



## **DIVERSify: Designing Innovative plant teams for Ecosystem Resilience and agricultural Sustainability**

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**Grant Agreement No.:** 727284

**Project Acronym:** DIVERSify

**Project Title:** Designing Innovative Plant Teams For Ecosystem Resilience And Agricultural Sustainability

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### **Policy guide on plant teams for intercropping (Report, Public)**

#### **Deliverable 1.6 (D10)**

**Deliverable Lead:** UPM

**Deliverable Due Date:** 30-March-2021

**Actual Submission Date:** 19-March-2021

**Version:** 1.0

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**Work Package:** 1

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History of Changes		
Version	Publication Date	Change
0.1	26 <sup>th</sup> February 2021	Initial draft version, sent to co-authors for comment
0.2	5 <sup>th</sup> March 2021	Updated draft version, incorporating co-author comments, sent to reviewers for comment
0.3	7 <sup>th</sup> – 13 <sup>th</sup> March 2021	Updated draft version, sent to reviewers for comments; several rounds
0.4	16 <sup>th</sup> March 2021	Final draft sent to reviewers for comments
1.0	19 <sup>th</sup> March 2021	Final version



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727284



# DIVERSify: Designing InnoVative plant teams for Ecosystem Resilience and agricultural Sustainability

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### Executive Summary

The report provides an overview of the gaps and opportunities of multiple benefits of intercropping and the policy and the advisory environments necessary to bring forward intercropping as a mainstream activity in arable food and fodder production. Intercropping with cereal-grain legume crops or with other species is a cropping practice that can help farmers reach several ambitions of the European Green Deal. More specifically, it can contribute to targets established in government strategies and legislation such as the European Union's (EU) Farm to Fork Strategy, the EU Biodiversity Strategy, and the UK Agriculture Act 2020. The targets that relate to intercropping are reducing N fertiliser, pesticide and herbicide use, and increasing agro-biodiversity. Through the DIVERSify project, we have also established evidence that intercropping can contribute through increased legume growing towards increased production of home-grown proteins, climate change resilience and rural innovation. The DIVERSify policy toolbox can be used to search this evidence at [www.plant-teams.org](http://www.plant-teams.org).

The Common Agricultural Policy (CAP) can support farmers in the transition towards inclusion of intercropping in their practices by facilitating changes in crop management, need for new or adapted machinery, and/or income foregone or smaller profits that are agronomy and market related. Intercropping could obtain support through several of CAP's schemes: a) Inclusion of intercropping as a specific eco-scheme; b) Inclusion of intercropping in eco-schemes generating more complex rotations; c) Inclusion of intercropping as an agri-environmental and climate measure; d) consideration of "intercropping equivalence" as an enabler for reducing nitrogen fertiliser and pesticide use and/or through increased biodiversity in rotations. Farmers' access to Farm Advisory Services should be facilitated to achieve these outcomes. The report is targeted to diverse stakeholders, including farmers, advisory services and policy makers, to give an insight into current hindrances for intercrop adoption and to design forward-looking sustainable pathways that facilitate changing from monoculture to intercropping practices.

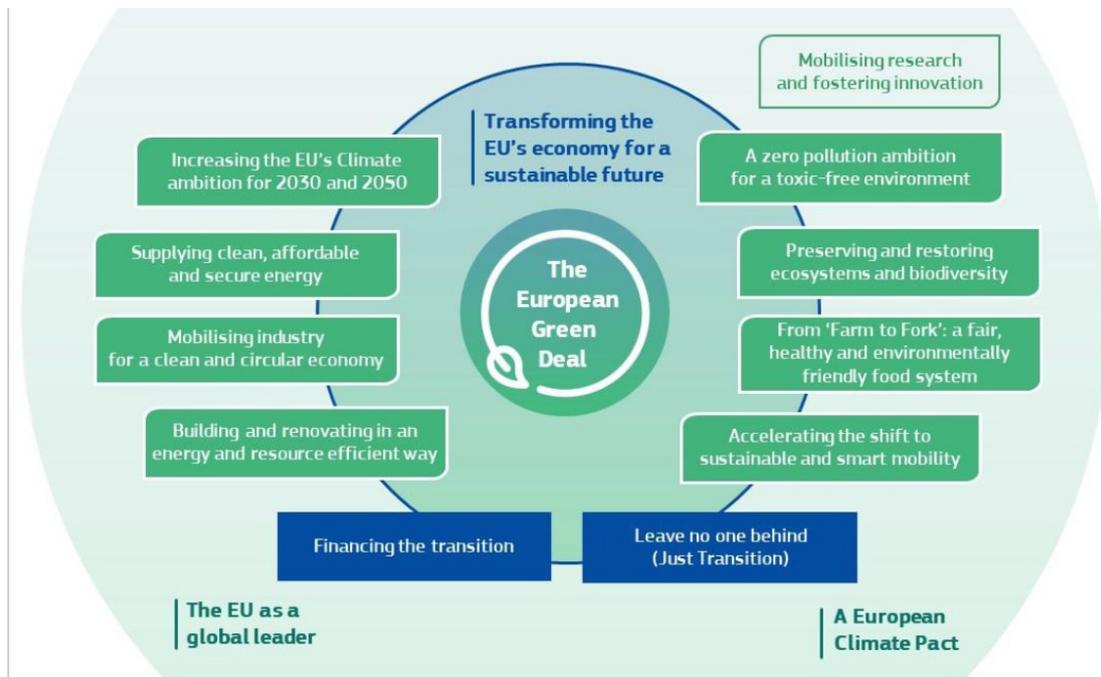


## 1. Introduction

The DIVERSify project aimed to optimise the performance of crop species mixtures, also known as intercrops or ‘plant teams’, to improve yield stability, reduce pest and disease damage, and enhance stress resilience in agricultural systems. It had a focus on improving the productivity and sustainability of European agriculture via the development of an ecological approach to crop production whereby cereal-legume and grassland species mixtures were optimised through the study, both in the field and via modelling, of traits and mechanisms that drive improved performance. Learning from the experiences of key stakeholders, the project has developed the evidence base of the strengths and weaknesses of working with plant teams and how their use can contribute to wider environmental and societal goals.

## 2. Policy context of DIVERSify: the European Green Deal

The European Green Deal (2019) ([https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal\\_en](https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en)) established an “initial roadmap of the key policies and measures needed to achieve the European Green Deal” as an “integral part of this Commission’s strategy to implement the United Nation’s 2030 Agenda and the sustainable development goals” (SDG, 2015; <https://sdgs.un.org/goals> and <https://sdgs.un.org/2030agenda>).



**Figure 1.** The EU Green Deal outlines headline targets that the Commission has set to achieve sustainability.



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The general position of the EU Green Deal has framed the strategies, goals and targets of more focused documents that followed, in particular those related to the agricultural sector. For example, the EU Farm to Fork Strategy has as general objectives to attain the Sustainable Development Goals (SDGs), most notably:

- #12: Responsible production and consumption
- #13: Climate Action (here climate adaptation and resilience)
- #15 Life on Land as collateral: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss.

Agricultural activities have been linked to more specific environmental, biodiversity, and climate mitigation and resilience goals and targets in the **Farm to Fork Strategy (2020)** ([https://ec.europa.eu/food/farm2fork\\_en](https://ec.europa.eu/food/farm2fork_en)) and in the **EU Biodiversity Strategy 2030 (2020)** ([https://ec.europa.eu/info/sites/info/files/communication-annex-eu-biodiversity-strategy-2030\\_en.pdf](https://ec.europa.eu/info/sites/info/files/communication-annex-eu-biodiversity-strategy-2030_en.pdf)), and these are feeding into the development of the new Common Agricultural Policy (CAP 2023-2027) that is currently being discussed by the EU Parliament, Commission and Council. The move towards 'green growth' is on the agenda of many countries outside the EU and influencing agricultural policy therein. In the UK, **the Agriculture Act 2020** links farmers' financial support to practices that will deliver public goods, namely: clean and plentiful water; clean air; thriving plants and animals; reduction in and protection from environmental hazards; adaptation to and mitigation of climate change; beauty, heritage, and engagement with the environment (<https://commonslibrary.parliament.uk/research-briefings/cbp-8702/>).

From the goals and targets specified in these documents to implementation on farms and at plot level there is the need for **"mobilising research and fostering innovation"** (Figure 1): this is where DIVERSify has contributed by **linking research to farmers and moving towards innovative implementation**.

Research in DIVERSify has also demonstrated where intercropping with **cereal-legume plant teams has transverse and specific effects on cropping systems that are linked to the objectives** of the Farm to Fork Strategy, EU Biodiversity Strategy 2030, and the UK Agriculture Act 2020.

This **Policy Guide on Plant Teams** will outline (below) our proposals for support for intercropping practices in the new **Common Agricultural Policy (CAP)**, that can be extrapolated to other policy contexts and schemes. For example, we briefly touch on the Environmental Land Management scheme being developed by the UK government and on the European Innovation Partnerships (EIP <https://ec.europa.eu/eip/agriculture/en/european-innovation-partnership-agricultural>).

The **DIVERSify Policy Toolbox** (available at [www.plant-teams.org](http://www.plant-teams.org) from April 2021) provides decision makers with access to the evidence produced by the DIVERSify project, and other Crop Diversification Cluster projects ([www.cropdiversification.eu](http://www.cropdiversification.eu)) in relation to how plant teams can **contribute towards policy targets relating to: 1) input reduction; 2) increased production of home-grown proteins; 3) reducing biodiversity losses; 4) resilience to climate changes; and 5) rural innovation**. As such, when drawing together the evidence produced within the project, it became clear that plant teams have the potential to **contribute to broader policy targets** such as those outlined in the EU Protein Plan





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([https://ec.europa.eu/info/food-farming-fisheries/plants-and-plant-products/plant-products/cereals/development-plant-proteins\\_en](https://ec.europa.eu/info/food-farming-fisheries/plants-and-plant-products/plant-products/cereals/development-plant-proteins_en)), Promoting healthy and sustainable diets in the EU initiative (<https://www.eesc.europa.eu/en/our-work/opinions-information-reports/opinions/promoting-healthy-and-sustainable-diets-eu-own-initiative-opinion>) or the UK National Food Strategy (<https://www.nationalfoodstrategy.org/>).

### 3. Role of Plant Teams in the EU Farm to Fork Strategy

In the **EU Farm to Fork Strategy (2020)** the introductory statements establish the umbrella for changes:

- “The EU’s goals are to reduce the environmental and climate footprint of the EU food system and strengthen its resilience.”
- “To accelerate and facilitate the transition and ensure that all foods placed on the EU market become increasingly sustainable, the Commission will make a legislative proposal for a framework for a sustainable food system before the end of 2023.”
- “A sustainable food system will be essential to achieve the climate and environmental objectives of the Green Deal, while improving the incomes of primary producers and reinforcing EU’s competitiveness.”

DIVERSify is addressing ‘hands on’ the specific objectives of the Farm to Fork Strategy. DIVERSify’s research outcomes and practical work with farmers and other stakeholders helps to implement cropping practices that will sustain the path to reaching these goals/targets.

Intercropping affects the following actions proposed in Farm to Fork Strategy as specified on:

p9. “to **reduce the overall use and risk of chemical pesticides by 50%** and the use of more hazardous pesticides by 50% by 2030” and “It will revise the Sustainable Use of Pesticides Directive, [as it can] **enhance provisions on integrated pest management (IPM)** and promote greater use of safe alternative ways of protecting harvests from pests and diseases. IPM will encourage the use of alternative control techniques, such as crop rotation and mechanical weeding, and will be one of the main tools in reducing the use of, and dependency on, chemical pesticides in general” as evaluated in DIVERSify (Villegas-Fernández et al. 2019. Deliverable 4.4)

p9. Tackle the excess of nutrients and use. This includes the target to **reduce “use of fertilisers by at least 20% by 2030”** as well as addressing the nutrient load reductions needed to achieve these goals, applying **balanced fertilisation and sustainable nutrient management** and by managing nitrogen (N, and phosphorus) better throughout their lifecycle. Intercropping with legumes helps maintain crop yields whilst reducing N inputs (Villegas-Fernández et al. 2019 Deliverable 4.4; Scherber et al. 2019 Deliverable 2.10).

p10. “The market for organic food is set to continue growing and **organic farming needs to be further promoted**. It has a positive impact on biodiversity.” This can be supported by tackling its main challenges: **nutrient inputs in particular N supply, and pest and weed control**. The role of cereal-





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legume intercropping in organic agriculture has long been established in relation to N supply (since Columella and his treaty 'On Agriculture' (translated in 1941) to, for example, Hauggaard-Nielsen et al. 2008) with integration of legumes in crop rotations being a key feature of organic cropping systems. The role of intercropping in pest and weed suppression has been addressed in DIVERSify and is considered a major topic to be further explored (Villegas-Fernández et al. 2019 Deliverable 4.4; Scherber et al. 2020 Deliverable 2.4).

### 4. Role of Plant Teams in the EU Biodiversity Strategy 2030

The **EU Biodiversity Strategy 2030 (2020)** is launched to work (see p8) “in tandem with the new Farm to Fork Strategy and the new Common Agricultural Policy (CAP), including by promoting eco-schemes and result-based payment schemes. In implementing the Biodiversity and the Farm to Fork Strategies, the Commission will closely monitor progress and improvements in terms of food security and farmers income. (...)” as well as achieving environmental outcomes. The **Member States will establish National Plans** that should lead to sustainable practices, of these, precision agriculture, organic farming, agroecology, and extensive permanent grassland are the main focus.

“**Farmland birds and insects, particularly pollinators**, are key indicators of the health of agroecosystems and are vital for agricultural production and food security”. The full implementation of the [EU Pollinators initiative \(2018\)](#) is stressed which links with positive impacts of intercropping and other practices: “(...) there is an urgent need to bring back at least 10% of agricultural area under **high-diversity landscape features**. These include, inter alia, buffer strips, rotational or non-rotational fallow land, hedges, non-productive trees, terrace walls, and ponds.”

Finally, “the Commission will work with the Member States and stakeholders to ensure that from the outset the **National Strategic Plans for agriculture** fully reflect the ambition of the Green Deal and the Farm to Fork Strategy”. The Common Agricultural Policy (CAP) will present the support needed to help the transition towards cropping systems that align with these goals/targets.

### 5. Plant Teams and the new Common Agriculture Policy

The current Common Agricultural Policy (CAP) aims to help farmers to “achieve sustainability through a more results-oriented model, better use of data and analysis, improved mandatory sustainability standards and new voluntary measures”.

The future CAP, due to start in January 2023, presents a new architecture that includes four pillars:

- enhanced conditionality
- eco-schemes
- agri-environment-climate measures
- farm advisory services.





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Its aim is to expand the production-focussed policy of the current CAP, with its two pillars of “Common organisation of the markets (CMO) in agricultural products”/ “Direct payments to farmers” and “Rural development policy”, to facilitate ecological transition that includes the **restoration of agrobiodiversity**, and **input reduction**, in particular nitrogen fertiliser, pesticides, and herbicides.

This new architecture and reinforced objectives have brought into the limelight certain cropping practices such as plant teams, also referred to here as mixed cropping or intercropping.

**Intercropping can reduce N fertiliser, pesticide and herbicide use, and can increase biodiversity in cropping systems.** These effects impact at different scales in agricultural systems and markets. When legumes, in particular grain legumes, are included intercropping contributes towards increased production of home-grown protein. The required changes in the cropping systems can foster farmers’ efforts in a way that pulls in rural innovation and extension services.

As part of the DIVERSify project, and related projects within the Crop Diversification Cluster, changes in productivity and in yield-stabilising effects due to intercropping have been tested under very different environmental, farm-structural conditions and production systems. **Intercropping tends to improve productivity under low-input systems and in organic production systems, however yield-stabilising effects need further research** (Weih et al. 2021a, 2021b). These results highlight the importance of **pursuing improvement of mixed cropping systems and design of locally adapted crop/cultivar combinations**. The role of CAP, non-EU farmer payment schemes, and research and innovation initiatives (e.g., EIP-Agri) in backing **participatory research** in intercropping is crucial. It remains a challenge to determine direct effects on productivity due to the variable nature of the externalities that influence it.

We can also consider intercropping from the point of view of the **changes to operational management of cropping systems** in a disaggregated approach so that each description highlights the value of including intercropping as an option within the new CAP.

In the final point for this section (5.5), we consider how intercropping could be recognised within the new CAP architecture for support payments.

### 5.1. Fertiliser management: towards N input reduction

Forage or grain legumes included in intercropping/crop mixtures/plant teams can reduce the need for high inputs of synthetic nitrogen fertiliser because of their ability to fix atmospheric N<sub>2</sub>. Absorption of soil mineral N by cereal or other species induces legumes to rely on N<sub>2</sub> fixation, thus an increased rate of N<sub>2</sub> fixation can be found in legumes when intercropped and when soil mineral N is low (Cowden et al., 2020; Ghaley et al., 2005). In conventional or integrated production, the balance between the non-legume and legume N requirement, and N input fertiliser must be established per plant team and expected economic yield of the particular farm. Maintenance of soil organic matter or soil organic carbon (SOC) is another component of fertiliser programmes and crop residue management. In





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organic agriculture, organic matter mineralisation and N<sub>2</sub> fixation are the principal N inputs to support crop growth and maintain SOC.

A decrease in N fertiliser requirement in conventional systems is documented when intercropping with cereal-legumes. Intercropping can improve yields in low-input conventional systems and decrease N fertiliser use. This has been described for instance by Bedoussac and Justes (2010a, 2010b) for wheat-pea intercropping, by Xu et al. (2020) in 7t/ha maize intercropped with soybean, or in the meta-analysis recently conducted by Rodriguez et al. (2020). This needs to be contextualised in relation to yield gap analyses and the maintenance of farm profits (Villegas-Fernández et al. 2019 Deliverable 4.4).

Another aspect is energy reduction in the crop inputs *via* reduced use of synthetic N, which will have to be assessed in more detail through further research.

### 5.2. Pest, disease and weed control: towards pesticide input reduction

Evidence of improved pest, disease and weed control in cropping systems using plant teams is increasing, although still limited. Experiments under controlled conditions and in the field, with specific mixtures and under determined environmental conditions, are shedding some light on the mechanisms underlying these improvements. In DIVERSify some evidence has been described in Villegas-Fernández et al. (2019) Deliverable 4.4 and Scherber et al. (2020) Deliverable 2.4. Success in managing arthropod pests through intercropping may depend on the specific pest and plant-pest combination (Smith and McSorley, 2000), thus pointing to the need for more testing, particularly on-farm. Examples in the literature are increasing, such as reduction of rust on faba bean and of powdery mildew on pea when intercropped with cereals (Villegas Fernández et al. 2017; Li et al. 2020). Intercropping in DIVERSify goes further than use of trap crops and further study of the mechanisms at play within specific plant teams will enable more specific recommendations.

However, as pointed out above, the enormous variability between individual farm characteristics requires on-farm trials by farmers in parallel to research experimentation.

### 5.3. Agro-biodiversity

Most agricultural systems are less diverse and present shorter and fewer trophic chains than ecosystems because they aim to maximise energy transfer to production (yield). Agroforestry systems, such as the dehesa silvo-pastoral system in Spain and Portugal, or smaller subsistence farms, such as those that DIVERSify's African research partner KEFRI (Kenya) can present greater diversity. In cropping systems for major crops, e.g., staple cereals, increased diversity relies on rotations (crop sequences); in contrast to monocultures referring to a sequence of a single species. In the DIVERSify project, we considered monocropping of one crop species in a certain land area to be less diverse than intercropping two or more species. However, despite being inherently more diverse, there remain complexities for consideration when aiming to define how plant teams will lead to increased agro-





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biodiversity. Temporal and spatial diversity vary among farms and plot sizes, environment, ownership structure, labour costs, access to capital and technology, and markets.

Results from the DIVERSify project indicate that intercropping has the potential to lead indirectly to increases in agro-biodiversity if the need for pesticide and herbicide use can be reduced (Brandmeier et al. 2021). Information of the frequency with which to include plant teams in a crop rotation over time and space is needed, as well as continued research into species and variety choice for use in plant teams.

### 5.4. Resilience to weather extremes in the context of climate change trends

In the DIVERSify project, researchers worked with farmers to test plant teams on-farm. One of the motivations of the participatory farmers (PFs) to use plant teams was the possibility of increasing resilience to extreme water deficits and heat waves, i.e., extreme weather events. The on-farm trials of our participatory farmers coincided with extreme seasonal droughts during autumn 2017-summer 2018 in northern and central regions and autumn 2018-summer 2019 in southern regions. However, when farmers sow a dual-purpose mixture (grain or forage) and can use it on-farm or have a market for this forage/feed, this can limit income decrease (Sears et al. 2021, Deliverable 1.2).

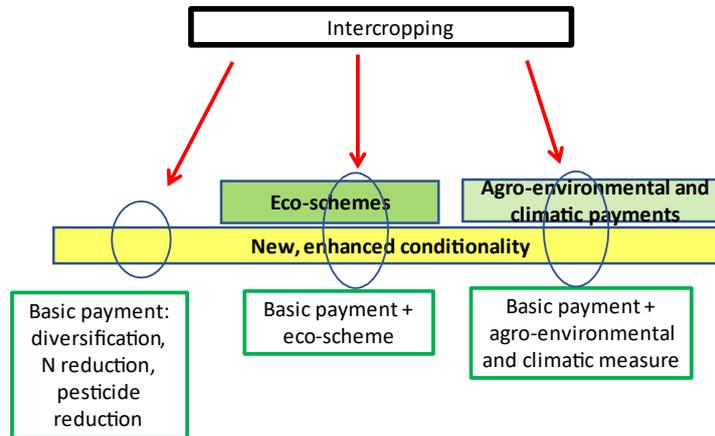
Various PFs indicated that their experience during these extreme seasons led them to believe that the choice of cultivars, plant team species and management options need to be taken into account in line with a changing climate (Sears et al. 2021, Deliverable 1.2). This is a complex issue that needs further research.

### 5.5. Improvements in CAP support

The new CAP architecture is presented in **Figure 2**. The challenges in implementation will be balancing the known benefits of a certain practice, for example in terms of fertiliser management or agrobiodiversity, against a need for monitoring and clear results in light of spatial and seasonal variability. Intercropping could obtain support through several schemes within CAP as indicated by the arrows in **Figure 2**. There are several possibilities:

- Include intercropping in specific eco-schemes such as practices to improve soil organic carbon, arable soil quality and fertility: promotion of soil-improving crops
- Include intercropping in eco-schemes as another possibility for (more complex) rotations
- Include intercropping as an agro-environmental and climatic measure (multi-year practice)
- Intercropping in organic agriculture
- Intercropping equivalence: consider intercropping on a farm as enabling:
  - N fertiliser and pesticide use reduction
  - increased biodiversity of rotations





**Figure 2.** New CAP architecture showing where intercropping could be considered for support.

## 6. Plant Teams and the UK Agriculture Act 2020

In parallel, the **UK Agriculture Act 2020** is focusing on **Public Goods** (Coe and Finley, 2020, p18) obtained through agricultural practices and non-agricultural practices and aims to be results-driven. For instance, in England (Table 1. P19) this includes: a) managing land or water in a way that protects or improves the environment; (h) protecting or improving the health of plants (related to reducing the risk of introduction and spread of harmful plant pests and disease). **Environmental Land Management (ELM)** is the scheme by which farm payments will be determined in England with Scotland, Wales and Northern Ireland developing similar schemes that align with the overarching policy direction and legislation laid out in the Agriculture Act 2020. ELM is being gradually phased in between now and 2028 and is made up of three components: **1) the Sustainable Farming Incentive (SFI); 2) Local Nature Recovery; 3) Landscape Recovery**. Plant Teams could reasonably be included as an action within the SFI that warrants receipt of farming subsidies because it has a body of evidence supporting the delivery of environmental outcomes based on its application. It could also be a component of a wider landscape level response that can deliver results for Local Nature Recovery or Landscape Recovery (DEFRA, 2019).

## 7. Barriers and management limitations: the need for farm advisory service

**Technological barriers** are partly a consequence of current management that is based on sole crop rotations or monocropping. DIVERSify has identified multiple barriers as outlined in project reports: Tippin et al. (2019) - Deliverable 4.5: Report on practical restrictions imposed by plant teams, and George et al. (2020) - Deliverable 4.6 Report on trouble shooting matrix of PAT practical solutions.

These barriers are generally site specific: barriers extend from sowing (e.g. different seed sizes and in some cases sowing times, sowing rates, and depths, need for adapted machinery) to agronomic



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management related to pest, disease, and weed control, harvest timing and grain separation, and not least, the plant team management itself: crop-crop competition and nutrition management.

**Socio-economic barriers** were highlighted through a series of project activities: a) interactions with farmers and other agricultural stakeholders attending Stakeholder Workshops (see: Pearce et al. (2018) - Deliverable 1.1-D1-Synthesis report on national stakeholder meetings) and farmers that then became Participatory Farmers engaged in on-farm trials as part of the project; b) Scherber et al. (2019) - Deliverable 2.10-D19-Report on performance of stakeholder-driven plant teams) resulted in the acknowledgment that other farmers were also testing intercropping, not only the Participatory Farmers of DIVERSify, and c) in the specific surveys, interviews and analysis of barriers that fed into the development of the project (Sears et al. 2021. Deliverable 1.2).

Enhancing profit and minimising risk remain the priority goals when running a farm business and whatever the differences among the PFs farms, the socio-economic considerations and bottlenecks found when implementing intercropping, there were **three key variables determining the financial viability of plant teams**. These were: a) access to quality seed mixes, b) labour involved in implementing intercropping, including access to suitable machinery, and c) access to receptive markets beyond the farm gate. More broadly, **barriers were found to relate predominantly to institutional, agronomic, technical, and economic factors**. Many of farmers that engaged in the DIVERSify project were establishing on-farm trials of intercropping by their own initiative, testing plant teams and machinery solutions based on specific motivations. They reported that engaging in on-farm trials to establish the optimal plant teams for their local conditions can expose them to reduced profit (or income foregone) and the **support of the project incentivised them to test intercropping**, and deliver the associated wider benefits, on their farm.

Consequently, Sears et al. (2021) highlights:

- The need for supporting these innovating farmers for multiplicative effects from applying measures established in the CAP and Agriculture Act 2021.
- The importance of training farm advisors in more sustainable cropping practices that would include intercropping given its complexity and its site-specificity.

**Access to information and advice** has been highlighted as an important enabler to encourage the uptake of intercropping practices in the DIVERSify project and across Crop Diversification Cluster project results. Furthermore, working collaboratively with farmers and stakeholders throughout these projects has highlighted the value that engagement in participatory research can bring to encouraging the adoption of more complex, knowledge-intensive practices by individual farmers. This will also require funding and systems in place to enable the necessary processes and collaborations between researchers and practitioners to develop.





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### 8. Proposals for improvement of policy tools

Further policy-level proposals that will enable the wider adoption of plant teams should be considered from a producer network (i.e., beyond the circumstances of an individual farm business) or market level.

**At a producer network level**, further improvements would encompass:

- Facilitating access to farm advice.
- Facilitating cooperation among farmers for transfer of results of species-cultivars-ratios-densities used in intercropping.
- Providing more support for more farmers to engage in participatory research with scientists, research centres or universities. e.g., via EIP-AGRI or Horizon Europe.
- Development of tools for intercropping monitoring.

**At a market level**, further improvements would encompass:

- Promotion of home (EU)-grown legumes.
- Certification schemes: include intercropping in certification of 'Integrated farming'.
- Use of mixed cereal-grain legume flours in valorisation of products such as pasta and bread.

### 9. Conclusions

Three aspects of intercropping allow advancement towards a greater sustainability of European agriculture and the potential to reach the targets established in the new CAP as derived from the Farm to Fork Strategy, particularly:

- Reduction of fertilisers
- Reduction of pesticides and herbicides
- Increased agro-biodiversity

Intercropping with plant teams is a practice with environmental benefits that represents a change in production systems thus requiring support in the new environmental structure. Consequently, Member States should consider support for intercropping through:

- Eco-schemes: support changes in crop management, need for new or adapted machinery, income foregone or smaller profit.
- Agro-environmental measures: compensation for income foregone or smaller profit.
- Facilitating access to Farm Advisory Services and funding participatory research.

However, there are further actions to be taken:

- Elimination of barriers linked to institutional, agronomic, technical and economic factors.
- Scaling up across landscapes and farmer networks.
- Improving access to appropriate and innovative (new) markets.





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Support of intercropping as a practice through the European Innovation Partnerships “Agricultural productivity and Sustainability” EIP-AGRI should also be explored.

A summary table is included in **Appendix 1** to systematise the links between intercropping, policy targets and the objectives of the new CAP and UK Agriculture Act 2020, and possible support available within these. The DIVERSify Policy Toolbox can be found at [www.plant-teams.org](http://www.plant-teams.org). It summarises the key evidence coming from the four years of research within the DIVERSify project in relation to how intercropping can contribute towards input reduction, increased production of home-grown proteins, reducing biodiversity losses, resilience to climate changes, and rural innovation.

### References

#### **EU and UK Strategy and Policy Documents**

Farm to Fork Strategy. (2020). [https://ec.europa.eu/food/farm2fork\\_en](https://ec.europa.eu/food/farm2fork_en)

EU Biodiversity Strategy 2030. 2020. [https://ec.europa.eu/info/sites/info/files/communication-annex-eu-biodiversity-strategy-2030\\_en.pdf](https://ec.europa.eu/info/sites/info/files/communication-annex-eu-biodiversity-strategy-2030_en.pdf)

EU Pollinators Initiative. (2018). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0395&from=EN>

The European Green Deal. (2019). [https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal\\_en](https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en)

CAP Common Agricultural Policy: [https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-strategic-plans\\_en](https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-strategic-plans_en) and <https://www.europarl.europa.eu/factsheets/en/section/196/the-common-agricultural-policy-cap->

Commission Staff Working Document (2020). Analysis of links between CAP Reform and Green Deal Brussels, 20.5.2020. SWD (2020) 93 final. [https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/sustainability\\_and\\_natural\\_resources/documents/analysis-of-links-between-cap-and-green-deal\\_en.pdf](https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/sustainability_and_natural_resources/documents/analysis-of-links-between-cap-and-green-deal_en.pdf)

SDG Sustainable Development Goals (2015). United Nations, Department of Economic and Social Affairs. <https://sdgs.un.org/goals> and the agenda: <https://sdgs.un.org/2030agenda>

UK Agriculture Act (2020):

- Coe, S. and Finley, J. 2020. The Agriculture Act 2020. Briefing paper Number CBP 8702, 3 December 2020: <https://commonslibrary.parliament.uk/research-briefings/cbp-8702/>
- <https://www.legislation.gov.uk/ukpga/2020/21/contents/enacted>





## DIVERSify: Designing InnoVative plant teams for Ecosystem Resilience and agricultural Sustainability

DEFRA, 2019. Farming is changing. Department for Environment. Food and Rural Affairs., [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/939683/farming-changing.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/939683/farming-changing.pdf)

European Innovation Partnerships- 'Agricultural Productivity and Sustainability' EIP-AGRI <https://ec.europa.eu/eip/agriculture/en/european-innovation-partnership-agricultural>

### DIVERSify Deliverable reports

George D.R., Manfield, A., Banfield-Zanin J.A. (2020). **Deliverable 4.6** (D32) – Report on Trouble Shooting Matrix' of PAT based solutions to plant team limitations. Developed by the EU-H2020 project DIVERSify ('Designing innovative plant teams for ecosystem resilience and agricultural sustainability'), funded by the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement Number 727284.

Pearce B.D., Bickler C., Midmore A., Tippin L., Schöb C., Elmquist H., Rubiales D., Kiær L., Tavoletti S., Vaz Patto M.C., Adam E., George D., Banfield-Zanin J., Fustec J., Bertelsen I., Olesen A., Otieno J., Sbaihat L., Scherber C., and Barradas A. (2018). **Deliverable 1.1** (D1) - Synthesis report on national stakeholder meetings. Developed by the EU-H2020 project DIVERSify ('Designing innovative plant teams for ecosystem resilience and agricultural sustainability'), funded by the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement Number 727284.

Scherber C., Kiær L., Weih M., Rubiales D., Villegas-Fernandez A., Tavoletti S., Vaz Patto M.C., Adam E., Barradas A. and Karley A.J. (2019). **Deliverable 2.10** (D19) - Summary report on performance of stakeholder-driven plant teams. Developed by the EU-H2020 project DIVERSify ('Designing innovative plant teams for ecosystem resilience and agricultural sustainability'), funded by the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement Number 727824.

Scherber C., Karley A.J., Schöb C., Schmutz A., Weih M., Tavoletti S., Vaz Patto C., Rubiales D., Villegas Fernández Á. (CSIC), Kiær L.P. (2020). **Deliverable 2.4** (D20) - Key mechanisms promoting performance of plant teams. Developed by the EU-H2020 project DIVERSify ('Designing innovative plant teams for ecosystem resilience and agricultural sustainability'), funded by the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement Number 727284.

Sears, R.R., Mínguez, M.I., Bardají, I., Bickler, C., Ghaley, B.B. and Karley, A.J. (2021) **Deliverable 1.2** (D2) - Report on socio-economic factors affecting farmer adoption of plant teams. Developed by the EU-H2020 project DIVERSify ('Designing innovative plant teams for ecosystem resilience and agricultural sustainability'), funded by the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement Number 727284.

Tippin L., Banfield-Zanin J.A., Midmer A., Pearce B., Bickler C., Manfield A., George D.R. (2019). **Deliverable 4.5** (D31) – Report on practical restrictions imposed by plant teams. Developed by the EU-H2020 project DIVERSify ('Designing innovative plant teams for ecosystem resilience and agricultural sustainability'), funded by the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement Number 72728.





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Villegas Fernández A.M., Rubiales, D., Karley A., Mitchell C., Newton A., Elmquist H., Weih M., Bertelsen I., Fog-Petersen J., Tavoletti S., Vaz Patto M.C., Barradas A., Maalouf F., Banfield-Zanin J.A., George D.R. (2019). **Deliverable 4.4** (D29) – Interim report on the applied benefits of plant teams. Developed by the EU-H2020 project DIVERSify ('Designing innovative plant teams for ecosystem resilience and agricultural sustainability'), funded by the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement Number 72728.

### Other References

Bedoussac L. and Justes E. 2010a. The efficiency of a durum wheat-winter pea intercrop to improve yield and wheat grain protein concentration depends on N availability during early growth. *Plant Soil* 330:19–35.

Bedoussac L. and Juste, E. 2010b. Dynamic analysis of competition and complementarity for light and N use to understand the yield and the protein content of a durum wheat–winter pea intercrop. *Plant Soil* 330:37–54.

Brandmeier J., Reininghaus H., Pappagallo S., Karley A.J., Kiær L.P. and Scherber C. (2021) Intercropping in high input agriculture supports arthropod diversity without risking significant yield losses. *Basic and Applied Ecology* (published online; DOI: <https://doi.org/10.1016/j.baae.2021.02.011>)

Columella. *On Agriculture*, Volume I: Books 1-4. Translated by Harrison Boyd Ash. Loeb Classical Library 361. Cambridge, MA: Harvard University Press, 1941.

Cowden, R.J.; Shah, A.N.; Lehmann, L.M.; Kiær, L.P.; Henriksen, C.B.; Ghaley, B.B. 2020. Nitrogen Fertilizer Effects on Pea–Barley Intercrop Productivity Compared to Sole Crops in Denmark. *Sustainability*, 12, 9335. <https://doi.org/10.3390/su12229335>

Ghaley, B.B., Hauggaard-Nielsen, H., Høgh-Jensen, H., Jensen, E.S. 2005. Intercropping of Wheat and Pea as Influenced by Nitrogen Fertilization. *Nutrient Cycling in Agroecosystems* 73, 201–212. <https://doi.org/10.1007/s10705-005-2475-9>

Hauggaard-Nielsen H., Jørnsgaard B., Kinane J. and Jensen, E.S. 2008. Grain legume-cereal intercropping: The practical application of diversity, competition and facilitation in arable and organic cropping systems. *Renewable Agriculture and Food Systems*, 23: 3-12

Li X., Lv J., Zhao Q., Chen L., Dong Y. and Dong K. 2020. Wheat/faba bean intercropping improves physiological and structural resistance of faba bean to Fusaric acid stress. *Research Square* <https://doi.org/10.21203/rs.3.rs-80689/v1>.

Smith H.A and Mc Sorley R. 2000. Intercropping and Pest Management: A Review of Major Concepts. *American Entomologists*: 46: 154- 161.

Villegas-Fernández A. M., Amarna A., Moral Moral J. and Rubiales D. 2017. Faba bean rust and pea powdery mildew management by intercropping with cereals and by cultivar mixtures, *International Conference Advances in grain legume breeding, cultivations and uses for a more competitive value-chain*. <http://hdl.handle.net/10261/167110>





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Weih M., Ajal J., Kiaer L.P., Karley A.J., Newton A.C., Scherber C., Brandmeier J., Pappagallo S. and Tavoletti S. (2021a) Grain yield stability of individual cereal-legume mixtures grown across Europe. *Aspects of Applied Biology* 146: 241-247.

Weih M., Karley, A.J., Newton, A.C., Kiaer, L.P., Scherber, C., Rubiales, D., Adam, E., Ajal, J., Brandmeier, J., Pappagallo, S., Villegas Fernández, A., Reckling, M. and Tavoletti, S. (2021b, accepted). Grain yield stability of cereal-legume intercroops is greater than sole crops in more productive conditions. *Agriculture*.

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### **Citation**

Please cite this report as follows:

Mínguez, M.I., Bardají, I., Bickler, C. 2021. Deliverable 1.6 (D10). Policy guide on plant teams for intercropping. Developed by the EU-H2020 project DIVERSify ('Designing innovative plant teams for ecosystem resilience and agricultural sustainability'), funded by the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement Number 727284.





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### Appendix

Table summarising how intercropping relates to specific policy objectives and targets but can also have a more diffuse horizontal effect on the pursuit of more sustainable farming.

DIVERSify has explored the effects of intercropping in	Intercropping links to EU and UK objectives and targets	Support from CAP, UK and other EU initiatives
N input reduction	Farm to Fork Strategy (p9). Reduce the use of fertilisers by at least 20% by 2030	CAP: - eco-scheme or - agro-environmental and climatic measure ELM: - sustainable farming incentive
Reduction of chemical pesticide use	Farm to Fork Strategy (p9). The Commission will take additional action to reduce the overall use and risk of chemical pesticides by 50% and the use of more hazardous pesticides by 50% by 2030 Pesticides national action plan currently in draft in the UK	CAP: - eco-scheme or - agro-environmental and climatic measure
Increase of agro-biodiversity at plot level	EU Biodiversity Strategy UK Agriculture Act 2020 links farmers' financial support to practices that will deliver public goods UK Environment Bill 2020	CAP: - New conditionality: basic payment - eco-scheme ELM: - Support for public goods delivered related to increased biodiversity at plot and landscape level
Improved organic farming	Farm to Fork Strategy (p10-11). The Commission will put forward an Action Plan on organic farming (...) This approach will help to reach the objective of at least 25% of the EU's agricultural land under organic farming by 2030	CAP: - eco-scheme or - agro-environmental and climatic measure





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N input reduction + Reduction of chemical pesticides use + increase of agro-biodiversity at plot level	UK Agriculture Act 2020 links farmers' financial support to practices that will deliver public goods: reduction in and protection from environmental hazards; also to be further explored: adaptation to climate change; engagement with the environment	- UK: Support for public goods delivered
N input reduction + Reduction of chemical pesticides use + increase of agro-biodiversity at plot level	Environmental Land Management (ELM)	- Sustainable Farming Incentive (SFI)
Optimising mixtures for intercropping	Participatory research with farmers	- EIP-AGRI European Innovation Partnerships 'Agricultural Productivity and Sustainability' and other research funding mechanisms

