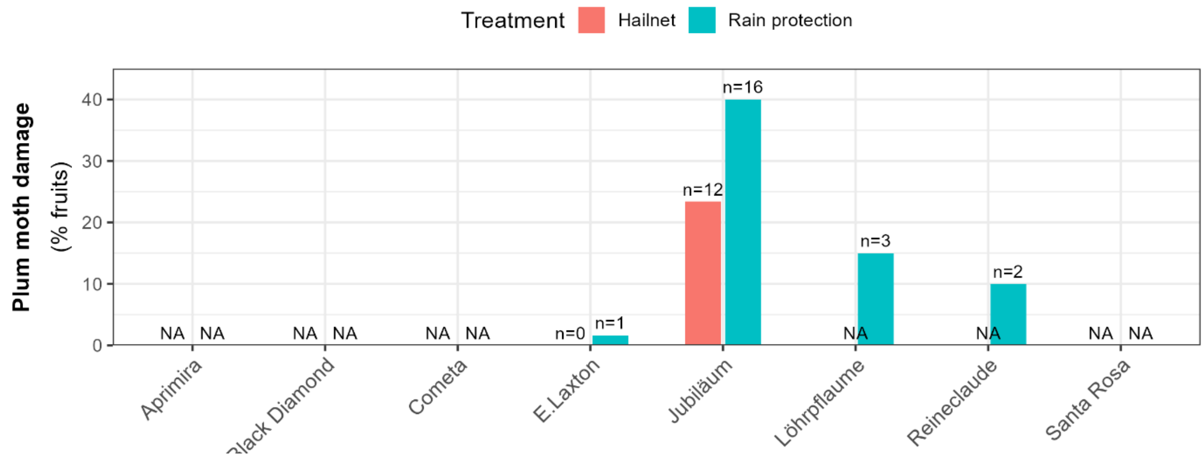

Figure 12. Plum moth damage caused by Grapholita funebrana on different plum cultivars under hail net and rain protection systems in 2025. Damage is expressed as the percentage of fruits showing visible symptoms of infestation. Assessments were conducted only on cultivars with fruit set.

The higher proportion of visible damage observed in 'Jubiläum' may partly be explained by the timing of the assessments, which were conducted shortly before harvest. At this stage, symptoms were still clearly visible in 'Jubiläum', whereas earlier-maturing cultivars such as 'Early Laxton' may have already lost infested fruits through premature drop. Overall, rain protection tended to be associated with higher plum moth damage. However, given the very limited number of fruits available for assessment, these observations should be interpreted with caution and do not allow for firm conclusions.

1.2 Korean field experiments

1.2.1 Plum pocket disease

The absence of disease in 2025 contrasts sharply with the results observed in 2024. In 2024, frequent rainfall combined with cool April temperatures (~10 °C) resulted in infection rates exceeding 10% in certain Uiseong orchards. That year's trial showed that two lime sulfur applications at bud break markedly reduced disease incidence, from 9.5% to 0.1% (See Figure 13).

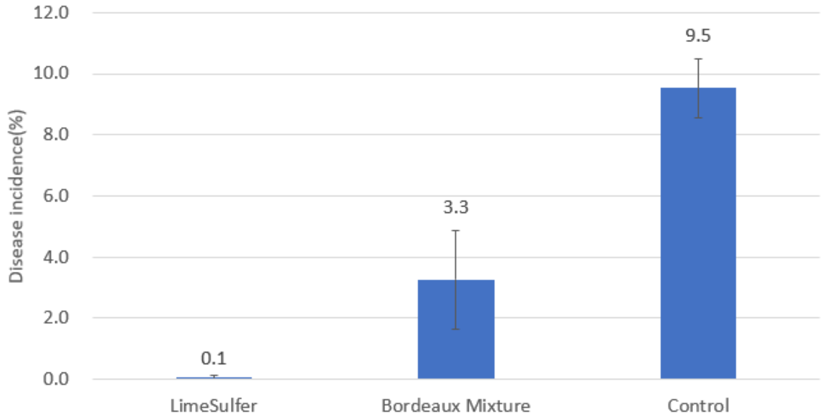

Figure 13. Effect of different treatments on plum pocket disease incidence in 2024. Disease incidence (%) was lowest following lime sulfur application (0.1%), intermediate with Bordeaux mixture (3.3%), and highest in the untreated control (9.5%).

In 2025, south-eastern Korea experienced exceptionally dry conditions accompanied by elevated temperatures from February to April. Notably, temperatures in late March exceeded the long-term average by more than 10 °C, creating environmental conditions opposite to the cool and moist climate required for pathogen infection. These climatic anomalies likely disrupted the pathogen's life cycle and accelerated plum tree development, thereby shortening the window of host susceptibility.

Disease incidence data support this observation, with infection rates reaching 13.4% and 11.1% on 25 April and 9 May 2024, respectively, whereas no disease was detected on the corresponding dates in 2025

Date	Disease incidence (%)	
	2024	**2025**
25th April	13.4	0.0
9th May	11.1	0.0

These results suggest that organic control strategies must involve a precise decision-making system based on meteorological data rather than relying solely on scheduled applications. The success in 2024 established lime sulfur as a standard model for organic plum pocket management, while the 2025 data highlight the importance of managing the uncertainties of disease occurrence caused by climate change.

1.2.2 Bacterial shot hole disease

The Uiseong experiment for bacterial shot hole was conducted on the 'Formosa' cultivar, which is known for its large fruit size but high susceptibility to the disease. The primary objective was to evaluate the efficacy of Microbe (*Bacillus subtilis QST713*) as a biological alternative to traditional Bordeaux mixture treatments. Microbe (*Bacillus subtilis QST 713*) produces lipopeptides that disrupt the cell membranes of bacterial pathogens and colonizes the leaf surface to physically prevent pathogen attachment. Unlike cooper, it does not cause phytotoxicity and helps maintain a balanced microbial community on the foliage.

Final assessments on 16th July showed that disease pressure remained very low across all plots, with no statistically significant differences between treatments. The number of diseased fruits recorded during the growing season is as follows:

Product	Number of diseased fruit / per treatment? / Per tree?			
	2nd Jun	11th Jun	19th Jun	30th Jun
Microbe	1.3a*	0.3a	0.0a	1.3a
Copper	0.7a	2.0a	2.0a	1.7a
Control	0.0a	1.3a	0.3a	0.7a

*DMRT(α=0.05)

Numerically, the microbial treatment showed an average of 1.3 diseased fruits, which was comparable to the copper treatment 1.7. While the microbial plot discovered zero symptoms on 30th Jun, the overall low disease pressure makes it difficult to conclude superiority. However, the fact that there were no significant differences in post-harvest fruit quality suggests that microbial agents have high potential to replace copper.

Ⅳ. Conclusions and Suggestion

1.1 Preliminary findings and perspectives for future Swiss experiments

The experiments conducted in Switzerland provided initial insights into cultivar-dependent differences in flowering intensity, yield formation, and susceptibility to plum moth damage in young plum trees grown under different protection systems. However, the overall low yield levels and the absence of fruiting in several cultivars clearly indicate that the orchard is still in a juvenile phase. Consequently, the results obtained to date should be considered preliminary and interpreted with caution. Despite these limitations, several important tendencies were identified. First, flowering intensity did not consistently translate into final yield, highlighting the importance of fruit set efficiency and natural fruit drop, particularly in young trees. Second, strong cultivar-dependent differences were observed across all assessed parameters, including yield performance and plum moth damage, suggesting that cultivar choice is a key factor influencing orchard performance. Third, protection systems appeared to influence flowering, yield, and pest damage, but their effects were not uniform across cultivars.

Based on these observations, continued experimentation in Switzerland is strongly recommended. Future trials should focus on multi-year monitoring as trees reach full. In addition, integrating complementary measurements such as fruit set, fruit drop dynamics, and phenology-based pest monitoring would improve the interpretation of yield and damage data.

1.2 Preliminary findings and perspectives for future Korean experiments

Lime sulfur has been reconfirmed as the most effective organic control option for plum pocket disease. Two applications applied around the bud break period were sufficient to reduce infection rates from nearly 10% to below 0.1%. In contrast, management strategies for bacterial shot hole should be refined to incorporate the active use of microbial agents such as *Microbiome*, in order to reduce phytotoxicity risks and overall environmental burden.

Future Research and Recommendations

Based on the results of this study, the following management guidelines are proposed for organic plum production in Korea:

- First, to prevent plum pocket disease, lime sulfur should be applied twice at two-week intervals starting from bud break in late February.
- Second, for bacterial shot hole occurring after May, microbial bactericides such as *Bacillus subtilis* should be proactively applied to protect fruit quality and maintain soil health.
- Third, in years characterized by high temperatures and low rainfall resulting in reduced disease pressure, production costs can be minimized by implementing precision spray programs guided by meteorological data.

The collaborative research between GBARES and FiBL has provided valuable insights into the interactions among host plants, pathogens, and control measures under complex climatic conditions. Future research should focus on long-term monitoring of disease dynamics and yield performance in mature orchards (beyond five years) to support the development of more refined guidelines for organic stone fruit production.