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CropBooster-P

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EXECUTIVE SUMMARY

Cropbooster-P aims to create a roadmap to future-proof European crops to meet a growing population's future food demands given the ever-increasing climate risks, changing labour dynamics, and limited agriculture land.

The current report presents the results from six online workshop focus groups with 30 participants from across the European agri-food sector. We engaged with farmers, non-governmental organisations, reporters, community leaders, agri-food researchers, plant breeders, and businesses to understand the societal future-proofing needs and expectations regarding applying new plant breeding strategies in the European agri-food system. In the workshops, we discussed a wide range of potential future-proofing strategies and their expectation and acceptability of new plant breeding techniques, leading to general agreements in decreasing order of importance as mentioned:

- **Increasing food system resilience** should go beyond the sole focus of plant improvement. It should also include integrated approaches on:
  - Digitisation to manage agricultural production systems
  - Improvement of soil quality
  - Reduced food loss and waste.
- Nonetheless, **crop improvements** are vital and should include strategies aimed at improving
  - protein quality,
  - nutrient uptake and
  - water-use efficiency.
- **For innovative plant breeding techniques,** regulation and communication are deemed critical.
  - Regulations that keep up with technology are essential as large numbers of new plant varieties developed is difficult to trace from farm to fork and complicated by the geographically dispersed initiatives.
  - Open and transparent communication about the risks and benefits of the production chain and society is essential.
  - Involving society is essential to avoid the backlash GMOs faced.

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1 INTRODUCTION

Food security, increasing crop yields in the face of climate change while having to feed 9.7 billion people by 2050 sustainably and are some of the most significant challenges facing humankind. These must be delivered while society has to transition from a fossil fuel-based economy towards a bio-economy to minimise global climate change effects. These transitions will require a doubling of global crop productivity to produce enough plant biomass to achieve food and nutrition security and meet a future bio-economy's demands. Projections from the current crop yield rates suggest that we will fall 40-70% short of future demand without agricultural innovations aimed at increasing crop production. Increasing crop production must be achieved while maintaining crop nutritional quality. It will require crops that combine sustainability, efficient use of scarce resources (e.g., water and minerals), and cultivation schemes and practices that preserve Earth's biodiversity. The crops must also have good yield stability with high resilience to adverse climate and volatile weather conditions.

Creating new crops using state of the art plant improvement techniques may not suffice to meet these aspirations. It was argued that societal crop improvement needs and expectations regarding novel technologies also need to be analysed. Mapping out these societal needs may provide concerns that should be taken into account when prioritising plant breeding strategies and goals. Progress could be mired by the complexity of many possible crops and genetic changes, combined with multiple environmental changes, policy, and societal challenges.

The CropBooster-P project is a Consultation and Support Action within the EU H2020 research programme that aims to address this by identifying opportunities to adapt and boost productivity in a background of environmental and societal changes. The Cropbooster-P's objective is to develop a roadmap for future-proofing our food system and the European economy, with a specific focus on making crop production more sustainable, resilient, and responsible while at the same time guaranteeing nutritional food quality.

Taking a Responsible Research and Innovation (RRI) approach, CropBooster-P involves vital stakeholders, such as scientists, businesses, farmers, consumers/citizens, and policymakers, to relate the process and its outcomes with the values, needs, and expectations of society. In a series of work packages, we consider technologies and stakeholder responses, leading to a roadmap for future-proofing Europe's agri-food sector. The first work package (WP1) identified several techniques and strategies for crop improvement. These strategies were later refined in WP2, and their (potential) impacts assessed. In WP3, to which the current report contributes, we relate crop improvement needs and outcomes from WP1 with society's values, needs, and expectations.

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1.1 Overview of Work Package 3

Work Package 3 (WP3) of Cropbooster-P aims to i) understand societal crop improvement needs and expectations associated with novel technologies and ii) elaborate on an appropriate strategy to increase public awareness and trust in these novel technologies in the mid-term. To do so, it takes a mixed stakeholder-focused approach building on results from Work Package 1 and Work Package 2 (illustrated in Figure 1).

This deliverable reports on society's crop improvement needs and expectations associated with novel technologies. These opinions are collected through qualitative exploratory stakeholder workshops. The stakeholder workshops consisted of a series of focus groups centred on crop improvement needs, expectations on using new plant breeding techniques, and acceptability. We interviewed societal actors where the topics of discussion were: crop improvement goals and those options arising from WP1 and WP2 and its prioritisation. In these workshop focus groups, and in contrast to WP1 and WP2, where the focus was on plant developments, we discussed the broader acceptability of employing new plant breeding techniques in the agri-food system and the communication and information needs of society.

The outcomes of these activities combined with WP1 and WP2 results (i.e., the toolbox and associated impact assessments) will inform the citizen's jury in Task 3.2, the communication development in Task 3.3 and the development of the roadmap in WP5. Specifically, the provided approaches and assessments will be presented to participants in-depth, and reasoned judgment and condition for their societal desirability will be explored for the citizen jury.

1.2 Societal Needs and Expectations of CropBoosting

To further investigate societal needs, we asked societal stakeholders about crop improvement needs and their expectations vis-à-vis new plant breeding techniques. We built on the "CropBooster-P" technologies (identified in WP1, drawing on state of the art from the plant science community). Specifically, we follow up on the simplified and harmonised representation of these technologies developed through consultation between WP1 and WP2 researchers. These techniques were presented to stakeholders in Work Package 3 through workshops, and section 2 details the methodological approach and research questions.

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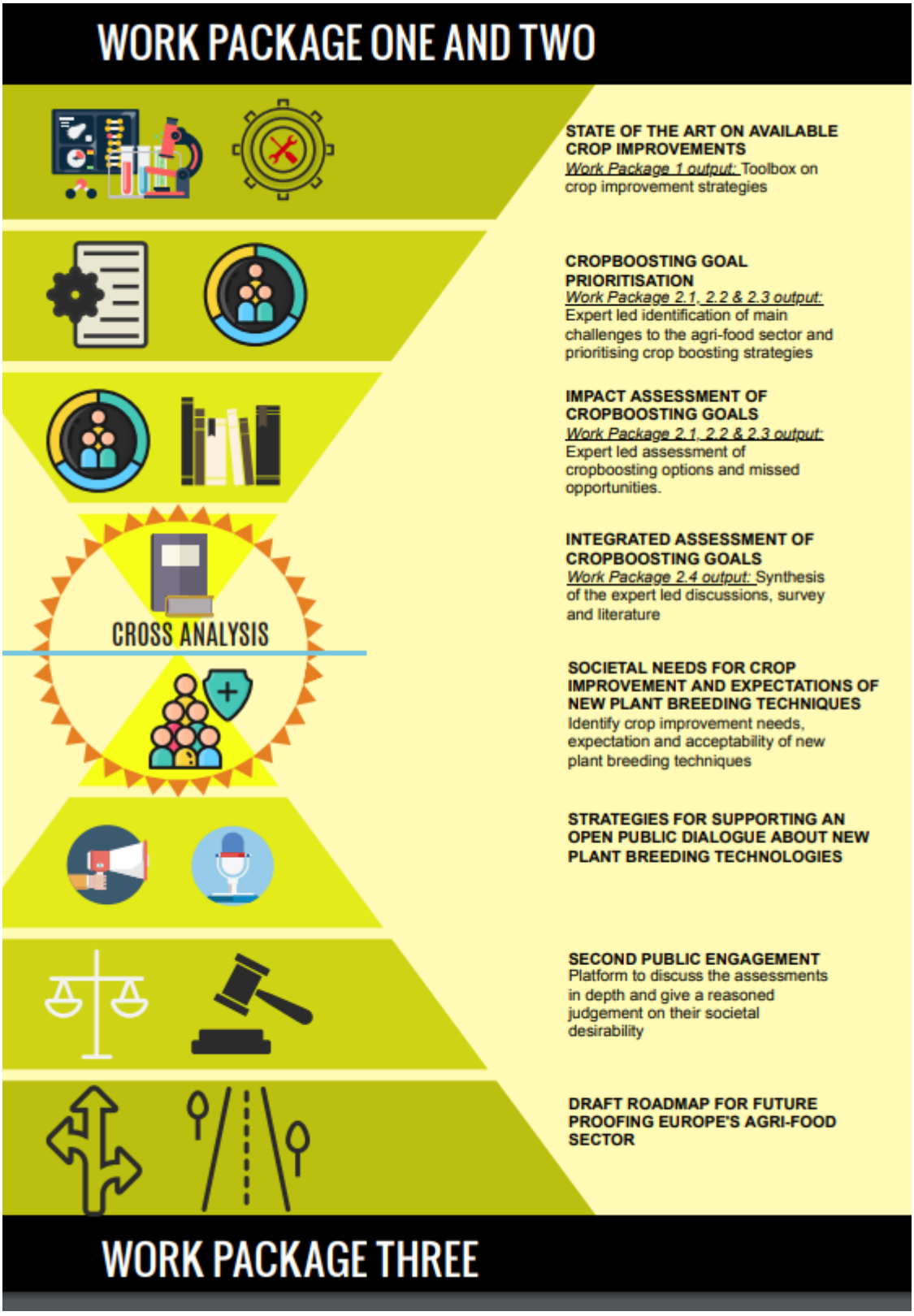

FIGURE 1: OVERVIEW OF WORK PACKAGE 3 IN THE CONTEXT OF THE LARGER CROPBOOSTER-P PROJECT

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2 METHODS: ASSESSING NEEDS AND EXPECTATIONS OF NEW PLANT BREEDING TECHNIQUES

The study reported in this deliverable provides qualitative data from focus groups to analyse crop improvement needs and expectations about new plant breeding techniques. A second public[1] consultation with citizens will evaluate these reviews and results from Work Package 1 and Work Package 2 (i.e., the toolbox, associated impact assessments, and the drafted roadmap). The figure shows the methodological approach used to consolidate the findings (**Figure 2**). Described here are the methods employed in the first public engagements and interviews with targeted groups regarding knowledge diffusion and outreach.

2.1 Focus group protocol

A series of online focus groups were held with relevant agri-food stakeholders from across Europe to understand stakeholders' needs, values, and future-proofing expectations. The focus groups helped elicit views regarding crop improvement strategies that they felt were important and acceptability on using new plant breeding strategies.

We designed a detailed semi-structured protocol based on previous experience in converting face-to-face focus group discussions into online workshops (see: Menary et al., submitted for publication). The protocols were pre-tested to guide the researchers through the workshop focus groups and ensure consistency and comparability between each stakeholder group (for the full protocol, see **Annex**). The primary questions were:

1) What are the biggest challenges for Europe's food and agriculture sector?
2) What are the important crop improvement strategies that we should consider for future-proofing Europe's crops?
3) What are your views regarding new plant breeding techniques available for crop improvement?
4) What are your expectations regarding applying new plant breeding techniques for crop improvement, and how can we responsibly innovate to achieve these?

[1] The second public consultation is planned in Spring 2021 and Deliverable 3.2 is due in Month 34

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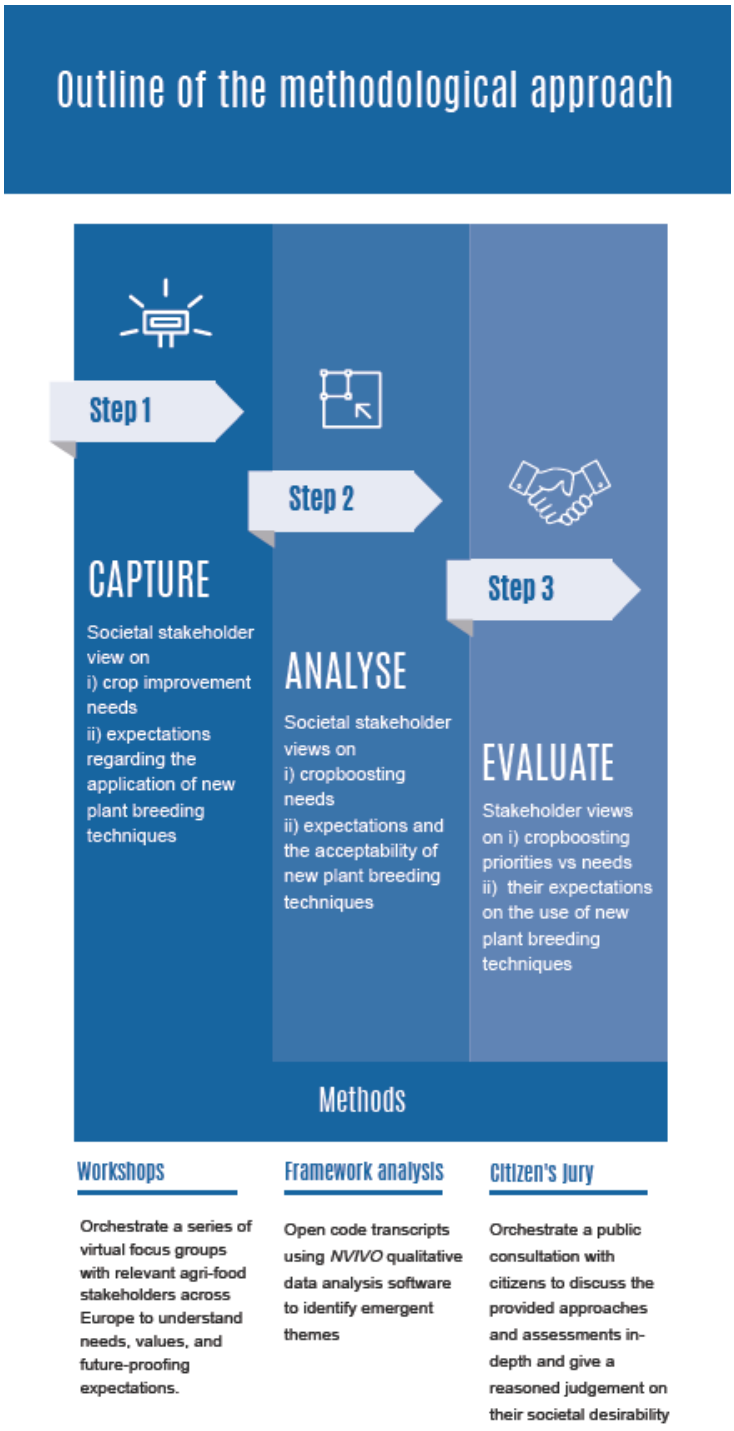

FIGURE 2: METHODOLOGICAL APPROACH

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Societal stakeholders brainstormed crop improvement needs using a whiteboarding software called Mural[2]. The responded in a prepared whiteboard shown in Figure 3. They were also allowed to discuss the acceptability of using new plant breeding techniques to future-proof the food and agriculture sector. The technologies identified in Work Package 1 through consultation with WP1 and WP3 researchers were simplified and harmonised as outlined in **Figure 4** and presented using Microsoft PowerPoint (see Annex).

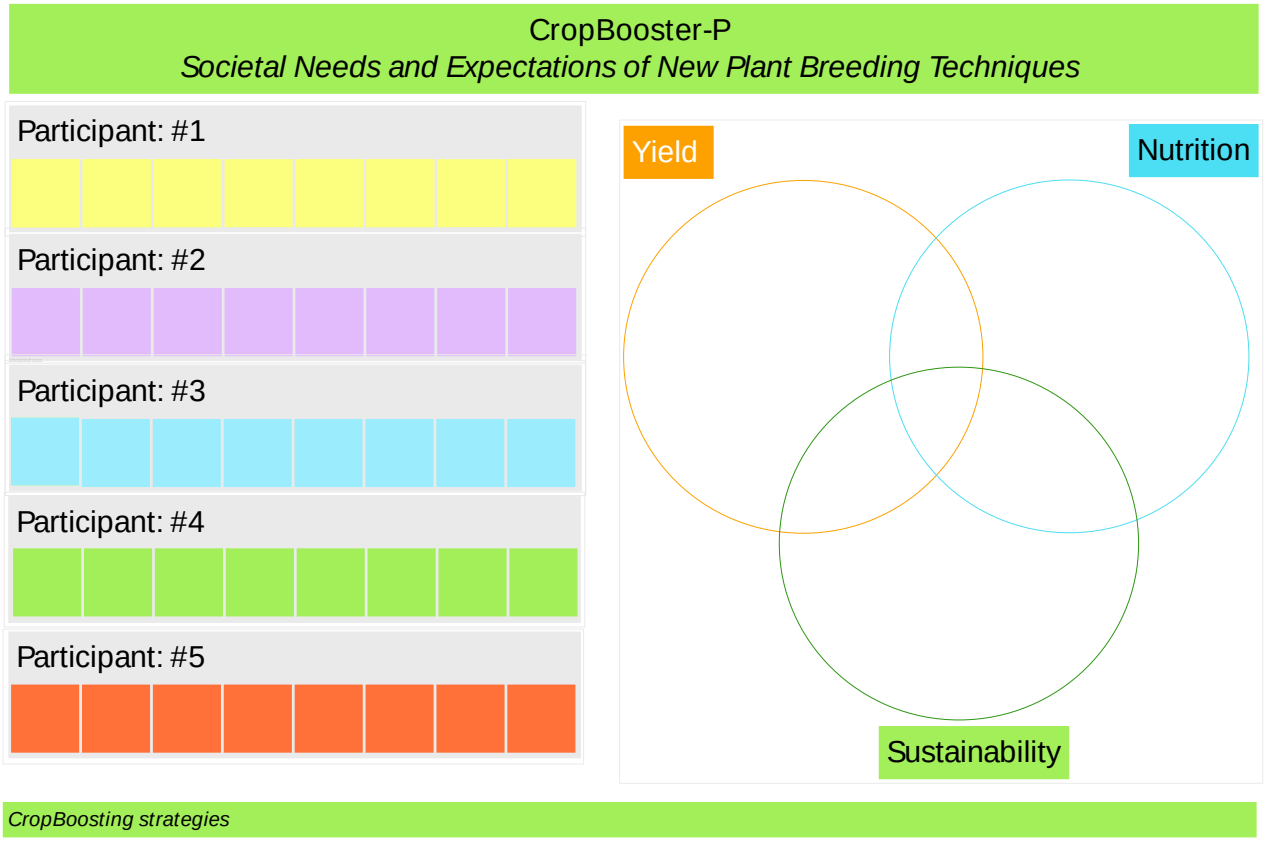

FIGURE 3: MURAL FOR BRAINSTORMING CROP IMPROVEMENT NEEDS (NB: PARTICIPANTS ACCESSED THIS MURAL DURING THE SOCIETAL NEEDS AND EXPECTATIONS WORKSHOP FOCUS GROUPS)

[2] https://www.mural.co

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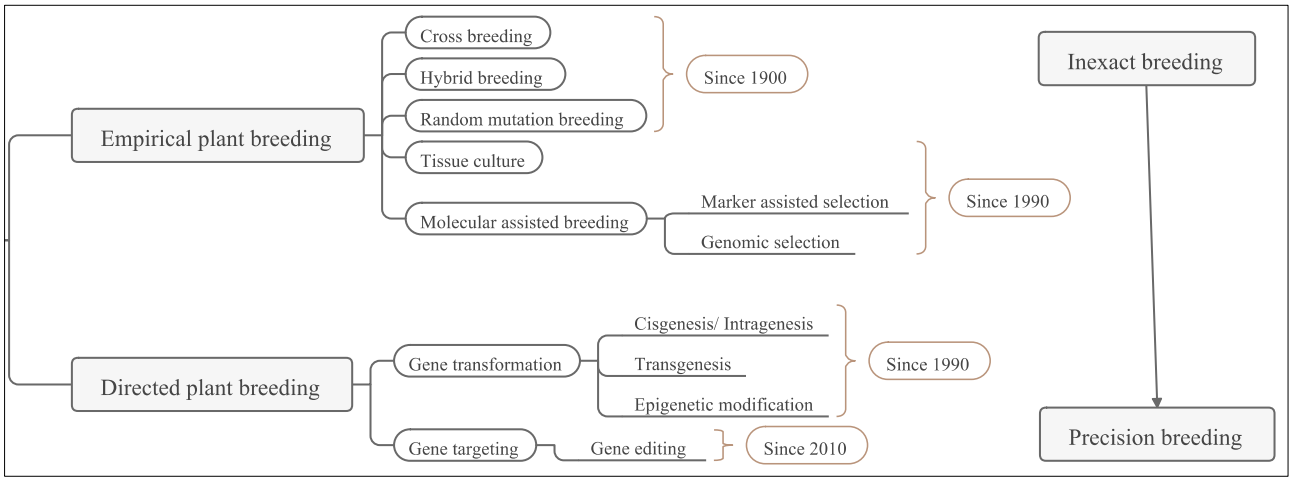

FIGURE 4: AVAILABLE PLANT BREEDING TECHNIQUES FOR CROP IMPROVEMENT

Additionally, to discuss techniques possibly missed in Work Package 1, societal stakeholders were provided with a content-free Mural (see Figure 5).

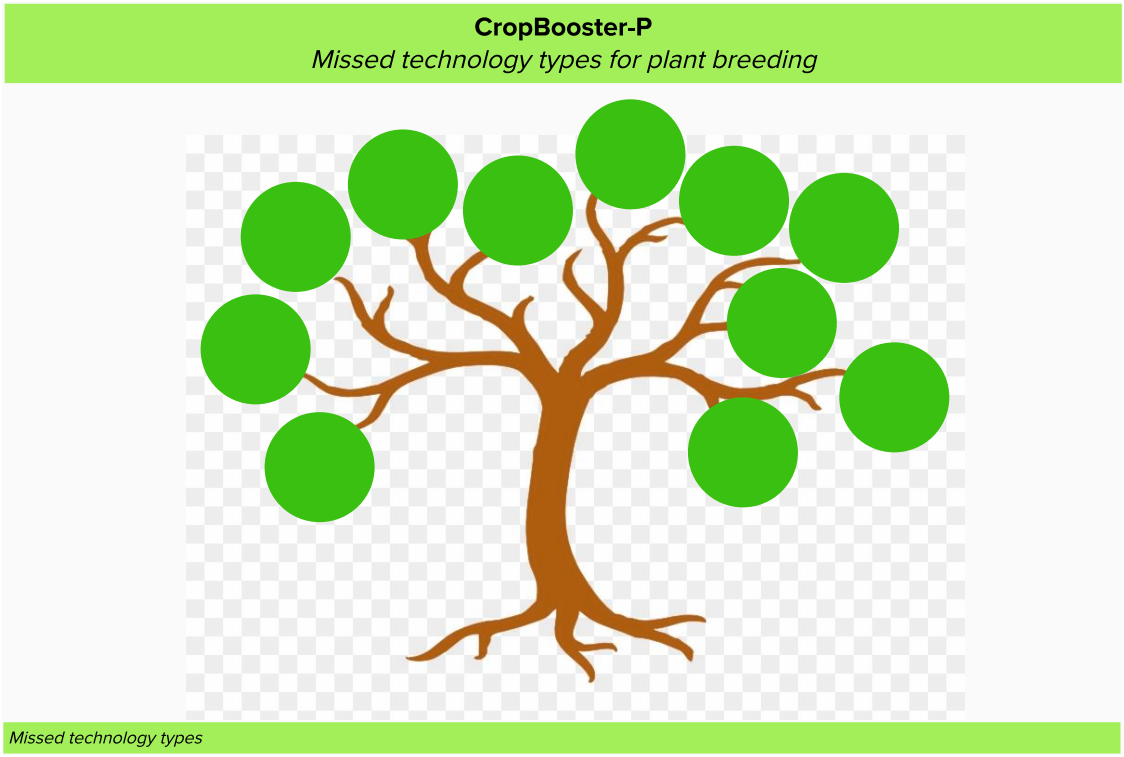

FIGURE 5: A CONTENT FREE MURAL TO DISCUSS MISSED TECHNOLOGIES FOR CROP IMPROVEMENT

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Focus groups were used as they provide a mechanism for both the generation of new ideas and the assessment of potential ideas. They offer insights into the differences of opinions among selected groups of people and generate a large amount of data in a relatively short period (Breen, 2006; Rabiee, 2004). Thus, focus groups were considered an appropriate tool to investigate a broad range of opinions on the various crop improvement strategies summarised for this purpose.

Although conceived and planned as more conventional in-person workshops, the COVID19 lockdown measures in Europe required the protocols for an online application. Virtual focus groups offer comparable data to in-person groups of the same kind (Woodyatt, Finneran, & Stephenson, 2016). Transferring an existing protocol fully online was not specified in a single source. Drawing on a similar experience in WP2 of Cropbooster-P (see Menary et al. submitted for publication), we adopted the following steps to transfer our workshops online while retaining relevance:

1. Identify a suitable hosting platform and means of recording the focus groups.
2. Determine the best way to adjust the protocol to facilitate brainstorming and in an online environment.
3. Scrutinise the extent to which the adjustments in materials and platform change the discussion about the main research questions.

We detail these steps further below.

To identify a suitable hosting platform: We considered several potential options. We decided that *Microsoft Teams* would serve as a unified hosting platform for the virtual discussions as:

- Meetings can be audio and video recording
- The research team had experience with the software, and the software is relatively easy to use.
- Screensharing made it possible to guide participants through the options cards easily
- Participants can join meetings from an internet browser and are not required to create an account to attend the meeting
- It is a widely available platform with fair stability and sufficient security/privacy

To facilitate brainstorming regarding current crop improvement needs and present the new plant breeding techniques, we combined Microsoft Teams with a web-based app called *Mural (*www. Mural. Co*)* and Microsoft PowerPoint. The Mural is a platform for multi-person, interactive whiteboarding, while Microsoft PowerPoint is a platform to present graphical information. A content-free Mural whiteboard also helped brainstorm missed techniques (see **Annex**).

These steps helped us design the focus group protocol to facilitate discussion online. Some demands for the online tools had also to be met, particularly around ease of use. For example, we selected a whiteboard and videoconferencing tool that did not require workshop participants to create an account (as this may slow down the workshop, and some participants may not have felt comfortable creating an account). It offers participants the choice to navigate the Mural whiteboard themselves or follow along via screen

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sharing – similar to handling offline option cards or sticky notes. To capture the full interaction online, and in contrast to offline focus groups, no physical products or lasting geographic ordering of messages could be created; it was necessary to record video footage next to the planned initial audio recordings. Specific for the online environment, safe collection and storage of video images (which contain personal data in recognisable faces) became a demand for the platform. Microsoft Teams met these demands as it saves recorded meetings to a secure, encrypted platform called *Stream*.

After addressing the issue of taking the workshop online, recruitment of potential participants began. Our research specified involving societal stakeholders, and primarily purposive sampling targeted people belonging to one of the stakeholder categories mentioned in section 2.2. Some participants provided additional suggestions as co-nomination "("snowball sampling"). Potential participants were approached using an email based on a standardised template (see **Annex**) by one of our partner organisation representatives.

2.2 Workshops

We hosted three workshops (in total, six focus group), hosted by CNR, Italy, USAMV CULJ, Romania, and WU, the Netherlands, respectively. We organised these workshops from different host locations to gain access to participant networks across Europe. We engaged with 30 societal stakeholders (18 Females and 12 Males) between mid-November 2020 and late January 2021 which included (inter/non-) governmental organisations (n=7), plant breeders (n=6), agri-food researchers (n=14), reporters (n=1), farmer/politician (n=1), and businesses (n=1). These involved:

- **7** Societal 'stakeholders' participated in two focus groups sponsored by CNR centred on South-Western Europe (Italy, Spain, France and Portugal)
- **9** Societal 'stakeholders' participated in three focus groups hosted by WU centred on North-Western Europe and attracting some participants from beyond (participants from Belgium, Netherlands, France, Switzerland, Germany, Romania, Greece and Lithuania).
- **14** Societal 'stakeholders' participated in a single focus group hosted by CULJ centred on Romania (South-Eastern Europe) (Romania)

Due to difficulty in synchronising schedules and last-minute cancellations, not all groups or regions were equally represented. Due to the Romanian focus groups' overwhelming attendance, not all topics were discussed at the same level of depth as in the other groups. Nevertheless, given the seniority of attendees (5 juniors, 13 mid-senior and 12 senior professionals) in all workshops and content of materials, the results provide a sufficiently broad scope for Europe.

Three researchers from (CNR, USAMV CULJ and WU) convened the workshops. None had any pre-existing relationships with the participants. The focus groups lasted between seventy and one-hundred twenty

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minutes, with the average time being one hundred minutes. The researchers used a standardised form to keep notes as they progressed through the focus group protocol.

2.3 Analysis approach

A GDPR-compliant company was used to transcribe each focus group video recordings – with non-disclosure agreements signed in advance. These transcripts were checked for errors and anonymised by removing identifying information. Adopting a *Framework Analysis* approach (Ritchie & Lewis, 2010; Srivastava & Thomson, 2009), an initial coding framework was developed by open coding the transcripts associated with each Work Package 3.1 task. The transcripts were fully coded and analysed using *NVIVO* qualitative data analysis software for Windows and Mac. An overview of the emergent themes was shared in the broader Work Package 3 consortium for comments. Several overlapping themes – were identified. These are outlined in the results section (section 3). Quotes to illustrate the analysis are provided after translation into English (where needed). Quotes are given with an indication from which group they were derived (Eastern European groups: “EE”, Mediterranean groups “ME1” and “ME2” and North-Western European groups “NW1”,” NW2” and “NW3”.

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3 RESULTS OF THE FIRST PUBLIC ENGAGEMENT

3.1 Societal views on the main challenges to the agri-food sector

Societal stakeholders mentioned that increasing crop yields to meet the demand of a growing population and a changing European market is vital for future-proofing Europe's food and agriculture sector. Particularly in the light of the global challenge of feeding many more people in the near future and the subsequent pressure on Europe to provide its own foods. This necessity to produce more foods within Europe is recognised as illustrated by the following quotes:

"… as you know, we have to feed more, I think, nine billion people by 2050. So, we need to produce more." – NW3

"…I think the biggest challenge for the European Union is to be more open towards food production because it happens that we import a lot of food from other countries." – ME2

Participants highlighted urbanisation as a problem regarding the challenge to produce sufficient foods on a global scale which puts a variety of pressures on agriculture. On the one hand, cities tend to be built in fertile locations, and urbanisation contributes to the loss of high-quality agricultural land availability.

"… cities keep increasing … and farmers are pushed to lower quality lands. – NW1

Additionally, rural-urban migration changes labour dynamics and labour availability in rural areas, which are significant problems for the agricultural sector, exacerbated by the pandemic, needs innovation to keep it viable.

"… we have to provide farmers with new ways to make agriculture viable; otherwise, we are going to have a huge problem…" [related to agricultural labour dynamics and rural-urban migration] – NW2

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"So, in this pandemic, we realise that more vulnerable communities and smallholders are in trouble. The solution is to promote the self-supportive capacity of an ecosystem to produce more sustainably, reduce chemicals go back to traditional practices while incorporating innovation in agriculture and the food system" – ME1

These social demographics' changes require producing more food, while available land and labour are becoming increasingly limited. Participants also cited external pressures on agriculture, generally related to climate change. In particular, they raised concerns about increased weather variations, extreme temperatures, precipitation, drought and floods as leading issues. These effects were seen causing (a)biotic stress in crops, leading to crop losses and reduced yields, while suggesting that the simultaneous impact of a changing climate could introduce new pathogens into a region, causing severe biotic stresses that make the agricultural system vulnerable.

"… with climate change will come more precipitation in certain areas and more drought in others. That means a shift in pathogens that have not been seen in certain areas before." – NW1

Concerns for increasing droughts were a severe worry for the southern and eastern countries.

"… particularly in our case from the South of Europe, we are going to have many challenges to deal with, and stress is going to be a problem, water availability is going to be a problem." – ME2

These effects required improved agricultural practises geared at reducing food loss as much as possible. At the same time, new agricultural processes and crops that could maintain the supply for high-quality foods given the changing climatic situation were raised as a priority issue:

"… generally, it is found that future food security will require reducing crop losses due to environmental factors and including climate changes. Also, transformative advances that provide major gains in yields in the next decades must satisfy demands for nutritious, food, fibre and animal feed in the highly variable climate." – NW3

"[there is a need for] …cultivating plants resistant to new climate change and I mean drought, salinity or other biological and even abiotic factors…" – EE

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From that, they raised the issue that waste reduction is essential to maintain sufficient food production levels. However, that waste in itself also contributes to environmental problems. Waste, nullifying the benefits reaped from invested resources, contributes to global warming. They were thus providing another reason to prioritise waste reduction.

"…a lot of what we have today, climate change, comes from the way we produce [food], and because we produce more than we need and do not use it which results in wastes." – NW2

They argued that producing healthy and safe foods at low waste levels as paramount. They also considered a further reduction of chemical crop protection interventions to be secondary. These remain an important goal to achieve under the condition that better alternatives leading to healthy and safe foods would be available:

"I would like to capture it in quality as there are mainly breeding goals. So [producing] healthy food, safe food, and those kinds of things … should focus on, using less crop protection products but only where reasonably good alternatives are available." – NW3

The previously reported ambitions are considered very important. However, participants claimed that without societal support, these could not be achieved. They worried that society at large currently does not have the urgency of boosting crops and argued to bring awareness about the role of agriculture in our society:

"I think that for me probably the most challenge or the biggest challenge is that people need to realise, they need to invest in the food sector they need to invest in agriculture." – ME1

3.2 Future-proofing needs and potential strategies for the food and feed system

Regarding future-proofing needs, societal stakeholders elaborated on strategies that improve the agri-food system's resiliency, production efficiency and competitiveness. They mentioned that it was unavoidable to improve the agri-food system's resiliency as it plays a vital role in transforming the food and feed system.

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Participants recognised the increasing role of digital technology in agriculture. They reflected on the role of digitisation in identifying and responding to threats in the agri-food production chain. Allowing farmers to monitor their crops comprehensibly and make more targeted decisions when to harvest. They considered that such digital technologies could improve agricultural production independently (and not requiring) from improved plant breeds.

… Digital technologies right now that can be used by almost everybody…, the ease of having different kinds of data being taken up from other parts of your farm and being put into a farm management system…" – NW2

"… Digital technologies can estimate when the yield is ready and when there is a loss. So, it is more about just optimising the land that we already have rather than, you know, manipulating the seed itself to create more per area…" – NW2

Participants also looked for other factors beyond improving plant breeds per se. They voiced the need to protect and improve soils. Improving soil quality (e.g. by decreasing ammonia level) was considered an important issue:

"Investigations were carried out, including by satellite, in which soil quality and the consequences of intensive agriculture were assessed in certain areas of Europe. Also, taking into account the stress induced by global warming, the situation is far from good." – EE

"…focus breeding, on a systems level and on improving soils … NH_3 is one of the most underestimated drivers of climate change and in big quantities, not good for soil health." – NW3

Participants also argued that given the abundantly poor soils, developing plant varieties and associated agricultural approaches targeted at coping with these poor soils could provide an essential contribution to food production.

"… crop improvement could help to face abiotic stresses … if we can make sorghum varieties through plant breeding that can go on poor soils, then all of a sudden those farmers that happen to have poor quality soils can have another crop. This can generate both foods and feed for European, consumers, feed for animals." – NW1

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Participants raised fostering local food production, encouraging buying from local producers and promoting clean/eco-labelling products to increase market competitiveness through sustainability transitions. They considered these are essential steps towards making agriculture more sustainable, regardless of the crops involved. The need for differentiated solutions was also highlighted:

"…the meaning of sustainability to reduce the impact on the environment (that) is something to be evaluated, case by case, region by region, crop by crop, not assuming as a very general issue is different from case by case" – ME1

"I think, now is the time to think about the local produce and it is from this from this unit, we have to develop in the future because the local produce takes care of the local economy." – NW2

"… increase our [Europe's] capabilities for food production… this [crop import] aspect is important because it decreases the CO_2 emissions if you produce locally, which decreases the costs." [related to crops imported] – ME2

"… replace all the palm oil ingredients, in our [European] cookies, in sauces, in soups with, sunflower, use a specific sunflower oil from European soil this can have a big impact because the food labelling directive can help promote these as healthier alternatives. These [eco labelled products] may be appreciated by European consumers and also the health system." – NW1

Most societal stakeholders mentioned that it was necessary to reduce consumption, environmental pollution and mitigate greenhouse gas emissions. One approach to improve food security in Europe, in their opinion, was to change their consumption pattern towards a more sustainable diet:

" … in [country], … 700 Kg per person/every year [food consumed] is consumed which is very high… we have to push people towards a dietary shift not to reduce food but to improve their diet by reducing some foods and increasing the consumption of other foods…" – ME2

They also considered the relevance of transparency in food information in the hopes that once consumers realise the number of resources being allotted to food production. They would then be able to recognise the intrinsic value of food and be less likely to waste food.

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"…Hopefully, this [digitisation] allows people to understand what is going on behind the food products that they choose and hopefully make more educated consumer choices so that we have less food waste." – NW2

A general concern about the use of fertiliser was voiced where participants not only looked at the carbon footprint related to the production transport and use of these fertilisers

"… we also need to transform the whole food system, right? … this means that we will have to reduce fertilisers to reduce the carbon footprint and of course, this means less inputs." – NW1

Nevertheless, they also mentioned that overuse of fertiliser could easily lead to environmental problems when residual fertiliser leaks into the environment:

"I would like to mention is a better use of fertilisers. We are still seeing much leaching of nitrogen and probably also other minerals into the soil, water into the groundwater with all kinds of negative effects." – NW2

3.3 Future-proofing needs and potential strategies for crop improvement

Figure 5 gives an example of the brainstorming activity on future-proofing needs for Europe's food and agriculture sector. It shows the results from the first focus group orchestrated by Wageningen University (NW1). In Figure 5, societal future-proofing needs are grouped under the CropBooster-P goals of increasing yield, nutrition, and sustainability. These were grouped based on the explanations given by our societal stakeholders. For example, when asked to position different future-proofing options towards nutrition, yield and sustainability, participants placed the vast majority of options contributing to improving both sustainability and yields or even spanning all three. Figure 5 presents an example of such an exercise, and Table 1 shows the list of strategies in Figure 5. Results across the focus groups were used to interpret the themes and are integrated into the following section's texts.

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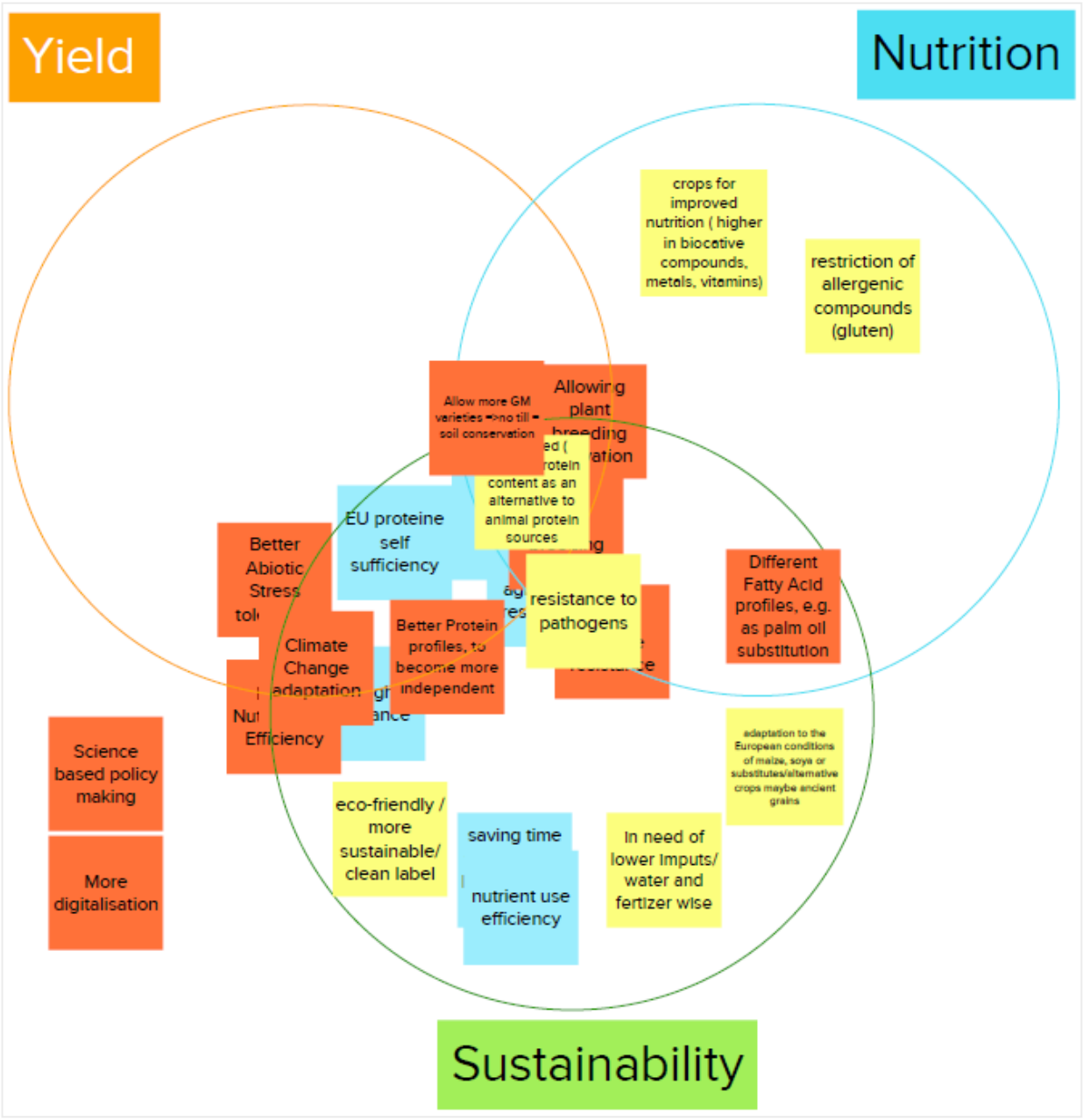

FIGURE 5: BRAINSTORMING ACTIVITY RESULTS FROM THE FIRST FOCUS GROUP (NB EACH POST-IT COLOUR REPRESENTS CROP IMPROVEMENT STRATEGIES IDENTIFIED BY A SOCIETAL STAKEHOLDER)

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TABLE 1: LIST OF STRATEGIES FROM FIGURE 5

Participant 1: Orange post-it	**Participant 2: Yellow post-it**	**Participant 3: Blue post-it**
Allow more GM varieties	Improve protein content as an alternative animal protein source	Bio-aggressor techniques
Allow plant breeding innovations	Resistance to pathogen	New breeding techniques
Better disease resistance	Adaptation to EU conditions	EU protein sufficiency
Better abiotic stress tolerance	Lower input and fertilisers	Drought resistance
Climate change adaptation	Eco-friendly/ sustainable/clean label	Less fertiliser use
Better nutrient use efficiency	Restrict allergenic compounds	Nutrient use efficiency
Better protein profiles	Improve crop nutritional profile	
Different fatty acids		
Digitisation		
Science-based decision making		

Societal stakeholders highlighted a few critical crop improvements and discussed their implications on society and the environment (see, Figure 5, Table 1).

Societal stakeholders in most focus groups discussed increasing protein content as an important plant breeding strategy. They also mentioned that improving plants' protein content was pivotal for reducing Europe's protein imports.

"… we see a huge amount of imports of soybean and other proteins into Europe. But, there is a bit of societal reluctance because a large part is of GM origin that's not necessarily a problem. But, I think for any country to become more independent of those imports, is advisable." – NW1

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"I also think improving crops for higher protein quality, higher protein content to start with, because we have to seek, plant-based resources, for protein and sustainability reasons, and as another available source." – NW1

The also suggested that improving fatty content in plants that grow in Europe's climate and soils could help achieve palm oil independence, reducing deforestation in South America.

"I worked in the past years on a sunflower variety that had a changed [improved] fatty acid profile with higher amounts of fatty acids compared to palm oil. So this variety [improved sunflower] could be a palm oil substitute grown in Europe." – NW1

Participants raised those plant breeding strategies that aimed at more effective and efficient use of resources are essential. In particular, given the increasing droughts improving water-use, and given the need to limit fertiliser use, nutrient use efficiency was essential in promoting environmental sustainability and mitigating greenhouse gas emissions.

"it is [improving water-use efficiency] related to yield, but also sustainability in the sense that it allows a crop to be more adapted. As we mentioned, water uptake efficiency is crucial if we consider water availability to decrease in many world regions. – NW3

"I would say increase nutrient efficiency … Some groups are trying to have this -omics approach it to have a general view of how interconnected things are. … and increasing it [nutrient use efficiency] you don't have to add many fertilisers like nitrogen and phosphorus." – ME2

Improved photosynthesis in plants was recognised as a potentially promising innovation. Participant recognised that while modern crops had been optimised for efficiency, the use of light in photosynthesis was still problematic. Participants considered that increased photosynthesis could become important in improving yields and improving food security.

"… breeders can work on morphological things of crops. Therefore, generally, modern crops are highly efficient but do not maximise light perception, and because of this, I think that it can be very important, including breeding programs." – NW3

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Table 2 is an illustration of the perceived socio-economic and environmental benefits of crop improvement strategies. The shaded area indicates associations made between the crop improvement strategy with at least one perceived social, economic or environmental benefit. In contrast, white areas indicate where associations were not made.

Crop breeding strategies	Social impact	Economic Impact	Environmental Impact
Improving protein content			
Improving fatty acid content			
Improving water-use efficiency			
Improving nutrient uptake			
Improving photosynthesis			

TABLE 2 PERCEIVED SOCIO-ECONOMIC AND ENVIRONMENTAL BENEFITS OF CROP BREEDING STRATEGIES (GREY AREAS INDICATE ASSOCIATIONS OF IMPORTANCE, WHITE CELLS ARE NON-IDENTIFIED COMBINATIONS

3.4 Societal expectation and acceptability of available new plant breeding techniques

During the focus group discussions, we asked societal stakeholders for their views on new plant breeding techniques. They cited that all of these techniques must be regulated. Nonetheless, they expect classical Genetic Modification (trans- and cis-genesis and similar) and precision breeding techniques to be regulated separately. They also mentioned that the regulation of new plant breeding techniques needs to be changed. They mentioned that current regulation was outdated and treated new plant breeding techniques as traditional genetic modification.

"Yes, because I mean, there are two approaches, right? The trade-based approach and technology-based approach. For organic technologies, it is important because there are certain risks associated with specific technologies. I include all of these [New plant breeding techniques] technologies as they will have their own risk, which is why regulation must play a role." – NW3

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"I think it is just disproportionate that they [New plant breeding techniques] are subjected to the extremely cumbersome, lengthy and costly EU authorisation system. This is the only thing I can say, and I think that really farmers are at a great disadvantage compared to the rest of the world, with its completely different approach." – NW3

Participants also pointed out regulators' hesitation as a critical issue hindering the development of legislation tailored to this new generation of plant breeding techniques. This, in-turn encumbers farmers and limits the EU agricultural sector's market competitiveness. Besides, they consider this hesitation in influencing consumer confidence about the new techniques negatively.

"I think the very hesitant approach of the EU, about the regulation or not of these techniques, does not contribute to obtaining more consumer confidence in these technologies." – NW3

Societal stakeholders also mentioned that plant breeding experiments' outcomes need to be communicated and not the technique alone. They recommended communicating the experiments' outcomes to farmers regarding a new plant variety's, traits, benefits, and impacts. This communication, in their view, was seen as how to raise awareness about the potential of new plant varieties.

"…been mentioning it from the beginning that there is not enough communication with the consumer on these issues [new plant breeding techniques]…" – EE

"Our farmers are not informed well enough about what they need, … so we need precise information for them because sometimes it is not about only about buying and producing [technology] it is also about all the inputs which are sold in the market." – NW2

Participants discussed informing consumers and analysing consumer behaviour as crucial for accepting these new plant breeding techniques. In particular, they emphasise that benefits to the consumer, the current problems we face in agriculture, and the potential negative consequences (risks) should be shared. They emphasised consumers would need this information not only for food crops but also for crops aimed at industrial use, such as crops grown for biofuel:

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"I think an important part is, of course, consumer awareness, very important. They need to be aware of the benefits of these techniques and the need for these techniques. I think we should tell the consumers more about the problems we currently face while explaining why we need these techniques. Not only the what, but also the, why." – NW2

"I think if it [New plant breeding techniques] was used for something like biofuels, it is still important to know as a person in the world if I am consuming it directly or indirectly. If it is being used for food or feed, I would want to know the risks." – NW2

Recalling the debate around genetic modification, which has primarily focused on risks, societal stakeholders raised the issue of safety and traceability and the open-end transparent communication about risks (or absence thereof) as being of critical importance. They mentioned that this needs to happen early to avoid genetic modification pitfalls. The strategy to communicate risks was kept outside by the supporters, which later backfired and created distrust and objections against GM by the general public.

"I fully agree but is vital to inform the society and consumers because this discussion is useful for scientists, but importantly to explain it to politicians, and society the safety of this method, because it is necessary to avoid the same mistakes made during GMO's development." – NW2

Creating trust in such new technologies through transparency and traceability of products are often used in food chains. However, participants recognised this would likely prove not easy. They claimed that these new plant varieties could not readily be distinguished from naturally occurring plants, nor can production controls be easily put into action. They could also be hampered by the large number and geographically dispersed initiatives based on these techniques. They also mentioned that it could lead to natural varieties' genetic erosion if checks were not in place.

"… since they are precise, cheaper and efficient, many small companies worldwide are working on these techniques to produce new plant varieties. Regarding traceability, we have a big issue with tracing these kinds of techniques and product as they could have occurred naturally." – NW3

Regarding the new plant breeding techniques, societal stakeholders expressed their scepticism and views on whether the public would accept them. In general, participants claimed to favour innovation. However,

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they contested the acceptability of a few techniques, particularly those for which they perceived risks that outweigh the benefits to the natural ecosystem.

"… if we have techniques that might provide benefits, I think we should use them for all the hungry people and other challenges. In my view, we should use all the innovation and make sure it is safe, but use it and, and do the- do the checks that we all agree on." – NW1

Techniques such as random mutation breeding, GMOs specifically transgenic crops, were criticised as being imprecise. Moreover, they showed scepticism about how precise techniques like gene-editing are really and to what extent supporters might have oversold its capabilities.

"You said that these techniques are precise… this is not true if you consider the people working on human embryos; they claim not to make a genetic change to embryos as traits could be transferred to the future generation because the technology is not precise... So, how can you say that [gene-editing] technology is not precise for humans, but it is precise for plants?" – ME1

"Because by throwing these chemical agents and radiation, you create so many mutations that might also create many unintended mutations. The organic movement sees potential risk in using this technique." – NW3

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4 CONCLUSIONS

The current workshops were complementary to workshops in WP2 in that they focussed on identifying societal needs first before discussing potential technologies. The analysis in part confirms findings of WP2 that crops innovations and improvements are needed to adapt to the threats of climate change. Crop improvement strategies, such as improving water use and protein content, are considered vital by experts and societal stakeholders in WP2 and WP3.

Nonetheless, results also go beyond the findings of WP2 in emphasising that a focus on the larger agricultural systems beyond only creating more productive plants will be essential. Soil degradation is raised as an important issue, and agriculture's digitalisation is raised as an important strategy for managing and protecting crops. Moreover, it is acknowledged that plant improvement can play an important role in sustainable European agriculture within this context.

An issue raised in the workshops reflected the need for transparent, open and fair communication to the public with contents that needs to be transparent about both pro's and cons. In-depth discussion of societally acceptable risk-benefit trade-offs on a technology-by-technology basis is deemed essential to overcome potential scepticism.

Specific challenges are identified in this report. The most critical challenge is **producing enough food** to meet the demand of a 9.7 billion population by 2050, increasing climate risks, changing labour dynamics, and limited land available for agriculture while achieving protein and palm oil independence.

As a whole, the food and feed system should be future-proofed, a task that should go beyond the sole focus of crop improvement. This future proofing should include digitisation to manage agricultural production systems. Improving soil quality and reducing food waste are essential strategies for **increasing food system resilience**.

Crop improvement strategies are also seen as a vital part of this; improving protein quality, nutrient uptake and water-use efficiency are essential for **reducing protein dependency, improving environmental sustainability and adapting to climate change threats**.

Technological innovations in gene editing are considered an excellent way to support new plant breeding techniques, but stakeholders were still sceptical regarding its use. Furthermore, there is also scepticism regarding GM techniques because of the **difficulty in tracing** new plant varieties and setting up production control due to the large number and geographically dispersed initiatives. They expect better **regulation that keeps up** with advancements in technology while ensuring safety and traceability. Finally, they expect **consumers and farmers to be well informed** about the risks and benefits of the technology and the new plant varieties at an early stage to avoid the backlash that GMOs faced.

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7 ANNEXES

CropBooster-P

Annex 1: Workshop Protocol

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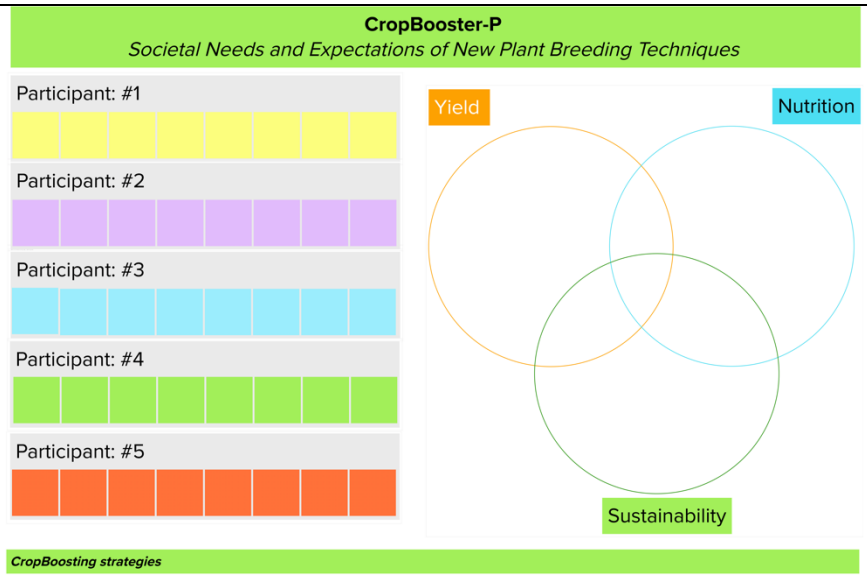
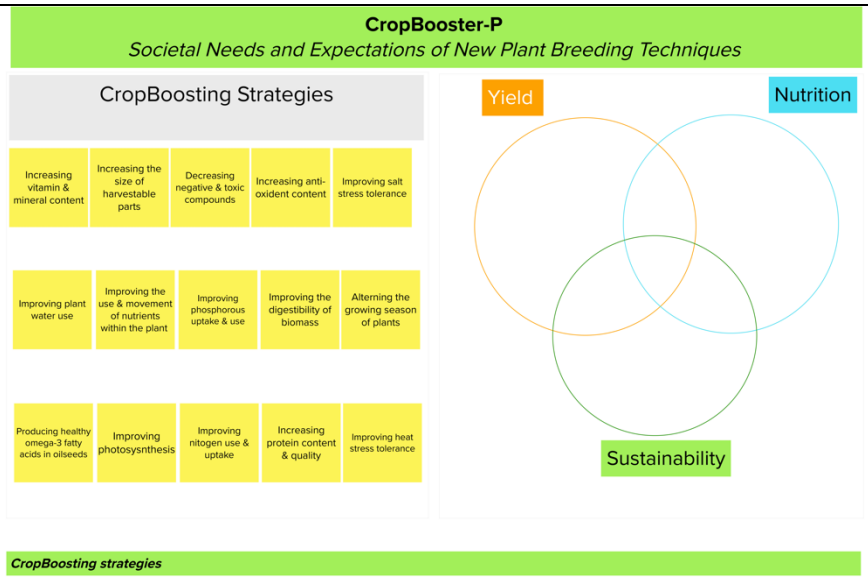
	Online workshop outline	The purpose of these workshops is to understand societal values, needs and expectation on future-proofing Europe's crops. The specific objective is to understand i) cropboosting strategies important for future-proofing Europe's crops, which fall within three headings: yield, nutrition, and sustainability. ii) ii) societal expectations regarding applying new plant breeding technologies (NPBTs) for future-proofing Europe's crops. The workshops are an opportunity for non-expert stakeholders to help build the roadmap for the future-proofing of Europe's crops. We will be asking stakeholders about cropboosting strategies they consider are needed for improving • Yield • Nutrition and • Sustainability, their views on NPBTs for • selecting new plant varieties, and • creating new plant varieties by inducing a genetic variation and their expectations regarding the application of these NPBTs for future-proofing Europe's crops
	Main questions	1. *What biggest challenges for Europe's food and agriculture sector?* 2. *What are the important crop improvement strategies that should be considered for future-proofing Europe's crops?*

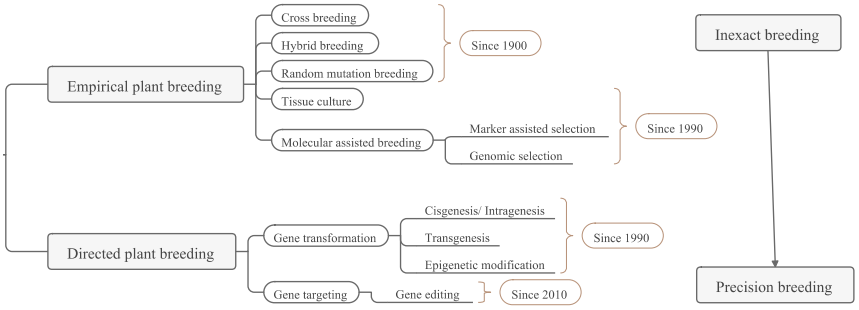
		3. *What are your views regarding new plant breeding techniques available for crop improvement?* 4. *What are your expectations regarding the application of new plant breeding techniques for crop improvement?*
	Details	WU, USAMV-CLUJ and CNR will facilitate up to six workshops: 1. *WU (X2) [**Time – Date (Mural #); 14 – 16:00 CET – 10.11.2020 (Mural #)**]* 2. USAMV-CLUJ *(X2) [**Time – Date (Mural #); 14 – 16:00 CET – 10.11.2020 (Mural #)**]* 3. CNR *(X2) [**Time – Date (Mural #); 14 – 16:00 CET – 10.11.2020 (Mural #)**]* We are aiming for 4-5 participants at each online workshop In the first part of the workshop, each participant is asked to write down possible crop improvement strategies that they consider important for future-proofing Europe's crops. Once these strategies are identified, participants will be asked to classify them under the three CropBoosting goals: improving yield, nutrition, and sustainability. *Mural 1*(a whiteboarding software) will be used to capture and classify possible options and strategies under the three CropBoosting goals. Next, the participants are asked about each crop improvement strategy and its socio-economic and environmental impacts.



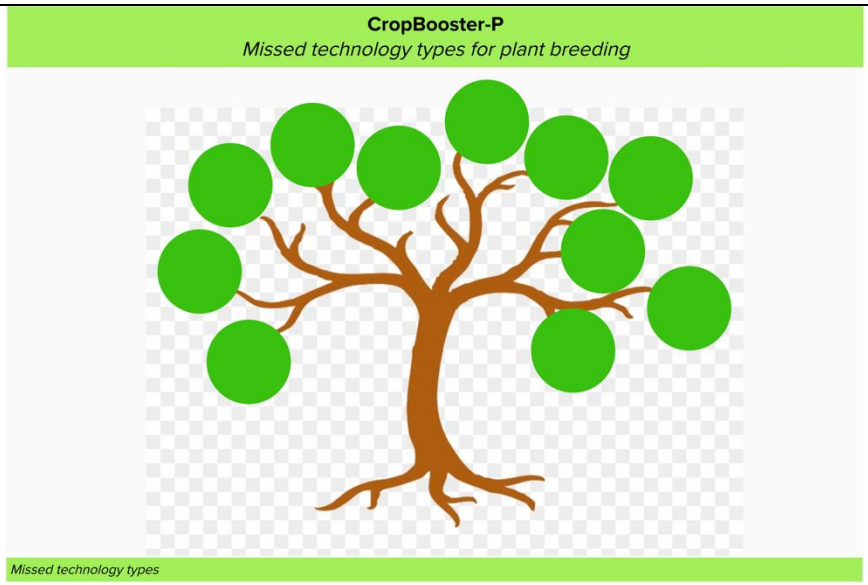
If participants cannot envision or conceive more than three crop improvement options or strategies for future-proofing Europe's crops, ask them for their views on the 15 cropboosting options identified in WP1 and WP2 their implication on society and the environment. Additionally, the moderator, with input from the participants, will classify each cropboosting option (starting from the most important) under the three CropBoosting goal(s) based on that the discussion (VENN diagram). *Mural 2* will be used to classify cropboosting options under the three CropBoosting goals.



In the second part of the workshop, participants will cycle through virtual stations where Plant Breeding Techniques (NPBTs) will be presented. Their views and expectations regarding the application of these techniques will be elicited. The technologies will be explained from a breeding perspective (see notes on PBTs).



In the final part of the workshop participants will be given the chance to detail Plant Breeding Techniques (PBTs) or strategies that have been missed out and need to be considered. *Mural 3* will be used to elicit these missed technology types/strategies.



To facilitate this process, three *Mural* whiteboards and two *MindMaster* presentations have been created. Several versions of these *Murals* and *MindMaster* presentations will be made to reduce any *order bias* and the effects of tiredness as participants move through the session:

- **Mural 1:**
https://app.mural.co/invitation/mural/wp37840/1601477737623?sender=abhisheknair8738&key=29b1f98c-262d-4c89-9790-57fb4f3ecc38

- **Mural 2:**
https://app.mural.co/invitation/mural/wp37840/1602664921265?sender=abhisheknair8738&key=781d6105-f3f1-45f5-820a-6b2be3eb29ff

- **MindMaster 1:**
https://viewer.edrawsoft.com/public/s/55f75506935774

- **Mural 3:**
https://app.mural.co/invitation/mural/wp37840/1601489221827?sender=abhisheknair8738&key=4a080917-42ef-431c-b474-49e58d3f376a

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	Materials	Make sure: • You have sent the participant information sheet (PIS) to all participants by email at least 24 hours in advance of the online workshop; preferable attached to the invitation email. • You have created the event as a Teams meeting (this is mandatory for video recording) • You have created a back-up meeting in Webex • You have a draft email to all participants with the back-up Webex link prepared and ready to be sent in case of any issues with Teams • You have sent a follow-up email that details the **time**, Teams **link** and **agenda** for the meeting • Make sure: ○ You have **screen capture software** set up or a **voice recorder to record audio via laptop/tablet speakers (this is back up in case Teams does not record correctly)** ○ You know how to use the voice recorder ○ You have checked that the voice recorders work (**battery**) ○ You have provided participants with a link to the consent form ○ You have checked in advance that all participants have filled in the online consent form ▪ Have links to consent forms ready in case anyone has not yet done it/wants to remind themselves of what was in it ○ You have links to materials and are comfortable using them ○ You have a **note pad** ○ **You have the printed-out notetaking sheet** ○ **You have two pens** ○ List of (expected) attendees • The partner organisation is either A. attending to give a short presentation, B. sending a prepared video which you have ready, or C. not attending, and you have added a thank you slide to the presentation • You have a spare computer already switched on, with the links for the Teams and Webex calls ready to act if need be • You have a LAN to connect to the internet directly

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		• You have a set of headphones (preferably with a microphone) - unless you are using the dictaphone as a back-up, in which case check that your audio quality is acceptable • You know who is attending and who is missing
Allow ~10 minutes for people to arrive and mingle	**Before starting**	Ensure that you: • Greet people as they arrive and make them feel welcome • Chat with them, try not to leave anyone out • You explain to participants that you will be recording the event • Check everyone's microphone and video connections individually • We have a designated back-up moderator ready to help out • Send out a link to consent forms in advance of the meeting

1-15	**Welcome presentation**	• A hosting partner can give a quick introduction (1-2 minutes)
		• Explain about CropBooster-P
		
		The CropBooster project aims at mapping and assessing current and future strategies, methods and technologies for crop improvement. In the first focus group, we will discuss these strategies, and in the second one, which most of you have agreed to participate in, we will discuss the technologies used for boosting and future-proofing crops. The project's end goal is to develop a Roadmap for future-proofing Europe crops that is i) technologically possible, ii) socially acceptable and iii) sustainable
		
		• Explain ground rules
		  ○ There are no wrong answers
		  ○ We are video/audio recording, so we do not miss anything, and your responses will be kept anonymous
		  ○ Online meetings are not as fluid as in-person meetings, so please be patient with each other, and I'll try to make sure everyone gets a turn speaking.
		  ○ Glitches usually resolve quickly – 'here's how we will deal with them
		  ○ If you have issues with audio during the call, please use the chat function to alert the moderator

		○ If the moderator drops out of the call and does not return within 5 minutes, please 1) check your email to see if we have sent you anything and, if not, 2) contact the emergency moderator (put the emergency moderator's email in the chat) **[REMIND EVERYONE THAT THEY NEED TO SIGN THE CONSENT FORM IF THEY HAVEN'T DONE SO]**
15-20	**Introduction**	**[START TEAMS RECORDING AND VOICE RECORDER/SCREEN CAPTURE SOFTWARE]** I would like each person to introduce themselves briefly: • Can you tell us your first name and a little about your organisation? **[MAKE A NOTE OF PEOPLE'S NAMES]** • Explain the aims of the workshop.
20-25	**Warm-up question**	OK, now I would like to ask what you think about the challenges for European food and agriculture: 1. What do you think the biggest challenges will be for the food and agriculture sector over the next few decades?
25-60	**Elicit possible strategies for improving yield, nutrition and sustainability of crops**	**[PROVIDE A LINK (ABOVE) TO THE APPROPRIATE MURAL START – EXPLAIN THAT YOU WILL ALSO SHARE YOUR SCREEN SO THAT YOU CAN HELP GUIDE PARTICIPANTS WITH THE WHITEBOARDING TOOLS AND ISSUES THEY MIGHT RUN INTO]**

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		[HELP EVERYONE FAMILIARISE THEMSELVES WILL THE TOOLS IN MURAL] Based on the question 2. Given these challenges, can you tell me a few crop improvement strategies that should be considered for future-proofing crops? Ask participants to navigate Mural 1 and use sticky notes to write down at least one crop improvement strategy. Next, ask participants to place their respective crop improvement strategy under the CropBoosting goal(s) they feel will be impacted/improved. **PROMPT:** ⇒ To what extent does strategy XXX improve YYY? **[REPEAT THIS FOR EVERY STRATEGY]** **PROBE:** ⇒ Did anyone else have that strategy? ⇒ What about [social/economic/environmental] impacts? **PROMPT:**

		⇒ Does anyone agree/disagree about the impact of that strategy?
65-70	**Insurance question**	Lastly, I would like to know: 3. How do these strategies meet the challenges you outlined earlier?
	Contingency: If participants are unable to envision crop improvement strategies	**[PROVIDE A LINK (ABOVE) TO THE APPROPRIATE MURAL START – EXPLAIN THAT YOU WILL ALSO SHARE YOUR SCREEN SO THAT YOU CAN HELP GUIDE PARTICIPANTS WITH THE WHITEBOARDING TOOLS AND ISSUES THEY MIGHT RUN INTO]** Based on the questions 4. Given these challenges, can you tell me what cropboosting option do you feel are the most important for the future-proofing of Europe's crops? **PROBE:** ⇒ What about [social/economic/environmental] impacts? **PROMPT:** ⇒ Does anyone agree/disagree about the impact of that strategy? Based on the discussion and in collaboration with the participants the moderator will place each cropboosting option under the CropBoosting goal(s).

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		Additionally, moderators may change the sticky notes' colour to help visualise cropboosting options that are most/least important. **PROMPT:** ⇒ To what extent does strategy XXX improve YYY? ○ Repeat for each strategy ⇒ Does anyone agree/disagree about the impact of that strategy?
70-110	**Elicit view and expectations regarding NPBTs for crop improvement**	**[PROVIDE A LINK (ABOVE) TO THE APPROPRIATE MIND MASTER START – EXPLAIN THAT YOU WILL ALSO SHARE YOUR SCREEN SO THAT YOU PRESENT THE NPBTs FOR CROP IMPROVEMENT]** Based on the question ⇒ What are your views regarding new plant breeding techniques available for creating new plant varieties? **PROMPT:** ⇒ Can you tell us what your views are about these new plant breeding technologies? ⇒ Are they specific ones that stand out, and why? **PROBE:** ⇒ What about [social/economic/environmental] impacts? ⇒ Does anyone agree/disagree about the impact of the XXX technique?

		PROBE: ⇒ Do you consider speeding up plant innovation is needed? ⇒ Do you consider speeding up breeding processes is needed? **PROMPT:** ⇒ How does speeding up plant innovation and plant breeding contribute to solving the food and agricultural sector's challenges mentioned before? **PROMPT:** ⇒ What are your expectations if such a technology is used for future-proofing Europe's crops? **PROBE:** ⇒ What about governance, regulation, safety, consumer attitudes; household incomes and food security; and nutrition?
110-120	**Activity: NPBTs not considered**	**[PROVIDE A LINK (ABOVE) TO THE APPROPRIATE MURAL START – EXPLAIN THAT YOU WILL ALSO SHARE YOUR SCREEN SO THAT YOU CAN DOCUMENT POSSIBLE PBTs NOT CONSIDERED]** Now you have an opportunity to tell us what **other PBTs** you feel that we have not mentioned, which you feel must be considered for crop improvement.

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		PROMPT: ⇒ Why is this PBT important for crop improvement? **PROBE:** ⇒ Why should XXX PBT be the focus for crop improvement? ⇒ How does this technique contribute to improving yield, nutrition or sustainability? **PROBE:** ⇒ What about [social/economic/environmental] impacts? ⇒ Does anyone agree/disagree about the impact of the XXX technique? **PROMPT:** ⇒ Can we agree on technique XXX should be included as a missed PBT? **[YOU CAN ADD TEXT ONTO THE GREEN CIRCLES, THEY ARE STICKY NOTES]**
120-125	**Debrief**	• Inform participants that you have now reached the end of the formal workshop. • Ask if they have any remaining questions. • Thank participants for their time and tell them ways in which they can stay in touch. • Mention that their input would feed into the citizen's jury, where a verdict would be made on the roadmap for NPBTs.

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		[END RECORDING]
	Contingencies	1. What should I do if a participant(s) does not join the online workshop? What is the minimum number with which we will run the call with? At <2 participants, switch to an alternative protocol [link]. 2. What should I do if Teams does not work? Send participants a link to Webex (or another back-up software). 3. What should I do if neither Teams nor the back-up software works? Ask a back-up moderator if they can take over or find another suitable date with participants by email. 4. What should I do if there is a glitch and a participant drops out? Continue and note when they left the call – if they manage to reconnect, then bring them up to speed with what has been said. Invite them to join a subsequent workshop (if possible). 5. What should I do if there is a glitch and the moderator drops out temporarily?

		Send them a chat/email informing participants that you will reconnect. If you cannot reconnect after 5 minutes, inform the back-up moderator and ask them to take over. 6. What should I do if a participant's video does not work? Continue with audio only. 7. What should I do if a participant's audio does not work? Ask them to reconnect – if the problem persists, ask them to check their audio settings. Invite them (by chat/email) to the subsequent workshop. 8. What should I do if one or more participants can't use the Mural? Use screen sharing – if fidelity is still too low, send PPT slides to the Teams group. 9. What should I do if a voice recorder does not work? Use your mobile phone to record audio (most have applications for dedicated audio recording, otherwise record a video). 10. What should I do if too many participants come to the event? Take their details, give them a name tag, and join any of the other focus groups.

		11. What should I do if someone is very late? If they join before the presentation of the NPBTs, bring them up to speed with what has happened and include them in the focus group; else tell them, we would try to include them in another focus group. 12. What should I do if one person is dominating the focus group? Start by asking for direct responses from other participants (e.g. "Does anyone have a different view?"). If it persists, you can directly ask the disruptive person to give others a chance to speak or throw them a stern look. As a last resort, they can be asked to leave.
	Transcription	Video/audio files should be uploaded to secure [drive] ASAP in the following format: *[date] – [moderator initials] – [organisation] – [workshop nr.]* Example: **20200930 – AN – WU – 4**

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CropBooster-P

Annex 2: Mural for brainstorming future-proofing strategies

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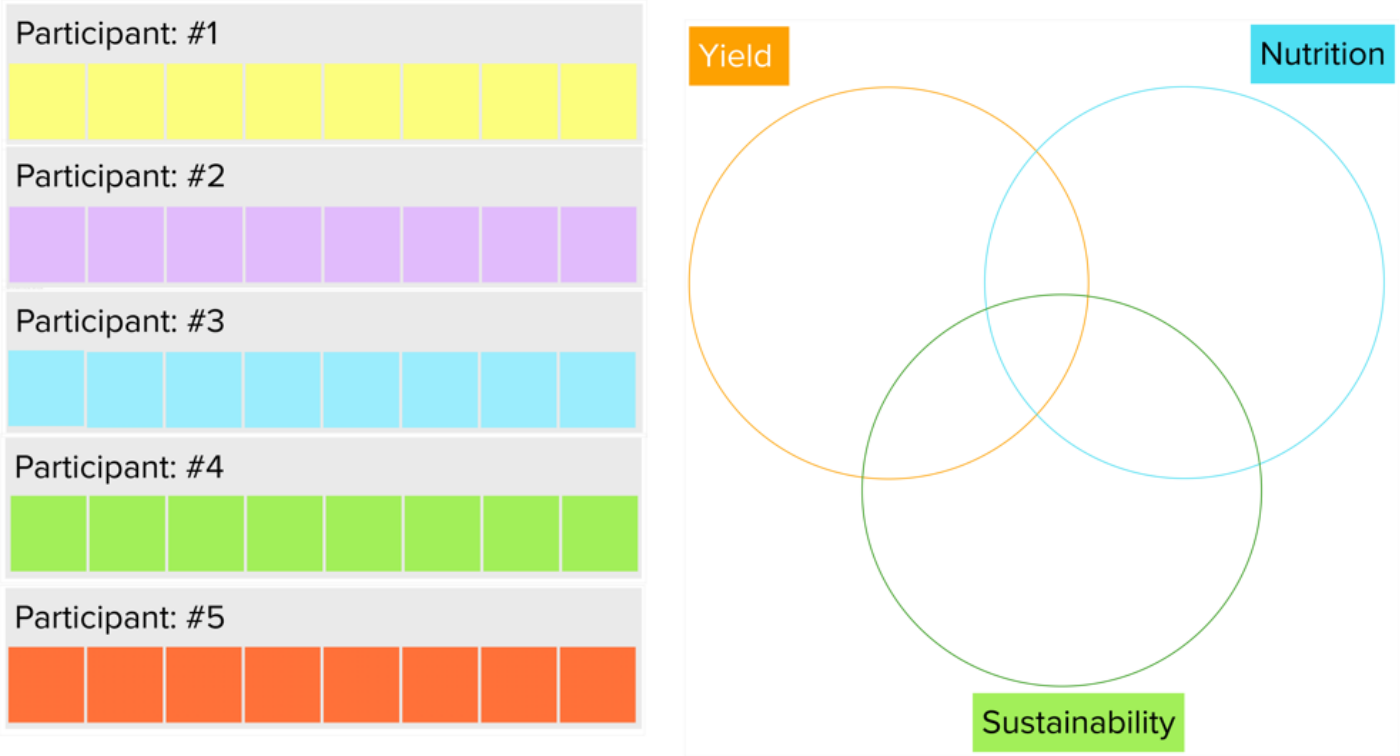
CropBooster-P

Societal Needs and Expectations of New Plant Breeding Techniques



CropBoosting strategies

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CropBooster-P

Annex 3: Mural for brainstorming missed technologies

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CropBooster-P

Missed technology types for plant breeding

Missed technology types

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Annex 3: Standardised Workshop Invitation

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Invitation: CropBooster-P's Societal Needs and Expectations workshop

Dear [Participant name],

I am hoping this finds you and yours well.

I am mailing you as we have identified you as an important societal stakeholder for future-proofing Europe's crops given your extensive experience in bio agriculture.

We invite you to share your knowledge in an online focus group on societal needs and expectations for crop improvement in Europe hosted by Wageningen University for the European project Cropbooster-P.

The focus group will last about two hours and take place on [date] between [time]. Please indicate you availability by responding to this email. We hope that you are willing to help us i) identifying strategies that you consider important and ii) understand expectations regarding the application of new technologies for crop improvement in Europe.

If you have any questions, please do not hesitate to get in touch with me.

Attached in this mail you can find a document with some more background information.

Sincerely yours,

Name]

Organisation]