SusCrop – ERA-NET
Cofund on Sustainable Crop Production
FACCEJPI

FUTURE RESEARCH NEEDS IN SUSTAINABLE CROP PRODUCTION

SusCrop White Paper

Introduction

One of the grand societal challenges of the 21st century is to ensure food and nutrition security (FNS) for a growing population under climate change and pressure on natural resources.

To do this, sustainable crop production needs to be secured and enhanced. Current food production methods utilise excess energy, water, pesticides and chemicals. New ways of sustainable crop production are necessary to increase productivity, reduce the amount of chemical inputs and/or improve the quality of the crops. This will be crucial to maintain access to affordable, safe and nutritious food for a healthy life, and to serve the increasing demand for industrially used biomass whilst keeping and improving a healthy environment, natural habitats and increasing biodiversity. Modern crop production must be addressed by taking into account the whole food value chain, crop diversity and resilience, resource use efficiency, nutrient recycling, ecosystem services, environmental impacts, integrated pest management and waste reduction and use in order to achieve food and nutrition security.

To meet this challenge, the EU Member States established the ERA-NET Cofund SusCrop under Horizon 2020, which aimed to strengthen the European Research Area (ERA) in the field of Sustainable Crop Production. SusCrop brought together owners and managers of national and regional R&D&I programmes of EU Member States, EU-associated countries and Third countries with significant experience in research funding and coordination who participated in funding 38 research projects over the period 2018-2023. Additionally, the partners of SusCrop analysed research gaps, through desk studies, exchange with stakeholders, and 2 expert/stakeholder workshops. The conclusions of this work are presented here.

Future research needs

Work in SusCrop highlighted both research needs and a methodology for working. The initial focus concerned protein crops, primarily for food but also including feed. Here the term protein refers to proteins coming from plants (but not algae) and therefore including e.g. grasses. Further, the focus was on production (crop improvement and cultivation) but taking into account the value chain. More generally, there was a focus on "niche crops", which have huge potential in the future, given that there is sufficient investment in research and a step-by-step approach to developing and sharing knowledge on such crops.

Topic 1. Knowledge generation in relation to nutritional value and health benefits of protein/niche crops

This gap concerns the nutritional quality of protein/niche crop species for human health by increasing micronutrients (phytochemicals, (pro)-vitamins, trace minerals), decreasing anti-nutrients, optimising bioavailability, improving amino acids as well as the associated processing techniques to safeguard the beneficial plant compounds.

Exploring a set of traits for a chosen protein/niche crop species:

Biological research combining plant biology, physiology, genetics and 'omics' would be carried out for each of the chosen species on its nutritional quality for human health:

a. Developing "-omics" approaches and researching metabolic pathways to identify compounds beneficial for human nutrition, such as proteins, vitamins, micronutrients (including phytonutrients) and fibres in niche crops;

b. Investigating bioavailability of beneficial as well as non-beneficial nutrients for human and animal health. Then explore how to change bioavailability to increase beneficial and decrease non-beneficial compounds for human/animal digestion;

c. Verifying health benefits[1], with research investigating whether there is increased beneficial and/or decreased antinutrients or non-beneficial compounds. This could make use of compounds for humans (clinical trials) and/or animals. Research should also take in consideration that target nutrients (beneficial and non-beneficial) can be in the same plant or different plants but combined in the product/diet;

Through interdisciplinary research combining plant science, human nutritional science and human health science, steps a-c can be linked to have complete pathways for improvement of beneficial compounds and decrease of non-beneficial ones.

d. Investigating the role of microbiomes (in crop, soil, humans, animals) for nutritional quality in crops and bioavailability in humans and animals.

This knowledge will then be used for crop improvement for the chosen species, through developing genetic and genomic knowledge and resources for plant breeding.
Starting with these traits, further research could investigate the plant breeding/crop management and crop processing through a systems approach, e.g. combining compounds from different crops, preserving nutritional quality compounds, improving bioavailability of nutrient.

Finally, knowledge on this/these particular species could be used to understand other species (i.e. bridge species for related crops) in the region and also to explore how this species develops and behaves in different regions.

For the small number of species chosen in a first step, future research needs to be provided with critical mass funding in order to have a systems approach on each one of them, including all components described above for that species so as to achieve the best impact and move that species from a niche to a main crop. In a second step, more species can be chosen to improve.

1] Note that a health claim for a defined compound supported by public funds can benefit all reeders/farmers/processors/retailers and consumers to develop many niche crops with this compound.

Topic 2. Knowledge generation and transfer on multi-stress resistance for stable yield

Further research is needed on the links between yield and biotic (pests, diseases etc.) and abiotic stress (drought, salinity due to climate change, CO2, temperature). In addition to investigation of resistance to individual and combined stresses, better linking genetics and genomics, and making more use of bridge species, an important research question is the investigation of multi-stress resistance and this requires first mapping then modelling of the matrix: "crop-region-climate", e.g. to increase knowledge on high potential species and mixes of species in a specific region. Once this matrix is documented, it would be possible to project it into future climate scenarios looking specifically at the changes by crop (niche, minor crop) and by type of stress. This research should also allow for a global monitoring of emerging pathogens and for prediction of climatic stressors in different European regions for the future.

Further, research will be required to translate and test these scenarios in the field and real conditions to investigate:

- How do (emerging) crops respond to stresses (biotic/abiotic stress factors including competition). This should cover all pests and abiotic stresses;
- How to improve basal immunity;
- How to predict intensity and length of drought in different areas of Europe and which crops are best fitted. Research should also explore improvement of suited crops for stress response (e.g. protein crops in northern Europe);
- The epigenetics of stress memory (genetics of epigenetic memory);
- The best processes for global monitoring of pathogens.

Another important research need would be to further explore the root/microbe/soil interaction (rhizobiome, microbiome, rhizosphere) and the consequences on yield efficiency: soil-borne diseases, water uptake, nutrient uptake.

Finally, research should also focus on mixed cropping systems and land management as well as post-production challenges for farmers. This concerns e.g. consistency between cropping systems and agronomic practices: exploring e.g. possible species mixes and optimising practices over growing seasons, proper knowledge on mixed crops combining niche crops with stable crops.

Research should explore these mixed crops starting with one or a small number of minor/emerging crops. The studies need to investigate diversification for optimisation of yield in different conditions, including various land uses, input reduction, and impact on farmers' income. This research should start at small scale (1-2 species) and explore how to include legumes in crop rotations.

Research needs to build on examples of mixed/strip cropping (e.g. agroforestry), multipurpose crops, and catch crops. Research should also bring insights on the implications for production and value chains, as well as financial/risk aspects and benefits (relations with market; see below).

For a given biogeographic region, research would provide information on:

- What mixes are best fitted;
- What practices including harvesting, biofertiliser, biorefineries for side streams should be implemented;
- What equipment is necessary.

To build this knowledge basis by region, there is a need to test management practices in different regions and to ensure that best

practices are shared across regions so research efforts should also support the establishment of a network project to share data and knowledge.

Important enabling conditions would be to develop adequate research infrastructures, including seed banks: testing locally adapted varieties and genotypes.

A network focusing on genetic diversity would allow for comparative genetics and further exploration of links between phenotypes and genotypes.

TOPICS 1 AND 2 SHOULD BE SUPPORTED BY THE FOLLOWING ITEMS

A toolbox for researchers investigating protein/niche crops, including:

a. Development of fundamental tools at the research level for protein/niche crops: genomes, markers + mapping populations + seeds/seedbanks especially with vouchers of sequenced accessions as well as transformation methods;
b. Efficient pathways to move from lab models to real life production (including microbiome);
c. Understanding the value chain for protein/niche crops beyond the farm gate, including policy and society (feeding back into a and b).

Although research infrastructures exist, there is a need to promote more innovative paths in building up large collections, in generating and mapping of populations and in linking up with phenotyping aspects (physiology, metabolites, proteomes). For coherence and long-term accessibility, data repositories, gene banks, and the cooperation of gene banks should be financially supported and coordinated.

Concrete information for farmers on a particular species for decision-making on cultivation practices:

As a consequence, for them further research is necessary as described below:

- Better understanding of growth and biology/genetics:
  - Looking at genotype/breeding/ crop improvement;
  - Growth conditions: above/below soil behaviour and consequences for rotation times and soil pathogens;
  - Adaptation through agronomic practices (e.g. spring-winter cycles in relation to day light) and how to manage land use;
  - Development of synchronised cycles for harvesting.
- Better understanding of crop management:
  - Associated cropping/mixed livestock cropping and cutting;
  - Effect of microbiome on plant protection: factors affecting microbiome composition.

This systemic approach will benefit the studies of niche crops and allow their incorporation into farmers' practices, taking into consideration a large number of factors.

Topic 3. Innovation pipeline: Protein/niche crops for food and feed value chains: How to build up a value chain for uncultivated protein/niche crops

To support the development of the protein/niche crop food value chain, research is needed as efforts so far have supported mainly the feed value chain.

In particular, research should focus on better understanding the needs, barriers and incentives:

- Making use of several innovative approaches such as big data analysis;
- Developing multi-stakeholder participatory approaches for identifying needs and incentives for both producers and consumers as well as ensuring knowledge transfer and capacity building of all actors in the value chain. A particular focus of research should be on the potential incentives to change the mindset of consumers and society at large. Research would need to focus on how to ensure long-term consumer commitment to the transition to new crops based on current consumer behavioural science: how niche crops could be made attractive for consumers;
- Promoting interdisciplinary studies involving socio-economics and health sciences. For example, apply socio-economic sciences to identify incentives and barriers for producers and consumers, to better understand how the value chain could be catalysed and further developed.

These efforts should support the development of networks integrating consumers and producers and helping the understanding of the "biology of food". The use of citizen science could be explored for generating a better understanding on protein/niche crops and involvement in value chain development.

Enabling conditions would require the strengthening of research infrastructures (e.g. big data/databases) and a supporting and catalysing effect from policy, for example by developing public procurement opportunities for plant protein use, niche crop use, reduction of environmental footprint (independent of the technologies/methods used).

Topic 4. Impact assessment and trade-offs

Research needs concern the impacts of switching our current land use and production to protein/niche crops with emphasis on the shift to systemic approaches and on resulting consequences with regard to climate change. Socio-economic research is also needed to identify and demonstrate the value of protein/niche crops and to develop better understanding of both global environmental impact and of the potential for protein/niche crop value chains for food at local, national and international levels. To support the transition to protein/niche crops, research should provide feasibility studies on how to integrate these crops into value chains (combining socio-economics, sustainability etc.). Research should explore for example the levers and enabling conditions that promote economic feasibility of niche crops, at different levels: farm level, but also value chain and consumer/society levels, the barriers and risk management at different levels, as well as the impact of subsidies versus risk capital investment, incentives and barriers due to policy frameworks (are they appropriate/dynamic) and in particular how to harmonise breeding policy/common breeding policy.

- Questions at macro-level include:
  - How to develop protein/niche crops in the EU?
  - How to use EU resources to replace imports (costs and benefits)?
  - What are policy impacts and policy incentives?

Economic modelling is required to give as realistic as possible answers to these questions, taking into account regional specificities and multiple interactions between environmental, genetic, agronomic, and socio-economic factors.

- Questions at micro-farm level ("to grow or not to grow") include:
  - How to convince farmers?

    The socio-economic impacts have to be investigated at farm level to support farmers in their decision-making to switch to protein/niche crops with a better understanding of trade-offs and risks.
  - What crops make sense in which conditions and with which trade-offs?

Research can help building a decision support system for farmers in order to assess risk and benefits for growing protein/niche crops under various conditions, and to manage risk by properly managing value chains.

Another important research priority is the development of scenarios to better inform policy decisions in particular concerning the need to diversify our food sources for more resilient food systems (looking both at food and feed production). These research efforts should include:

- Identifying the dimensions/criteria that scenarios should consider throughout the value chain: nitrogen cycle, fertilizer use, economic return for farm industry, creation or destruction of jobs, feeding more people/limiting denutrition etc.;
- Estimating costs and benefits of growing protein/niche crops considering transportation costs and externalities, land use trade-offs and local production costs etc.;
- Exploring consumers' habits and diets: dietary shift incentives and barriers;
- Impacts of a potential shift of protein consumption from meat-based to plant-based, in particular in terms of imports/exports balance and impacts and consequences on the global market;
- Investigating the functionality of food and nutritional quality: convenience versus quality versus sustainability.

In terms of environmental impact, further research is required on the interactions between species traits, ecosystem resilience and agronomic cultivation practices (e.g. with regards to climate change).

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