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ROBS4CROPS

D5.3 Feedback to pilot community and manufacturers on the capabilities and limitations of the delivered integrated solution of implements, vehicles and supervision software (1)

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Abstract:	This deliverable encompasses observations, lesson learnt and feedback on the of first versions of the smart implements, smart vehicles and supervision software that were used in the four large scale pilots, the Minimum Viable Products number 1 (MVP1). Working hands-on in the fields with the systems often showed their limitations and raised a lively discussion within the project on wanted future functionality. This wish list differs per country and pilot. Working with the systems also confirmed that many of the developed R4C modules are already working as designed. The pilot community should make use of the given feedback during their further development iterations.

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List of Abbreviations and Acronyms	
ECU	Electronic Control Unit
FAT	Factory Acceptance Test
FC	Farming Controller
GNSS	Global Navigation Satellite System
RTK	Real Time Kinematic positioning
SAT	Site Acceptance Test
MVP	Minimum Viable Product
LSP	Large Scale Pilot
R4C	Robs4Crops project

1 Introduction

The objective of the test work package (WP5) in R4C is to ensure that the combinations of smart implements from WP2 and the vehicles from WP3 and supervision software from WP4 work as an integrated system. The limitations and the possibilities of the integrated systems should be identified before sending them into the large-scale field pilots. Next to defining test scenarios and performing tests, an important task of WP5 is to collect feedback from the pilots to support the future improvements. This feedback was collected by organizing and participating in meetings on technical developments and feedback that were organized in close collaboration with the technical WPs. These meetings were organized throughout the year for both the two LSPs on smart weeding (LSP1 and LSP4) and the two LSPs on smart spraying (LSP2 and LSP3). The meetings took place online every 2 weeks. Next to this also a number of visits and physical meetings took place at the different pilot sites (integration and acceptance test meetings). Moreover, WP6, that facilitates the execution of the LSPs, was a valuable source of information on how the pilot operators did experience the use of the robots.

This deliverable encompasses observations and feedback on the of first versions of the smart implements, smart vehicles and supervision software that were used in the large-scale pilots, the Minimum Viable Products number 1 (MVP1). Many capabilities and limitations of the integrated solutions became clear. The assessments that the large-scale pilot operators did during operation, provided valuable information. Lessons have been learnt and experience in how to use the equipment was gained. This experience helps to prepare the pilots for the next year. The concrete feedback for improvement serves the manufacturers, feeding their next iteration in developments. The feedback will also give insight in several issues that were solved to enable the continuous use of autonomous machinery on the farms.

Please note that there is an additional confidential appendix to this deliverable with more detailed feedback, available for consortium members only. Mentioning some of the issues observed when using products and devices of Robs4Crops consortium members could unnecessarily harm the business development of these consortium members. Therefore, some sensitive information is not shared in this public part of the deliverable.

2 LSP1 (France)

2.1 Activities in 2022

In LSP1 in 2022, the mission was mechanical weeding in vineyards. The autonomous vehicle used was the CEOL. The implement weeds with tines between the rows and knives within the rows. The knives are retracted each time the robot detects a vine stem. Another operation was weeding with an implement with finger weeders. A data connection to the Farming Controller (FC) was realized and used to log data.

The objective of this LSP was to mechanically weed and assess the robustness and the capacities of the robotic system, to show the farmers the option and possibilities to cultivate their vineyard with robots. The CEOL robot was tested in several types of vineyards: Tight rows using a 72 cm robot width in the Muscadet region; any type of plot; normal use in viticulture (alternating tractors and robots for weeding). In total, 14.5 hectares of wine plots were weeded with the robot, between the end of February and the end of June. This gave the end-users an idea of what it would be like to have a robot managing the plot in an autonomous mode.

Figure 1: CEOL robot with a mechanical weeder implement as used in the LSP1 in 2022

2.2 Observations and lessons learnt

Due to still ongoing implementation work, the electronic box with the middleware and analytics computer (in the R4C project also known as the fuse box) was attached to the implement during the real field operations only during small tests. Therefore, not much feedback can be provided on the middleware and the analytics. It was also decided not to use an ISOBUS terminal on the system this season because the same information would be also visible on the virtual terminal on the computer screen of the middleware PC.

In the beginning of the field operations, it was decided to not only use cameras to assess the weeding performance, but also hall effect sensors that detect the spinning metals and rotary encoders, to assess the correct functioning of the weeding implement. In addition, a potentiometer will be placed next season to detect the position and working depth of the implement, since that was found to be important.

The CEOL robot operates using a complete system of AGC: land survey, mission generation, path planning and HMI (application). The robot creates a safety boundary and a virtual fence using GNSS RTK (SAFENCING) to prevent it from leaving the perimeter. The robotic system of CEOL adds to that a minimum headland distance of 6 m for U turns.

Observations from the pilot crew when operating the robot:

- The mission will not start if the robot is not on the correct parking spot for the beginning of the mission. The robot was in these cases set in manual mode for starting the mission.
- The emergency stop bumper gets sometimes triggered in the headland during U-turns. The most likely reason was that the CEOL was operated too close to the defined safety boundary.
- The bumper gets triggered unnecessarily sometimes in the row as well. For example, when brushing against the vines when they are growing inward. Sensitivity of the bumper is sometimes a little irregular (in the middle of the bumper a very small shoot can trigger the stop, but on the outside end it may not detect).
- The robot optimises its path through choosing the biggest loop with the implement that reduces the soil compaction and avoiding soil compaction. This means that the robot doesn’t follow the same driving logic as a tractor.
- The CEOL robot would make 1.5 m wide U-turns and avoids the next row.
- It happened that cultivating the next row was started from the other side of the plot.
- Water infiltration caused eventually malfunctioning of the electronic components. Some buttons are not robust enough to dust.
- One day, no mission could load from the application to the robot. Reason: a special character in the land survey. This is an important lesson to take whenever uploading a land survey into the robot
- Seeming malfunctioning of the new batteries: If the batteries are not fully charged, they will turn off the robot since it is a hybrid system. The user has to keep the batteries fully charged or more than half to start the robot.

The robot operated in most of the chosen plots. It achieved 4 out of 5 passages. Some missions went more smoothly than others. One lesson learnt was that the autonomous mode does not always work as one would expect as a farmer. However, as long as the job gets done this is acceptable.

Weeding in narrow inter-row in Muscadet region

The Muscadet region is known for narrow inter-rows. A 72 cm wide robot was used with 80 cm implements. This created ruts of 80 cm that resulted in larger forces on the tracks to keep to a straight line.

- The tracks had to be tightened and adjusted often, making them more fragile
- The tracks had to be changed during the season

Therefore, it is important to make the right choices for the implements and their adjustment before entering the field.

Zigzagging

In one of the fields, the CEOL started zigzagging in the last row next to a building. It kept zigzagging after several retries (see Figure 2).

This plot had a tight headland. In this case it would be important to check:

- The land survey, whether no curved lines were taken during the land survey.
- Whether the mission generation is correct.
- Whether there is no GNSS interference due to the proximity of the building.

Figure 2: robot zigzagging through the field

Use of the robot after a manual weeding operation with a tractor

Farmers had weeded their own plots with tractors due to technical problems with the CEOL. It was very difficult for the robot to maintain its navigation, because of the deep soil-ridges the tractors had left on the soil.

The soil ridges are too deep for the CEOL robot to pass. The robot risked tipping over to the side. Therefore, it was not possible to make it pass automatically, and the robot was driven carefully in manual mode. On one plot, the ridges created by the tractor were not so deep and autonomous mode was tried. Even though the ridges where not that deep, it impacted the robot's navigation. It had difficulties keeping straight lines. The robot had difficulties to correct its trajectory even at low speed (2km/h). And with this low speed, mechanical weeding was not efficient enough.

Cambered rows and heavy slope (Not part of LSP1 but tested by the French team)

The robot was not designed for slopes and cambers bigger than 10%. In the pilot however, several fields with slopes of 10% to 15% and a camber of 10% were tested. The robot was not able to correct its trajectory. The weight of the tool made it skip sideways. The robot was switched to manual mode, which worked better.

Figure 3: Slope, the CEOL has trouble staying on track

R4C electronic cabinet for middleware and analytics oversized

For the analytics of the weeding, an electronics cabinet (fuse box) was mounted on the robot between the robot and the implement. First tests running the robot in the vineyard caused the box to come loose as the mounting was not solid enough. It was proposed to the technical work packages to make the fuse box smaller and less heavy. In the end, middleware and analytics were not used in 2022, not only because of the mounting problems but also because the analytics sensor integration at the implement side and the correct cabling/connector between implement and autonomous vehicle was still pending.

Figure 4: Bulky electronics cabinet with middleware and analytics hardware mounted on implement

Some lessons learnt

- It is important to check the rows chosen before generating the mission (path planning). It is possible to avoid working on some rows, due to detected obstacles or other reasons.
- It is important to check the order of the rows to be worked in the mission: Even rows only, odd rows only or all the rows or avoiding some rows.
- Special characters when saving the mission or during land survey should be avoided as they can cause trouble.
- Sometimes, the robots' choices for certain rows or U-turns are not logical from a driver's point of view.

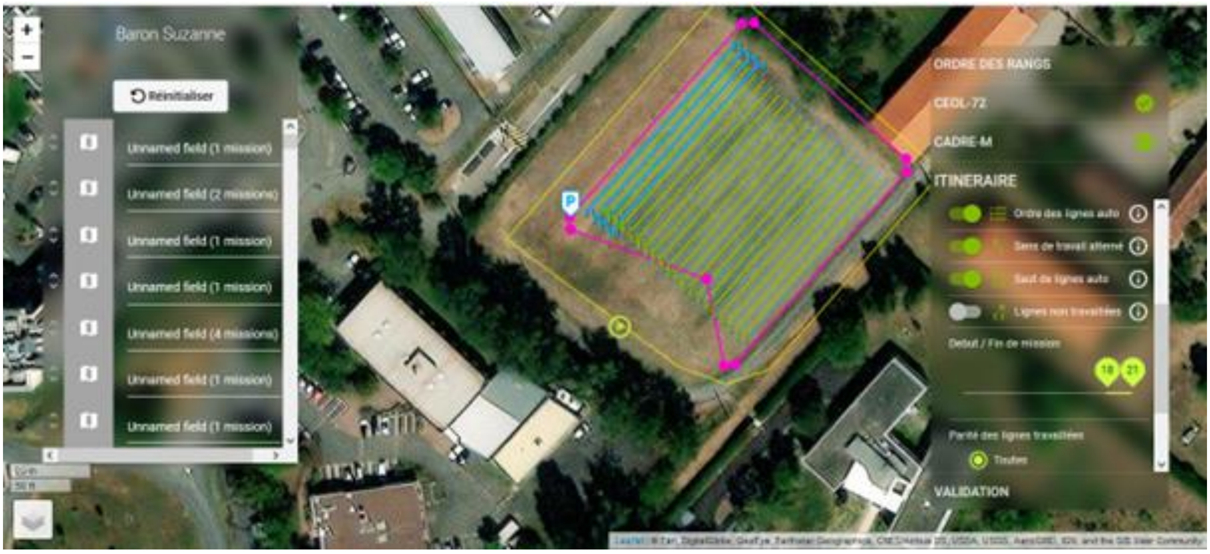

Figure 5: Photo of a mission planning for a field with chosen rows (AGC mission planning and generation)

2.3 Feedback

Since no middleware and weeding analytics were used in the pilot, the feedback focuses on problems that occurred when using the robot with a weeding implement. The weeding implement was not yet smart. Most of the issues this season are not related to developments in the R4C project, but are more general issues with the robot and the mission planning software. However, the CEOL drives straight and accomplishes the mission smoothly in 80% of the fields.

Overall evaluation

The robot can weed vineyards, but it is not autonomous yet. If it is left on automatic mode, it will encounter too many stops or breakdowns that need the operator to be on site or to come back to the site. The overall **robustness** of the robot in the field should be increased.

The operator needs to stay in the field in cases where the robot stops and must be restarted (except in case of GNSS-RTK signal loss). A bumper that brushes against the vines is activated and immediately deactivates the robot.

It would be useful to have notifications about the current battery and the fuel level of the robot.

Currently, there is no input parameter available to define the maximum level of engine power.

D5.3 Feedback to the pilot community and manufacturers

In the chosen setup for the MVP1 there is no solution to automatically and dynamically adjust the working depth of the tool. It would be very useful to add this functionality. Also, there is not (yet) a blockage detection of the implements and no detection that the robot gets stuck.

A general remark from the farmers was that the robot would have to do the operation more often than a tractor. They mentioned two reasons:

1. The more the machine is used, the earlier the plots are weeded. And the fewer weeds there are, the easier the work will be during periods of heavy growth.
2. The more the machine can be used in autonomous mode, the faster the investment pays back.

3 LSP2 (Greece)

3.1 Activities in 2022

LSP2 in the first season was supposed to focus on robotic spraying for table grapes on commercial farms of the PEGASUS farmers' cooperative. The original plan was to use as MVP1 a modified, more powerful CEOL as autonomous vehicle (see also Deliverable 5.2). Due to production delays, it was not possible to ship a CEOL to Greece and the plan was changed to uses a new tractor, to be retrofitted with and AGCBOX from AGC. As smart implement, the 3-point hitch lifted ASM 200 sprayer (TEY) equipped with camera-based analytics module (AUA) that can detect the canopy and adjusts spray volume was used.

It took more time than expected to get the tractor. In October 2022 field operations were carried out with an alternative, manual steered tractor that was already available on the premises of PEGASUS. This tractor got equipped with an AGCBOX and the sprayer from TEYME (Figure 6). The sprayer was controlled by the perception unit, but with a simulated speed as communication between AGCBOX and sprayer was still work in progress.

Finally, during a project meeting late November in Kiato (Greece) the sprayer, the ISOBUS terminals, and a range of sensors that will be used for navigation, were demonstrated to the entire R4C group. A human driver steered the tractor through the vineyard, while sensors measured the size of the canopy and adjusted the spray rate accordingly.

There was very limited interaction with farmers in 2022, but now that all machinery is present and prepared, it is expected to work autonomously next season and to have good interaction with farmers.

Figure 6: Temporary tractor with TEYME ASM 200 sprayer

3.2 Observations and lessons learnt

The LSP2 uses very much the same components/modules that are also used and tested in the LSP3 (Spanish pilot, see more details below in section 4). Due to the delay described above the feedback from the Greek Pilot is limited this year.

The focus of the activities of the large-scale pilot staff was shifted from working with the equipment in the field to installation and addressing all technical issues that were still present. The main lesson learnt is that making everything work is quite complex. Proper manuals and described individual procedures for the use of the several different systems is needed. |This is also true for guidelines/training on how to run tasks on terminal and how to create tasks files and boundaries files for example.

Furthermore, the experiences can be summarized as follows:

- The TEYME sprayer worked well from the start, with support from TEY.
- The sprayers liquid and air assistance were operational.
- The sprayers could spray in manual (operated from the screen) and in auto mode (taking spraying commands from the perception unit) properly.
- There was a small leakage from the sprayer that could be fixed.
- The AGCBOX was installed on the last day of field testing, but some geographic zones where not yet covered until a modification was done on the system of AGCBOX. The setup and configuration are the same as what was done in Spain and the TEYME sprayer worked according to specs.
- The messages for ground speed and GNSS from AGCBOX could not always be received.
- It is crucial that the signals that are included in the AGCBOX messages are correct. The IDs of the messages should be the same as in the ".dbc" file.
- The ISOBUS network sometimes was out of order (network management from the TEYME sprayer controller). It is possible that the simulated Isobus terminal on the middleware "cought" the .IOP of the sprayer, so the Anedo was not able to properly show the sprayer mask.
- The middleware was working as expected.
- The FC received the messages from the middleware.
- AUA perception unit gathered data, it was able to see canopy density and was able to communicate with the sprayer.

3.3 Feedback

As the Greek pilot could not be tested in its definitive form yet, feedback is limited, and as technical work is still in progress some points might change or be solved soon.

- Clear instructions how to do so is needed for the end-user. For example, when the tractor engine is restarted, communication between the systems is interrupted and restart in the correct order might be necessary.
- Agreement on the ID, format, content and name of the messages over ISOBUS is important to make systems work together.
- The pilot is looking forward to using a full robotic system next season in the field.

4 LSP3 (Spain)

4.1 Activities in 2022

LSP3 focuses on apple orchard spraying with a retrofitted tractor in Spain. The tractor pulls the sprayer. As shown in Figure 7, a New Holland tractor purchased for R4C is used in combination with a TEYME EOLO 2000 sprayer. In 2022 the tractor was driven manually. The system is equipped with camera-based analytics module (developed by AUA) that can detect the canopy and adjusts spray volume. Data from the vehicle and implement can be sent to and logged by the remote FC developed in the R4C project by LMS.

Next season the tractor will be further retrofitted to allow autonomous navigation.

Figure 7: MVP1 in the LSP3 with New Holland T4 110F Tier 4B tractor and the TEYME EOLO 2000 sprayer and on the bottom right a screenshot of the TEYME sprayer interface.

4.2 Observations and lessons learnt

Search for the right ISOBUS terminal

When technical integration progressed, the integration of an ISOBUS terminal into the R4C system faced problems. First, a terminal from the brand Raven was tested, but several unexpected incompatibilities and drawbacks were found for this terminal such as no shapefile support. The task interface for spraying was not user friendly enough. In search for the most suitable terminal more tests were done with different brands of terminals. In the end, it was decided that the Spanish and Greek pilot will use a terminal form the brand Anedo. TEY, UHOH and AGC have been working together to have proper ISOBUS GNSS data on the Anedo Terminal to properly execute Task Controller functionalities

General issues encountered

- The middleware PC (Pokini) that was added to the control cabinet of the sprayer got too hot during operation and then shut down automatically. This was solved by adding a cooling fan.
- The middleware PC does not have an own internet connection. This connection is needed to exchange data and commands with the FC. For MVP1 this was solved with

an 4G internet router placed in the cabin of the tractor by EUT. When equipped with a SIM card this router provides Wi-Fi and Ethernet internet connection to the system's components.
- It was found that the used ECU (of type EPEC 3724) of the sprayer has an incompatible software library. The current ECU of the sprayer is designed with the library of Task Controller (TC) with version 3.x which does not support the "peer-to-peer" control function of TC, for this function version >= 4.0 is required. The solution for that in the MVP1 was to set a direct communication between the perception unit and the ECU and not through the middleware.
- When operating the system under a plastic net (as can be seen for example in Figure 7) GPS data loss occurred occasionally. This will be critical when GPS is essential for autonomous navigation.
- Data from the pilot system could be sent to the FC. In the current design the FC does not store camera data.

4.3 Feedback

A general remark after this season from the pilot crew is that the tractor with the smart sprayer is not yet ready to work on a commercial farm. At this moment It is too uncertain if it sprays correctly.

The instruction manual with a start-up procedure for the equipment that was provided by TEY has proven to be very helpful.

General suggestions for MVP2 for the season 2023:

- Improve the end-of-row detection accuracy to turn the sprayer on and off at the correct position. The sprayer shouldn't open the nozzles when it's turning. At this moment there is a bit of delay in turning on the nozzles when a new row is entered.
- Improve the leaf density detection using the camera. The current system has issues with sunlight, it inhibits correct detection by the cameras.
- Increase the working speed of the tractor from 4 km/h to 8-9 km/h
- GNSS data should not only have LON and LAT data but also altitude data.
- We are looking forward to the autonomous navigation with the retrofitted tractor. In autonomous mode automatic malfunction detection (clogged nozzles/empty tank etc.) and the possibility to send (emergency) stop commands from the smart implement and/or the FC to the vehicle become essential.

5 LSP4 (The Netherlands)

5.1 Activities in 2022

The field operations done in LSP4 were:

- Mechanical weeding in precision sown pumpkins
- Mechanical weeding in sugar beets (after the pumpkins)

The Robotti from AGI was used as autonomous vehicle, with mechanical weeders. A tine weeder was used first (Figure 8). Later a mechanical hoeing implement with a camera-based row-steered side-shift module was used. The hoeing implement was equipped with multiple cameras to observe the weeding quality and detect anomalous conditions, using analytics hardware and software. During this first season, the cameras were only used to collect image data. There was no real-time assessment developed yet.

Figure 8: Tine weeding in pumpkins with Robotti

The missions for the robot were generated using the existing planning software from AGI. Before starting in the field, the field boundary was measured. Based on these boundaries a plan for the Robotti was made in the AGI platform and uploaded to the Robotti (Figure 9).

As mentioned in paragraph 2: LSP1 (France), for both weeder pilots no physical ISOBUS terminal was used this season. Information could be seen on the simulated virtual terminal on the computer screen of the middleware PC. Next year a terminal from the brand Raven will be used in both France and the Netherlands.

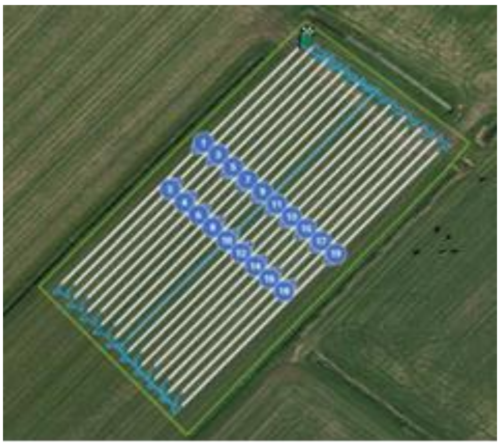

Figure 9: Route planned and uploaded to Robotti terminal

5.2 Observations and lessons learnt

The pumpkins were seeded in a square pattern with the idea to allow weeding in the seeding direction as well as perpendicular to the seeding direction. However, it turned out that the seeding was not carried out precisely enough, so weeding perpendicular to the seeding direction with the robot was not possible. As a consequence, manually weeding within rows was still necessary.

The analytics module of the smart weeder can publish data (such as the weeding quality in the future) on the ISOBUS. It was successfully tested that this data, together with Robotti GNSS location, can be sent to the FC.

The platform has a 'safety boundary' of 1.81 m. This means that when the field is measured with 2 cm accuracy, the field boundary where the robot is working decreases with 1.81 m because of this safety boundary.

- It is important to check if the right coordinate system is used.
- It is important to make the right choices for the adjustments of the implement.
- It is currently not possible to set the oil flow of the hydraulics in the platform.

Tine weeding

Tine weeding generally worked well with the Robotti, the implement had to be adjusted only once at the beginning of the season.

- Barley on field next to the target field (see Figure 10) activated frequently the Robotti's emergency stop. To circumvent this the robot's LIDAR safety sensor was covered.
- The headlands cannot be done in autonomous mode.

Figure 10: Barley field next to pumpkin field frequently activated the Robotti's LIDAR sensor-based emergency stop.

Hoeing pumpkins and sugar beets with mechanical hoeing implement

In the pumpkins the side-shift option of the mechanical hoeing implement was not used. This was because in the beginning the camera could not yet see the plants and detect the rows. Later, the canopy of the pumpkins closed and no more hoeing with the robot was possible. During the pumpkin weeding, the wheels were on 3.15 m trackwidth in a 75 cm crop row distance. In the sugar beets, seeded on 50 cm, it was not possible to have the wheel track on 3.15 m. So, it was adjusted to 3 m. After adjusting, the hoeing machine was too wide. Some of the bars from the hoeing machine were cut and made it fit into the Robotti.

- When working in a 3 m track width, the side-shift could not move between the wheels of Robotti enough to work. This was solved temporarily by the user with a mechanical adaptation (taking away the physical limit).
- The hoeing implement was touching the Robotti wheels. An extended frame was used to avoid this, but it was still not long enough. Adjusting the position of the Robotti's rear wheels completely inward solved this issue. Temporary solution was to have longer parallel bars holding the implement, so not big adjustments were necessary.

In the beginning of the pilot there have been issues with the Robotti driving straight lines. This issue was later solved. However, because of this, hoeing in the pumpkins was difficult, as the rows were not seeded straight. It was needed to make the space between the hoes around 13 cm. The deviation from driving straight was around 5-6 cm with seeding and with weeding (see Figure 11). The deviation from the planned route was measured using an additional external GNSS antenna.

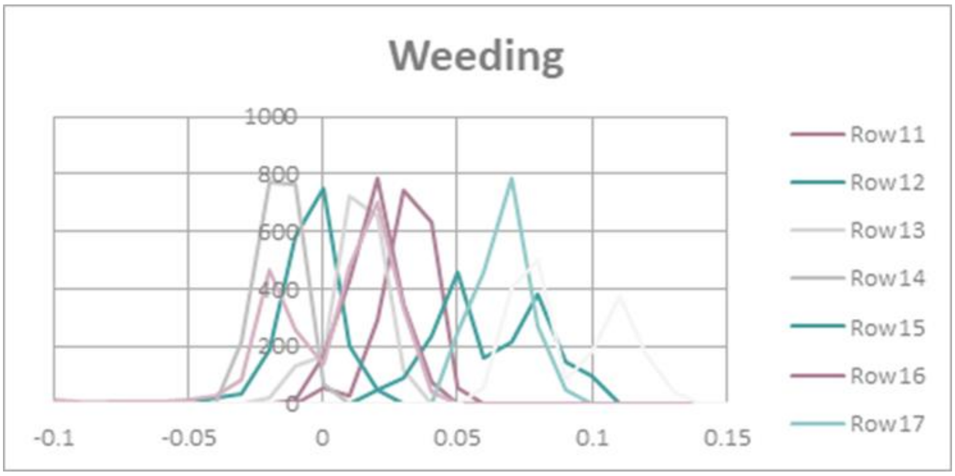

Figure 11: Deviation of planned paths by the Robotti during weeding. The x-axis gives the deviation in meters between the planned path and the driven path. The y-axis represents the absolute number of GNSS sampling points.

- Sometimes the Robotti got stuck during a headland turn and it had to be restarted to fix this. It happened 3 times in 1 hour and 20 minutes.
- On another day, an error happened twice in half an hour: the Robotti stayed on the headland without turning, after 2 to 3 minutes waiting the Robotti went on.
- The Robotti often makes complex turns for no reason; when it is standing right in front of the row it should just start in.
- When hoeing sugar beets, it turned out that the tires were too wide, narrower tires are needed for hoeing crops with 50 cm row spacing.

During the weeding operations in sugar beets in some parts of the field different problem and error scenarios were manually created. Examples are: missing plants, extra high weed pressure, a missing or broken hoeing element. By doing so, valuable image data could be collected for the development of the analytics module.

Figure 12: One hoe is in the row, destroying the beets because of side-shift problem

5.3 Feedback

The feedback the pilot users would like to give is for the largest part a wish list for future functionalities and capabilities of the robotic system:

- An option for a live video stream from a camera on the robot for manual supervision (for example when supervising the robot while sitting in a car next to the field).
- An external and maybe even remote ISOBUS display to supervise the correct operation of the robot.
- Additional options for route planning (closer to the edge of the field, 90-degree turn).
- Possibility to work on the entire field, without using a safety boundary. At least this should be possible when using certified field boundaries.
- Next season seeding headlands should be possible, because headland weeding with the robot is also a target.
- An option to set hydraulic pressure in mission planning tool.
- An option for variable speed control.
- An option for minimal waiting time at headland.

6 Discussion and recommendations

First versions

In this year, the first versions of the smart implements, smart vehicles and supervision software (MVP1) were supposed to be used in the four large-scale pilots of the project. Due to technical and operational issues, some pilots have not yet been able to use the developed equipment fully as planned. Especially LSP2 (Greece) suffered from delays in getting the equipment on site. As a consequence, not much pilot feedback could be collected.

The retrofitting process of the tractors is still ongoing. In MVP1, no autonomous navigation was done with the retrofitted tractor, and the weeder analytics modules are still under development. The sensors and cameras of the weeder analytics modules were used only to collect data this first season. Also, the supervision software (the FC) was used only to collect and store data from the robots in the field, not yet to send commands. Therefore, the large-scale pilots could not give feedback on these parts of the R4C systems.

Instruction manuals

For most operators and farmers in the pilots, this season was a first experience with autonomous field robots. Therefore, it is not surprising that their learning process played a central role. Several of the pilots have emphasized the importance of having clear and understandable instruction manuals for the robotic systems. A recommendation for MVP2 is to create manuals for all pilots and for each component of the pilot. It is also recommended to simplify the configurations where possible.

Mind the limits

From the received feedback it appears that operators sometimes used the robots beyond their specifications and beyond the goals defined by the R4C project. This was especially true for the LSP1 in France, where the robot was tested in a field with a larger slope and camber than the specifications allow. It is acceptable to test the robot beyond its specifications, in order to assess its performance under different circumstances. But bear in mind that the robot might not work eventually.

Robot behaviour

From a tractor drivers' point of view, some of the robots' behaviour seemed illogical. Examples are going to the end of the field to perform a U-turn, or not following an expected sequence in the order of rows. For the CEOL, for example, the robot's real-time choices are based on the guidance algorithm to make a big loop to avoid soil compaction. A tractor and a robot's path aren't necessarily the same. This might be also a lesson to learn for the users.

Desired functionalities

Working hands-on in the fields with the systems often showed their limitations and raised a lively discussion within the project on desired future functionalities. The wish list differs per country and pilot. The relevance of all desired functionalities needs to be further discussed, as the feasibility to develop them within the R4C project.

Working with the systems in the field also confirmed that many of the developed R4C modules are already working as designed.

Robot pilots focused on driving

The CEOL from AGC (LSP1) and the Robotti from AGI (LSP4) have been driving autonomously this season. Feedback from these two pilots was logically a bit more detailed. There were questions and issues related to the autonomous driving. The other elements of these pilots (smart functionality of the implements and the FC) were much less visible and tangible for the pilot operators. Next year when working with the improved robots *and* for the second time, these elements will become more important.

Way forward

The pilot community, the technical work packages and the robot manufactures of the R4C consortium should discuss this feedback together and use it during their further development iterations.