Root2Res

Root phenotyping and genetic improvement for rotational crops resilient to environmental change

Policy brief 1

Roots in policy: How to encourage breeding for root-related traits for more resilient crops

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D7.4 includes the first Root2Res policy brief focussed on Roots in policy: How to encourage breeding for root-related traits for more resilient crops. It explains the participatory process used to develop the policy brief as well as the next steps to publish and disseminate the policy brief.

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Type of deliverable	R	Document, report (excluding periodic and final reports)	x
	DEM	Demonstrator, pilot, prototype, plan designs	
	DEC	Websites, patents filing, press & media actions, videos, etc.	
	DATA	Data sets, microdata, etc.	
	OTHER	Software, technical diagram, algorithms, models, etc.	

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Dissemination level	PU	Public, fully open, e.g. web (Deliverables flagged as public will be automatically published in CORDIS project's page))	x
	SEN	Sensitive, limited under the conditions of the Grant Agreement	

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1. Process and next steps

The first Root2Resilience policy brief was developed through a participatory process, gathering input from actors with research, breeding and policy perspectives, including the Root2Res stakeholder advisory board. It aims to:

- make policy makers aware of the importance of the root-soil interface in improving the resilience of agricultural systems (i.e. mitigating and adapting to climate change, and improving biodiversity and adaptability), and
- highlight the need for policies that support breeding for root-related traits which foster resilience to environmental change.

Once the deliverable has been approved, the policy brief will be published in an attractive format for policy makers, including visual elements. It will be disseminated through established Root2Res channels as well as partner channels and sent to relevant policy organisations. We will also assess the need to translate it into other project languages for use at the national policy level.

2. Policy brief

Roots in policy: How to encourage breeding for root-related traits for more resilient crops

Key messages

- Roots are important for climate resilience.
- Novel crop cultivars are needed that are more resilient to environmental stress, through improved root traits and interactions with the soil.
- These cultivars will be critical to support the EU Green Deal goals and the Farm to Fork and Biodiversity strategies.

Policy recommendations

It is essential to support breeding for root-related traits which foster resilience to environmental change. This should be incentivised through initiatives to promote the use of resilient crops with better root systems.

Policies should:

1. Diversify cultivar trialling and recommendation systems in EU member states:
    a. Expand systems that mainly promote the release of crop varieties only if they are superior to existing varieties (i.e., higher yielding and other single factor criteria) under optimal conditions. Instead, advocate for and subsidise evaluation criteria such as yield stability and adaptability under a range of stress conditions and variable environments to simulate future climate conditions. This should be addressed through legislation, such as the plant reproductive material (PRM) legislation.
    b. Include the selection of crop varieties for sustainable systems including reduced tillage, cover crops, intercropping, etc.

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c. Specify which cropping systems should be tested in trialling and recommendation systems (i.e., lower nitrogen in potato production; use of intercropping with legumes, etc).
d. Increase focus on the interaction between the plant genetics, the environmental conditions and the management practices applied to cultivate it from breeding programmes to practical recommendations for farmers via an advisory network.

2. Provide impartial, non-commercial "advisory" positions to serve as intermediaries between breeding programmes and farm practices. These positions should champion varieties that are adapted to local conditions and challenges, which will in turn incentivise seed merchants to provide varieties adapted to local conditions and markets.
3. Foster public-private partnerships that facilitate breeding for sustainable objectives that promote positive externalities.

Introduction

The evidence for climate change is unequivocal. Changing climate patterns are already affecting agricultural eco-systems (Muluneh 2021; Malhi et al. 2020) and a higher frequency of extreme weather events in the future (Pugnaire et al. 2019) will increase the instances of droughts, flooding and heatwaves, and reduce winter frosts (Dempewolf et al. 2014; Calleja-Cabrera et al. 2020). Therefore, while the unpredictability of the environment will increase, it is predictable that these changes will have consequences on productivity, sustainability, biodiversity conservation, and other functions in agricultural ecosystems.

Crops need to be adapted to this changing climate and contribute to mitigation of resulting effects. While research and breeding efforts have often focused on aboveground traits, **we highlight that many of the environmental stresses associated with climate change will be most acutely perceived by the plant at the root-soil interface and are also likely to be mitigated at this globally important interface**. Plants have various root-based strategies to adapt and to compensate the negative effects of different stresses and constraints. Such adaptations may involve changes in how roots grow, how they function and how they take up water and nutrients (Hazman and Brown, 2018; Klein et al. 2020; Li et al. 2022a; Deng et al. 2021). However, breeders often lack effective and scalable tools to select for varieties with such traits.

Society needs us to use and expand this knowledge to develop crops for the future which are resilient to environmental stresses. However, this is not currently being incentivised. In many countries in the EU and beyond, decisions on which cultivars to use in a specific region are often based on performance indicators from optimal conditions. Varieties are mostly chosen based on high yield, tolerance to a set of mandatory crop diseases and post-harvest quality for feed or food. Varieties that are added to these recommended lists are more likely to secure a large market share. This system incentivises breeding companies to develop new cultivars with greater yield under optimal conditions. It does less to incentivise breeding for increased stress conditions caused by climate change (drought, heat, waterlogging etc), and utility in sustainable systems (e.g., reduced tillage, reduced fertiliser input, intercropping, cover crop systems). Such incentives could be promoted through legislation being

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developed for Plant Reproductive Material (PRM) and Value for Sustainable Use or Cultivation (VSCU) currently. While breeding for root related traits is difficult, a more nuanced approach to trialling new varieties for a range of environmental and sustainable management systems will help identify new cultivars with better below ground traits.

The European Green Deal, the Farm to Fork Strategy, the biodiversity strategy and other policies that aim to reduce fertilizer and pesticide use are already changing the breeding focus. Integrating these policies and ensuring policy coherence will be key to incentivising the development of root- specific traits by referencing them in different policy mechanisms e.g., CAP Ecoschemes, carbon removal certification framework etc.

Results

Root2Res is using a combination of novel and existing data, which will be supported by mathematical modelling and the literature to identify ideal sets of below-ground traits. Improving root traits in this way is not only expected to increase resilience to environmental stress but also help improve nutrient uptake efficiency, thereby reducing the risk of nutrient run-off and direct and indirect GHG emissions by reducing fertilizer requirements, and contributing the Farm to Fork goals.

The ideal root traits identified from the first round of development are listed in Table 1. In summary, the ideal traits presented include root architectural traits (larger and deeper root systems), root anatomical traits (more and longer root hairs and aerenchyma formation) and rhizosphere traits (more mycorrhizae, elite rhizobia strains and phosphate solubilising bacteria). These traits will now be used to interrogate the available genetic material, both genotypically and phenotypically, to identify existing individuals which best embody the ideal traits and adaptability. These will be trialled in multiple environments and assessed for their impact on resilience to stress, but also the ability to mitigate against climate change by reducing GHG emissions, reliance on external inputs, and sequestering carbon to soil. Once the ideotypes are validated, there will be an opportunity to exploit this information by designing a translational pipeline for breeding which will have the aim of generating novel cultivars of key crops which have the ideal traits. A number of routes can be taken including conventional breeding and gene editing, should the policy environment allow it.

In order to help speed this process up, Root2Res is also developing phenotyping tools for below-ground traits that can be used to create a more nuanced trialling and recommendation system in EU Member States and beyond. Including these phenotyping tools in selection of cultivars under a wider range of environmental and management systems will create a system that encourages the delivery of new crops for resilient to environmental change.

Table 1 Target root and rhizosphere traits divided into architectural/developmental root traits, anatomical root traits and rhizosphere traits.

	Traits	Environmental stresses: Water logging	Water deficit	Phosphorus deficit
Root Traits – Architectural/ developmental	**Greater root dry weight**		✓	✓
	Deeper rooting		✓	
	Increased lateral root number		✓	✓
	Early root vigour		✓	✓
	Increased distribution of roots at depth		✓	
	Root surface area			✓
	Increased root length density			✓
Root Traits - Anatomical	**Aerenchyma formation**	✓	✓	✓
	More root hairs (inc. density)		✓	✓
	Greater root hair length			✓
	Greater adventitious root porosity	✓	✓	✓
Rhizosphere Traits	**Arbuscular mycorrhizal fungi**		✓	✓
	Rhizobia – elite strains with specific functionality		✓	✓
	Phosphate solubilizing bacteria			✓
	Root exudates		✓	✓
	Increased rhizospheric phosphatase activity			✓

A ✓denotes if the trait contributes resilience towards one of the abiotic stresses addressed in the review (water logging, water deficit or phosphorus stress). Traits listed were identified at least three times and those traits in bold were identified at least 5 times. Results were identified in a literature review.

Conclusion

Despite the current focus on aboveground traits, roots and their interaction with soil play a crucial role in mitigating climate change. Novel crop cultivars that are resilient to environmental stress, through improved root traits and interactions with the soil, will be critical to support the EU Green Deal goals and the Farm to Fork and Biodiversity strategies, including:

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- ensure food security in the face of geopolitical uncertainties, climate change and biodiversity loss;
- reduce the environmental and climate footprint of the EU food system;
- strengthen the EU food system's resilience;
- improve positive economic and social externalities from farming systems, and
- lead a global transition towards competitive sustainability from farm to fork.

Breeding companies need to deliver these novel crop varieties to ensure that farmers have the genetic tools necessary to deliver food security and environmental stewardship in more extreme and variable climate. Root2Res is contributing to this goal by developing tools and knowledge that will help breeders to deliver new crop varieties, with improved root traits, that are resilient to environmental stresses. However, policy incentives are essential to ensure this.

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