SolACE

Solutions for improving Agroecosystem and Crop Efficiency for water and nutrient use

Proceedings of the Second SolACE Stakeholder Event

Foggia, Italy

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Contact

Dr. Philippe Hinsinger, SolACE Project coordinator, National Institute for Agricultural Research (INRA), UMR Eco&Sols, 2 place Viala, 34060 Montpellier Cedex 2, France, Phone +33 4 99 61 22 49, philippe.hinsinger(at)inra.fr, www.umr-ecosols.fr/index.php/en/

Dr. Helga Willer and Laura Kemper, SolACE dissemination, Research Institute of Organic Agriculture FiBL, Ackerstrasse 113, 5070 Frick, Switzerland, Phone +41 62 865 72 72, Fax +41 62 865 72 73, e-mail helga.willer@fibl.org, Internet www.fibl.org

Layout: Helga Willer, FiBL, Frick, Switzerland

Language editing: Laura Kemper and Helga Willer, both FiBL

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The Second SolACE Stakeholder Event

The Second Stakeholder Event of SolACE - Solutions for improving Agroecosystem and Crop Efficiency for water and nutrient use - took place on May 16, 2018 in Foggia, Italy, hosted by SolACE project partner CREA, the Council for Agricultural Research and Economics. The event took place directly after the first SolACE annual project meeting and managed to attract several external stakeholders, who provided some great input and feedback on the developing technological innovations.

During the second SolACE stakeholder event, SolACE project partners presented innovations that are being tested in the project with the aim to receive feedback and comments.

Stakeholders, farmers, farm advisors, breeders and agri-business actors across the entire production chain were present.

During the event, a "Dragon's Den" approach was applied, where SolACE scientist presented five key innovations for the stakeholders (the "dragons"), who, in turn, asked critical questions. Furthermore, comment forms were distributed to give participants the opportunity to express additional views about the innovations.

The following innovations were presented and discussed:

- Second generation microbial inoculants (bread wheat and potato)
- Genotypes mixtures (durum wheat)
- Decision support systems (bread and durum wheat)
- Participatory breeding schemes (durum wheat)
- Accounting for below-ground traits for improving tolerance against water/nitrogen deficiency (bread wheat)

Having a two-way communication channel between the external stakeholders and the SolACE partners is a crucial part of this the SolACE project. The "Dragon's Den" format served the dual purpose of informing participating stakeholders of innovations being tested within the SoLACE project as well as challenged the scientists to present their work in a clear, concise manner that could be readily understood by the general public. It also helped the scientists improve their innovations to ensure they will be useful and applicable outside of the lab, and served to build relationships between scientists and other stakeholders. This is an essential part in making sure that SolACE is participatory, collaborative and includes knowledge from multiple sources.

At the event, project partners, stakeholders as well as members of the SolACE Stakeholder Advisory Board participated. The event was linked to the 2018 Durum Days[1] in Foggia, which is why there was a strong focus on durum wheat.

For these proceedings, we have summarized the presentations, the discussions as well as the feedback received based on the feedback forms.

[1] More information about the Durum days is available at http://www.caione.it/2018/05/14/durum-days-2018/

At the Second SolACE Stakeholder Event, SolACE partner LEAF took a video[2], which is available on the SolACE YouTube channel.

[2] The video is available at https://www.solace-eu.net/service/videos/stakeholder-engagement-in-solace.html

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  Dr. Philippe Hinsinger, INRA, France
- Closing remarks
  Dr. Glyn Jones, Newcastle University, UK

Welcome and introduction to the event

Nicola Pecchioni[3], from the Italian Council for Agricultural Research and Economics CREA welcomed the participants to the second SolACE stakeholder event.

In particular, he welcomed the companies that came, who represented important players in the durum wheat and potato supply chains as well as in the area of agricultural inputs.

He said this broad and qualified audience of stakeholders was in a good position to give valuable advice to the project, and he thanked the audience for their interest in the project.

[3] Prof. Dr. Nicola Pecchioni, CREA - Council for Agricultural Research and Economics, CREA-CI, S.S. 673 km 25,200, 71122 Foggia, Italy, Phone +39 0881 71 10 73, nicola.pecchioni(at)crea.gov.it, www.cerealresearchcentre.it/main/

Introduction to the “Dragon's Den” approach

Glyn Jones[4], from FERA, UK, introduced the “Dragon's Den” approach to the audience.

As an economist, he and his group work with scientists to assess how successful technological developments might be. They use different techniques to engage with stakeholders in order to get their views of how successful a technology might be. This process is called a “Dragon’s Den”, named after the popular British TV show, where people with business ideas have 5 minutes to pitch their ideas to investors – the “dragons”.

He explained that during the stakeholder event, the stakeholders in the room would be the “dragons”. They were asked to crticise the innovations and ask questions to determine if the ideas are practical, viable, interesting, and if they would ultimately be willing to invest.

As part of this exercise, the audience received forms to indicate whether they thought the innovation was a good or bad idea and explain why. After each presentation, the participants were asked to fill in the very short and anonymous questionnaire.

Glyn Jones explained that when expressing views, it was not important to be polite but to be honest as honesty is much more helpful to develop and improve the technologies and to make sure they are applicable to end-users. The SolACE project will use the information within the research to show how end-users can engage with each other in the development of new technologies and practices. There will be a follow up with the scientists to see how they react to the feedback.

Glyn Jones also expressed his appreciation to the audience for their time and for providing honest feedback on the innovations. It is an exciting opportunity for the participants to help shape the development of these technologies, and the project is very eager to be able to be able to learn from the participants’ views regarding how these technologies are developed.

[4] Dr. Glyn Jones, FERA, UK

Second generation microbial inoculants (bread wheat and potato)

WOLFGANG VOGT[5]

Roughly, one-billon microorganisms are present in 1 gram of soil. Good ones and bad ones; fungi and bacteria. Among them, one can find plant growth-promoting bacteria as well as antagonistic fungi and bacteria of plant pathogens, but also human and plant pathogens.

It is the work of scientists to select suitable microorganisms. They are looking for N-fixing bacteria, P-mobilisation fungi or bacteria, and microorganisms that increase the stress tolerance of plants.

Thanks to former work, the SolACE project was able to start with consortia of microorganisms in pot trials. Consortia of three microorganisms (fungi and bacteria) are available. Based on the results of the pot trials on potatoes and wheat, we selected three consortia for each crop. These will be tested in the SolACE field trials, which will start this year for wheat and next year for potatoes.

We aim to find a consortium, which can provide a higher tolerance against combined stress to the crop.

We need feedback from you in terms of in which direction we should go – do you want a liquid formulation, a powder formulation, and a granular formulation? What kind of application would you like? We need your help to reach our goal for potatoes to perform well under combined stress.

Discussion

Question: Could you tell us more about the consortia? According to which principles did you put them together?

Answer: We were quite happy that before the start of the project, we worked with different groups, which had already worked on this. Therefore, it was easy to choose the first consortia, which we chose for the pot trials. We have consortia with three microorganisms, which we will use in the field trails, which will start this autumn and next year in April for potatoes. Now we hope we chose the right ones.

Q: Isn't there a problem with these inoculants not persisting in the soil because the local population just overruns them?

A: Yes and no. There are 1 billion microorganisms in 1 gram of soil, but what we apply is 10^{11} or 10^{12} times this per hectare. This means that we apply ten times or 100 times more than what is in one gram of soil. What's in the soil is nothing compared to what we apply. So one idea is to apply it on the seed. When it germinates you have a relatively fresh root - nothing is on it. Especially we are working with endophytes, which go *in* the roots, in the plant. There are not so many other bacteria or fungi.

However, maybe a second application is necessary. Therefore, the situation about the application is a big issue.

We have older results with other bacteria, which show that the bacteria we apply are no longer detected after four weeks of application. However, you get a great effect.

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[5] Dr. Wolfgang Vogt, Agrobiota, Lembergstrasse 18, 72071 Tübingen, Germany

Results from feedback forms

The stakeholders considered the innovation potentially useful in theory (rating: 1.2), but less useful in practice (rating: 0.4) and did not feel strongly about using it in the future (rating: 0.2). One stakeholder noted that although they have tested microbial inoculants, it has not yet impacted the culture. The questionnaire is available in Annex 1.

Key: 2 = strongly agree, 1 = agree, 0 = neutral, -1 = disagree, -2 = strongly disagree

Genotypes mixtures (durum wheat)

Philippe Hinsinger[6]

Most of our modern agriculture is based on simplification and considerable reduction of diversity, monocropping of maize being an extreme. With the need for sustainable intensification of agroecosystems and the transition towards more agro-ecological approaches, we shall see more biodiversity-based agricultural systems emerging.

Indeed, in natural ecosystems, ecologists have long shown that increasing plant diversity usually results in increasing the productivity.

This has been used in agriculture in developing countries and was formerly used in European agriculture as well, prior to mechanization and intensification in the 1950s and 1960s. I am talking about intercropping systems, mixing different plant species in a given field, such as legume-cereal systems. These have proven very efficient at achieving stable yields and high protein content in cereals such as durum wheat. Systems that are even more diverse are agroforestry systems. However, such systems are difficult to manage, as they require special harvesting machines or pose some constraint related to their spatial heterogeneity.

An alternative approach is to increase the diversity within the crop one is using. Most of our arable lands are composed of single-species systems, in which every plant individual is almost identical as they share identical genetic characteristics: they are composed of a single genotype/variety.

Why not use mixtures of genotype/ varieties instead?

It has long been shown in species such as rice that such mixtures are more resistant against the spread of disease or pests. Although it is less documented, they are likely to be more tolerant against abiotic stresses, such as drought, or nutrient deficiencies, which is the reason why we aim to test these mixtures in the context of our SolACE research project.

The underlying concept is quite simple: Whatever genetic progress one can achieve, it is unlikely that it will be feasible to obtain all the desired traits in a given genotype. Instead, combining those traits by using adequate mixtures of genotypes is easier to achieve. However, the plasticity of some traits makes their expression more difficult to predict. For example, root depth or plant height depends on competition for resources by neighbouring plants.

The big challenge is that combining different genotypes or varieties offers so many possibilities of mixtures (depending on the number of genotypes to be mixed) that it is difficult to assess and requires extensive testing. You should design your own mix! Have a try. In the worst case scenario, you will get the same yield as you normally achieve with a single genotype!

Discussion

[6] Dr. Philippe Hinsinger, Institut National de la Recherche Agronomique (INRA), UMR Eco&Sols, 2 place Viala, 34060 Montpellier Cedex 2, France, Phone +33 4 99 61 22 49, philippe.hinsinger(at)inra.fr, www.umr-ecosols.fr/index.php/en/

Question. When I use these mixtures, does this mean it changes year by year, so that when I am sowing I do not know what I get this year?

Answer: You know what you are sowing, as you design your mixture. Depending on the conditions of the year, for example, if there is a specific disease developing, maybe one genotype will take over and another one that is less resistant will not make it. But you will still get an acceptable yield. Past studies have shown that you generally get at least the same yield as the average yield of the individual varieties, or even better. That is the plasticity of the combination, which makes it efficient.

Q: Do experiences with the use of genotype mixtures exist?

A: In France, there was a project on durum wheat where we mixed two, four or eight varieties. Moreover, there have been many other studies. Many of them have targeted the resistance against pest or diseases. However, in this project we are looking for tolerance against drought in combination with nitrogen stress.

Q: Do you think this is a way to give more power to the farmers and the breeders?

As long as we are talking about mixtures of genotypes, we are still relying on genotypes produced by seed companies. We could have even more diversity if farmers would use their own seeds. This is really far from the conventional way that farmers are using seeds from the seed industry using specific genotypes. There are two different things we are going to try in the context of this project for mixtures of genotypes: either we buy commercial genotypes that we mix or we use genotypes we have been producing ourselves. Whatever the mixture, depending on the growth performances of each genotype, once harvested, you get a new mixture, which is still made of the same genotypes, but the proportion of the different genotypes changes. Moreover, that is a difficulty for reusing them.

Results from feedback forms

The stakeholders considered the innovation to be potentially useful in theory (rating: 0.83) and slightly less likely to be useful in practice (rating: 0.67). Most stakeholders agreed that they would use it in the future (rating: 0.83). A researcher noted that they are already implementing genotype mixtures and an agronomist noted the growing importance of biodiversity and resilience of production systems from an agroecological point of view. The questionnaire is available in Annex 1.

Key: 2 = strongly agree, 1 = agree, 0 = neutral, -1 = disagree, -2 = strongly disagree

Decision support systems (bread and durum wheat)

BAPTISTE SOENEN[7]

In SolACE work package 3[8], we will test a new decision support tool to manage N on winter wheat.

Our technological environment is changing (e.g., quick evolution of computing power and data processing tools; more detailed knowledge on agronomy, soil sciences or ecophysiology; increasingly powerful and accessible sensors; increasingly useful and interoperable decision support tools), so our decision support tools have to change too.

One example is N management. We can now use crop models to develop a new N balance method on winter wheat with a dynamic approach. In France, we test the "CHN" crop model (C for Carbon, H for H2O and N for Nitrogen) with this goal.

In the French context, N management begins with the estimation of a forecast N rate (using a balance sheet method). This is a theoretical step. Then we adjust the flag leaf application, using decision support tools, based on plant indicators, such as the chlorophyll meter. Approximatively 60% of French farmers use these decision support tools. The most famous is Farmstar, based on remote sensing by satellite. It was launched in 2002 and is now used on one million hectares. Finally, some farmers use intra-field modulation systems, which permit the user to modulate the N amount into the field.

With French farmers, advisors and scientists, we recently developed a radically new method for managing N fertilization (see figure 1).

- Step 1: The first step is to define favourable condition periods, according to a climatic analysis.
- Step 2: Then the second step is to estimate the Nitrogen Nutrition Index (NNI) using real time modelling (for example with CHN, or/and sensor measurements).
- Step 3: During periods of favourable conditions, the estimated NNI is compared to a minimum NNI path.
- Step 4: If there is a risk of not maintaining NNI above the minimum path until the next period with favourable conditions, a nitrogen application is advised, and the rate is calculated to maintain NNI above the minimum path until the next period with favourable conditions.

[7] Baptiste Soenen, ARVALIS - Institut du végétal, Ingénieur R&D en Fertilisation / Gestion de l'eau, Responsable du pôle Agronomie, Station inter-instituts 6 chemin de la côte vieille 31450 Baziège, France, Tel. 00335 62 71 79 52, Mobile 0033 7 87 87 81 45, E-mail b.soenen@arvalis.fr

[8] For more information about SolACE Work package 3: Novel agroecosystem management strategies and tools, see the SolACE website at https://www.solace-eu.net/about/work-packages/work-package-3.html

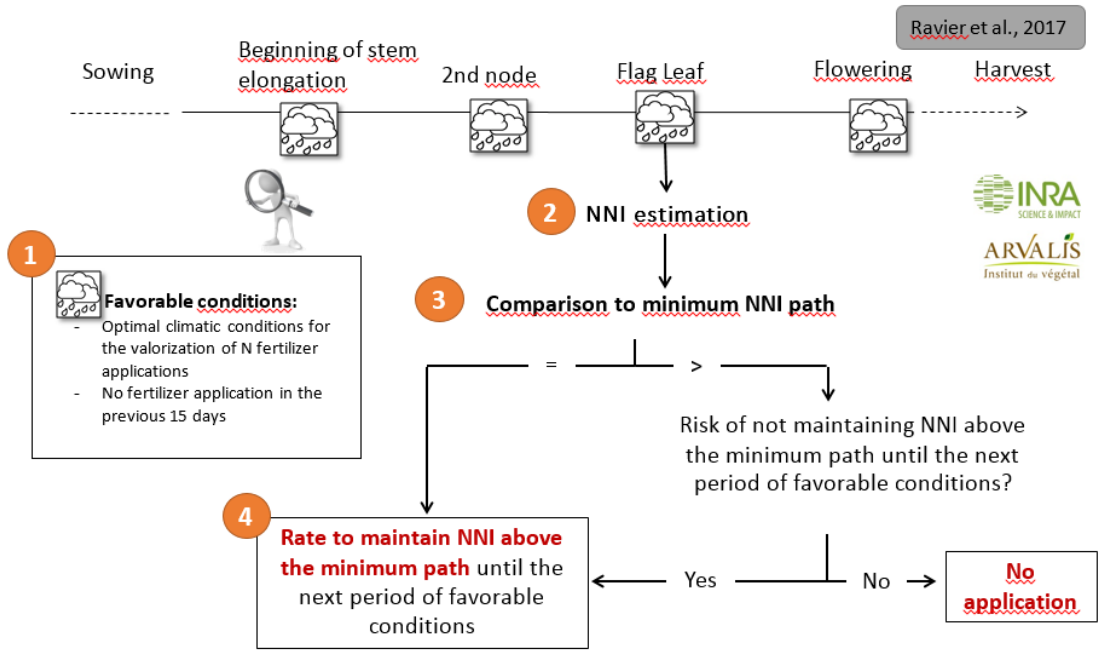

Figure 1: INRA-Arvalis method for managing N fertilization

Source: Ravier C., Jeuffroy M.H., Gate P., Cohan J.P., Meynard J.M. 2017. Combining user involvement with innovative design to develop a radical new method for managing N fertilization. Nutr. Cycl. Agroecosyst.

NNI: Nitrogen Nutrition Index

Models are never perfect. To improve their efficiency, we can use remote sensing and data assimilation.

We began to test this new approach two years ago on bread wheat and durum wheat, and the first results are good. Therefore, we are confident that it is effective, but we have to continue those tests in various contexts.

Discussion

Question: Does the method also provide suggestions for the other stages such as the tillage stage and not just the flag stage? Does it make suggestions for the type of nitrogen to be used in particular areas? Does it contain data about varieties?

Answer: It is not only for the last application in flag leaf application; it is for every application. We do not advise one fertiliser specifically, but we take into account the nitrogen losses, which can be different according to the fertilizer product. For example, urea ammonia nitrate (UAN) or urea show more ammonia volatilisation. The model can simulate those losses.

Q: Is there a user-friendly version? Does it run on a PC or smartphone?

A: At the moment, there is no a commercial tool; it runs on a PC or a network. However, in the future, the model will work on a network and you could watch the results on a computer or on a smartphone.

We could use a smartphone like a vector to consult the model, but also like a sensor.

Q: In Italy, there is the very successful DSS, granoduro.net, which was implemented six or seven years ago. It was funded privately and designed by a spinoff of Vicenza University. Why does the European Commission support this model, if a model is already on the market?

A: we developed our own model to be able to connect to our databases (e.g. the fertilizer database) to be able to make projections until the end of the growing season. There are many models from research, and they are not very easy to use, but the CHN model is. This model was developed before the SolACE project, and it is not funded by SolACE. However, it is used in the project; it is not a commercial product. However, there is contact with the developers of the other models.

Comment: there is another public, open source tool, Agrosat, which will be presented in Rome in May.

Results from the feedback forms

The stakeholders considered the innovation to be potentially useful in theory (rating: 0.71) and less likely to be useful in practice (rating: 0.29). While some stakeholders agreed that they would use it in the future, others were not sure or said they would not (rating: 0.29). A researcher noted that it would depend on usability and cost and that is seems less useful in low-investment systems. An agronomist noted that they would need to have DSS integrated models and sensors. Similarly, a stakeholder involved in transfer technology said that they were neutral because there are durum wheat DSS that don't function very well and that the solution would need to be improved. The questionnaire is available in Annex 1.

Key: 2 = strongly agree, 1 = agree, 0 = neutral, -1 = disagree, -2 = strongly disagree

Participatory breeding schemes (durum wheat)

JACQUES DAVID[9]

In SolACE work package 4[10] (Task 4.3) we conduct experiments in order to better monitor heterogeneous populations of durum wheat for their use in participatory breeding.

First, we will study a set of 96 micro evolutionary units under two contrasted and controlled environments, in which we will follow the evolution of traits such as plant height, earliness and spike traits as well as quality traits. After three generations we will verify that the chromosomal regions identified for above and below grounds traits in the other work package 4 tasks are really those implied in the adaptation of the evolutionary units.

Second, we launched a participatory breeding action in three countries: Hungary, Italy and France. A very diverse population has been sent for seed amplification to get a sufficient amount of seeds to launch a participatory breeding network using organic farming practices. Each farmer (from 4 to 5 in each country) will grow plots of 1000 m², in which they will be invited to breed according to different practices: spike or seed sorting, discussion about the traits of interest. In SolACE we will exchange and co-construct our participatory breeding practices. We will focus on the assets provided by the diversity within each population to allow adaptation and stress mitigations.

A the end, we would like to know how farmers can get used to such original material to promote changes in their durum wheat populations, and if they can find some advantages to breed for some local and specific uses and practices. These populations will also be monitored for their evolution in allelic frequencies of chromosomal regions identified for some traits on individual genotypes in other work packages.

At the end, both the farmers and the SolACE project will own the seeds.

Question: How fast will we lose genetic variation in the field if farmers use their own seeds year after year?

Answer: I am not afraid that we will lose diversity. We will still have a network of farmers; we will still have diversity in the research stations. The important thing is not if there is more or less diversity, but that the variety is adapted to the needs of the farmer. It is not the end of the breeding activities but it is a complementary way; a new way of thinking. So if you want to use diversity, you can implement this in the field, but if you implement it, you will reduce diversity, but you will transform it into genetic progress.

Q: how do you do that, do you this with single crosses and then you put together F2 F3?

A: We launched this experiment in 1997 in France. Therefore, we took a composite cross of durum wheat that already existed, in which we had a male sterility gene. This gene allows the population to cross at a 10-20 % rate. So this was the starting point from the durum side. We crossed this population with a bunch of

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[9] Dr. Jacques David, Génétique & Amélioration des Plantes, Montpellier SupAgro, Centre International d'Etudes Supérieures en Sciences Agronomiques, Département Biologie & Ecologie, Bat 33, 2 place Pierre Viala, 34060 Montpellier cedex 2, France. jacques.david@supagro.fr, http://www.supagro.fr/

[10] More information about SoLACE Work package 4 "Novel breeding strategies and tools" is available at https://www.solace-eu.net/about/work-packages/work-package-4.html.

old varieties that were forgotten, even wild forms, and we used the male sterility gene in order to introduce it into the population. These populations started to evolve in the South of France. So we sent a sample of the populations to the three partners. In each, you will find a number genes - resistant genes. Farmers will be in charge of modifying it in their own ways, to fit their needs.

Q: What do you expect in term of yield and quality?

I would not say that it is magical, but I would expect a change in what is considered a variety by the farmers. I would also expect that we prove that we get local adaptations. In SolACE, we have plenty of things about genetics, we will detect important genomic areas to evolve. We will identify which genes were responsible for the change in the different generations and if those genes could be linked to specific adaptations. For example, we saw that we had some very strong Septoria attack. I know that in this population, there are some resistant genes. So I would expect that after a strong attack, the frequency of the resistant genes to Septoria would increase.

Concerning quality, I think we need to, for example, join with people that are able to measure very quickly small objects, such as optical seed sorters. It would be a very good complementary tool for breeding for quality since these farmers will breed for quality.

Q: What does this mean for 2021? Will organic farmers become seed companies?

A: Currently, farmers are not allowed to sell their seeds. In 2021, they will be able to sell seeds. This means that some good organic farmers would be able to sell seed to other organic farmers. I think this will change the game. Those farmers could be associated with Syngenta or other seed companies, but some could go on their own. Depending on the demand for organic food, we will need more organic grain, which will require more acreage. If this is successful, the market is open

People will have to be very careful, as there are some diseases in organic such as tilletia. However, seeds will need to be clean.

Results from the feedback forms

The stakeholders considered the innovation to be potentially useful in theory (rating: 1) and less likely to be useful in practice (rating: 0.4). While some stakeholders strongly agreed that they would use it in the future, others were not sure or said they would not use it (rating: 0.4). A researcher said that participatory breeding schemes are critical for efficient breeding programs and an agronomist noted that they were interested in the methodology to extend it in other productive sectors. The questionnaire is available in Annex 1.

Key: 2 = strongly agree, 1 = agree, 0 = neutral, -1 = disagree, -2 = strongly disagree

Accounting for below-ground traits for improving tolerance against water/nitrogen deficiency

Philippe Hinsinger

We know virtually nothing about belowground traits compared to aboveground traits, as much (if not all) of our breeding effort has been concentrating on the shoots, not on the roots.

This seems strange at first sight, as roots are key organs for a plant to take up belowground resources - water and nutrients in the first place. I'll come back to this; it is central in our SolACE research project.

In addition to these key functions, roots play additional key roles in plants: they provide anchorage to plants! They create porosity and soil structure. They are also important organs for storage of sugars, especially in perennial plants. They are a major source of carbon, hence soil organic matter that is stimulating soil microbial and faunal communities. These functions shall not be ignored. Nowadays, with increasing concerns about carbon sequestration in soils, roots are key features for sequestration at depth. With increasing concerns about biodiversity, roots and their rhizosphere microbiome are of considerable interest.

Let us come back to coping with drought and nutrient limitations, e.g., nitrogen deficiency, which are major issues in wheat production, especially in Mediterranean agriculture. What could be desirable belowground traits? Obviously, rooting depth is a major one, as soils dry in the topsoil in the first place, when water is still available at depth. For nitrogen, as nitrate is susceptible to leaching, it also makes sense to develop deep roots to capture nitrate at depth and avoid nitrogen losses and contamination of belowground water.

Efficient capture of resources also requires branched root systems and fine roots, possibly symbiotic associations with mycorrhizal fungi. This becomes even more crucial for the least mobile nutrients such as potassium, phosphate and micronutrients. We shall not overlook physiological traits involved in plant nutrition and all the complex interactions at play in the rhizosphere.

So why are we not considering belowground traits? Because they are not visible, they require tedious investigations to be assessed, because they are difficult to measure!

And on top of that, they usually exhibit considerable plasticity. That is why they need to be further taken into consideration actually: For the sake of designing more resilient crops, that are more efficient at capturing belowground resources.

Discussion

Question: as long as we have cheap fertilizers and enough water why should we be aware about roots?

Answer: Well, there are many place, where we do not have enough water, especially here in the South of Europe and in many other countries. Indeed, fertilizers are cheap, but we know that they're responsible for a considerable impact on the environment: it is really our responsibility to use less of them and try to achieve adequate production with lesser use and to better use the resources that we have and have been adding to the soil due to past fertilisation.

Q: Hasn't modern breeding been directed at increasing a transfer to above ground component of the plat for top yields and feeding the world ultimately. So if we go towards selecting for plants that allocate more resources to roots, are we not possibly going sacrifice aboveground yield?

A: In this case, you are talking more about allocating carbon from within the plant to the above ground parts of the plant, to brain, for instance, or to the roots. This is an interesting question and indeed plants usually allocate carbon where there is the better benefit. Therefore, whenever plants do not have constraints in

terms of acquisition of water or nutrients, they will not allocate much more carbon to those organs that are responsible for acquisition of those resources.

That is why in the context of former intensive agriculture practices, there was no real need to look at those traits. In the context of reducing inputs in more frequent conditions where there is a limitation below ground, the plant will naturally react by delivering more carbon to the below ground parts. In many plants, carbon is not really limiting resource, compared to water or nutrients. Therefore, if we come back to this story of having a trade-off between production – what we need in terms of grain and fruit, etc. – and the need to incorporate enough carbon in the soil for soil organic matter and soil quality, roots are really key players as they are injecting carbon into the whole depth of the profile. We have to further look at these traits now. There have been new efforts in this direction, not only looking at roots as suppliers of nutrients or water, but also as organisms that are responsible for the supply of carbon to the soil.

Results from feedback forms

The stakeholders considered the innovation to be potentially useful in theory (rating: 1) and less likely to be useful in practice (rating: 0.33). While some stakeholders agreed that they would use it in the future, others said they would not use it (rating: 0.33). A researcher said that it is critical to the development of future resource-efficient crops. The questionnaire is available in Annex 1.

Key: 2 = strongly agree, 1 = agree, 0 = neutral, -1 = disagree, -2 = strongly disagree

Annex 1: Questionnaire for SolACE innovation presentations

Innovation title: _____

Your profession: _____

Please circle as appropriate below

1. This innovation is potentially likely to be useful to me **in theory**

Strongly agree Agree Neutral Disagree Strongly Disagree

2. This innovation is potentially likely to be useful to me **in practise**

Strongly agree Agree Neutral Disagree Strongly Disagree

3. I will use this innovation in the future

Strongly agree Agree Neutral Disagree Strongly Disagree

4. **Please provide comments in support of your answers** i.e. if you disagree is that because it is addressing a minor problem or is it because it is not in your area of work, or you agree because of another reason