

On-farm experimentation in agronomic research: an Italian perspective

Vittoria Giannini,¹ Elisa Marraccini²

¹Department of Agronomy, Food, Natural Resources, Animals and Environment (DAFNAE), and Department of Land, Environment, Agriculture and Forestry (TESAF), University of Padua, Legnaro; ²Department of Agricultural, Food, Environmental and Animal Sciences (DI4A), University of Udine, Italy

Highlights

- Only 14 papers on on-farm experimentation (OFE) in Italy have been found in a Scopus search.
- Few papers explicitly deal with participatory approaches engaging researchers and farmers.
- None of the papers mentioned digital technologies as enablers of OFE.
- OFE is an opportunity for developing agronomic research at a scale that is meaningful for farmers in Italy.

Correspondence: Vittoria Giannini, Department of Agronomy, Food, Natural Resources, Animals and Environment (DAFNAE), and Department of Land, Environment, Agriculture and Forestry (TESAF), University of Padua, Viale dell'Università 16, 35020 Legnaro (PD), Italy. E-mail: vittoria.giannini@unipd.it

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Abstract

On-farm experimentation (OFE) renovates agronomic research since it brings researchers out of their experimental field stations to the farms, shaping the direction of research in collaboration with farmers. In the context of increasing interest in OFE, this paper aims to map the current picture of agronomic research articles published on OFE in Italy. We observe that few articles are published on OFE in Italy. Moreover, among these articles, only a few explicitly mentioned farmers' opinions or involvement, while none of them mentioned digital technologies as enablers of OFE. Therefore, we started a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis to identify the main weaknesses and threats limiting OFE developing in Italy, along with the opportunities and strengths enabling OFE development. Despite the time-consuming research underpinning OFE, the lack of recognition by the academic community, the risk of not robust statistic, and difficulties in publishing, there are a series of opportunities emerging at the national level for which the implementation of OFE could be crucial to properly target the scopes set by the EU concerning agricultural research and innovation.

Introduction

In recent years, on-farm experimentation (OFE) has drawn a lot of attention, not only in scientific literature (Lacoste *et al.*, 2022; Toffolini and Jeuffroy, 2022), but also worldwide as the main topic of several conferences and workshops such as the 2024 *International Conference for on-farm precision experimentation* sponsored by the USDA and the *Conference on farmer-centric on-farm experimentation* held for the first time in Montpellier in 2021 and sponsored by OECD and INRAE among others (Bellon Maurel *et al.*, 2022). As Italian researchers in agronomy, perceiving the growing interest in OFE worldwide, we were interested in understanding the positioning of Italian agronomic research about OFE, trying to depict possible limits and the opportunities for its development in the near future. Starting from the definition provided by Lacoste *et al.* (2022), OFE is “an innovation process that brings agricultural stakeholders together around mutually beneficial experimentation to support farmers' own management decision, addressing complexity and uncertainty through joint exploration embedded in real-world farm management as a means to bridge sources of knowledge and foster open innovation”. Some

authors identified OFE as the proper environment to foster the renovation of farming systems in order to increase their adaptation and resilience to global trends, like climate change (Ripple *et al.*, 2019), but also to local trends (Hazell & Woods, 2008). To achieve the success of this transition in agricultural systems, many authors highlighted the importance of the involvement of all actors participating in the Agricultural Knowledge and Innovation System, including farmers (Coquil *et al.*, 2018; Šūmane *et al.*, 2018). Other authors suggested that digital technologies can be considered as enablers for OFE, innovating the way these experiments with farmers are designed, managed and analysed (Bramley *et al.*, 2022).

In this perspective, the OFE approach has to fulfil some requirements: a farmer-centric perspective meaning that farmers' questions fuel the process, a co-innovation process scaled on systems meaningful for farmers, evidence driven insights anchored in data, the involvement of different experts in engaging co-learning environments, and scalable activities from both social and analytic perspectives (Lacoste *et al.*, 2022). Under the current European scenario on research and innovation in agriculture, pushing for new large-scale initiatives (*e.g.* Horizon Europe 2021-2027 or the EU mission *A soil deal for Europe*) and highlighting agroecosystem living labs as the targeted environment for the co-creation and the innovation (Toffolini *et al.*, 2023), OFE could represent the 'mediating object' of the social learning process animating those living labs (Ceseracciu *et al.*, 2023). In this context, several research teams have been promoting agricultural research and innovation in specific national or regional contexts such as the ECOPHYTO plan and the DEPHY network in France (Lamichhane *et al.* 2019), or the European Innovation Partnership and Operational Groups in Italy (Arzeni *et al.* 2023). To the best of our knowledge, no information is available on the state of OFE in Italy, questioning its diffusion as experimental method in agronomy research. This paper focuses on mapping the available scientific literature on OFE in Italy and then, through a SWOT analysis, to identify the main external and internal factors that have influ-

enced its development in Italy but also those factors that can push or constrain its spread in both Italy and other countries.

On-farm experimentation: from the dawn to the current picture

The power of the mutual exchange of knowledge between scientists and farmers, the necessity of reversing the traditional top-down linear 'transfer-of-knowledge' model to promote experiential knowledge driven innovation founded the groundwork for OFE in the late 1800 (Knoblock, 2003, Šūmane *et al.*, 2018). In those years, in Italy some new ideas about the involvement of farmers in the innovation process were arising. During the first meeting of Italian agricultural Scientists held in Pisa in 1839, Ranieri Sbragia introduced the idea of the 'Itinerant Chairs of Agriculture' (namely, *Cattedre Ambulanti d'Agricoltura*), that were intended for an active dissemination of knowledge on the territory rather than an active co-development of innovation (Zucchini, 1970). In the same period, in the USA, Seamon Knapp, President of the Iowa Agricultural College, started to promote demonstration farms as a place of active interaction. A century later in 1991, in New Zealand, the push for a mutual relationship between scientists and farmers was provided by the Farmer First Programme, with the purpose of developing an innovation platform to operationalize a farming system research and extension approach within the primary sector (Reid and Brazendale, 2014). That programme was strongly influenced by authors such as Chambers and Jiggins (1986) writing that "the farmer must be part of the research team, involved in making plans and decisions at all levels and stages and sharing credit for results" contributed to identify agricultural research priorities and made possible implementation with the pivotal role of active farmers involved. In this line, in Italy several research projects were also developed related to increasing engagement in cooperation programmes (Bocchi *et*

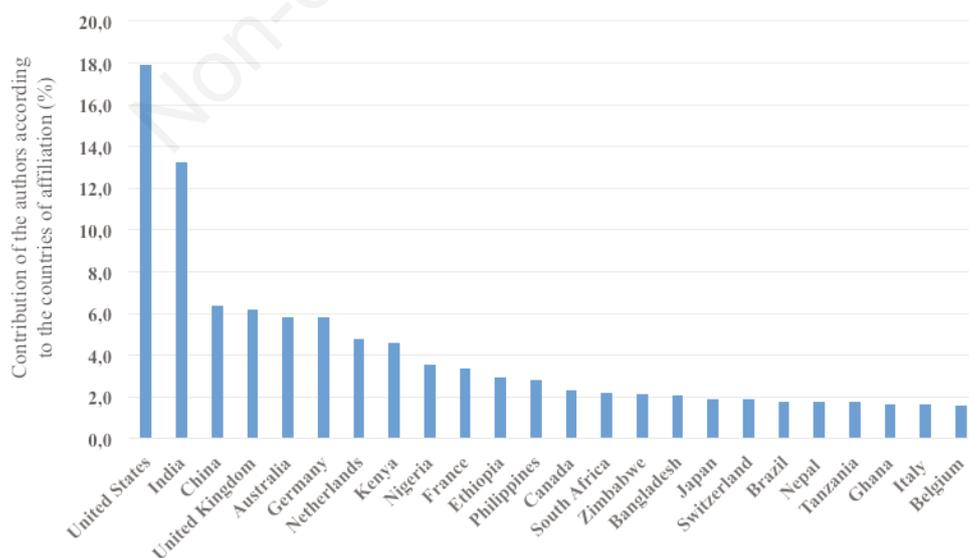


Figure 1. Contribution of the authors to on-farm experimentation (OFE) literature according to their country affiliation. Represented in the Figure are the countries having more than 30 articles published on OFE. The number of authors per affiliation is higher than the number of published articles.

al., 2012), but also in the new agro-environmental measures introduced in the late 90's (Allan *et al.*, 2013).

Those experiences constituted the beginning for OFE, which has since developed across the world, adapting the approach to the specific contexts of each case study. For many scientists OFE was used to simply refer to experimentation hosted by private farms but conceived and managed according to their ideas, in other cases OFE was used to refer to co-researching practices joining the competences of both scientists and farmers that were run on private farms according to the main purpose of the experiment (Toffolini and Jeuffroy, 2022; Jackson-Smith and Veisi, 2023).

On-farm experimentation in the Italian scientific literature

A review of the peer-reviewed publications about OFE was undertaken in Scopus in December 2023 using the following query: (TITLE-ABS-KEY (“Farm experiment*” OR “Farm trial*”). This query allowed us to select papers not generically referring to on-farm research, but on experimentations conducted at the farm scale. However, the query has some limits: i) it did not allow us to distinguish among the areas of experimentation, *e.g.* arable crops, permanent crops and livestock, ii) it could miss research that did not contain in the text the specific keywords selected, but could have been considered consistent with the concept of on-farm experimentation, as in the case of research experiments carried out on grasslands and common lands, where the farm is not necessarily the ideal management unit to consider, or other cases in which the authors' focus was on the outcomes of the experiments than about describing the co-researching process.

From 1953 to 2023, 1790 articles have been published on OFE worldwide. According to the affiliation of the authors, two countries emerged as the leading producers of research on this topic (Figure 1): US (18% of the authors' signing articles) and India (13% of the authors signing articles). All of the other countries of affiliation contributed less than 10%, and Italy contributed 1.6% of articles on this topic).

The articles having at least one co-author with an Italian affiliation were first selected, then analysed through an abstract screening. From these articles, five were removed since they were not consistent with agronomic research (*e.g.* fish farming, wind farms, veterinary focus), six were reviews or methodological papers, six were the outcomes of research activities carried by Italian authors outside of Italy usually as part of an international research team. An in-depth analysis was performed on the remaining 15 articles according to the typology of experimental practices associated with OFE presented by Toffolini and Jeuffroy (2022). This analysis required a full text analysis of the selected articles (Table 1). From that analysis, another article was removed since it only mentioned OFE with another focus, resulting in a final selection of 14 articles. Two of the seven OFE types mentioned by Toffolini and Jeuffroy (2022) were not found in the articles selected: Type 1 “Exploring and explaining a phenomenon through the diversity of a farmers' circumstances and practices” and Type 6 “Developing on-farm research based on multi-year trials and surveys”, whereas Type 5 “Considering farm fields as the locus of experiments without mentioning farmers” seemed to be associated with other OFE types and was then excluded. In most of the articles, farm fields were considered the location of the experiment, but the farmers' opinions or involvement in the experimentation were not mentioned, except for the articles authored by Mantino *et al.* (2021), Pellegrini *et al.* (2021), Zanetti *et al.* (2022) and Antichi *et al.* (2022). As a consequence, the experimental practices were often similar to those that can be commonly used in experimental stations. Considering the areas of research, the selected papers mostly deal with weed/pest management (5), nutrient management (2), innovation in agroecosystem management (6), water management (1), and animal grazing (1); therefore, covering a wide set of research areas. None of the selected papers mentioned the use of digital tools for OFE implementation, whereas digital tools have been indicated in the literature as one of the main levers for the development of OFE (Lacoste *et al.*, 2022). Funding sources for the research were in 9 cases out of 14 from Europe (FP7 projects, operational groups, rural development measures), only 2 out of 14 from national funding (Italian Ministry of agriculture or university company partnership), while 3 out of 14 articles did not mention any specific funding.

Table 1. Classification of the selected Italian articles according to the on-farm experimentation categories identified by Toffolini and Jeuffroy (2022). Among the practises mentioned by Toffolini and Jeuffroy (2022), only the ones matching the selected articles are reported.

Experimental practices associated with OFE	Papers retrieved, n.	Areas of research	References
Validating models or technologies in a large range of biophysical contexts through standardized protocols	4	Integrated pest/weed management; nutrient management	Vasileiadis <i>et al.</i> (2016); Grillo <i>et al.</i> (2021); Razinger <i>et al.</i> (2015); Vasileiadis <i>et al.</i> (2015)
Comparing new strategies and combinations of techniques with farmers' practices	5	Water management; weed management; management of innovative crops; nutrient management; profitability of cover crops	Campi <i>et al.</i> (2010); Raffaelli <i>et al.</i> (2010); Lazzeri <i>et al.</i> (2009); Giannini <i>et al.</i> (2023); Severini <i>et al.</i> (2021)
Demonstrating or testing new technologies on farm fields to convince future adopters	1	Weed management	Fontanelli <i>et al.</i> (2015)
Adapting participatory and farmer-managed trials to individual farms	4	New crop introduction; cropping system management; intercropping; animal grazing	Zanetti <i>et al.</i> (2022); Antichi <i>et al.</i> (2022); Pellegrini <i>et al.</i> (2021); Mantino <i>et al.</i> (2021)

OFE, on-farm experimentation.

What is the future for on-farm experimentation in agronomic research in Italy?

From the picture drawn through a SWOT analysis focusing on the perspective of Italian researchers in agronomy, it was possible to evaluate the strengths and weaknesses related to internal factors, and the opportunities and threats related to external factors for OFE development in Italy (Table 2). The internal factors were those directly related either to agronomic research in Italy, to experimental methods in agronomy, or to those stakeholders collaborating in OFE, *e.g.* farmers. On another side, as external factors were considered those related to academic careers in Italy or those related to fundraising in research.

According to Table 2, potential opportunities seem to have overcome threats, due to the funding opportunities provided mainly by the EU, the parallel development of digital technologies (Lacoste *et al.*, 2020; Bramley *et al.*, 2022), and to the new emerging criteria for the recruitment of researchers and university professors in Italy that can represent an opportunity for developing innovative methods and approaches in agronomy research. On the other side, from the perspective of researchers, OFE development in Italy can be threatened by the following: i) outreach activities are starting to be valorised for researchers' careers thus affecting collaborative research with farmers differently to other countries (Anzivino *et al.*, 2021); ii) given its large scale, OFE is characterized by great variability that in principle generates more difficulties in finding significant statistical effects of treatments, making it harder to produce scientific articles outside the comfort zone of randomized and replicated plot experiments (Roques *et al.*, 2022). Some of the weaknesses are directly related to the characteristics of OFE. In fact, managing OFE is complex for Italian agronomy researchers from different perspectives: i) academics are more familiar with field crop research methodologies based on randomized plot experiments than methods relying on the participatory approaches, digital tools and advanced data management, *e.g.* using artificial intelligence, which can be required by OFE (Allan *et al.*, 2013; Rakshit *et al.*, 2020); ii) the management of collaborative experiments with farmers and other stakeholders is more time consuming (Pagliarino *et al.*, 2020) than studies in

experimental farms where there are often technicians, facilities and tools for data acquisition. In the competitive research framework, another factor justifying the constrained development of OFE in Italy can be related to the topics defining the boundaries between scientific sectors, mentioned as 'Agronomy and Field Crops' (MIUR, 2015) to which the researchers' papers and activities in agronomy must be compliant for their career progression in academia. Finally, another limiting factor to the development of OFE in Italian agronomic research is the lack of *ad hoc* national project calls and funding, contrary to what happened for example in France with the DEPHY network for at least one decade (Lamichhane *et al.*, 2019). Another driver of the greater success in other countries concerning publication on OFE than in Italy can be related to the complex farmland structure and ownership of the Italian farms. In Italy the average farm size is 11 ha (ISTAT, 2022), and almost 30% of the farms are partially or totally managed by contractors (CREA, 2023). Moreover, the field size in Italy is smaller compared to other countries in the Global North (Lesiv *et al.*, 2018), but also fragmented (Weissteiner *et al.*, 2016), thus slowing down the diffusion of digital agro-equipment among farms that have been recognized as enablers for OFE (Lacoste *et al.*, 2021; Bramley *et al.*, 2022).

All these weaknesses and threats considered, there are also some strengths that can push OFE development. Among them, the large involvement of the Italian agronomic research community in the operational groups (Arzeni *et al.*, 2023) adopted in many (but not all) administrative regions of Italy, represents a notable opportunity for collaborative research with farmers. However, in the Italian scientific literature there is still little evidence of these experiences in terms of OFE results classified according to the criteria used in this paper. As research centres and universities represented almost 50% of the actors involved in the 365 operational groups (Arzeni *et al.*, 2023), we can suppose a strong implication of academics in collaborative research and a potential for the capitalisation of this experience in the next few years, given the different implementation of European Innovation Partnership (EIP) in Italian administrative regions.

We can mention as a strength the fast development of digital tools (Jindo *et al.*, 2021). Innovations in digital tools represent a potentially valuable source of data for researchers in designing and

Table 2. SWOT analysis (strengths, weaknesses, opportunities, and threats) of the development of on-farm experimentation in Italian agronomic research. Strengths and weaknesses refer to the internal factors, while opportunities and threats refer to the external factors.

Strengths	<ul style="list-style-type: none"> • Experience of Italian academics and farmers in participatory research gained through operational groups. • Training of new generations of academics on digital tools through new national PhD programmes in Italy. • National research programmes already funded within the national recovery plan on innovation in agriculture.
Weaknesses	<ul style="list-style-type: none"> • Consolidated methodologies in agronomy for glasshouse and on-station field experiments. • Pre-defined topics in the Academic Field of 'Agronomy and Field Crops' in Italy defining the topic coherence of career progression criteria. • OFE is a time demanding methodology. • Poor training on participatory research for Italian agronomy scholars. • Small-sized and fragmented farmland, farm management by contractors limit the adoption of OFE in Italy.
Opportunities	<ul style="list-style-type: none"> • Development of an international scientific community on OFE (GOFEN). • Development of new digital tools for agriculture acting as enablers for OFE. • European research programmes on innovation in agriculture requiring stakeholder involvement. • New emerging evaluation criteria for researchers and university professors at international and national levels. • Possible contribution from training new professionals (<i>e.g.</i> innovation brokers).
Threats	<ul style="list-style-type: none"> • Academic acknowledgement of interdisciplinarity in the Italian research assessment framework. • Uncertain contribution of outreach activities to the assessment of academic careers in Italy.

OFE, on-farm experimentation.

exploiting OFE results; thus, overcoming some of the researchers' concerns on farm trials as suggested by Bramley *et al.* (2022). In this perspective, the development of new monitoring technologies based on on-site sensors, remote sensing, spatial analysis tools and data science (Bullock *et al.*, 2019) could enable the collection and the analysis of a huge amount of data of agronomic interest including several covariates of difficult estimation in small plot experiments (Paccioletti *et al.*, 2021). The development of these new technologies makes it possible to gain new information on field space-time yield variability and to support decisions in experimentation (Bramley *et al.*, 2022). Obviously, collecting "big-data" adds new challenges in terms of data management and analytics. At the EU level, the European Partnership "Agriculture of Data" will address this issue by boosting the uptake of digital technologies and enhancing the use of agricultural data (Stendal *et al.*, 2023). In the Italian context, the creation of new national initiatives fostering digitalization and interdisciplinarity in research, such as the Agritech National Center funded in 2022 or the new National PhD programme in Artificial Intelligence in 2021, are opportunities for training a new generation of agricultural scientists to implement digital tools and use them in different research activities including OFE. Finally, the development of open access in science can support the spread of the innovations generated by OFE and allow the creation of large collaborative datasets in the Italian context of fragmentation of the agricultural universities and research centres. As shown by Laurent *et al.* (2019) there are innovative solutions to visualize online results from different experiments in different years, ranging from individual on-farm results to collective on-farm network data. These solutions can overcome the fragmentation of OFE in the Italian context, enabling the generalisation of results and can represent an inspirational tool for renewed OFE in Italy.

The scientific debate generated by the development of OFE activities can contribute to the creation of new professionals such as extensionists and innovation brokers who are lacking in agricultural sciences (Hermans *et al.*, 2015), and to overcome the compartmentalization of knowledge in socio-ecological systems (Pagliarino *et al.*, 2020). This growing interest in OFE finds a series of opportunities represented by: i) consolidated networks on OFE that have gained long-term experience in participatory approaches and data management that are able to provide training (e.g. GOFEN); ii) the increasing use of digital tools in agriculture; iii) new calls for OFE projects funded by the EU; iv) academic turnover resulting in a new generation of scientists potentially open to renewing experimental methodologies.

Conclusions

Starting from the current Italian picture with relatively little literature about OFE, we have investigated the main internal and external factors that could drive its future development in Italy. There is a potentially large path open for agronomic research in adopting or more explicitly considering OFE in Italy. The current scenario represented by European funding for research in agriculture could provide momentum to move towards OFE, even though an adaptation of new methodologies developed by other countries where OFE represents a consolidated approach to produce co-innovation. This will require researchers to explore and adapt new research methodologies beyond the researchers' comfort zone, to be more flexible to properly exploit the lively cross-talk happening in participatory approaches and to extend the boundaries of the

field experiments from the plot scale in experimental stations to the farm scale thus increasing the impact of agronomy research in shaping the farming systems of the future.

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