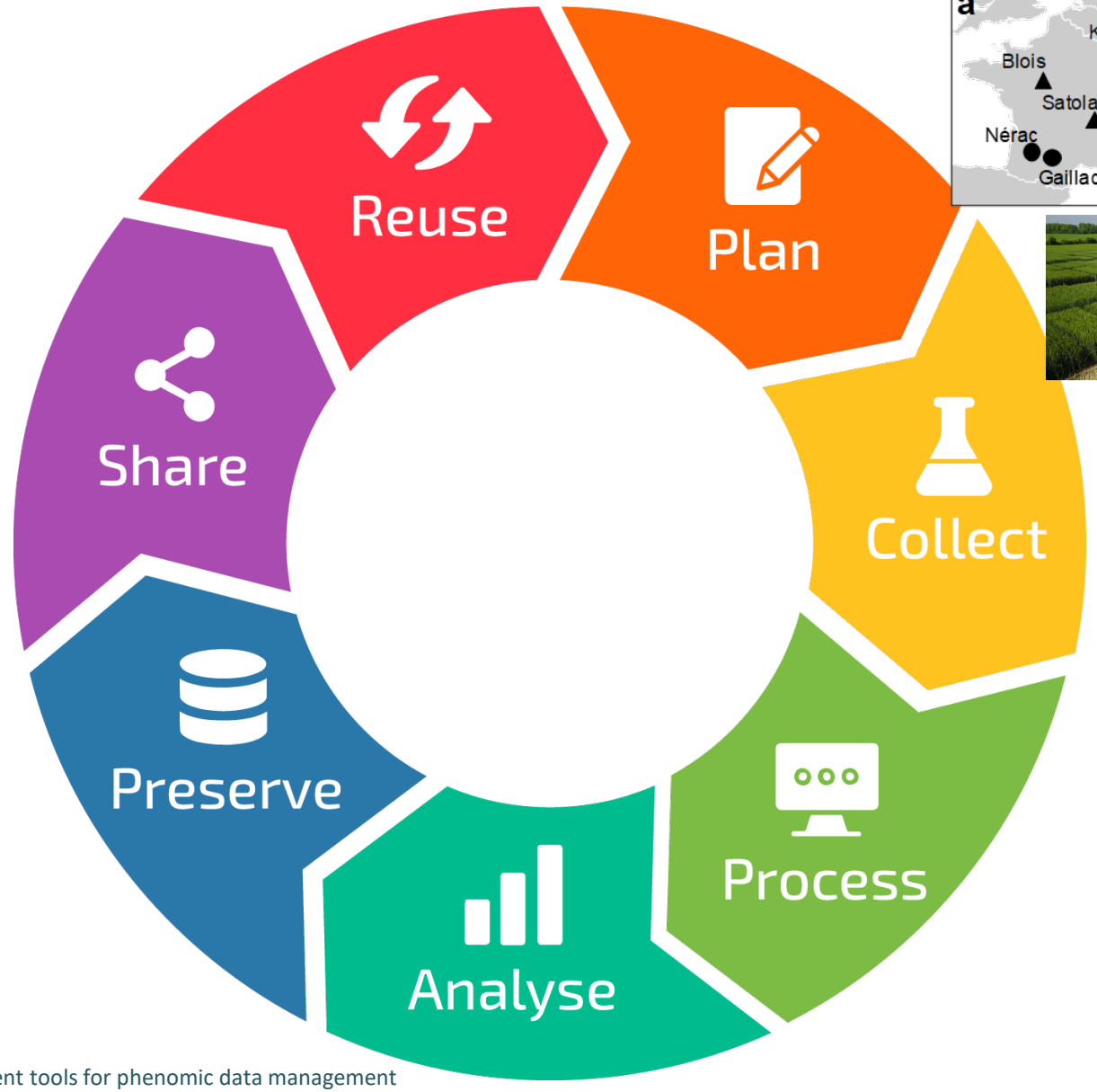
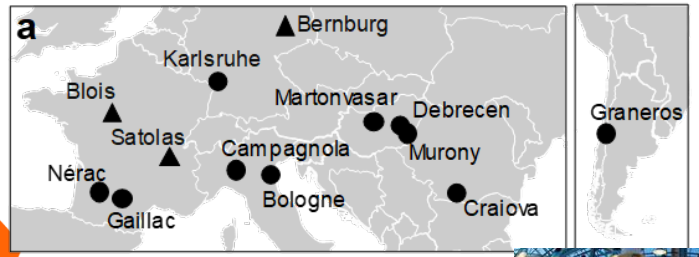
# Data management tools for phenomic data management

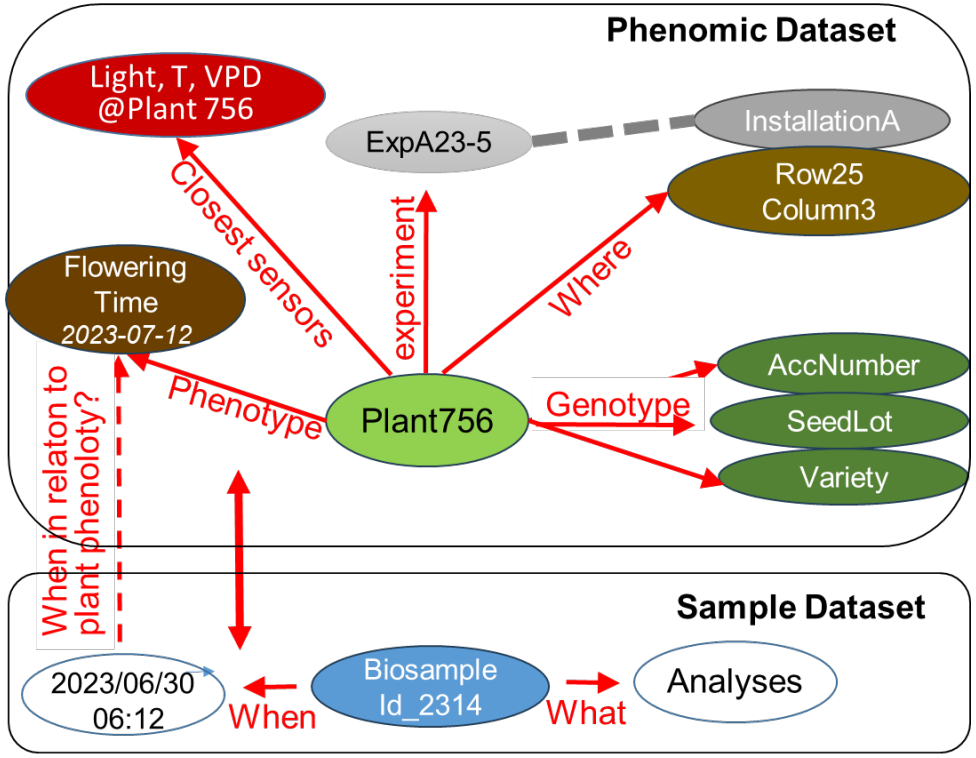
From acquisition to validation, integration and sharing.

# Data lifecycle




# Individual experiments: trace variables, conditions, events, plants, sensors…




PHIS

PHENOME EMPHASIS FRANCE

- Dedicated Information Systems
- Instrumented/complex experiment
- It works (with some difficulties)
- Sample part : implemented by hand
- Allowed organizing datasets for retrieving info

- Simpler datasets
- Little sensors
- Phenology, Yield, …

***Datasets organized for data acquisition → cannot be used for data analysis (way too complex)***

# Individual (or multiple) experiments: genetic analyses

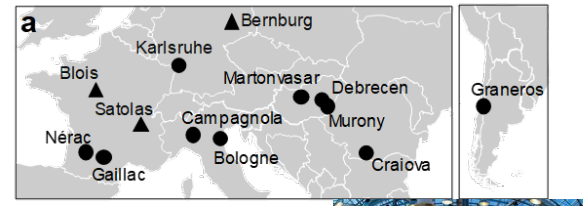
*Short names*

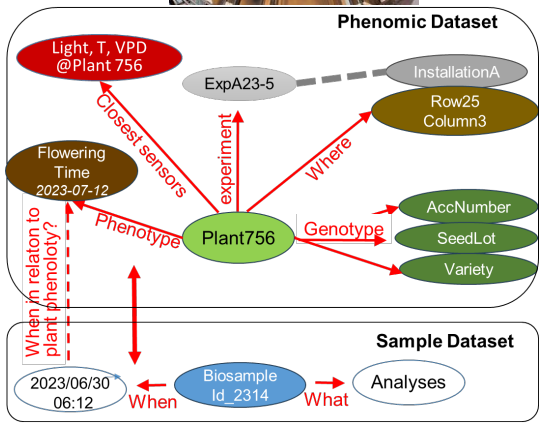
| Variety | Light interception | Water use | rhPAD | Plant_height | Ear_height | silk_length | Leaf_appearance_rate | leaf_number | End_Leaf_ap | ASI |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 20,267 | 101,006 | 0,323 | 176,720 | 75,087 | 227,340 | 0,931 | 16,705 | 50,402 | 0,000 |
| 2 | 18,003 | 105,690 | 0,248 | 164,129 | 76,403 | 188,438 | 0,469 | 15,380 | 47,206 | 2,608 |
| 3 | 18,655 | 106,167 | 0,322 | 201,606 | 92,296 | 244,781 | 0,584 | 15,810 | 49,467 | 0,026 |
| 4 | 20,483 | 114,731 | 0,298 | 212,911 | 100,835 | 157,812 | 0,569 | 14,955 | 42,230 | 2,906 |
| 5 | 19,114 | 100,946 | 0,226 | 174,685 | 83,253 | 190,663 | 0,791 | 14,580 | 45,425 | 0,564 |
| 6 | | | | | | | | | | |

*One figure per variety (necessary for genetic analyses)*

# Data lifecycle

Data publication
Scientific paper

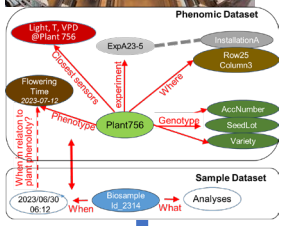



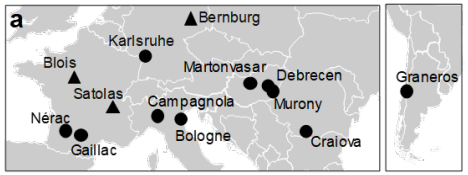




| Variety | Light interception | Water use | rhPAD | Plant_height | Ear_height | silk_length |
|---|---|---|---|---|---|---|
| 1 | 20,267 | 101,006 | 0,323 | 176,720 | 75,087 | 227,340 |
| 2 | 18,003 | 105,690 | 0,248 | 164,129 | 76,403 | 188,438 |
| 3 | 18,655 | 106,167 | 0,322 | 201,606 | 92,296 | 244,781 |
| 4 | 20,483 | 114,731 | 0,298 | 212,911 | 100,835 | 157,812 |
| 5 | 19,114 | 100,946 | 0,226 | 174,685 | 83,253 | 190,663 |
| 6 | | | | | | |

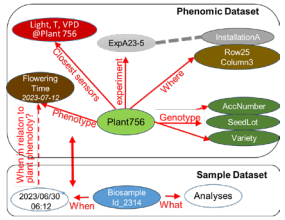
# Data lifecycleS

Data publication
Scientific paper

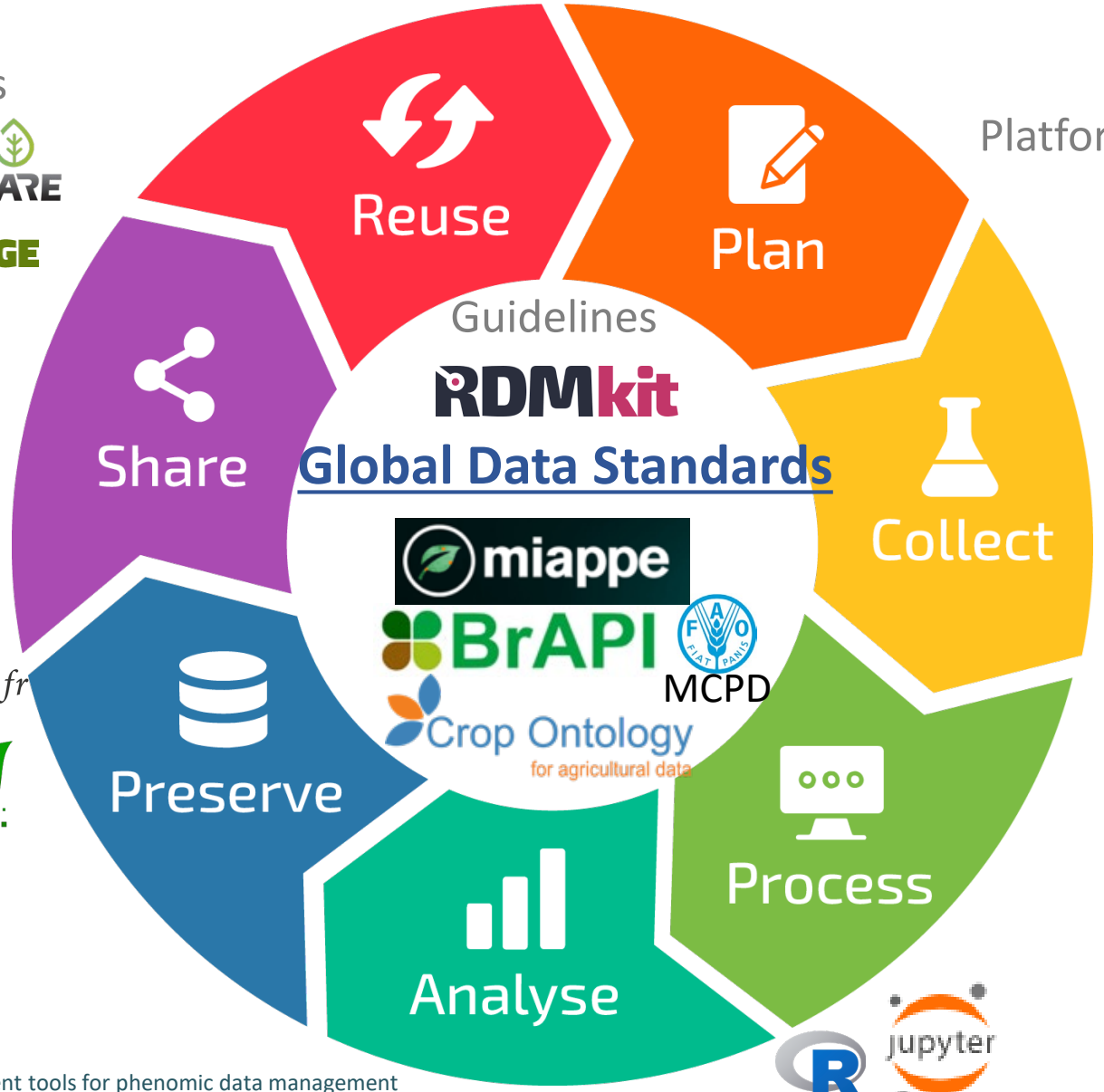

| Variety | Light interception | Water use | rhPAD | Plant_height | Ear_height | silk_length |
|---|---|---|---|---|---|---|
| 1 | 20,267 | 101,006 | 0,323 | 176,720 | 75,087 | 227,340 |
| 2 | 18,003 | 105,690 | 0,248 | 164,129 | 76,403 | 188,438 |
| 3 | 18,655 | 106,167 | 0,322 | 201,606 | 92,296 | 244,781 |
| 4 | 20,483 | 114,731 | 0,298 | 212,911 | 100,835 | 157,812 |
| 5 | 19,114 | 100,946 | 0,226 | 174,685 | 83,253 | 190,663 |
| 6 | | | | | | |




| Variety | Light interception | Water use | rhPAD | Plant_height | Ear_height | silk_length |
|---|---|---|---|---|---|---|
| 1 | 20,267 | 101,006 | 0,323 | 176,720 | 75,087 | 227,340 |
| 2 | 18,003 | 105,690 | 0,248 | 164,129 | 76,403 | 188,438 |
| 3 | 18,655 | 106,167 | 0,322 | 201,606 | 92,296 | 244,781 |
| 4 | 20,483 | 114,731 | 0,298 | 212,911 | 100,835 | 157,812 |
| 5 | 19,114 | 100,946 | 0,226 | 174,685 | 83,253 | 190,663 |
| 6 | | | | | | |

| Variety | Light interception | Water use | rhPAD | Plant_height | Ear_height | silk_length |
|---|---|---|---|---|---|---|
| 1 | 20,267 | 101,006 | 0,323 | 176,720 | 75,087 | 227,340 |
| 2 | 18,003 | 105,690 | 0,248 | 164,129 | 76,403 | 188,438 |
| 3 | 18,655 | 106,167 | 0,322 | 201,606 | 92,296 | 244,781 |
| 4 | 20,483 | 114,731 | 0,298 | 212,911 | 100,835 | 157,812 |
| 5 | 19,114 | 100,946 | 0,226 | 174,685 | 83,253 | 190,663 |
| 6 | | | | | | |

# Data lifecycle




Data portals

FAIDARE

FLORILÈGE

Genesys

Data repositories

The Dataverse Project

recherche.data.gouv.fr

zenodo

EMBL-EBI

PHIS

ECP/GR

eurisco Finding seeds for the future

Platform Information Systems

GRIN-Global

Outil Local de Gestion des Accessions

PHIS

PIPPA

Portable devices, sensors, …

donis

Scripts and Workflows

R

jupyter

# Plant Data standards

## Structure

- Formatting and Organizing
  - Data
  - Dataset description → Metadata
- Data Models, templates
- Phenotyping Variable, Biological Material
- Standards : VCF, GFF, MIAPPE, etc…

*Biologist & Computer scientist* driven

## Technical

- Data integration and sharing
- Interoperability : tools and systems
  - GA4GH
  - Breeding API www.brapi.org
  - *Computer scientist* driven

Persistent Unique Identifiers
Cultivars, Accessions, MCPD
…

## Semantic

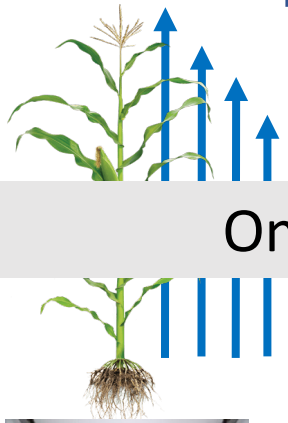
- Description of the data
- Controlled vocabularies: term name and definitions
- Phenotyping Variables (trait+method+scale)
- Ontologies: semantic links between terms
- *Biologist* driven

# Semantic Standard: Ontologies for Phenotype

- Describing traits/features in specific plant species
- Agreeing on trait name is not enough
- Crop Ontology model : Trait + Method + Scale

**Variable identification: Plant height example**

Trait + Method + Unit



M1: Total height

M2: First tassel branch

M3: Last expanded leaf

One trait → 11 phenotyping variables

T1: Plant Height

M5: Highest pixel corresponding to plant

U3: pixel

Slide from L. Cabrera-Bosquet

# Semantic Standard: Ontologies for Phenotype

- Describing traits/features in specific plant species
- Agreeing on trait name is not enough
- Crop Ontology model : Trait + Method + Scale

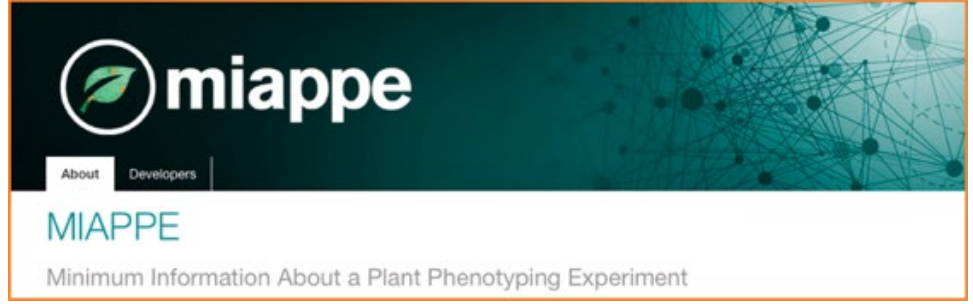
One trait → 11 phenotyping variables

| NameInDataFile | **ALA** | **Tmin** |
|---|---|---|
| TraitEntity | Canopy | Meristem |
| TraitCharacteristic | AverageLeafAngle | MinimumTemperature |
| Unit | Degree | DegC |
| Method | ModelInversion | sensor |
| VariableName | Canopy_AverageLeafAngle_ModelInversion_Degree | Meristem_MinimumTemperature_sensor_DegC |
| MethodDescription | Generated by inverting the radiative transfer model PROSAIL | Minimum temperature recorded via termocouples close to the apex of reference plants |
| PhenologicalStage | Vegetative | NA |

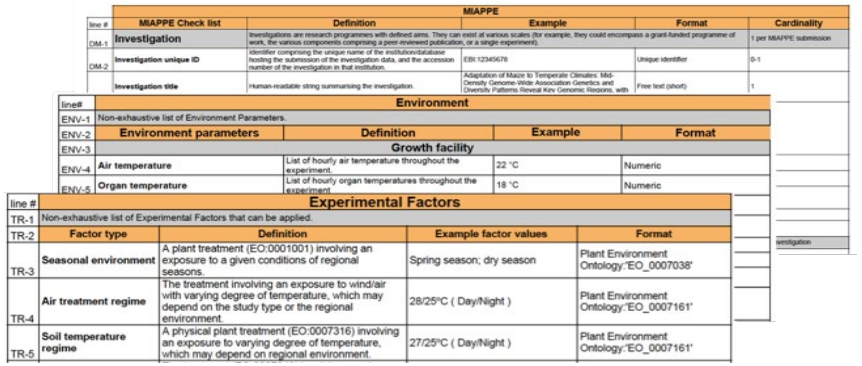
Per Community/Infrastructure/Network Reference Ontologies

# Phenotype Structure Standard

Minimal Information About Plant Phenotyping Experiments




- www.miappe.org
- Crops and woody plants
- Single experiment
- Multilocal multiyear network
- Field
- Greenhouse
- Many stakeholders
  - Elixir, Emphasis, Bioversity CGIAR, North American PPN
- Open Community
  - Request for comments
  - Github Feature requests
  - Mailing lists
  - Meetings & Workgroups



| | MIAPPE | | | |
|---|---|---|---|---|
| line # | MIAPPE Check list | Definition | Example | Format | Cardinality |
| OM-1 | Investigation | Investigations are research programmes with defined aims. They can exist at various scales (for example, they could encompass a grant-funded programme of work, the various components comprising a peer-reviewed publication, or a single experiment). | | | 1 per MIAPPE submission |
| OM-2 | Investigation unique ID | Identifier comprising the unique name of the institution/database hosting the submission of the investigation data, and the accession number of the investigation in that institution. | EBI:12345678 | Unique identifier | 0-1 |
| | Investigation title | Human-readable string summarising the investigation. | Adaptation of Maize to Temperate Climates: Mid-Density Genome-Wide Association Genetics and Diversity Patterns Reveal Key Genomic Regions, with | Free text (short) | 1 |

| line# | Environment | | | |
|---|---|---|---|---|
| ENV-1 | Non-exhaustive list of Environment Parameters. | | | |
| ENV-2 | Environment parameters | Definition | Example | Format |
| ENV-3 | Growth facility | | | |
| ENV-4 | Air temperature | List of hourly air temperature throughout the experiment. | 22 °C | Numeric |
| ENV-5 | Organ temperature | List of hourly organ temperatures throughout the experiment. | 18 °C | Numeric |

| line # | Experimental Factors | | | |
|---|---|---|---|---|
| TR-1 | Non-exhaustive list of Experimental Factors that can be applied. | | | |
| TR-2 | Factor type | Definition | Example factor values | Format |
| TR-3 | Seasonal environment | A plant treatment (EO:0001001) involving an exposure to a given conditions of regional seasons. | Spring season; dry season | Plant Environment Ontology:'EO_0007038' |
| TR-4 | Air treatment regime | The treatment involving an exposure to wind/air with varying degree of temperature, which may depend on the study type or the regional environment. | 28/25°C ( Day/Night ) | Plant Environment Ontology:'EO_0007161' |
| TR-5 | Soil temperature regime | A physical plant treatment (EO:0007316) involving an exposure to varying degree of temperature, which may depend on regional environment. | 27/25°C ( Day/Night ) | Plant Environment Ontology:'EO_0007161' |

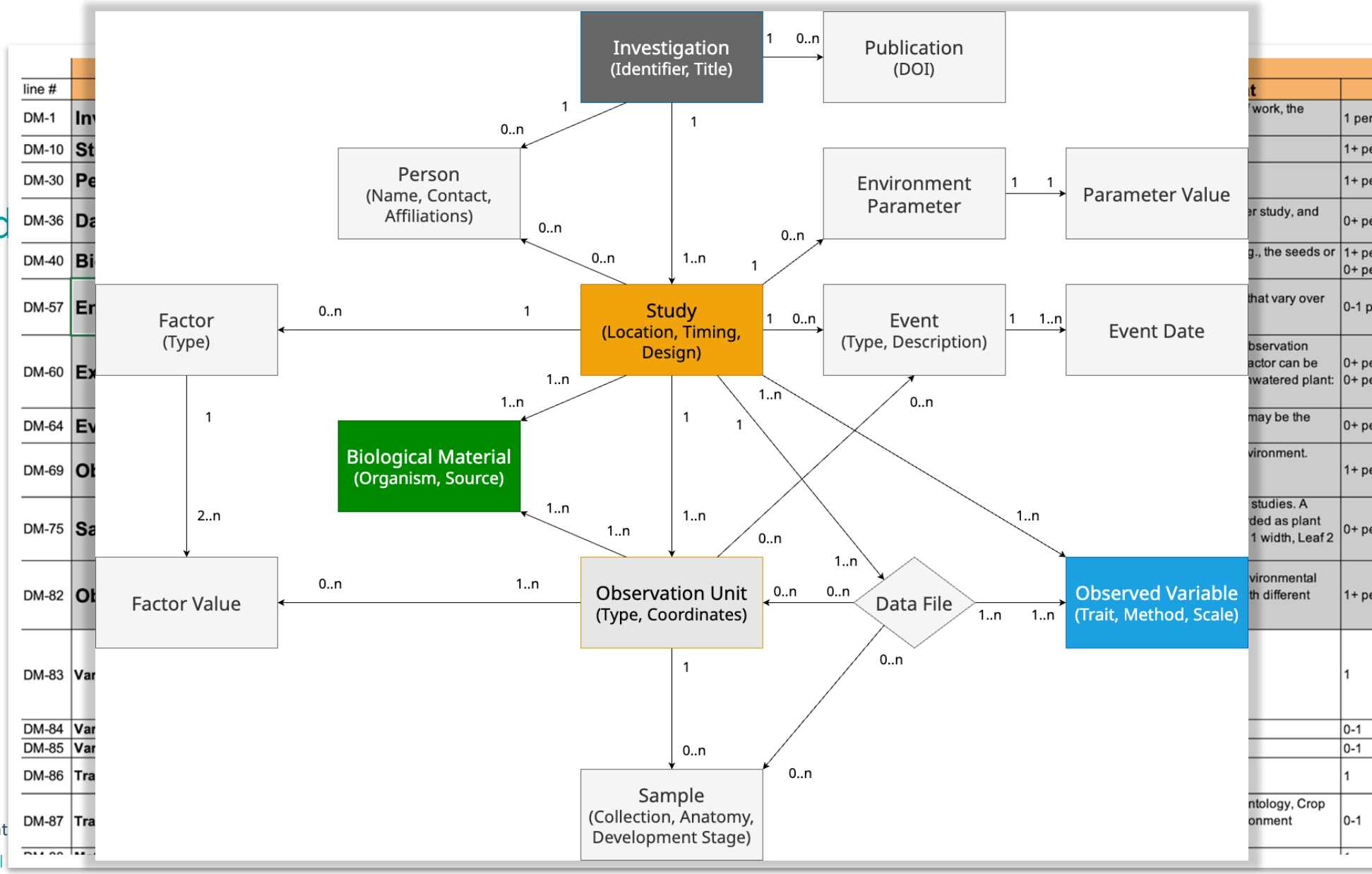
# MIAPPE Specifications

- Specification table
- Sections
- Metadata Fields

| | MIAPPE | | | | |
|---|---|---|---|---|---|
| line # | MIAPPE Check list | Definition | Example | Format | Cardinality |
| DM-1 | **Investigation** | Investigations are research programmes with defined aims. They can exist at various scales (for example, they could encompass a grant-funded programme of work, the various components comprising a peer-reviewed publication, or a single experiment). | | | 1 per MIAPPE submissi |
| DM-10 | **Study** | A study (or experiment) comprises a series of assays (or measurements) of one or more types, undertaken to answer a particular biological question. | | | 1+ per investigation |
| DM-30 | **Person** | A human involved in the investigation or specifically any of its studies. | | | 1+ per investigation / 0+ |
| DM-36 | **Data File** | A file or digital object holding observation data recorded during one or more assays of the study, typically in tabular form. Multiple data files may be provided per study, and each file can include observations for several observation units and several observed variables. | | | 0+ per study |
| DM-40 | **Biological Material** | The biological material being studied (e.g. plants grown from a certain bag or seed, or plants grown in a particular field). The original source of that material (e.g., the seeds or the original plant cloned) is called the material source, which, when held by a material repository, should have its stock identified. | | | 1+ per study;<br>0+ per observation unit |
| DM-57 | **Environment** | Environmental parameters that were kept constant throughout the study and did not change between observation units or assays. Environment characteristics that vary over time, i.e. environmental variables, should be recorded as Observed Variables (see below). | | | 0-1 per study |
| DM-60 | **Experimental Factor** | The object of a study is to ascertain the impact of one or more factors on the biological material. Thus, a factor is, by definition a condition that varies between observation units, which may be biotic (pest, disease interaction) or abiotic (treatment and cultural practice) in nature. Depending on the level of the data, an experimental factor can be either "what is the factor applied to the plant" (i.e. Unwatered), or the "environmental characterisation" (i.e. if no rain on unwatered plant : Drought ; if rain on unwatered plant: Irrigated) | | | 0+ per study;<br>0+ per observation unit |
| DM-64 | **Event** | An event is discrete occurrence at a particular time in the experiment (which can be natural, such as rain, or unnatural, such as planting, watering, etc). Events may be the realization of Factors or parts of Factors, or may be confounding to Factors. Can be applied at the whole study level or to only a subset of observation units. | | | 0+ per study/observatio |
| DM-69 | **Observation Unit** | Observation units are objects that are subject to instances of observation and measurement. An observation unit comprises one or more plants, and/or their environment. There can be pure environment observation units with no plants.<br>Synonym: Experimental unit. | | | 1+ per study |
| DM-75 | **Sample** | A sample is a portion of plant tissue harvested, non-harvested or extracted from an observation unit for the purpose of sub-plant observations and/or molecular studies. A sample must be used when there is a physical sample that needs to be stored and traced. Otherwise, observations made at the sub-plant level should be recorded as plant level observations using the observed variables to characterize the object of the observation (e.g. Berry sugar content, Fruit weight, Grain Protein content, Leaf 1 width, Leaf 2 width, Leaf 2 length). | | | 0+ per observation unit |
| DM-82 | **Observed Variable** | An observed variable describes how a measurement has been made. It typically takes the form of a measured characteristic of the observation unit (plant or environmental trait), associated to the method and unit of measurement. Multiple variables with the same combination of trait, method and scale can be used in association with different plant parts (leaf 1, leaf 2), when this distinction is necessary for observations referring to different parts of the same observation unit. | | | 1+ per study |
| DM-83 | **Variable ID** | Code used to identify the variable in the data file. We recommend using a variable definition from the Crop Ontology where possible. Otherwise, the Crop Ontology naming convention is recommended: <trait abbreviation>_<method abbreviation>_<scale abbreviation>). A variable ID must be unique within a given investigation. | Ant_Cmp_Cday | Unique identifier | 1 |
| DM-84 | **Variable name** | Name of the variable. | Anthesis computed in growing degree days | Free text | 0-1 |
| DM-85 | **Variable accession number** | Accession number of the variable in the Crop Ontology | CO_322:0000794 | Crop Ontology term | 0-1 |
| DM-86 | **Trait** | Name of the (plant or environmental) trait under observation | Anthesis time<br>Reproductive growth time | Free text | 1 |
| DM-87 | **Trait accession number** | Accession number of the trait in a suitable controlled vocabulary (Crop Ontology, Trait Ontology). | CO_322:0000030<br>TO:0000366 | Term from Plant Trait Ontology, Crop Ontology, or XML Environment Ontology | 0-1 |

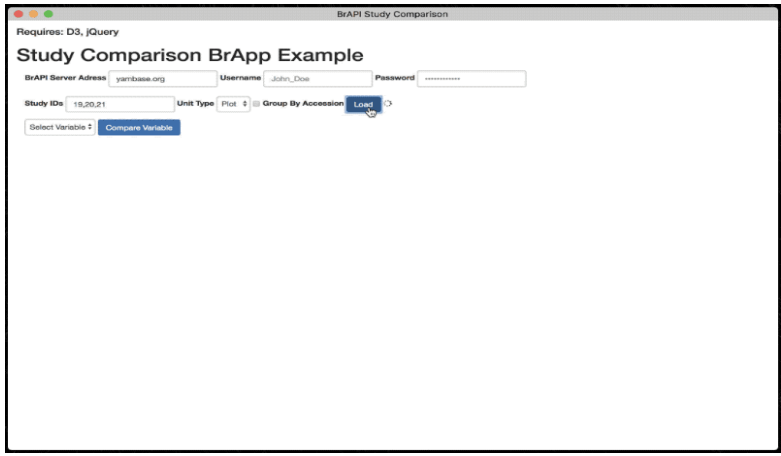
# MIAPPE Specifications

- Specification table
- Sections
- Metadata Fields
- Linked and organized

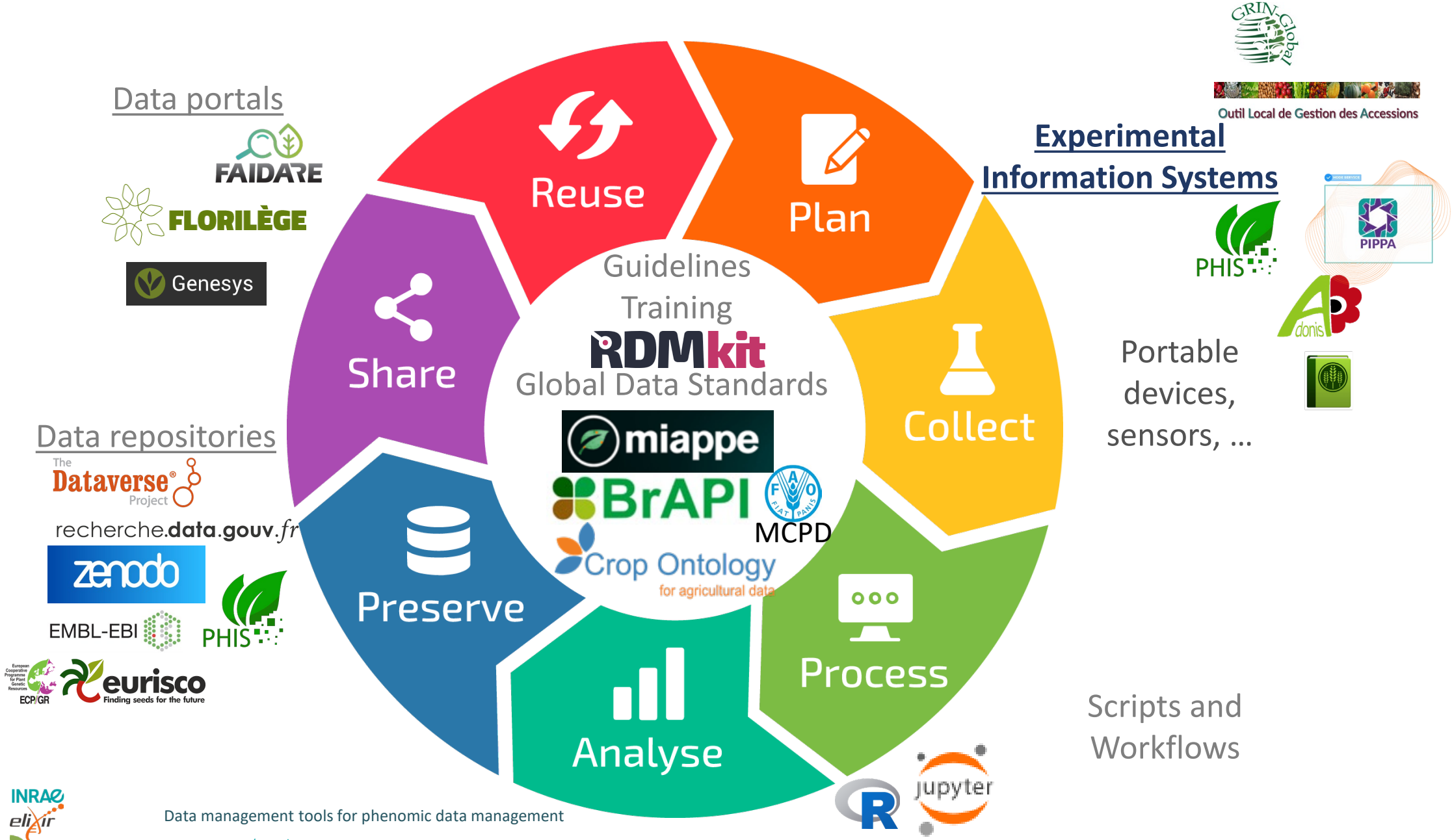


# Phenotype Technical Standard, MIAPPE Implementations

- Databases and data repositories
  - Any BrAPI compliant DB (GnpIS, PHIS, PIPPA, …)
  - Generic data repositories (Dataverse, Zenodo, e!Dale, …)
- File
  - MIAPPE XLSX Templates https://github.com/MIAPPE/MIAPPE/tree/v1.2/Templates
  - Project workflows
  - ISA Tab: data + metadata
  - RO Crate
- Web Services
  - Breeding API
  - International collaboration
  - Standard Open Web Service API
  - Information Exchange, Main target: Breeding
  - ELIXIR, EMPHASIS Excellence in Breeding platform (CGIAR, Peter Selby)
- Ontology, OWL Implementation
  - https://github.com/MIAPPE/MIAPPE-ontology
  - http://agroportal.lirmm.fr/ontologies/PPEO
  - Data model representation, Formal concepts and constraints

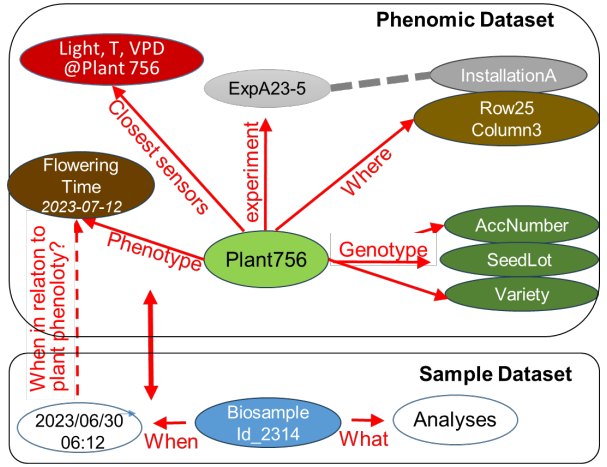


# Tools for data collection



# Tools for data collection and exchange

- MIAPPE/BrAPI compliant
- Platform information systems




| Variety | Light interception | Water use | rhPAD | Plant_height | Ear_height | silk_length |
|---|---|---|---|---|---|---|
| 1 | 20,267 | 101,006 | 0,323 | 176,720 | 75,087 | 227,340 |
| 2 | 18,003 | 105,690 | 0,248 | 164,129 | 76,403 | 188,438 |
| 3 | 18,655 | 106,167 | 0,322 | 201,606 | 92,296 | 244,781 |
| 4 | 20,483 | 114,731 | 0,298 | 212,911 | 100,835 | 157,812 |
| 5 | 19,114 | 100,946 | 0,226 | 174,685 | 83,253 | 190,663 |
| 6 | | | | | | |

# PHIS: an Ontology driven Information System for Plant Phenomics

Environmental data

Phenotypic data

Image processing
Advanced data extraction

**Image processing Analysis pipeline**

Community

User interface
Vue.js

WS User interface
Swagger UI

BrAPI

swagger

Scripts

REST API
Web App

PHIS

File storage system

iRODS

Analysis, sharing, etc.

- Metadata semantic description (experiments, plots, factors, sensors, variables, etc.)
- Data

# Tools for data collection and exchange

- MIAPPE/BrAPI compliant
- Platform information systems

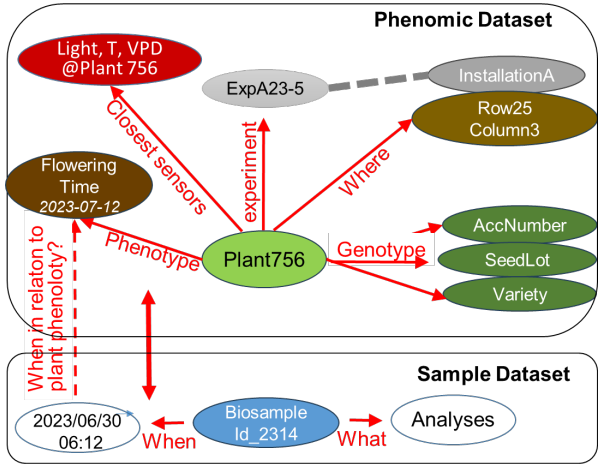
PHIS

PIPPA

- Phenotyping networks systems

BREEDBASE

FAIRDOM




| Variety | Light interception | Water use | rhPAD | Plant_height | Ear_height | silk_length |
|---|---|---|---|---|---|---|
| 1 | 20,267 | 101,006 | 0,323 | 176,720 | 75,087 | 227,340 |
| 2 | 18,003 | 105,690 | 0,248 | 164,129 | 76,403 | 188,438 |
| 3 | 18,655 | 106,167 | 0,322 | 201,606 | 92,296 | 244,781 |
| 4 | 20,483 | 114,731 | 0,298 | 212,911 | 100,835 | 157,812 |
| 5 | 19,114 | 100,946 | 0,226 | 174,685 | 83,253 | 190,663 |
| 6 | | | | | | |

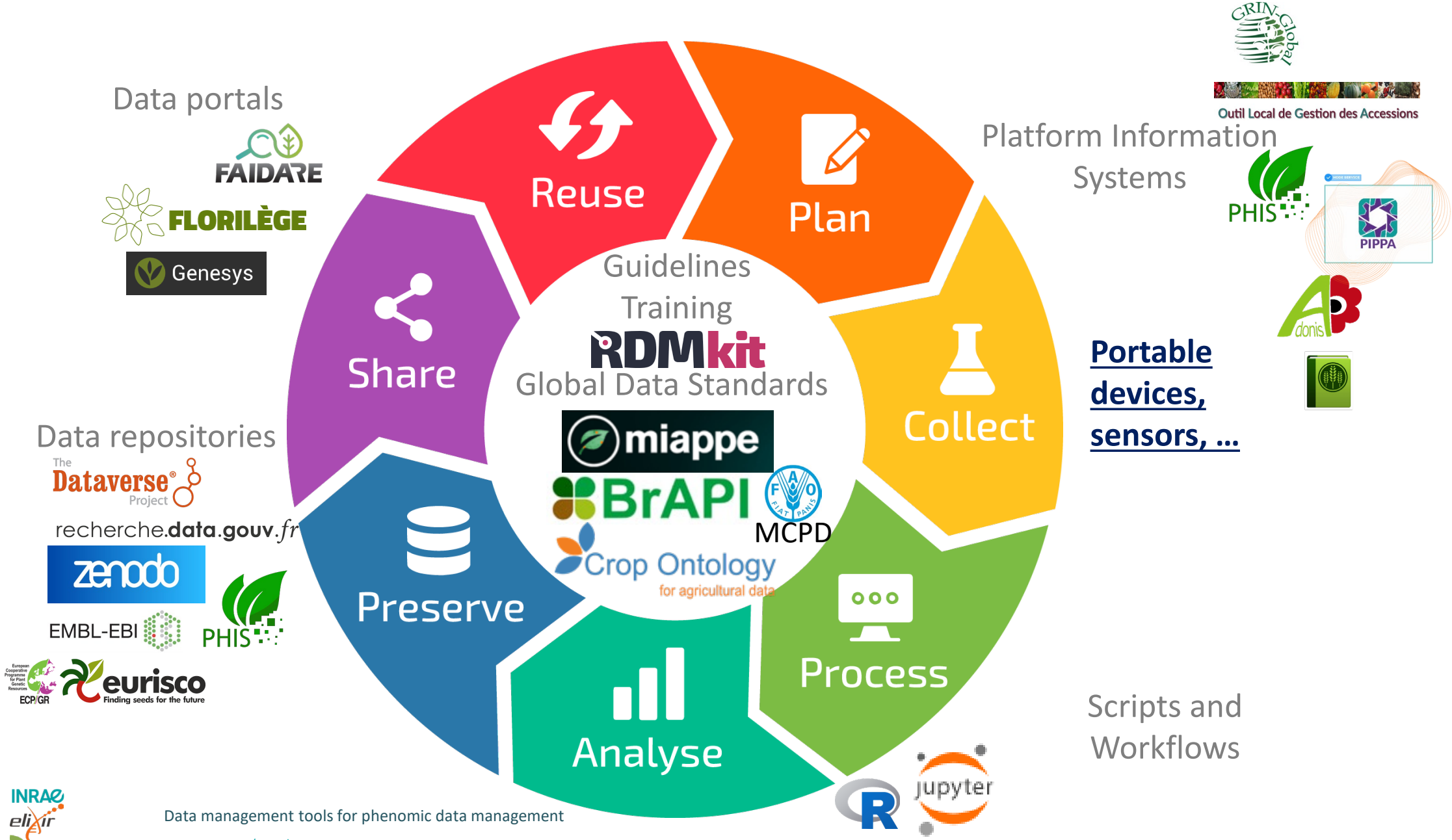
- Workflow, MIAPPE file template based

AGENT

  - to be published soon: https://zenodo.org/communities/agentproject
  - Feedback, recommendations
- Minimal and adapted version of the MIAPPE template, EVA network collaboration
- Central repository
- File validator

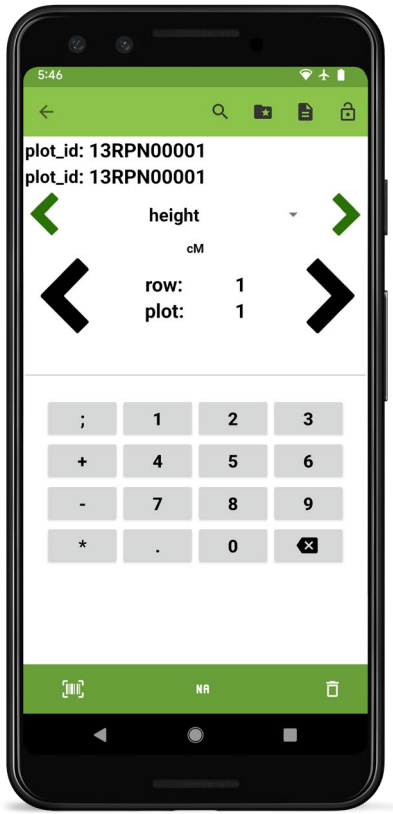
FAIRDOM

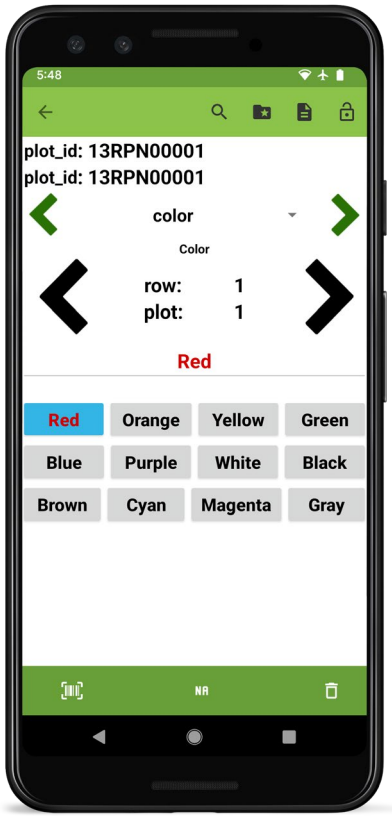
# Tools for data collection

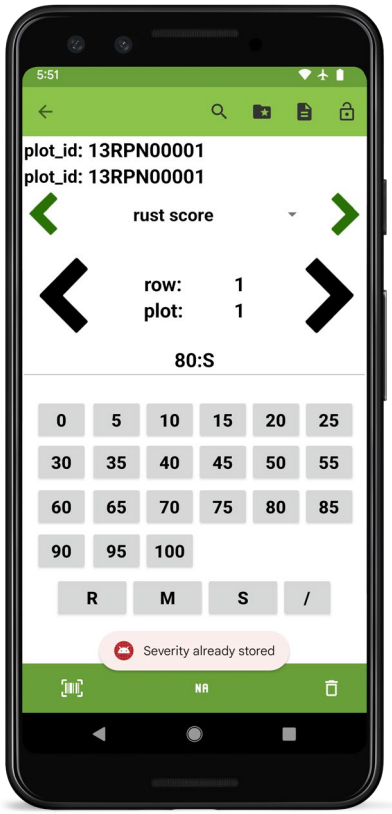


# Field Book

https://github.com/PhenoApps/Field-Book



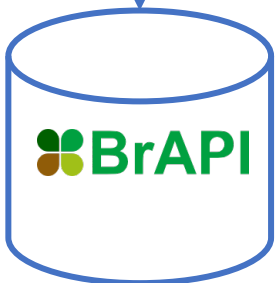




Table

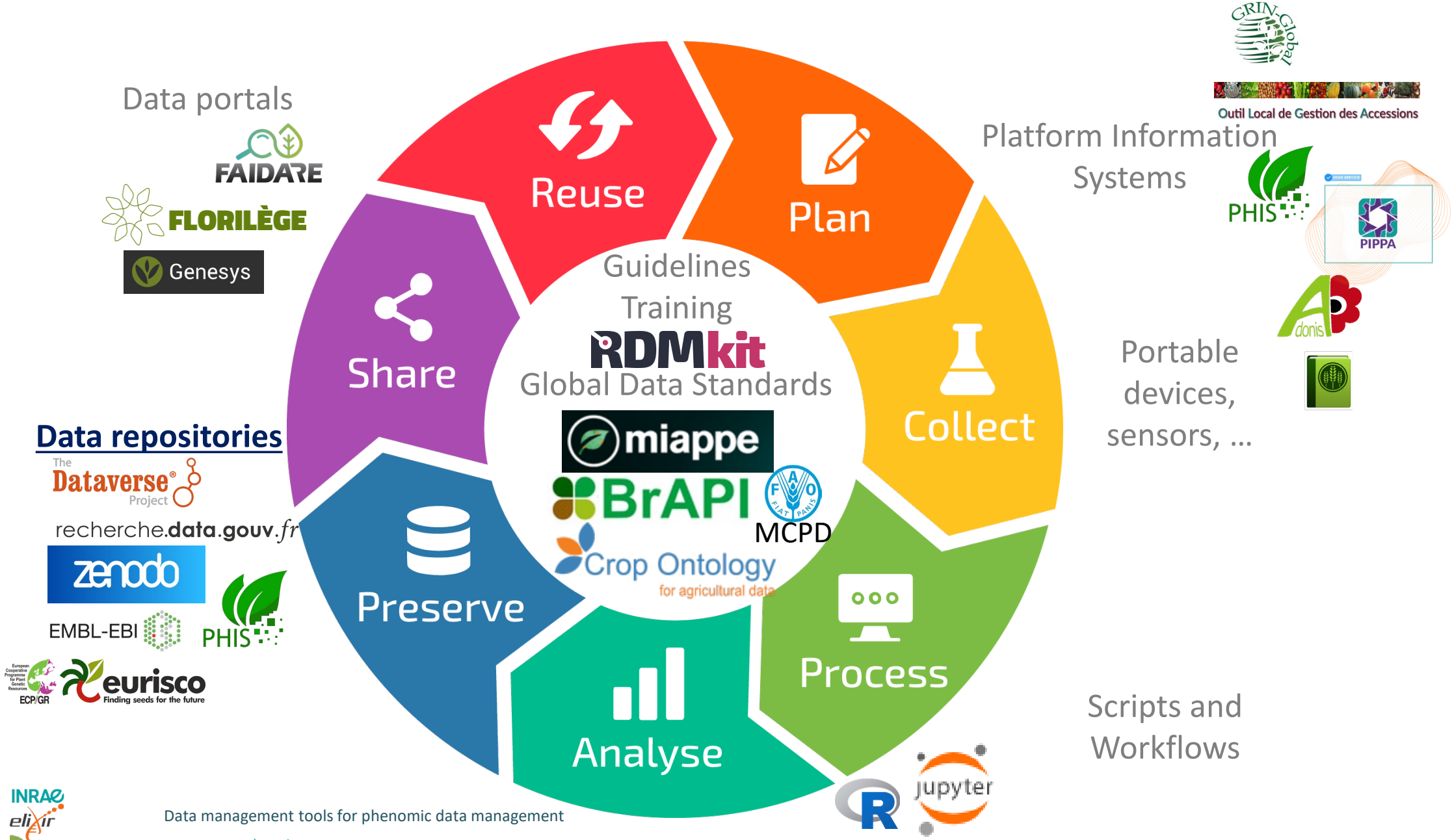
| plot_id | height | color | lodging |
|---|---|---|---|
| 13RPN00001 | 75 | Blue | 27 |
| 13RPN00002 | 45 | Yellow | 51 |
| 13RPN00003 | 63 | Yellow | 75 |
| 13RPN00004 | 14 | Purple | 57 |
| 13RPN00005 | 15 | Black | 27 |

Database

| plot_id | trait | value | timestamp | person | location | number |
|---|---|---|---|---|---|---|
| 13RPN00001 | height | 75 | 2023-05-22 11:25:57.304-04:00 | Trevor Rife | 35.9750949;-78.9786926 | 1 |
| 13RPN00001 | color | Blue | 2023-05-22 11:26:04.936-04:00 | Trevor Rife | 35.9750949;-78.9786926 | 1 |
| 13RPN00001 | lodging | 27 | 2023-05-22 11:26:11.278-04:00 | Trevor Rife | 35.9750949;-78.9786926 | 1 |
| 13RPN00002 | height | 45 | 2023-05-22 11:26:18.414-04:00 | Trevor Rife | 35.9739981;-78.9765391 | 1 |
| 13RPN00002 | color | Yellow | 2023-05-22 11:26:21.666-04:00 | Trevor Rife | 35.9739981;-78.9765391 | 1 |



# Tools for data collection



# Data repositories

## Long term sustainable data sharing

### Thematic repositories

#### Opened

GBIF

PANGAEA. Data Publisher for Earth & Environmental Science

NCBI

ENA European Nucleotide Archive

GEO Gene Expression Omnibus

EMBL-EBI UniProt

EMBL-EBI

BioFresh

ArrayExpress

BioStudies.

CELL IMAGE LIBRARY

#### Access Control

EUROPEAN GENOME-PHENOME ARCHIVE

### Generalist repositories

zenodo

EUDAT

DRYAD

HUB FAIRDOM

### Publisher repository

Mendeley Data

(GIGA)n DB

### Institutes Repositories

+ partners

Data INRAE

GnpIS

e!DAL Plant Genomics & Phenomics Repository

The Dataverse® Project

### National Repositories

+ partners

The Dataverse® Project

RÉPUBLIQUE FRANÇAISE Liberté Égalité Fraternité

recherche.data.gouv.fr

### Community Repositories

maizeGDB Maize Genetics and Genomics Database

BREEDBASE

PHIS

Sol Genomics Network

ECP/GR

eurisco Finding seeds for the future

# Generic data repositories for Phenomics

- Dataverse : general metadata
  - Year, Data type, Author
  - Organism: no controlled vocabulary
  - Keyword, Subject
- Plus plant phenomic specific metadata
  - Biological material, from species to genetic resource accession
  - Traits
  - Experiment locations
  - …
- Dedicated metadata scheme, added to generic data repositories
  - As companion files

➔ MIAPPE templates

## ➔ Guidelines

### Biological material

Use BiologicalMaterial.xlsx. This spreadsheet contains the following fields:

- "Biological material ID" (ex: INRA:W95115_inra_2001): Lot number or n
- "Material source ID" (ex: INRA:B73_usda) OR "Accession_number" (B73 INRA)
- Accession Number
- Genus
- Species Optional fields:
- "Material source DOI": accession DOI
- Organism: NCBITAXON:4577
- "Infraspecific name": variety names, cultivar names, etc...
- Genealogy:
  - Parent1or2_AccessionNumber
  - Parent1or2_TaxonGroup
  - Parent1or2_HoldingInstitutionName
  - Parent1or2_Type (father/mother/undefined)
- All MIAPPE Biological Material fields (DM-40 to DM-56)
- Free input: synonyms, project IDs, any relevant information on the plan

### Observed variables

Use ObservedVariables.xlsx. This file is needed for the description of phen methods.

### Studies or experiments

It is recommended to list the experimentation done in this dataset, includi the site name and the environmental parameters which characterize the e Studies.xlsx

## Data portals

FAIDARE

FLORILÈGE

Genesys

Data repositories

The Dataverse Project

recherche.data.gouv.fr

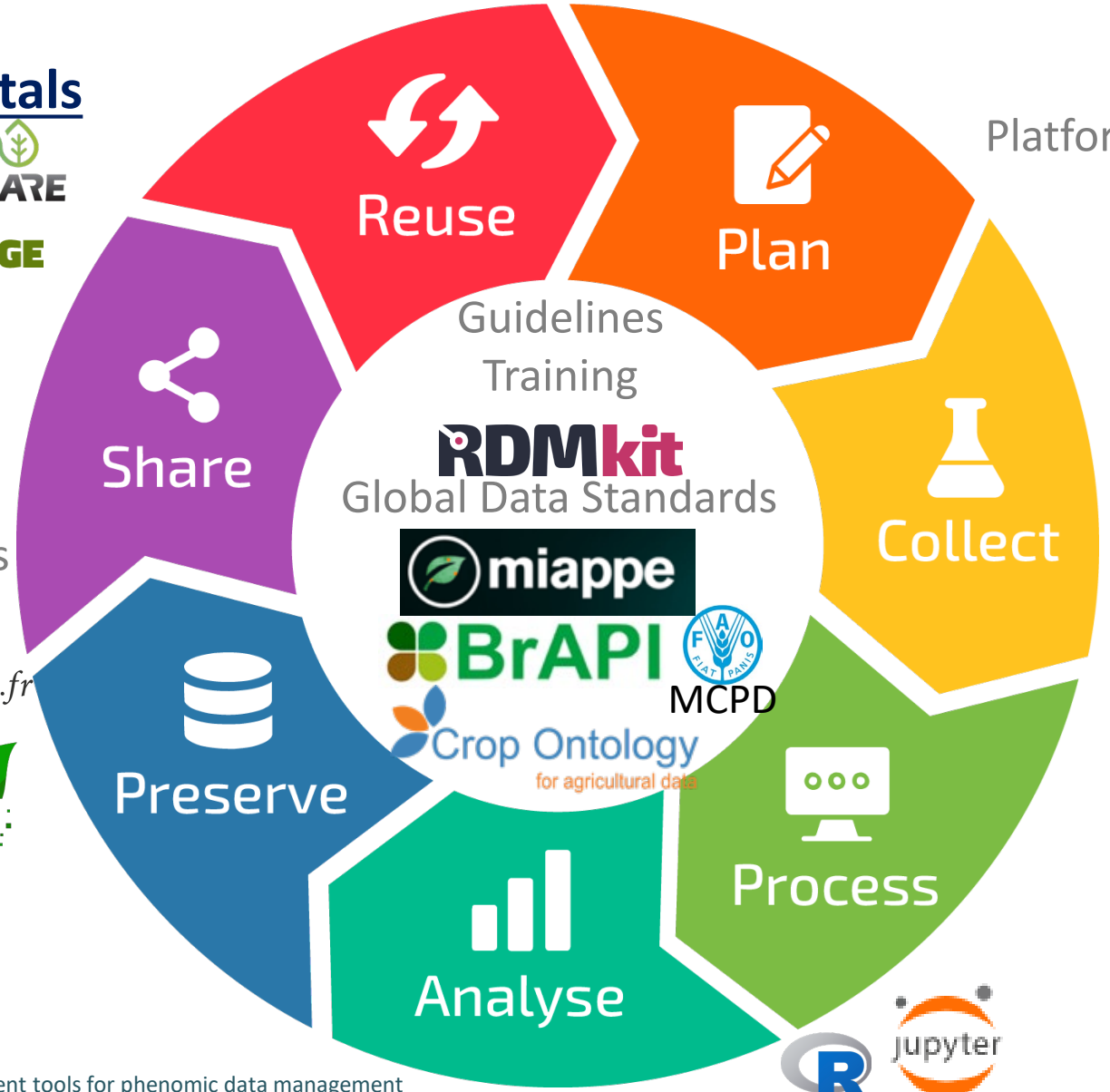
zenodo

EMBL-EBI

PHIS

ECP/GR

eurisco Finding seeds for the future




Platform Information Systems

GRIN Global

Outil Local de Gestion des Accessions

PHIS

PIPPA

donis

Portable devices, sensors, …

Scripts and Workflows

R

jupyter

# FAIDARE: Global Plant Research Data discovery portal

FAIDARE

miappe

**Phenomics**

EMPHASIS · PHIS · PIPPA · e!DAL · GnpIS

**Genetics Genomics**

EMBL-EBI

**Dataverse**

The Dataverse® Project

**Historical Datadiscovery**

WHEAT INITIATIVE

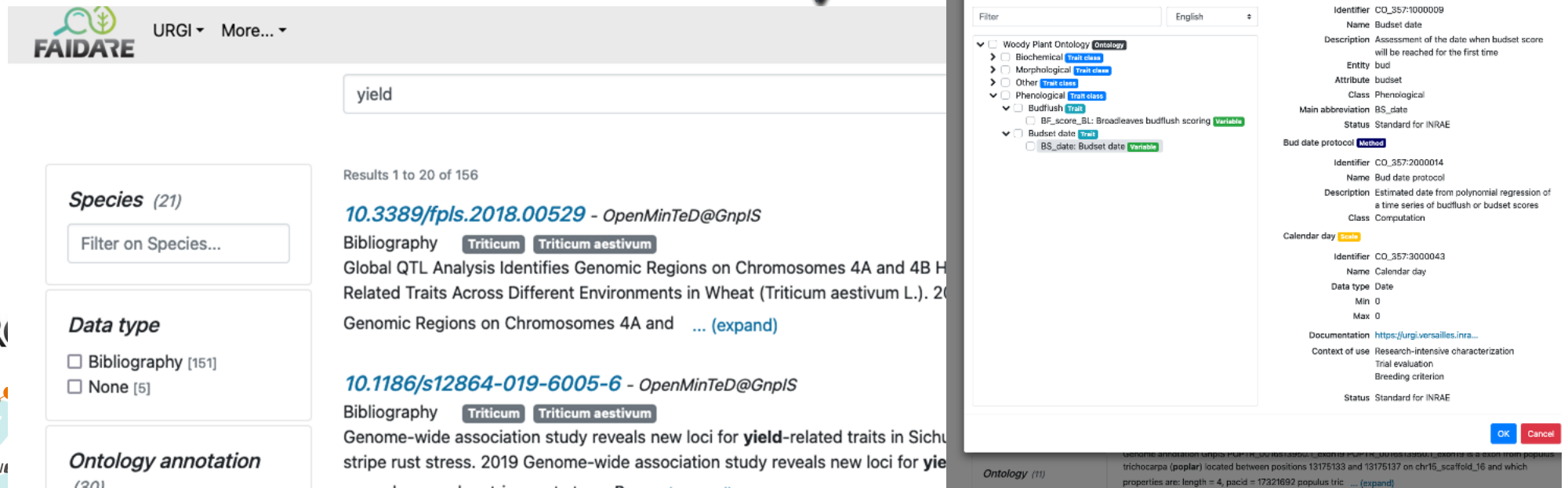
**Literature**

Europe PMC

**Bioschemas sources**

BrAPI

https://urgi.versailles.inrae.fr/faidare/







Full text

+

Fine criteria

+

**Link back**


Data portals

FAIDARE

FLORILÈGE

eurisco Finding seeds for the future

Genesys

Data repositories

The Dataverse Project

recherche.data.gouv.fr

zenodo

EMBL-EBI

PHIS

eurisco Finding seeds for the future

Platform Information Systems

GRIN-Global

Outil Local de Gestion des Accessions

PHIS

PIPPA

donis

Portable devices, sensors, …

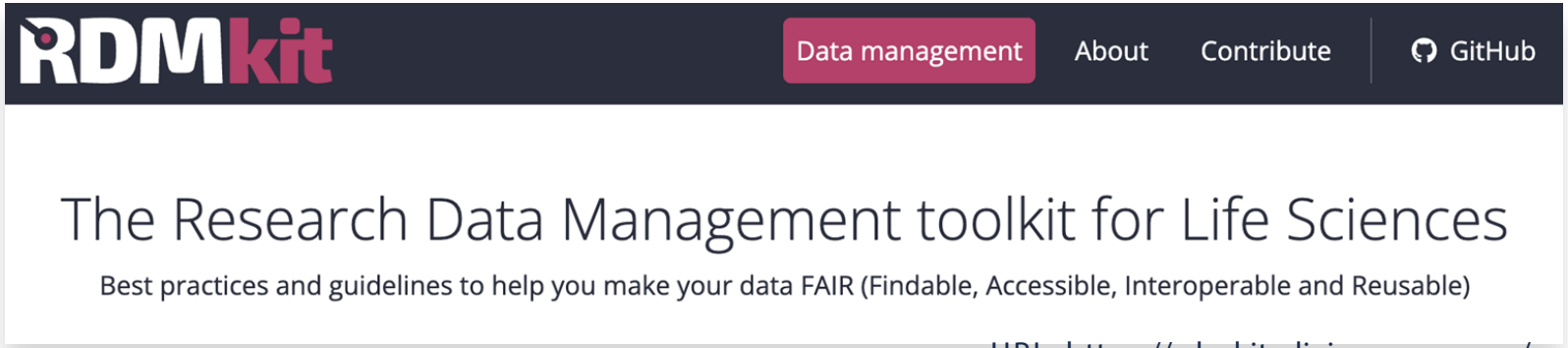
Scripts and Workflows

R

jupyter

# Community guidelines portal : RDMkit - Best practices and guidelines for FAIR data management

- A "wikipedia-like" knowledge base website, free and open
- Describes how to manage research outputs according to FAIR principles
- Portal to other online resources used by RDM professionals and researchers




URL: https://rdmkit.elixir-europe.org/

Recommended in the **Horizon Europe Program Guide** as the "resource for Data Management guidelines and good practices for the Life Sciences"

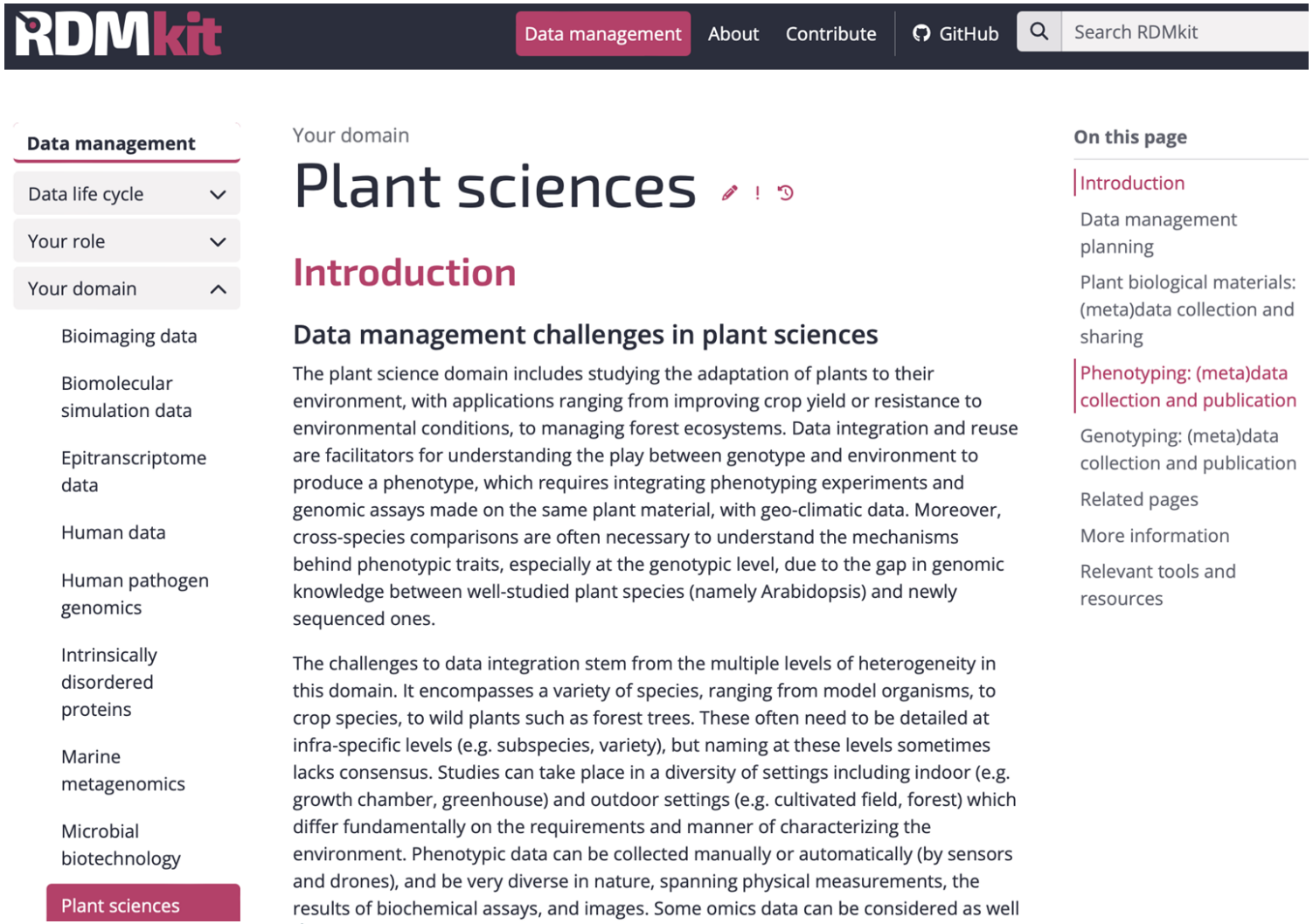
**179**
**Contributors**
The force behind RDMkit

**514**
**Tools & resources**
Explained in the context of real world problems

**122**
**Pages**
Helping you with data management

# Entry point: Plant Page

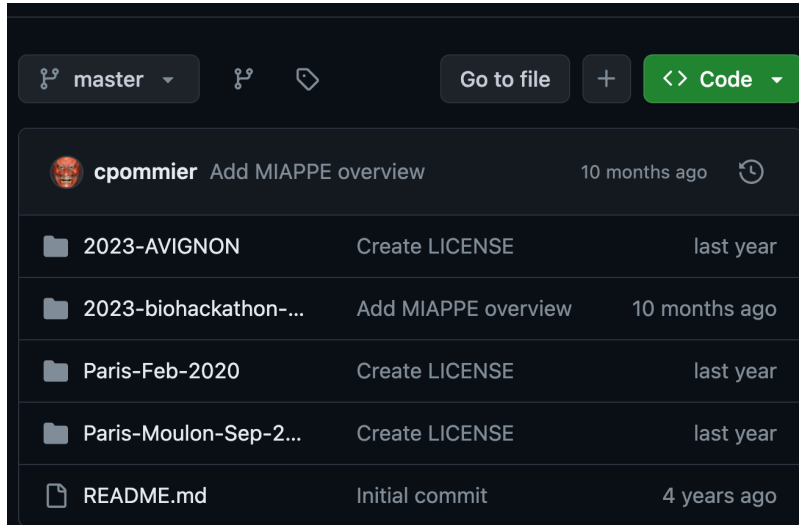
https://rdmkit.elixir-europe.org/plant_sciences

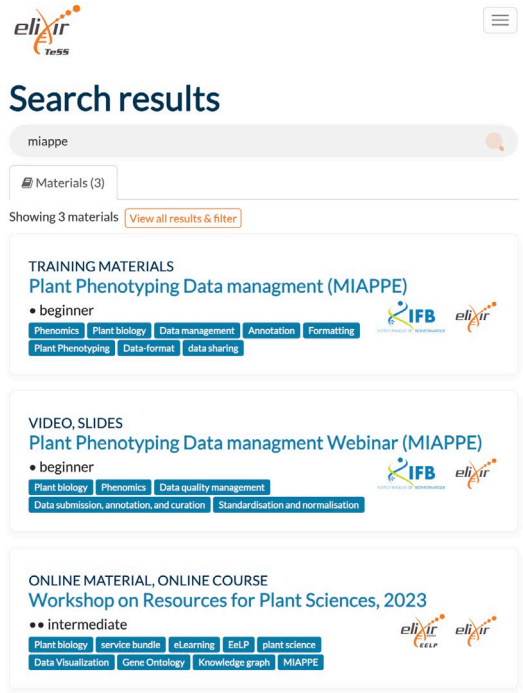


# Trainings

Some examples

- MIAPPE & BrAPI
  - Biologists & Computer scientist
  - Wheat community (WheatIS of the Wheat Initiative)
  - All plants
  - Shared training Material
  - Yearly since 2018
    - Versailles 2018
    - NordPlant 2019
    - Paris 2020 (Combined with ELIXIR Train the trainers)
    - Paris - Le Moulon 2021
    - Avignon 2023
    - Biohackathon Japan 2023
    - INRAE 2023
    - EMPHASIS 2023
- Phenome, EMPHASIS, ELIXIR, RARENET, Agroserv…
- Joint Training organisation are welcome!
  - 3-6 december Paris building in progress



# Aknowledgments


**Elixir Plant community & platforms**

Beier S., Gruden C., Pommier C., Coppens F, Scholz U., Lange M., Contreras B., Adam Blondon AF, Faria D, Chavez I, Miguel C, Droedsbek B, Finkers R, Papoutsoglou E, Olster R, Ramsak Z, …

**H2020 AGENT**

N. Stein (IPK, coord), P. Kersey (RBGK), M. Alaux (INRAE), S. Weise (IPK), C. Pommier (INRAE), M. Lange (IPK), R. Finkers (WUR), *J. Destin (INRAE)*

**Crop Ontology**

Arnaud E, Laporte MA, …

**MIAPPE community**

ELIXIR Plant Community,
Krajewsky P, Cwiek H, Tardieu F, Usadel B, Arend D, Arnaud E, Junker A, King G, Laporte MA, Poorter H, Reif J, Rocca-Serra P, Sansone SA, Kersey P,
And many more!

**Breeding API**

Selby P, Mueller L, Robbins K, Backlund JE, … ,
And many more!

**Emphasis**

Tardieu F, Usadel B, Arend D, Junker A, Poorter H, Neveu P, Alic I., Pierushka R, Shur U…
And many more!

# Aknowledgments


**Elixir Plant community & platforms**

Beier S., Gruden C., Pommier C., Coppens F, Scholz U., Lange M., Contreras B., Adam Blondon AF, Faria D, Chavez I, Miguel C, Droedsbek B, Finkers R, Papoutsoglou E, Olster R, Ramsak Z, …

**H2020 AGENT**

N. Stein (IPK, coord), P. Kersey (RBGK), M. Alaux (INRAE), S. Weise (IPK), C. Pommier (INRAE), M. Lange (IPK), R. Finkers (WUR), *J. Destin (INRAE)*

**Crop Ontology**

Arnaud E, Laporte MA, …

**MIAPPE community**

ELIXIR Plant Community,
Krajewsky P, Cwiek H, Tardieu F, Usadel B, Arend D, Arnaud E, Junker A, King G, Laporte MA, Poorter H, Reif J, Rocca-Serra P, Sansone SA, Kersey P,
And many more!

**Breeding API**

Selby P, Mueller L, Robbins K, Backlund JE, … ,
And many more!

**Emphasis**

Tardieu F, Usadel B, Arend D, Junker A, Poorter H, Neveu P, Alic I., Pierushka R, Shur U…
And many more!