Selecting the appropriate methodology for organic on-farm cultivar trials

A practical guide for researchers and facilitators

LIVESEED

www.liveseed.eu

Contents

This technical guide was produced within the LIVESEED project, which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 727230 and by the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract number 17.00090.

Editors

Frederic Rey and Emma Flipon (ITAB)

Authors

Pierre Rivière (for ITAB)

Isabelle Goldringer (INRAE)

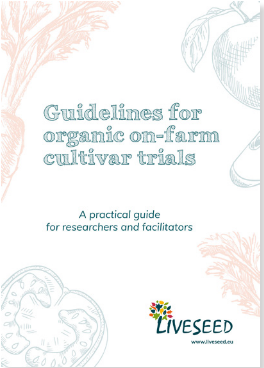
Frederic Rey (ITAB)

June 2021

itab

l'Institut de l'agriculture et de l'alimentation biologiques

Introduction



This technical guide complements the LIVESEED “Guidelines for organic on-farm cultivar trials”. It can be considered an add-on which deepens the “experimental design” aspects treated there. The reader should therefore be familiar with the guidelines before approaching this document.

The indications contained in this booklet are intended to support the selection of the most appropriate methodology for on-farm trials, based on specific objectives and constraints.
In the first part of the document, the four key aspects of participatory on-farm cultivar trials for the organic sector as presented in the main guidelines are briefly recalled. At its heart, this guide describes how to choose an experimental design among those available, and indicates which statistical analyses work best under each. To further aid the choice, two decision trees are proposed and related statistical methods discussed.

Setting up and optimising organic on-farm cultivar trials

Increased testing efforts for organic varieties call for a flexible, participatory, decentralized and low-cost structure, which builds on the capacities of farmers and food chain actors to meet a wide range of needs at different scales.

The methodology tackles four key aspects of participatory on-farm trials described in the figure below (Figure 1), and offers a strategy for working through them.

The frugal strategy proposed within the LIVESEED project for setting up and optimising cultivar testing networks for organic farming can be divided into three steps: Defining the objective(s) ⇨ Identifying the constraints ⇨ Applying a specific methodology (Rey and al. [2021]).

Define objectives ▶ Identify constraints ▶ Apply an appropriate methodology ▶

Defining objectives is a classical step in the breeding process. Here, the objective setting exercise keeps in mind elements specific to the on-farm setting such as G × E interactions, the need for sustainable biodiversity management, the participatory and multi-actor nature of research and evaluation networks. Once the objectives have been defined, a second step is to **identify the constraints,** which are also specific to the on-farm contexts (most existing protocols and procedures are designed for research stations and are not suitable for on-farm trials). The constraints will shape the properties of the cultivar testing model in several aspects (Figure 1 and Table 1).

In any case, the **animation and coordination of the network** are very important and constitute the core of the methodology. A cultivar testing network is generally organized around activities such as exchanging and capitalizing knowledge and information, prospecting, conserving, sourcing and/or distributing seed, conducting field experiments, disseminating results, managing equipment, infrastructure, material, etc. These activities require dedicated facilitation and coordination in order to be carried out by the members of the network. Key factors capable of influencing animation and coordination are the size of the network, the level of participation, the use of a multi-stakeholder approach, the development of common will and trust, the possibility of organizing regular physical meetings and of taking shared decisions about digitisation and ownership of data. Ideally, facilitators should possess a set of both soft and technical skills, in order to effectively promote participation and collective intelligence.

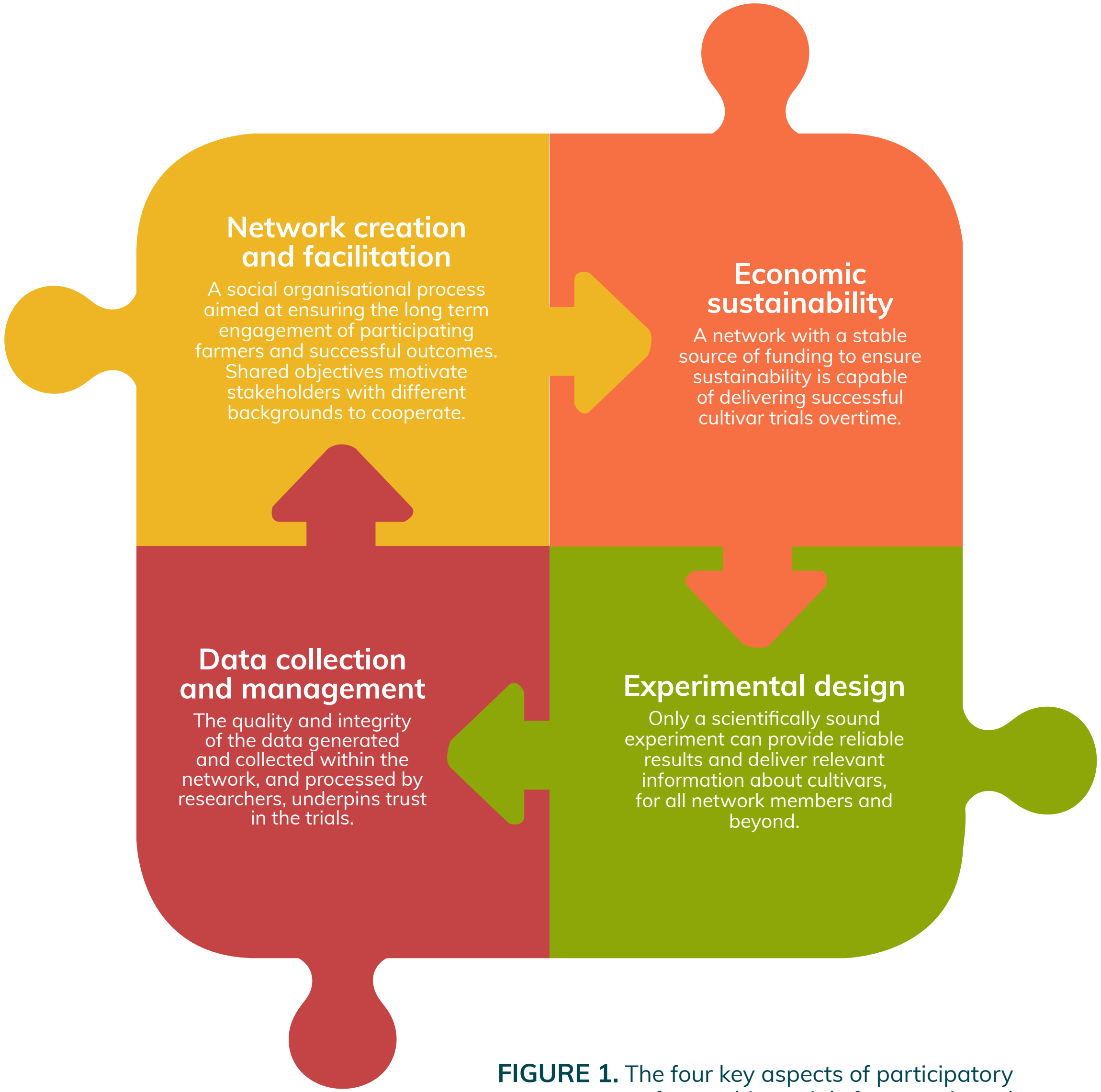


FIGURE 1. The four key aspects of participatory on-farm cultivar trials for organic and low input systems (de Buck and al. [2021])

Once the trial objectives are well defined, **the experimental aspects** can be planned. Possible constraints can emerge, such as:

- Constraints related to the experiment's design: seed sourcing methods, number of varieties, availability of seed, labour and equipment, number of plots per location, plot size, number of locations, number of varieties replicated, number of years.

- Constraints on data collection and management, related to the following questions: What kind of data am I able to produce? Can we trust this data? Several variables can be measured (Figure 2), generating different types of data such as text, rank, score, or quantitative data. Decisions about who will measure the variables and following which protocols are also important.

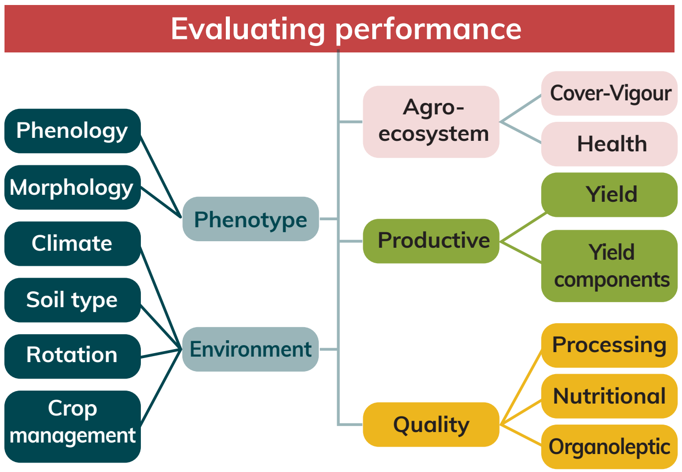


FIGURE 2. Different aspects of trait and environment evaluation (Costanzo [2019])

TABLE 1. Some pros and cons of staffing choices for the facilitators' role (de Buck and al. [2021])

	General objectives	Constraints	Methods
Network facilitation and coordination	• Ensure active participation and achievement of agreed objectives	• Size of the network • Coordination burden • Communication skills and tools	• Participatory approaches • Facilitation skills and tools
Economic sustainability	• Self-sufficiency • Value creation • Viability in the long term	• Fixed costs • Labour costs	• Public support • User subscription models • Value-chain collaborations • Hybrid models
Experimental design	• Balance reduction in cost and effort with robustness and reliability of results	• Resources and information, farm size, machinery and resources	• A decision tree of experimental designs and analytical packages targeted to different contexts and constraints
Data quality management	• Relevance • Usability • Accessibility of the information	• Decentralised on farm collection vs number of research variables • Balance between farm-specific and common information	• Protocols for different data types, documentation, data storage, data ownership and governance

More information on network facilitation aspects and the possible related constraints can be found in the LIVESEED project's deliverable D 2.3. (Rey and al. [2021]).

STEPS TO SET UP AN EVALUATION TRIAL

Regardless of the methods and designs chosen, the following steps are always needed to set up an evaluation trial:

1. **Co-constructing the project:** a workshop should be organized before sowing to set the objectives, protocols, measures, calendar, finance, respective roles, etc.

2. **Setting up the experiment:** trials are done on farms and may need specific material. A dedicated logistical arrangement is needed for providing each farm with seeds, and for sowing, harvesting, storing. The easiest option logistically is that farmers use their own equipment, carefully planning for the additional requirements of the trial.

3. **Taking the measurements:** this step is carried out on-farm by farmers, technicians, or both. Specific equipment may be needed to take the measures. All farmers/technicians should follow an appropriate and common protocol. In addition, phone calls or visits among farmers and technical staff may be useful to guide farmers in taking the measurements, at least in the beginning.

4. **Data management:** the facilitators or the research team take care of this. Retrieving and recording the data can be done on paper or directly through digital tools. Different databases are available to manage data coming from on-farm trials, each of them responding to different objectives.

For example:
- SHiNeMaS
  * https://sourcesup.renater.fr/projects/shinemas/
  * De Oliveira and al [2020]
- ClimMob https://climmob.net/
- SeedLinked https://www.seedlinked.com/

The two last databases are not on open-source software, meaning that the organisations willing to use it are dependent on the team that manages the software. As of today, they are free of charge, but this may change in the future (as mentioned in the terms of use).
Soil or climate data from public databases (such as :
- *European Soil Database & soil properties* for soil https://esdac.jrc.ec.europa.eu/resource-type/european-soil-database-soil-properties
- and *the Climate Data Store* for climate https://cds.climate.copernicus.eu/#!/home)

can be integrated in these systems.

5. **Analysing the data:** this is performed by the facilitators or the research team. R packages are available to this end, which are free and open-source. Note than some packages such as PPBstats (Riviere and al. [2020]) are still under development.

6. **Discussing the results:** the facilitator organises a meeting with all actors involved, to present, discuss and validate the results. It is important to identify both negative and positive aspects related to any given method.

Selecting the appropriate methodology for on-farm cultivar trials

Once the objectives and constraints are known, a suitable methodology can be defined. By focusing on trials for evaluating agronomic traits, we propose the following decision trees to devise the best suited experimental designs in the case of two different objectives:

- **To compare several varieties at farm level** within a network of farms (Decision tree 1, page 8). **This objective focuses on varieties' local adaptation at farm scale.** It may be the objective of choice among farmers involved in participatory plant breeding programmes or willing to assess which variety best perform on each farm.

- **To compare several varieties at network level** (Decision tree 2, page 10). This approach focuses on broader scales such as regions or pedo-climatic zones. It may be of interest to stakeholders (farmers, network facilitators, seed companies, cooperatives) wishing **to find varieties with broader adaptation through participatory varietal evaluation.**

Each tree is divided into 5 decision "branches":

- The number of locations within the network;
- The experimental design on the farm(s);
- Measures and protocols;
- The statistical model;
- References where the method is used.

Each tree is followed by a table which provides additional details on: the results that can be obtained by using the methods and designs described in the tree, the human resources required (clarifying for instance what can be done by farmers, technicians or researchers) and the pros and cons of each option.

NB:

- The level of detail required to discuss each design cannot be exhaustive in this guide: the reader is encouraged to delve further in the technical aspects through the references available in the resources section.
- The navigation within the tree is related to the objectives and constraints highlighted in the previous section.
- Please note that each branch of the tree is taken from a reference mentioned here after. The trees are not exhaustive and do not represent all the situations that may occur: their objective is to give insight on which methods can be applied depending on a number of possible constraints which may occur within a network of farms.

Objective: compare several varieties at farm level within a network of farms[1]

Decision tree 1

The first two steps in the process are dependent on **network size** (1) and **number of varieties** (2). These two factors determine which **experimental design** (3) is best suited for the trial. Depending on the trial's objectives (what kind of output data and information are desired) and constraints (how much data can be collected and by whom), a decision needs to be made in relation to **data collection and protocols** (4). Finally, for each experimental design, one or more statistical analyses will provide the desired results (5).

1 – Number of locations in the network

- Minimum 20 locations in the network. The more locations the better. Replication in time can compensate replication in space.
- Minimum 1 location on the network.

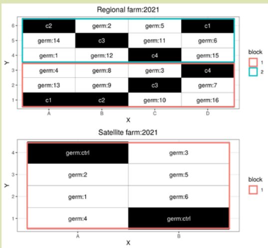
2 – Number of varieties

- many varieties (minimum 20 locations)
- few varieties (minimum 1 location) → fully replicated block design
- few varieties (minimum 1 location) → row column design

3 – Experimental design

REGIONAL/SATELLITE FARMS DESIGN

- 2 varieties or more per location.
- Suitable to evaluate lots of varieties.
- No need to share the same control on all locations.
- The farmer chooses the varieties on his farm.
- The number of varieties can vary between locations. The more the varieties in the network, the better.
- 1 variety replicated within location.
- The farmers choose the variety to replicate.



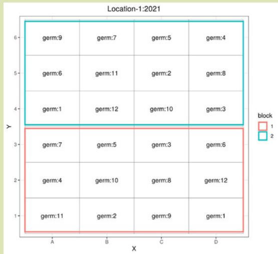
Regional farms receive several varieties in two or more blocks with some varieties replicated in each block.

Satellite farms have a single block and only one variety is replicated twice.

example performed by PPBstats (Riviere and al. [2020]).

FULLY REPLICATED BLOCK DESIGN

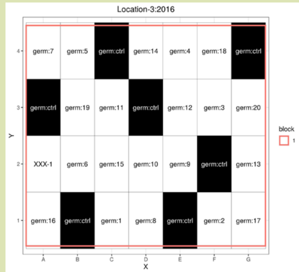
- All varieties replicated 2 or 3 times.
- Suitable if there are not too many varieties to evaluate.



example performed by PPBstats (Riviere and al. [2020]).

ROW COLUMN DESIGN

- 1 control variety replicated in row and column to capture as much of the variability as possible.
- All other varieties are sown once.
- Suitable if there are not too many varieties to evaluate.



example performed by PPBstats (Riviere and al. [2020]).

4 – Measures and protocols

- Regional/satellite farms design:
  - Quantitative measures
  - – scores from 1 to 5 or 1 to 9
  - – measures of quantitative traits such as yield or protein content
- Fully replicated block design:
  - Quantitative measures
  - – measures of quantitative traits such as yield or protein content
- Row column design:
  - Quantitative measures
  - – measures of quantitative traits such as yield or protein content

5 – Statistical model

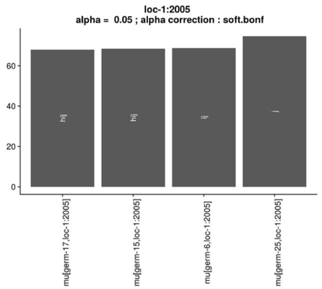
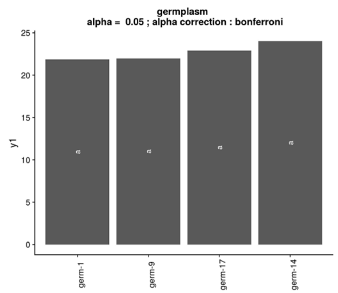
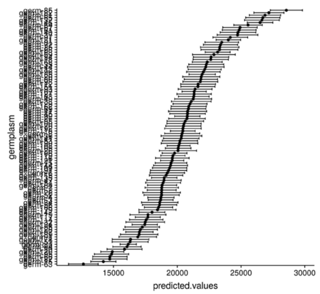
- Regional/satellite farms design: Bayes hierarchical intra-location model. The model assumes that each intra-location variance is taken from a common distribution gathering all intra-location variances of the network.
- Fully replicated block design: ANOVA. The model is a classic ANOVA.
- Row column design: Spatial analysis. The model captures the variation by replicating the control over the trial.

References

- Regional/satellite farms design:
  - Riviere and al. [2015]
  - van Franck and al. [2019]
  - Riviere and al. [2020]
- Fully replicated block design:
  - Riviere and al. [2020]
- Row column design:
  - Rodriguez-Alvarez [2017]
  - Riviere and al. [2020]

1. A location is a combinaison of a farm and a year

Details on the statistical methods of Decision tree 1

Methods	Results obtained	Staff	Pros	Cons
Bayes intra-location model	• Group(s) of significant differences between varieties. The varieties that belong to the same group are not significantly different.  example performed by PPBstats (Riviere and al. [2020]).	• **Set up the experiments:** On farm trials easy to set up by the farmer. • **Take the measures:** Variables that are measured by assigning a score on a predefined scale can be taken by farmers. Quantitative measures can be taken by farmers, technicians or both.	• Simple design for on-farm settings. • Large number of varieties evaluated. • Few seeds needed. • Software available to run the analysis: R package PPBstats https://priviere.github.io/PPBstats_web_site/ • As each farmer chooses the varieties, it is possible to use the design to answer several research questions based on farmers' objectives: varieties' response to selection, adaptation, mixtures' evolution, etc.	• Quantitative variables may be difficult to measure accurately: a standard protocol is needed as well as specific equipment.
ANOVA	• Groups of significant differences between effects of varieties. The varieties that belong to the same group are not significantly different.  examples performed by PPBstats (Riviere and al. [2020]). • Groups of parameters based on several variables per varieties. Varieties that share a similar behaviour for several variables are in the same group. 	• **Set up the experiment:** Trials on-farm can be difficult to set up by the farmer alone. Technicians' help may be required. • **Take the measures:** Quantitative measures can be taken by farmers, technicians or both.	• Software available to run the analysis: R package PPBstats https://priviere.github.io/PPBstats_web_site/	• It may be difficult to set up an on-farm trial if many varieties are evaluated. • All varieties are replicated, which requires a lot of space. • Quantitative variables may be difficult to measure: protocol calibration is needed as well as specific equipment.
Spatial analysis	• Estimation of variety effect (BLUPs) and confidence interval. The varieties that share a common confidence interval are not significantly different.  examples performed by PPBstats (Riviere and al. [2020]). • Groups of parameters based on several variables per varieties. Varieties that share a similar behaviour for several variables are in the same group. 	• **Set up the experiment:** Trials on-farm can be difficult to set up by the farmer alone. Technicians' help may be required. • **Take the measures:** Quantitative measures can be done by farmers, technicians or both.	• The space available for the trial is optimized as few controls are needed and the other varieties are present only once. • Software available to run the analysis: R package SpATS (https://cran.r-project.org/web/packages/SpATS/index.html) and PPBstats (https://priviere.github.io/PPBstats_web_site/).	• It may be difficult to establish an on-farm trial if many varieties are evaluated. • Quantitative variables may be difficult to measure accurately: a standard protocol is needed as well as specific equipment.

Decision tree 2

Objective: compare several varieties at network level

Like for decision tree 1, the first two steps in the process are dependent on **network size** (1) and **number of varieties** (2). These two factors determine which **experimental design** (3) is best suited for the trial. Depending on the trial's objectives (what kind of output data and information are desired) and constraints (how much data can be collected and by whom), a decision needs to be made in relation to **data collection and protocols** (4 - see the following chapter). Finally, for each experimental design, one or more statistical analyses will provide the desired results (5).

1 Number of locations in the network

2 (number of varieties)

3 Experimental design

4 Measures and protocols

5 Statistical model

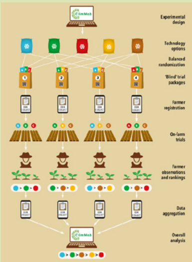
References

Minimum 100 locations in the network. The more locations the better.

few varieties

TRIADIC DESIGN

- One local variety at all locations.
- No need to share the same control on all locations.
- 3 varieties or more per location.
- Suitable if there are not too many varieties to evaluate (12 varieties in the example of van Etten and al. [2019]).
- The farmer cannot choose the varieties.
- The experimental design is balanced so that all varieties are represented with the same frequency.



Triadic design, van Etten, J. and al. [2020].

Measures and protocols:

- Rank: each farmer indicates for the three variety evaluated on his farm:
  - the best variety, the worst variety (e.g. * varA is the best * varB is the worst)
  - the performance of each variety against the local variety (e.g. * Local is better than varA * Local is better than varB *varC is better than Local
- Climate and soil variable: it can come from:
  – known pedo-climatic area
  – data taken on farm with specific material

Statistical model: Plackett Luce model, which uses rank data and determines subgroups based on pedo-climatic covariates

References:

- van Etten, J. and al. [2019]
- van Etten, J. and al. [2020]
- Heather and al. [2020]

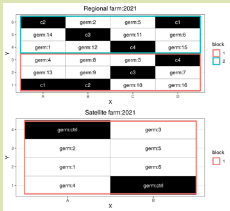
Minimum 20 locations in the network. The more locations the better. Replication in time can compensate replication in space.

many varieties

REGIONAL/SATELLITE FARMS DESIGN

- 2 varieties or more per location.
- Suitable to evaluate many varieties.
- No need to share the same control on all locations.
- The farmer chooses the varieties for his farm.
- The number of varieties can change between locations. The more varieties on the network the better.
- No varieties replicated within location.
- By chance, some popular varieties will be replicated between farms. The more varieties are replicated in different locations, the better the model estimates the results (a control among farms can be chosen). When the same farms are involved for several years in the experiment, the probability of replicating varieties over environments is higher than when having more farms participating for one year only.

Satellite or regional farms design. Regional farms receive more varieties than satellite farms.



example performed by PPBstats (Riviere and al. [2020]).

Measures and protocols:

- Quantitative measures
  – scores from 1 to 5 or 1 to 9
  – measures of quantitative traits such as yield or protein content

Statistical model: Bayes hierarchical G × E model. The model assumes that each effect (G, E and G × E) is taken from a common distribution.

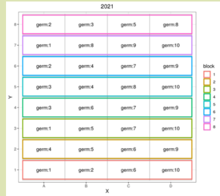
References:

- van Franck and al. [2019]
- Riviere and al. [2020]

Minimum 2 locations in the network.

many varieties: INCOMPLETE BLOCK DESIGN

- No replications within location.
- Some varieties are common to some locations.
- Suitable to evaluate lots of varieties.
- Blocks of varieties are independent units and can be allocated to any location.



example performed by PPBstats (Riviere and al. [2020]).

Measures and protocols:

- Quantitative measures
  – measures of quantitative traits such as yield or protein content

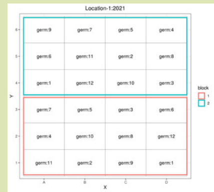
Statistical model: ANOVA or mixed model.

References:

- Zystro and al. [2018]
- Mandal [2019]
- Ceccarelli [2012]

few varieties: FULLY REPLICATED BLOCK DESIGN

- All varieties replicated 2 or 3 times in each location.
- Suitable if there are not too many varieties to evaluate.
- All locations have the same varieties.



example performed by PPBstats (Riviere and al. [2020]).

Measures and protocols:

- Quantitative measures
  – measures of quantitative traits such as yield or protein content

Statistical models:

GGE. The model is divided in two steps: an ANOVA followed by a PCA on interaction plus genetic (G + G × E) effects matrix.

References:

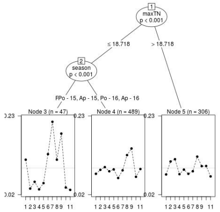
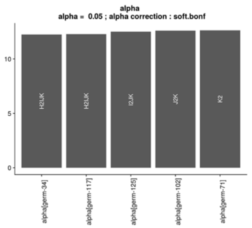
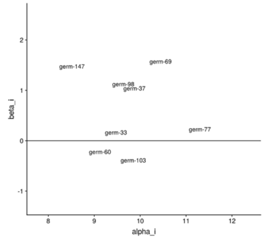
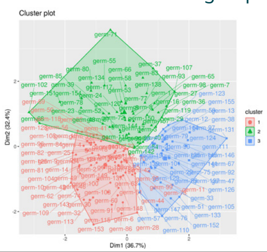
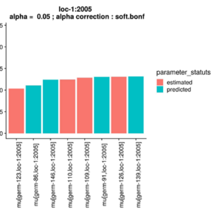
- Yan and al. [2007]
- Gauch [2006]
- Riviere and al. [2020]

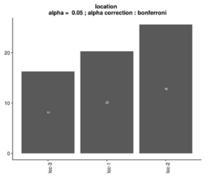
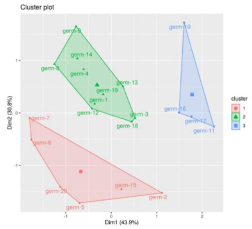
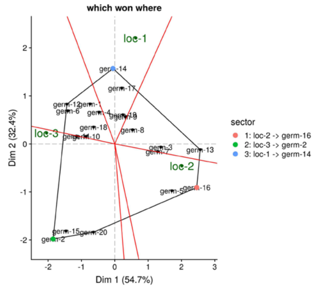
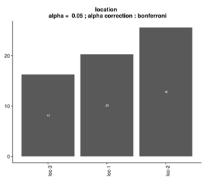
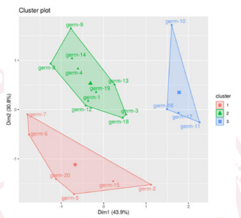
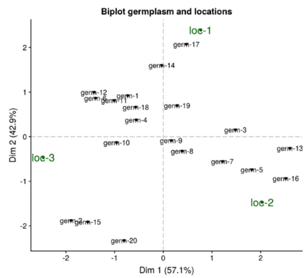
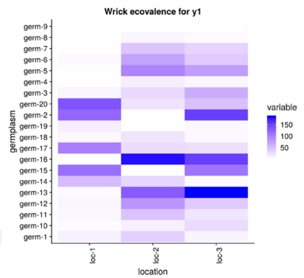
AMMI. The Additive Main effects and Multiplicative Interaction (AMMI) model is divided in two steps: an ANOVA followed by a PCA on a GxE interaction matrix.

References:

- Gauch [2006]
- Goldringer and al. [2020]
- Riviere and al. [2020]

Details on the statistical methods of Decision tree 2

Methods	Results obtained	Staff	Pros	Cons
Triadic	• Rank of varieties divided into subgroups based on pedo-climatic area.  example performed by PlackettLuce (Heather and al. [2020])	• **Set up the experiments:** On farm trials are easy to set up by the farmer. • **Take the measures:** ranking data are taken by farmers. Pedo-climatic data are managed by the facilitator.	• Simple design for on-farm settings • Easy protocol to record quality rank data. It can be done by gardeners or farmers even if not used to taking measures. Software available to run the analysis: R package PlackettLuce: https://hturner.github.io/PlackettLuce/index.html	• Great quantity of seeds needed. • Few varieties evaluated. • Many locations needed. • Access to pedo-climatic data may be difficult. • The farmers cannot choose the varieties.
Bayesian G × E	• Groups of significant differences between effects: variety, location, sensitivity to interactions. Varieties that belong to the same group are not significantly different.  • Biplot variety effect vs sensitivity effect. A variety with high genetic effect and low sensitivity to interaction can be a good candidate to test.  • Groups of parameters based on several variables: variety, location, sensitivity to interaction. Locations that share similar behaviours for several variables are in the same group.  • "Predict the past". The potential performance that each variety may have at each location can be estimated/ inferred.  examples performed by PPBstats (Riviere and al. [2020])	• **Set up the experiment:** on-farm trials are easy to set up by the farmer. It is not too much work and the amount of seeds required to replicate some varieties on-farm and use both Bayesian hierarchical G × E and intra-location models are not excessive. A common control between some farms will enhance the accuracy of the Bayesian hierarchical G × E model and also serve as a reference for farmers when they visit other farms or examine the results of other trials. It can be done for example on regional farms. Location can be set as a combination of farm and year: a few years may be necessary until sufficient data is accumulated for running the models. As some varieties are evaluated for several years on a given farm, the number of varieties in common between locations will increase. • **Take the measures:** Variables that are measured by assigning a score on a predefined scale can be taken by farmers. Quantiative measures can be taken by farmers, technicians or both.	• Simple design on farm. • Large number of varieties evaluated. • Few seeds needed. • Software available to run the analysis: R package PPBstats https://priviere.github.io/PPBstats_web_site/	• Quantitative variable may be difficult to measure accurately: standardized protocols are needed as well as specific equipment.
Incomplete block design	• Groups of significant differences between variety effects. • Groups of variety parameters based on several variables.	• **Set up the experiment:** on-farm trials can be difficult to set up by the farmer alone. Technicians' help may be required. • **Take the measures:** Quantitative measures can be taken by farmers, technicians or both.	• Simple design for on-farm settings. • Each location has to choose one or several pre-designed variety blocks. Therefore, the experiment can be handled by several locations that cannot receive a high number of plots. • No need for replication on farms. • Software available to run the analysis: - ibd: https://cran.r-project.org/web/packages/ibd/index.html - lme4: https://cran.r-project.org/web/packages/lme4/index.html - lmerTest: https://cran.r-project.org/web/packages/lmerTest/index.html	• It may be difficult to establish an on-farm trial if many varieties are evaluated. • Quantitative variables may be difficult to measure accurately: a standard protocol is needed as well as specific equipment.

Methods	Results obtained	Staff	Pros	Cons
GGE	• Groups of significant differences between effects: variety, location. The locations that belong to the same group are not significantly different.  • Groups of parameters based on several variables: variety, location. Varieties that share a similar behaviour for several variables are in the same group.  • «Which won where» (Which variety did best at which location): based on a PCA on the (G + G × E) matrix, one can tell which variety performed best in which location.  • Other results can be obtained (Ceccarelli [2012]; Riviere and al. [2020]): – ecovalence on (G + G × E) matrix – biplot of the interaction matrix – mean vs stability plot – discrimination vs. representativeness plot examples performed by PPBstats (Riviere and al. [2020])	• **Set up the experiments:** on-farm trials can be difficult to set up by the farmer. Technicians' help may be required. • **Take the measures:** Quantitative measures can be taken by farmers, technicians or both.	• Fine analysis of a (G+G×E) matrix structure. • Suitable to find varieties for mega-environments. • Software available to run the analysis: R package PPBstats https://priviere.github.io/PPBstats_web_site/	• It may be difficult to establish on-farm trials if many varieties are evaluated. • All farmers must have the same varieties. • All varieties are replicated, which takes lots of space. • Quantitative variable may be difficult to measure accurately: a standard protocol is needed as well as specific equipment.
AMMI	• Groups of significant differences between effects: variety, location, sensitivity to interactions. Varieties that belong to the same group are not significantly different.  • Groups of parameters based on several variables: variety, location, sensitivity to interaction. Locations that share similar behaviours for several variables are in the same group.  • Biplot to study interaction (G × E) structure based on a PCA on the (G × E) matrix.  • Ecovalence: the higher the (G × E) interaction effect, the higher the ecovalence.  examples performed by PPBstats (Riviere and al. [2020])	• **Set up the experiment:** on-farm trials can be difficult to set up by the farmer. Technicians' help may be required. • **Take the measures:** Quantitative measures can be taken by farmers, technicians or both.	• Fine analysis of the (G × E) matrix structure. • Software available to run the analysis: R package PPBstats https://priviere.github.io/PPBstats_web_site/	• It may be difficult to establish on-farm trials if many varieties are evaluated. • All farmers must have the same varieties. • All varieties are replicated, which takes lots of space. • Quantitative variables may be difficult to measure accurately: a standard protocol is needed as well as specific equipment.

References

S. Ceccarelli. Plant breeding with farmers a technical manual. Technical report,
ICARDA, 2012.

A. Costanzo. A guide to participatory experimentation with underutilised genetic resources. booklet #2. diversifood. 2019.

A. de Buck and al. Guidelines for organic on-farm cultivar trials. A practical guide for researchers and facilitators., 2021. Booklet. European project LIVESEED.

Y. De Oliveira et al. Shinemas: a web tool dedicated to seed lots history, phenotyping and cultural practices. Plant Methods, 16(98), 2020.

H. Gauch. Statistical analysis of yield trials by AMMI and GGE. Crop Sci, 46 (4):148-1500, 2006.

I. Goldringer et al. Agronomic evaluation of bread wheat varieties from participatory breeding: A combination of performance and robustness. Sustainability, 12(1), 2020. ISSN 2071-1050. doi: 10.3390/su12010128.
https://www.mdpi.com/2071-1050/12/1/128.

L. Heather et al. Modelling rankings in R: The PlackettLuce package. Computational Statistics, 35:1027{1057, 2020. doi: 10.1007/s00180-020-00959-3.
https://doi.org/10.1007/s00180-020-00959-3.

B. Mandal. ibd: Incomplete Block Designs, 2019. https://CRAN.
R-project.org/package=ibd. R package version 1.5.

F. Rey et al. Frugal, multi-actor and decentralised cultivar evaluation models for organic agriculture: methods, tools and guidelines, 2021. Deliverable number D2.3. European project LIVESEED.

P. Riviere et al. Hierarchical Bayesian Modeling for Flexible Experiments in Decentralized Participatory Plant Breeding. Crop Science, 55(3), 2015.

P. Riviere et al. PPBstats: A R package to perform analysis found within PPB programmes. Development version 0.26, 2020.
https://github.com/priviere/PPBstats_web_site.

M. Rodriguez-Alvarez. Correcting for spatial heterogeneity in plant breeding experiments with p-splines. Spatial Statistics, 23:52 { 71, 2017.
https://doi.org/10.1016/j.spasta.2017.10.003.

J. van Etten et al. First experiences with a novel farmer citizen science approach: crowd-sourcing participatory variety selection through on-farm triadic comparisons of technologies (tricot). Experimental Agriculture, 55 (S1):275296, 2019. doi: 10.1017/S0014479716000739.

van Etten, J and al. The tricot approach. Guide for large-scale participatory experiments. Alliance of Bioversity International and CIAT., Roma Italy, 2020.

G. van Frank et al. Influence of experimental design on decentralized, on-farm evaluation of populations: a simulation study. Euphytica, 215(126), 2019.

W. Yan, M. Kang, B. Ma, S. Woods, and P. Cornelius. GGE biplot vs. AMMI analysis of genotype-by-environment data. Crop Science, 47:643{355, 2007.

J. Zystro, M. Colley, and J. Dawson. Alternative Experimental Designs for Plant Breeding, pages 87{117. 12 2018. ISBN 9781119521310. doi: 10.1002/9781119521358.ch3.

Selecting the appropriate methodology for organic on-farm cultivar trials

How to cite this document:

F. Rey, E. Flipon (Eds.); P. Riviere, F. Rey, I. Goldringer (auts), 2021.

Selecting the appropriate methodology for organic on-farm cultivar trials:
a technical guide for researchers and facilitators. LIVESEED project.

ABSTRACT

Increased testing efforts for organic cultivar evaluation has an outstanding potential in enabling the success of organic farming and supporting the agroecological transition. However, current infrastructures are not fit for purpose in most European countries and new models need to be designed to address the needs of a rapidly growing organic sector. From an experimental design and data analysis perspective, the volume of information needed for meaningful organic cultivar testing is often higher and more nuanced than in a conventional setting. Suited **experimental designs for such organic cultivar testing, often on-farm, exist, and this technical guide aims to help** researchers and facilitators to **select the most appropriate to their specific working context.**

This technical guide complements the LIVESEED "Guidelines for organic on-farm cultivar trials". It can be considered an add-on which deepens the "experimental design" aspects treated there. The reader should therefore be familiar with the guidelines before approaching this document.
The indications contained in this booklet are intended to support the selection of the most appropriate methodology for on-farm trials, based on specific objectives and constraints.
In the first part of the document, the four key aspects of participatory on-farm cultivar trials for the organic sector as presented in the main guidelines are briefly recalled. At its heart, this guide describes how to choose an experimental design among those available, and indicates which statistical analyses work best under each. To further aid the choice, two decision trees are proposed and related statistical methods discussed.

LIVESEED