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CropBooster-P

Deliverable 1.7

Title: Digested outcome and recommendations of the workshop regarding sustainability improvement

Start date of the project: **November 1st, 2018** / Duration: 36 **months**
Planned delivery date: M8 (June 2019)
Actual submission date: 15 July 2019
Work package: WP1 / Task: 1.4

Work package leader: ULANC
Deliverable leader: INRA
Version: Draft 1
Date of version: July 2019

Dissemination level	Public

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1. Introduction

The future demands on our crops will be tremendous, both in terms of level and stability of production and nutritional security. And food systems have to adapt to the transition to a non-fossil carbon economy, climate change, and globally reduce most of its negative externalities, improving its sustainability. These will give a new purpose to the rural economy of Europe. So far, however, Europe has no long-term strategy for future proofing its crops to allow these possibilities to be realised. How to sustainably increase yields and ensure nutritional quality, i.e. how adapting crops for the future climates of Europe, but doing so with the needed decrease in inputs such as water, chemical fertilisers and pesticides? Obtaining an overview on the current state of sustainability development of crop production within Europe including breeding methods and technologies, and breeding targets from traits to genes, would therefore provide an insight into various aspects of plant improvement, contributing to a toolbox that would prove invaluable to the future directions of crop research.

The Brundtland Commission described Sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". There are three pillars defining Sustainability: Economical, Societal and Environmental Sustainabilities. Task 1.4 will center its action on Environmental Sustainability.

The WP1-Research toolbox Task 1.4 will comprise of an overview of the current and future focus areas and approaches to improve sustainability of crop production. This will include a survey of published scientific literature for all major aspects of crop sustainability in major, minor and niche crop species. Current and future methods and technologies to improve sustainability and existing geographical trends will be included in this study.

2. Objectives

WP1-Research toolbox Task 1.4 will map the different existing and future subject areas for sustainability improvement. These we expect to vary across the diverse agricultural regions of Europe. Literature studies, technology studies (incl. models) and trait studies will be performed to list and collect all available strategies, options and technologies to improve sustainability in different crop species. This will be cataloging exercise, yielding a bibliographic repository and internal database. In the end, common strategies/technologies/traits linking sustainability, quality and yield objectives will be identified and will serve as a basis for discussions with the SHG. Their expert advice will be important input to the toolbox (task 1.5).

3. Partners and fields of expertise

Organisation name	Short name	Country	Area(s) of specialization
Institut National de la Recherche Agronomique	INRA	France	• quantitative genetics, genetic control of tomato fruit quality (sensory and nutritional), fruit and vegetable quality in general • plant and crop physiology (maize, wheat, soybean, pea…), breeding, cultivar and species mixtures. • Large-scale Phenotyping, genomics, metabolomics… • agronomy, drought, nutrient use efficiency, water use efficiency, nitrogen, major crops, legumes, non-food crops.

Organisation name	Short name	Country	Area(s) of specialization
Københavns Universitet	UCPH	Denmark	• photosynthesis; regulation of photosynthesis, chloroplast biology, thylakoid membrane • plant development, microProteins, tissue culture
Centre National de la Recherche Scientifique	CNRS	France	• essential metal (Fe, Mn) transport and seed storage, toxic metal uptake in plants • biochemistry, metabolic engineering and functional analysis of plant metabolism
University of Nottingham	UNOTT	UK	• plant and crop physiology, wheat, rice, photosynthesis • crop physiology, agronomy, drought, nutrient use efficiency, nitrogen, wheat
Europese Organisatie voor Wetenschappelijk Plantenonderzoek	EPSO	Belgium	EPSO's mission is to improve the impact and visibility of plant science in Europe, providing advice on science policy towards a strategic approach and critical mass funding for basic and applied research across Europe

4. Meetings and teleconferences

The following meetings and teleconferences have been held to discuss the project status and refine T1.4 work:

- **20th of November 2019 – F2F meeting**
  Kick-Off meeting CropBooster-P project, WUR, Wageningen, The Netherlands
- **28th of November 2018 – TELECONFERENCE**
  General framework of the CropBooster-P project, Task leaders of WP1 + several WPL
- **21st of January 2019 – TELECONFERENCE**
  Teleconference to discuss the sustainability concepts and the expected outputs of the T1.4 work - Task 1.4 partners
- **22nd of January 2019 – TELECONFERENCE**
  Update teleconference with Task leaders of WP1
- **31st of January 2019 – TELECONFERENCE**
  Status quo call - WPL1 + SR + task leaders WP1
- **12th of February 2019 – TELECONFERENCE**
  Status quo call, INRA team involved in CropBooster-P
- **14th of February 2019 – F2F meeting**
  F2F 1 day meeting on sustainability Task definition and planning, INRA core team leading Task 1.4
- **18th of February 2019 – TELECONFERENCE**
  Update on sustainability concepts Task leaders WP1 + People of INRA involved in Task 1.4
- **27th of February 2019 - TELECONFERENCE**
  Task leaders of WP1
- **27th of February 2019 – F2F Meeting**
  F2F 1 day meeting on refining sustainability Task 1.4 definition and Ecosystem Services concepts, INRA core team leading Task 1.4
- **7th of March 2019 Teleconference- WP1 Task 1.3 partner**

Discussed format of data collection, level of detail, deliverables and assigned responsibilities according to expertise and areas of interest. Created shared folder for internal data collection. Data collection in progress.

- **15th of March 2019 - TELECONFERENCE**
  Teleconference to discuss the format of data collection, level of detail, deliverables and assigned responsibilities according to expertise and areas of interest. Created shared folder for internal data collection. Data collection in progress - Task 1.4 partners
- **3rd of April 2019 – F2F meeting**
  F2F 1 day meeting to finalize the common understanding of the output of WP1, Leader WP1 and task leaders of WP1, VIB, Ghent, Belgium
- **4th of April 2019 – TELECONFERENCE**
  Status quo call with SR (define/rephrase proxy variables, set expectations for 2-day workshop, which are key for the Scenario building exercise)- SR + Task leaders of WP1

- **15-16th of April – F2F meeting in PlantETP, Brussels- scenario building workshop (WP1 T1.1).**
- **7th of May - F2F meeting in VIB, Ghent –** Determination of the scope of WP1 (definition of species, Determine which data should collected in the database...)
- **14 th of May- TELECONFERENCE** with WP1 leaders, Database content and format discussion, connections between tasks…
- **25th of June 2019 – F2F ExCom meeting -** progress of the CropBooster-P project – WP + Task Leaders, **ULANC, UK**
- **2nd of July TELECONFERENCE** with WP1 leaders, Database contain discussion for Yield and sustainability
- **2nd of July TELECONFERENCE** with WP1 leaders, Database content and format discussion, connections between Yield and Sustainability…

- <u>Future events:</u>

• **July 2019 (exact date to be determined) - TELECONFERENCE with WP1 leaders,** Finalization of Database and planning of data collection

• **July 2019 (exact date to be determined) - TELECONFERENCE with WP1 partners**

• **August 2019 (exact date to be determined) - TELECONFERENCE with WP1 leaders,** Progress in data collection

• **August 2019 (exact date to be determined) - TELECONFERENCE with WP1 partners**

• **September 2019 (exact date to be determined) - TELECONFERENCE with WP1 leaders,** Progress in data collection

- **11th of September - F2F meeting in VIB, Ghent** – Progresses in WP1

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5. Trend cards corresponding to sustainability facets

In preparation for the scenario building workshop, a list of relevant trends and issues focusing on subtask nutrition was collected within T1.1 from among the partners and assimilated into a long list of trends. These were further sorted according to relevance to the CropBooster-P project. A final shortlist of trends was proposed which contained trends pertaining to crop yield, nutrition and sustainability subtasks. These trends were then further processed into trend cards.

Trend cards capture the key aspects pertaining to each trend for consideration by the stakeholder group. These include facts and figures relating to the trend, examples of key stakeholders and influencers, the related sub trends and the relevance for the CropBooster-P project.

Most of these cards, if not all, are highlighting facets of the three pillars of sustainability: Environmental, Economical and Societal sustainabilities.

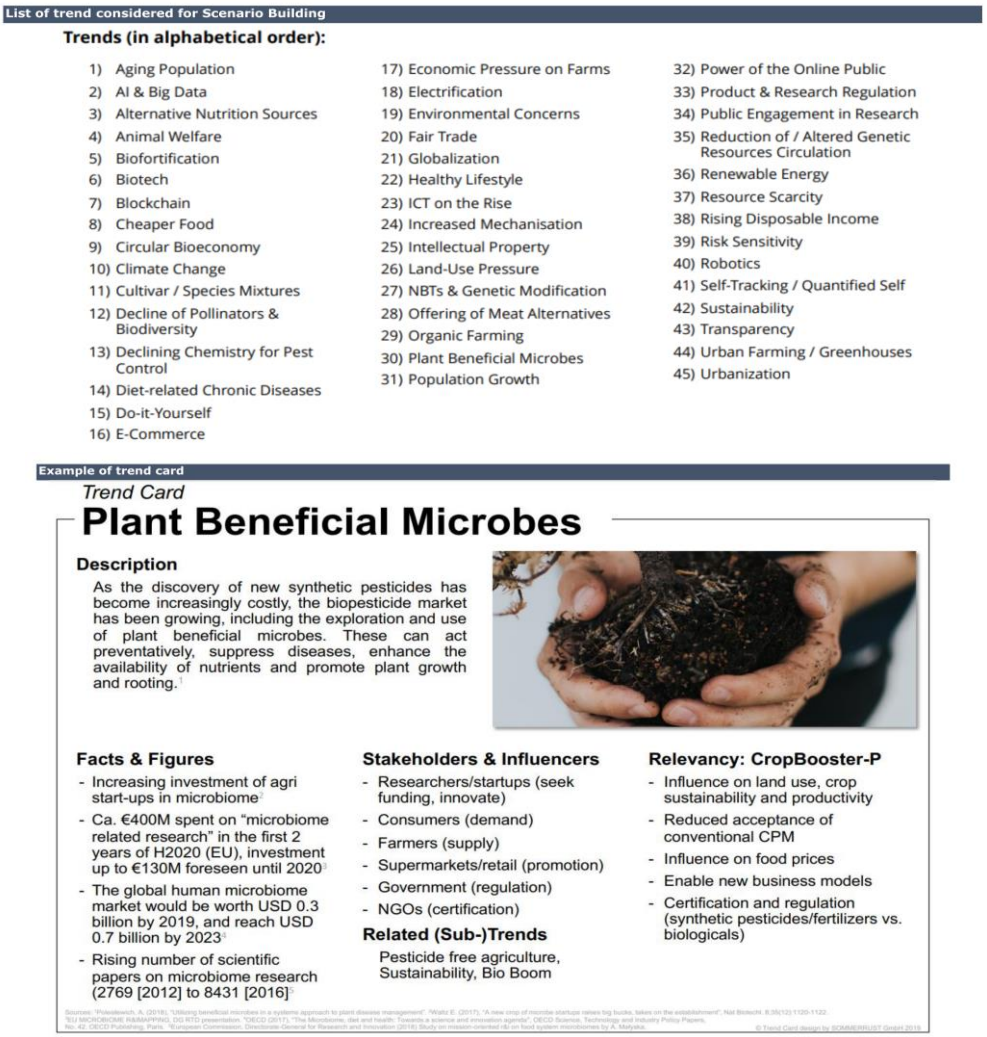

Fig.1 Final list of list of trends to be considered at the scenario building workshop in alphabetical order (above) and Example of a trend card for the scenario building workshop (below). Trends span aspects relating to crop yield, nutrition, and sustainability.

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Based on the trend card information and proxy variables raising questions regarding crop production in the future, themes were identified based on which four distinct scenarios were developed.

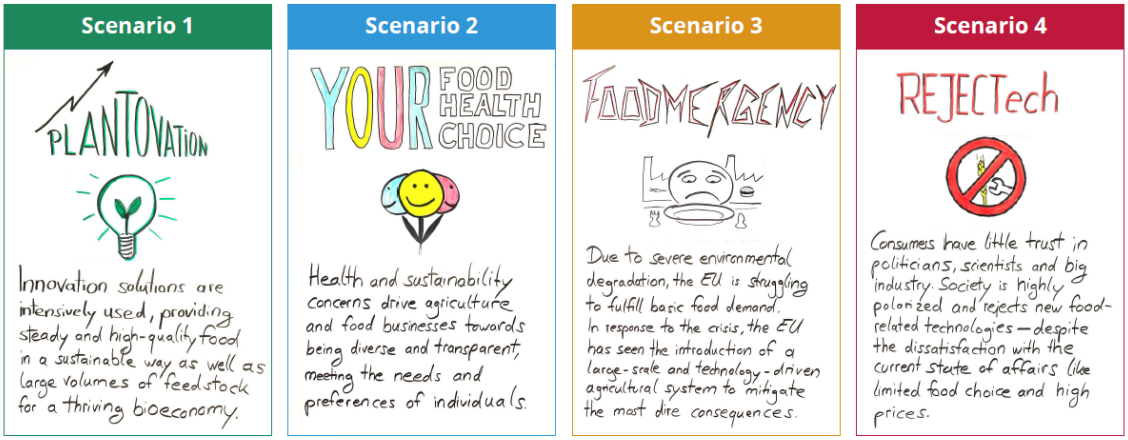

Fig.2 Overview of the four scenarios covering a wide range of outcomes. These scenarios will serve as a template for specific questions in the development of surveys within tasks 1.2-1.4.

Scenario 1- Plantovation
Fibres, high value crops
High value compounds/phytochemicals
Supercrops pushing limits of yield/area

Scenario 2- Your food, your health, your choice
High value compounds, superfoods
Alternative plant protein sources
GM alternatives

Scenario 3- Foodmergency
Calories are most important- Focus sugars and fats
Short growing time, robust crops
Soil quality/ nutrient availability concerns

Scenario 4- Rejectech
Alternative crops/ ancestral cultivation/landraces
Alternative nutrition sources to meet lack of biomass/yield

Based on these scenarios, a survey focused on Yield and Nutrition quality and their maintenance under highly fluctuating environment has been developed. Accordingly, specific aspects will be included in order to generate outcomes specific to sustainability.

6. Work plan for Tasks 1.2, 1.3 and 1.4

Overall revised phases:

To facilitate data collection, and in line with Task 1.2 and 1.3, WP1 Task 1.4 has been divided into distinct phases:

1) Definition of template, division of tasks among partners according to expertise and areas of interest (by M5 end)
2) Harmonization of template with Task 1.3
3) Data collection/ filling templates (by M11 end)
4) Compilation and filling in the gaps in the collected data,
5) Combination and harmonization of collected data with Task 1.3and filling in the gaps in the collected data
6) Arranging the collected information in a comprehensive format and upload to a central location (as part of T1.5 by M12 end)
7) Contribute to integration of the outputs of Task 1.2, 1.3 and 1.4, identify overlaps, trade-offs, etc. and align the data obtained by the different subtasks to generate a 'Research toolbox'.

Data collection templates:

- **MAPPING** - Bibliography: a comprehensive literature survey to identify Traits, and when available, pathways, processes and genes that have the potential to contribute to an increase in sustainability
- **GAPPING** - Gaps: identification of the gaps there are in our current knowledge that may hinder sustainability progresses

A 'mapping' and 'gapping' approach to identify traits, processes, and when available, pathways, processes and genes of which the potential can be exploited using a range of different technologies to increase Sustainability in distinct crops.

A common template between the subtasks of Work Package 1 - yield, nutrition and sustainability - was proposed to be developed in order to facilitate data collection and assimilation of overlaps between the subtasks for the final deliverable. This template would form the basis of a longer document outlining the current scientific progress and approaches known to improve plant traits. A technical annex will finally also be included to summarize key technologies and methods to improve crop yield, nutrition quality and sustainability.

Feedback from the partners at the scenario building workshop, F2F and teleconferences meetings:

A framework within which data collection of tasks 1.2, 1.3 and 1.4 was proposed:

Within the scope of tasks: (what data collected will account for)
Documentation of traits, processes and pathways pertinent to crop nutrition. This includes:

- Current trends/ state of crops within Europe
- Traits to improve or maintain yield, nutritional quality either under favorable or unfavorable environments
- Traits to improve and optimize nutritional yield/ content in crops
- Nutrient availability (to the crops)
- Breeding technologies relevant to nutrient use efficiency, uptake and metabolism
- Transferable technologies (value capture)
- Synthetic biology
- Aquatic crops
- Niche/ underdeveloped/ potentially beneficial crops
- Food and fodder crops
- Specialized metabolites with nutritive scope
- Toxic compounds/ anti-nutrients and their accumulation under unfavorable environment
- Document pathways, genes QTL, involved and their orthologues
- Tradeoffs between nutrition and yield and sustainability (to contribute to WP1.5 eventually)

- Spatial distribution of water nutrients/ partitioning
- Nutrient uptake/ availability changes based on Geographical location within Europe

Outside the scope of this task: (what data collected will not account for)

- Nutrient trends outside Europe/ non-European crops
- Non-measurable traits
- traits without genetic basis
- Social/ethical/environmental/physical factors (eg. GMO debate, global warming, weather inclemency and pests)
- Crop management
- Pathogens, pests and microorganisms
- Projections- predicting nutrient trends for future. (Capture current state of the art)
- Organoleptic quality (taste, smell…)

Based on this input, the partners suggested the following improvements to the data collection strategy:

Toolbox format

- Favor a searchable database as an output, which can be updated as new information/ technologies arise
- Compiling the toolbox into an encyclopedia format was suggested to be unnecessary (as this could go out of date)

Outcome: Toolbox will comprise shorter report outlining tradeoffs, as well as a searchable spreadsheet containing the main information for each gene/trait analyzed. The spreadsheet will be generated from smaller surveys, each survey contributing to a line of text/ data in the final spreadsheet.

Priority crops

- The suggested list of priority crops which will be considered in the database should also include vegetable, fruit, fiber producing species and algae examples
- Niche crops could be considered in a separate category distinct from priority crops, to ensure important information is preserved

Outcome: Data collection survey will include option to add examples (free text) for crops, traits, pathways …that are not predefined, to allow for additional input.

Accordingly, a list of crops has been established (crops in bold will be investigated in priority)

Algae : Fucus, ***Laminaria***, ***Porphyra***, ***Ulva***
Forage grasses / fodder : *Lolium, Alfalfa,* Clover, Sugarcane, Miscanthus
Grain Staples : *Wheat*, ***Maize***, Barley, Rice, Sorghum, Secale, Oat, Durum wheat, Millet
N2-fixers : *Soybean, Pea,* Field bean, Lupin, Clover
Oilseed : *Sunflower, Rapeseed*, Soybean, Olive, Maize
Vegetables: *Tomato, Lettuce,* Spinach (leafy vegetable), Brassica's, Pea, Carrots, Parsnip, Grape
Fibre & lignocellulose: *Poplar, Miscanthus,* Hemp, Willow, Switchgrass, Douglas, Sitkas, Eucalyptus, Spruce
Root Staples: *Potato, Sugar beet,* Onion
Model Plants: *Arabidopsis, Tobacco, Rice,* Spinach, maize
Others: *Grape, Pome (apple pear…),* Citrusses, olive trees, Strawberries, Raspberries

Traits

The major Traits pertaining to Sustainability, and considered within the CropBooster-P template for data collection belongs to **Acquisition and Resources Use Efficiency and Stress Tolerance/Resistance.** Their relevance will be considered for major crops, niche crops/underutilized crops, and aquatic crops.

These Major Traits have been refined in Traits and Sub-Traits, as exemplified in the following, non-exhaustive, list:

1. Acquisition and Resource Use Efficiency:

- Plant Phenology
  - Flower development
  - Flowering time and photoperiod sensitivity
  - Number of leaves before reproductive switch (determinate species)
  - Senescence, stay green, seed filling, remobilization
  - Early vigor, fertilization ...

- Plant Morphology

- Photosynthesis and Light Use Efficiency
  - Light harvesting, capture and pigments composition
  - Biochemistry of carbon assimilation
  - Plant above-ground structure/morphology
    ~ influence of plant architecture on canopy LUE
    * List of Sub-Traits: /Leaf anatomy [leaf shape (simple vs. compound leaves...)/size/SLA/Phyllotaxy/Leaf area/Leaf area density]/Erectness of leaves/Compactness/Leaf size/growth rate/Leaf expansion/cell expansion/cell size/Leaf life-time/senescence Self-shading/Growth/Plant Height/Branching/Tillering/...
    ~ influence of morphogenesis on plant architecture plasticity, and LUE
    ~ influence of architecture and plasticity on competition with weeds

- Gas ($C0_2$) Use Efficiency
  - Stomatal density/size/morphology/...
  - Leaf/Canopy architecture
  - CO_2 assimilation efficiency (Photosynthesis, see also link to Task 1.2 Yield)
  - ...

- Nutrient Use Efficiency
  - Plant below-ground structure/morphology
    ~ influence of root architecture on canopy LUE
    * List of Sub-Traits: Root shape/size/SRA/Growth/Length, Branching...
    ~ influence of morphogenesis on root architecture plasticity, and Nut UE
    ~ influence of architecture and plasticity on competition with weeds
  - Plant below-ground carbon physiology
    ~ Root exudates and their impact on plant nutrition☹impact on soil properties and microflore (pH, osmotic potential, …)
    ~ Carbon storage in root sinks
      - direct impact of root architecture on C storage efficiency

- indirect impact of stored organic matter on water, nitrogen, phosphorus macro and micro nutrients storage

- Water Uptake and Water use efficiency
  ~ Water uptake, transport in roots, shoots and leaves,
  ~ Impact of water availability on photosynthesis efficiency, biomass production and composition, nutritional quality… (metabolism, protein/carbohydrates)

- Nitrogen uptake and Use Efficiency
  ~ Nitrogen assimilation efficiency (transporters and metabolism)
  ~ Impact of low nitrogen on photosynthesis efficiency and biomass composition (metabolism, protein/carbohydrates)
- Phosphorus (Pi) uptake and Use Efficiency (link to decrease of natural resources)
  ~ Phosphorus assimilation efficiency (transporters and metabolism)
  ~ Impact of low Pi on biomass composition and photosynthesis
- Other Macro Nutrients Use Efficiency
- Micro Nutrients Use Efficiency

2 Stress Tolerance/Resistance

- Macro and micro Nutrients limitation/ deficiency
  - Nutrients uptake, storage, use efficiency…and impact on development, biomass production, photosynthesis efficiency and nutritional quality.

- Macro and micro Nutrients bio availability, form and quality
  - Nutrients uptake, storage, use efficiency…

- Drought tolerance
  - Water uptake, assimilation and storage efficiency, transport, evapotranspiration...
  - Crop varieties tolerant to drought stress (specific proteins and metabolic compounds)

- Flooding stress
  - Water uptake, transport and use
  - Anoxia tolerance

- High humidity
  - Water uptake, transport and photosynthesis maintenance

- Heavy metals (Cu, Mg, Mn, Cd, Zn …)
  - Heavy metals assimilation, toxicity and impact on growth, biomass production, photosynthesis efficiency and nutritional quality.
- Salinity Tolerance (link to land pressure)
  - Impact of salinization on development, biomass production, photosynthesis efficiency and nutritional quality.
  - Salt transporters and root-leaf transport and portioning
- Heat Stress Tolerance (link to climate changes)
  - water and CO2 use efficiency, structural and ultrastructural adaptation (specific proteins and metabolic compounds)
- Cold (frost/low temperature) Tolerance

  - water and CO2 use efficiency, structural and ultrastructural adaptation (specific metabolic compounds)
  - maintenance of growth and photosynthesis under low T
  - Stems, buds, leaves and flower survival under freezing T

- Physical constrains resistance
  - Shoot tolerance to mechanical constraints (wind, hail…)
  - Shoot tolerance to low or light intensity
  - Root ability to penetrate compact and dry soil and resist soil retraction

- Photoperiod constrains tolerance
  - Phenology and photosynthesis maintenance

- Chemical constrains resistance
  - Soil pH variations (nutrients availability, metals toxicity, nodulation …)

- Ozone/UV/Oxidative stress tolerance
  - Photo-protection and light assimilation efficiency
  - Leaf and shoot development

- Trade-off between Yield, Nutrition quality and Sustainability

Outcome: Space will be made available in the data collection surveys to add specific traits, stresses and crops as all cannot be foreseen/ impact assessed. Pests, microorganism and pathogens interaction are out of the main scope of the current exercise. However, provision will be made within the database to mark traits of outstanding interest for which there is a plant genetic basis.

Technologies

- All known technologies will be considered

Outcome: Cultural practices, microflore management… are out of the main scope of CropBooster-P and hence will not be included. However, provision will be made within the database to mark information of interest for which there is a plant genetic basis.

Revised template for data collection:

Based on the input from the Stakeholders, results from the WP 1.1 scenario building exercise and the extensive discussions, a revised plan for data collection was formulated. WP1.2- 1.4 will collect Data in the form of a common survey, with two sections:

Section 1, common to WP 1.2-1.4:

Column	Column 'choices'
Scale (by climate)	**Mediterranean**, humid subtropical, marine, humid **continental**, **subarctic**, **tundra** and **highland, other**
If other, specify	
Relevance to cropbooster..	Free text
Species group type	**Algae** **Forage grasses** **Grain staples** **N2 fixers** **Oilseed** **Vegetables** **Fibres and lignocellulose** **Root staples** **Model Plants** **Other**
If other, specify	
Species	Fucus, **Laminaria, Porphyra, Ulva** **Ryegrass, Alfafa,** Clover, Sugarcane, Miscanthus **Wheat,** Barley, Rice, **Maize**, Sorghum, Rye, Oats, Durum wheat, Millet, Field bean, **Soybean,** Lupin, **Pea,** Clover **Sunflower**, Soybean, **Rapeseed**, olive, maize **Tomato**, leafy vegetables (spinach), **Lettuce**, Brassicas, Pea, Carrots, Parsnip, Grapes, Hemp, **Poplar,** Willow, **Miscanthus,** Switchgrass, Douglas Sitka, Eucalyptus, Spruce, **Potato, Sugarbeet**, Onion **Arabidopsis, Tobacco,** Rice, Spinach, Maize **Grape, Pome,** Citrus,

Fig.3 Extract from the construction of columns for common data collection. Current updated version: See Annex 1

This section consists of preliminary information common between subtasks 1.2-1.4- These columns for data collection will be used as the basis for a clickable survey. Based on the choices made in this section, survey participant will be redirected to the specific subtask the entry is related to in the following section. The data entered in the common fields serve as a platform to integrate the final excel file generated, as well as identify and link commonalities between subtasks.

Section 2, specific to Tasks 1.2 and 1.4, Yield and sustainability

Based on the extensive discussions between partners and tasks 1.2 and task 1.4 leaders, it has been decided to use the same template for both tasks. Partners within the subtask 1.2 and 1.4 will be asked to complete the different sections either on yield or sustainability basis.

L1	L2 (classes)	L3 (traits)	L4 (subtraits)	L5 (factors affecting yield)
Yield or sustainability	Photosynthesis - photochemistry and biochemistry	Photochemistry	Light harvesting Light capture optimisation Pigment composition Light use efficiency (electron transport) Other	Stress - Nutrient deficiency Stress - Nutrient overload/form/quality Stress - Drought Stress – Flood Sress –Heavy metals Stress - Salinity Stress - Heat Stress – Cold/frost Stress - pH Stress O3, UV, oxidative Stress Ligth Stress photoperiod Stress Physical constraints (soil compaction, hail, wind, sun…) Stress - High humidity Stress - Soil composition
		Biochemistry – Carbon assimilation	Stomatal aperture Rubisco and other Calvin cycle enzymes Photosynthetic limitations (cofactor, TPU) Chloroplast-cytosol transporters Sucrose - starch balance Photorespiration Dark (mitochondrial) respiration Photosynthetic pathway (C4, C3, CAM, C3-C4 intermediary) Sugar pathways Photoacclimation Photosynthetic induction Other	
		Biochemistry - Photoprotection	NPQ Mehler reaction Repair pathways (Oxidative stress) Photosynthetic by-products Protective molecules Sugars and osmolytes Photosynthetic antioxidants Other	

Fig.4 Extract from the construction of levels specific within the subtasks 1.2 and 1.4 Yield and sustainability. Current updated version: See Annex 2

This section consists of 5 levels specific to task 1.2 and 1.4- Level 1 selects the mega trait (yield, nutritional quality or sustainability) Level 2 identifies traits, Level 3 and 4 lists categories and sub categories within each trait. Level 5 identifies the factors which influence the traits and nutritional quality. The aim of this data collection strategy is to precisely identify genes and traits that can be improved or targeted for sustainability which will serve as the basis for the report in task 1.5.

Finally, the fourth scenarios have been included in the survey and the partners will be requested to document the relevance of the considered traits for the different scenarios.

Construction of a survey

Based on the input from the common columns and the levels specific within each subtask, a data collection survey is being designed.

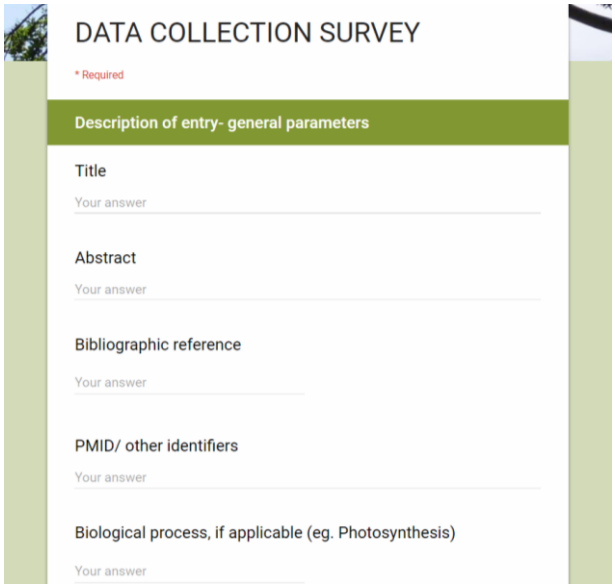

Fig.5 Extract from the current version of the data collection survey.

The survey is currently being developed, with input from all affiliated partners. A final version of the survey ready for data collection for subtask 1.2, 1.3 and 1.4 is expected to be launched by the second week of July and data collection will run until beginning of October.

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7. Points that have been discussed during ExCom meetings

The following points have extensively been discussed during meetings. Points 1, 2 and3 have been integrated in the template for data collection whereas other points have been considered out of the scope of CropBooster-P.

- 1) Bibliographic review to be performed at the TRAIT scale, and when possible, at Pathway and Gene levels. Some of the key traits will not have clear genes/pathways.

- 2) Traits involved in Plant-to-Plant interactions: Light/Nutrient/Molecular cues and related Pathways used by the plants to detect neighbor plants and adapt their growth/metabolism/…

- 3) Traits involved in Plant/soil Microorganisms interactions, as root exudates

- 4) Traits involved in Plant-Pathogen interactions, including physical/chemical processes linked to plant/tissue chemical and structural composition, from metabolism to architecture.

- 5) How Social and Economic Sustainabilities will be covered by WP2/WP3: Social/ethical/environmental/physical factors (eg. GMO debate, global warming, weather inclemency and pests)

- *6)* Developing an Ecosystem Services vision in CropBooster-P:
Task 1.4 proposed to develop in CropBooster-P an Ecosystem Services based vision of environmental sustainability, allowing to better list traits/functions contributing to sustainability, and better highlight trade-offs…

The T1.4 group has proposed a reduced and manageable list of services, derived from Costanza et al. 1997, see hereafter) and its interest for WP1, and to link WP1 to WP2 & WP3 could be discussed.

From Costanza et al. « The Value of the World's Ecosystem Services and Natural Capital ». Nature 1997:

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#	ECOSYSTEM SERVICE*	ECOSYSTEM FUNCTIONS	EXAMPLES
1	**Gas regulation**	Regulation of atmospheric chemical composition.	CO_2/O_2 balance, O_3 for UVB protection, and SO_x levels.
2	**Climate regulation**	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels.	Green-house gas regulation, DMS production affecting cloud formation.
3	**Disturbance regulation**	Capacitance, damping, and integrity of ecosystem response to environmental fluctuations.	Storm protection, flood control, drought recovery, and other aspects of habitat response to environmental variability mainly controlled by vegetation structure.
4	**Water regulation**	Regulation of hydrological flows.	Provisioning of water for agricultural (e.g., irrigation) or industrial (e.g., milling) processes or transportation.
5	**Water supply**	Storage and retention of water.	Provisioning of water by watersheds, reservoirs, and aquifers.
6	**Erosion control and sediment retention**	Retention of soil within an ecosystem.	Prevention of loss of soil by wind, runoff, or other removal processes, storage of silt in lakes and wetlands.
7	**Soil formation**	Soil formation processes.	Weathering of rock and the accumulation of organic material.
8	**Nutrient cycling**	Storage, internal cycling, processing, and acquisition of nutrients.	Nitrogen fixation, N, P, and other elemental or nutrient cycles.
9	**Waste treatment**	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds.	Waste treatment, pollution control, detoxification.
10	**Pollination**	Movement of floral gametes.	Provisioning of pollinators for the reproduction of plant populations.
11	**Biological control**	Trophic-dynamic regulations of populations.	Keystone predator control of prey species, reduction of herbivory by top predators.
12	**Refugia**	Habitat for resident and transient populations.	Nurseries, habitat for migratory species, regional habitats for locally harvested species, or over wintering grounds.
13	**Food production**	That portion of gross primary production extractable as food.	Production of fish, game, crops, nuts, fruits by hunting, gathering, subsistence farming, or fishing.
14	**Raw materials**	That portion of gross primary production extractable as raw materials.	The production of lumber, fuel, or fodder.
15	**Genetic resources**	Sources of unique biological materials and products.	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species (pets and horticultural varieties of plants).
16	**Recreation**	Providing opportunities for recreational activities.	Eco-tourism, sport fishing, and other outdoor recreational activities.
17	**Cultural**	Providing opportunities for non-commercial uses.	Aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems.

*We include ecosystem "goods" along with ecosystem services.

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8. Deliverables

The following WP1 1 Task 1.4- specific deliverables are planned:

Number	Deliverable Title	Lead beneficiary	Type	Dissemination level	Delivery month
D 1.6	Preparatory documents ready for discussions during workshop with (core) SHG on sustainability improvement	INRA	Report	Public	5
D1.7	Digested outcome and recommendations of the workshop regarding sustainability improvement	INRA	Report	Public	8

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9. Annexes

Annexe 1 Revised template for Data collection (tasks1.2; 1.3 and 1.4)

Column	Column information	Column 'choices'
Scale (by climate)		**Mediterranean**, humid subtropical, marine, humid **continental**, **subarctic**, **tundra** and **highland, other**
If other, specify		
Relevance to CropBooster..	Eg. Increased canopy cover, increases biomass	Free text
Species group type	Eg. Algae, forage grasses	**Algae** **Forage grasses** **Grain staples** **N2 fixers** **Oilseed** **Vegetables** **Fibres and lignocellulose** **Root staples** **Model Plants** **Other**
If other, specify		
Species	(can this be spit per species group type?)	Fucus, **Laminaria, Porphyra, Ulva** **Ryegrass, Alfafa,** Clover, Sugarcane, Miscanthus **Wheat,** Barley, Rice, **Maize**, Sorghum, Rye, Oats, Durum wheat, Millet, Field bean, **Soybean,** Lupin, **Pea,** Clover **Sunflower**, Soybean, **Rapeseed**, olive, maize **Tomato**, leafy vegetables (Spinach), **Lettuce**, Brassicas, Pea, Carrots, Parsnip, Grapes, Hemp, **Poplar,** Willow, **Miscanthus,** Switchgrass, Douglas Sitka, Eucalyptus, Spruce, **Potato, Sugar beet**, Onion **Arabidopsis, Tobacco,** Rice, Spinach, Maize **Grape, Pome,** Citrus, Olive, Strawberry, Raspberry, other
If other, specify		
Method summary*	Technologies employed to achieve y/n/s effect	Conventional Breeding Populations/Mapping, Magic, Diversity Sets Genome Available MAS GWAS Mutant Populations Tagged populations Mutagenesis Epimutation TILLING

		Transposon Mobilization Metabolic design Conventional GMO Gene Editing Plastid transformation Synthetic Biology Modelling Phenotyping Speed Breeding other
If other, specify		
Yield benefit**		Yes/ no
Yield benefit- how**		Free text
Nutrition benefit**		Yes/no
Nutrition benefit- how**		Free text
Sustainability benefit**		Yes/no
Sustainability benefit - how**		Free text
Biological process	Eg. respiration	TBD
Genetic pathway (if applicable)		Free text
Genes involved		Free text
Orthologues?		Yes/no
Orthologues in which crops		Free text
Bibliographic reference(s)		Free text
title		Free text
abstract		Free text
uniprot		Free text
PMID		Free text
Transferability potential		Yes/ no
Comments on transferability		Free text
What technology would make this example transferable?	CRISPR, GMO	Free text
General comments		

*This would help build into the technical annexes

**This will determine correlations and tradeoffs for WP 1.5

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Annexe 2: Detailed list of Levels used for Data collection in Task 1.2 and Task 1.4

L1	L2 (classes)	L3 (traits)	L4 (sub traits)	L5 (factors affecting yield)
Yield and sustainability	Photosynthesis - photochemistry and biochemistry	Photochemistry	Light harvesting Light capture optimization Pigment composition Light use efficiency (electron transport) Other	Stress - Nutrient deficiency Stress - Nutrient *(overload/form/quality)* Stress - Drought Stress - Flood Stress - Heavy metals Stress - Salinity Stress - Heat Stress - Cold/frost Stress - pH Stress - O3, UV, oxidative Stress - Light Stress - photoperiod Stress - Physical constraints *(soil compaction, hail, wind, sun…)* Stress - High humidity Stress - Soil composition Stress - microbes in the rhizosphere Other
		Biochemistry – Carbon assimilation	Stomatal aperture Rubisco and other Calvin cycle enzymes Photosynthetic limitations (cofactor, TPU) Chloroplast-cytosol transporters Sucrose - starch balance Photorespiration Dark (mitochondrial) respiration Photosynthetic pathway (C4, C3, CAM, C3-C4 intermediary) Sugar pathways Photo-acclimation Photosynthetic induction Other	
		Biochemistry – Photo-protection	NPQ Mehler reaction Repair pathways (Oxidative stress) Photosynthetic by-products Protective molecules Sugars and osmolytes Photosynthetic antioxidants Other	

Yield and sustainability	Uptake and spatial management of resources	Water and Nutrient uptake/assimilation vs use	Water and Nutrients uptake (transporter channel regulators…)	
		Primary and secondary metabolism	Osmolites, Proteins and metabolic compounds accumulation	
		Nutrient use efficiency (NutUE)	Local Water and Nutrients transport (root, stem and leaf tissues) Long distance Water and Nutrients transport (xylem) Nutrient metabolism Nutrient partitioning Nutrient storage Nutrients recycling Alternative metabolic pathways Ion homeostasis Other	
		Heavy metals and salt	Uptake (transporter channel regulators…) Local and long distance transport metabolism partitioning storage Alternative metabolic pathways Ion homeostasis	
		Other		

Yield and sustainability	Sink/source activity	Nutrient metabolism, transport, remobilization and partitioning	Sucrose metabolism (source) Nutrient metabolism (source) Water and nutrients storage Storage compound metabolism (source) Carbon transfer Nutrient transfer Coordination of C and Nutrient assimilation Other micronutrients Other	
		Source sink balance	Sink to source feedback Source to sink feedforward Senescence of source organs Sink/grain development Seed filling Senescence of sink organs Other	
		Other		

Yield and sustainability	Plant growth, architecture and phenology	Shoot architecture anatomy and canopy profile	Phyllotaxy Self-shading Compactness Stem anatomy and composition Shoot and canopy hydraulics Vascular tissues anatomy (density, structure) and functioning Profile of photosynthetic resources Leaf angle (erectness) Leaf morphology/shape Organ length/width/strength Wound healing Other	
		Leaf anatomy and activity	Cuticle thickness Wax/cutin ratio and content Stomatal properties (morphology, densities, distribution and location) Mesophyll thickness Mesophyll conductance Mesophyll resistance Mesophyll structure CAM/C3/C4 intermediary structure Vascular tissues anatomy (density, structure) and functioning Leaf hydraulics Stomatal aperture and functioning regulation Organelle properties (density, positioning and movement) Cellular subcellular and Ultrastructural adaptations Wound healing Other	

		Growth rate	Meristem activity Cell division Growth mechanics Cell expansion Cell wall composition Cell turgor Other	
		Root architecture, anatomy and activity	Root length Root number (lateral, seminal, adventitious) Root growth angle Root density Root plasticity Root competition ability Root hydraulics Cell layer number Cells layer structure Aerenchyma (PCD) Cell division/elongation Cell wall composition Lignification, Suberisation Cellular subcellular and Ultrastructural adaptations Wound healing Storage capacity Respiration Exudation Other	
		Root/shoot coordination	Root/shoot ratio Root/shoot transport and signaling Other	

		Phenology	Reproductive switch Flower development/abortion Flowering time Flower number Fertilization and seed set efficiency Seed number/abortion Seed filling rate Inflorescence plasticity Early vigor Ageing/senescence/juvenility Plastid/chloroplast lifetime Stay-green Other	