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## Plant Data Management for Phenotyping Experiments

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# ➤ Plant Data Management for Phenotyping Experiments

Data standards and use cases for plant scientists  
and informaticians



## > Overview

Plant Phenotyping standards : why and who  
MIAPPE overview and Crop & Forest use case

Questions

Crop ontology

Questions

MIAPPE tools & web services: BrAPI, PPEO Ontology

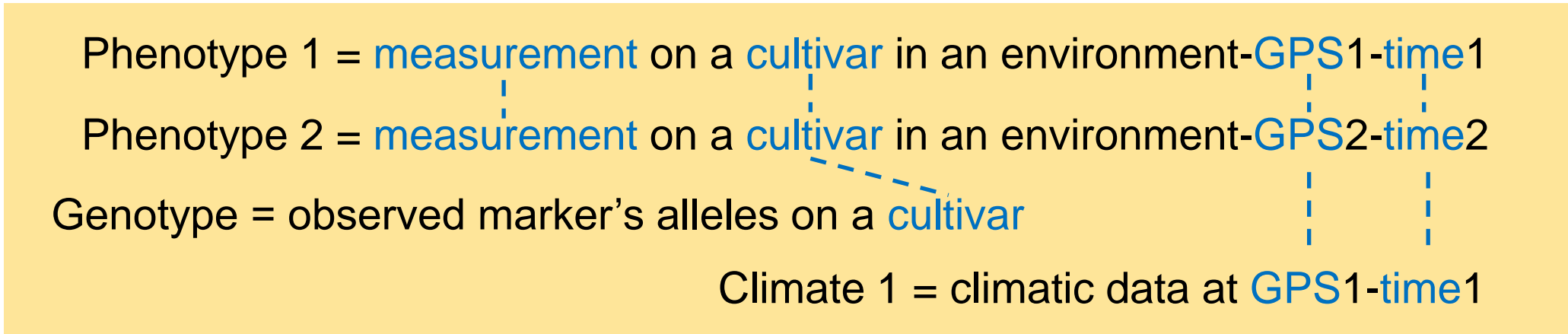
Questions

## ➤ PLANT PHENOTYPING STANDARDS : WHY



# Why should we standardize phenotyping data?

- To enable anyone (including yourself) to reuse it: **metadata about the experiment** (who did it, for what purpose, where and how)
- To enable the (automatic) integration with other types of data: **unique identification of the concepts used to link different data sets**

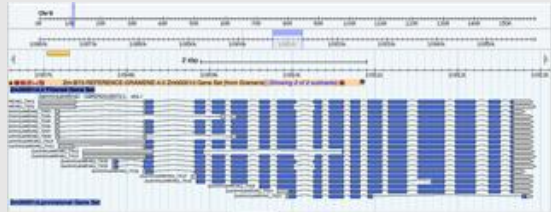


- To enable knowledge discovery: **metadata about the experiment, controlled vocabularies, ontologies**



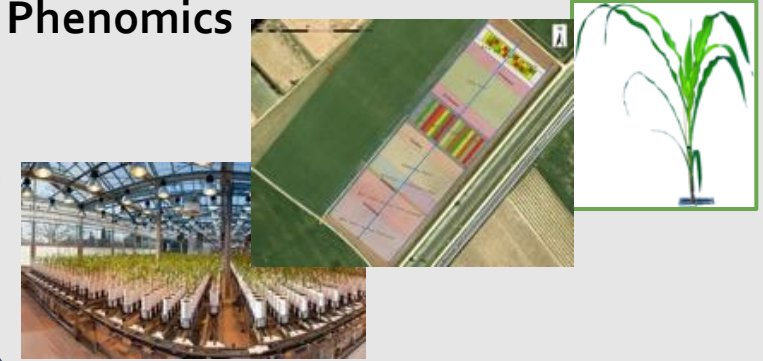
# ➤ Genome / Environment / Phenome

## Genetics & Genomics




Homogenous (Mostly)  
Central Access (Mostly)

## Phenomics



Heterogenous  
Distributed

**Plant Breeding**  
Genetic variations by Traits  
  
**Climate Change Studies**  
Genotype by Environment  
Phenology

## Environment



Heterogenous  
Distributed



## ➤ Europe open access and interoperability policy

# Open Access

# FAIR



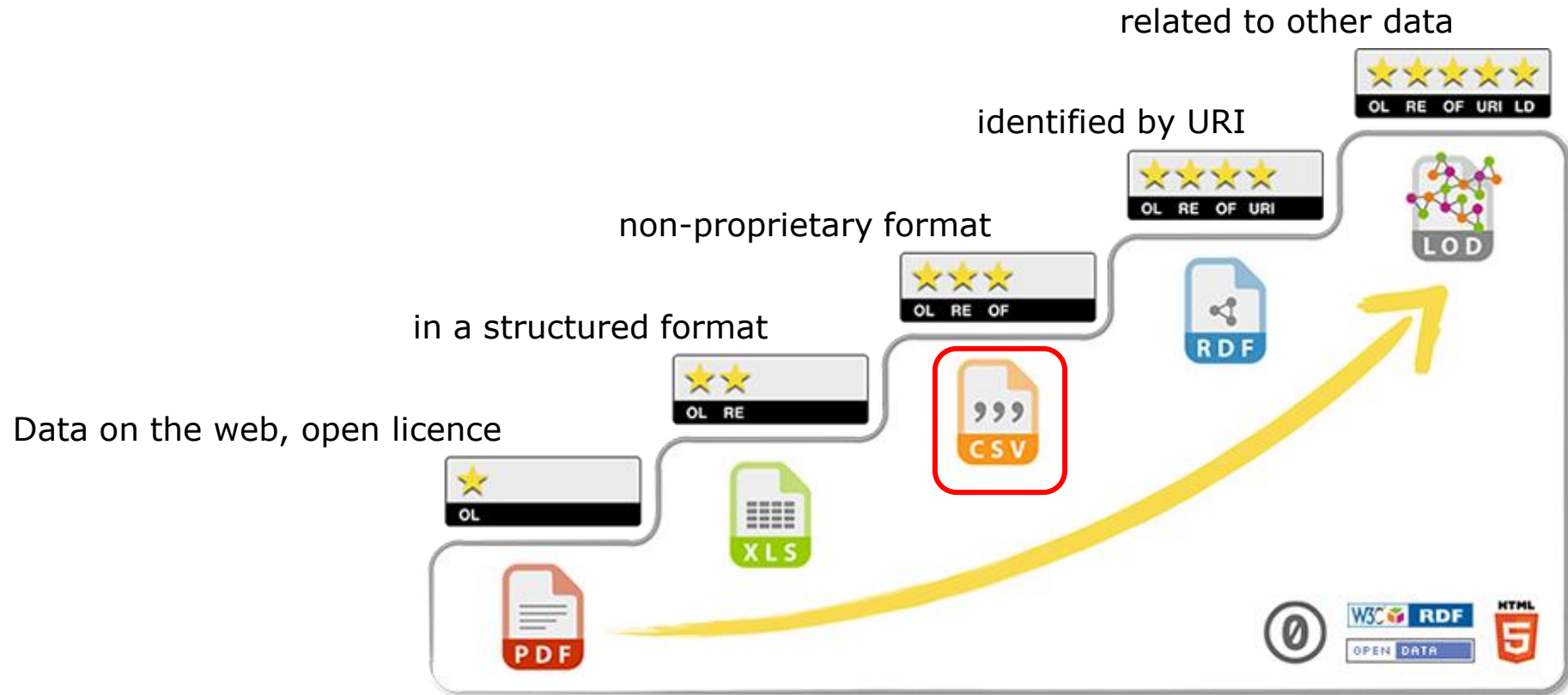
“Facilitating access to results encourages the re-use of research outputs and supports Open Science. This is essential for Europe's ability to enhance its economic performance and improve the capacity to compete through knowledge. [...] Results of publicly-funded research can therefore be disseminated more broadly and faster, to the benefit of researchers, innovative industry and citizens.



All funded projects are asked to add a WP supporting a FAIR compliant Data Management Plan



## ➤ 5 stars Open Data



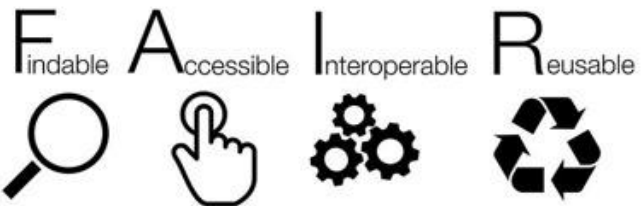
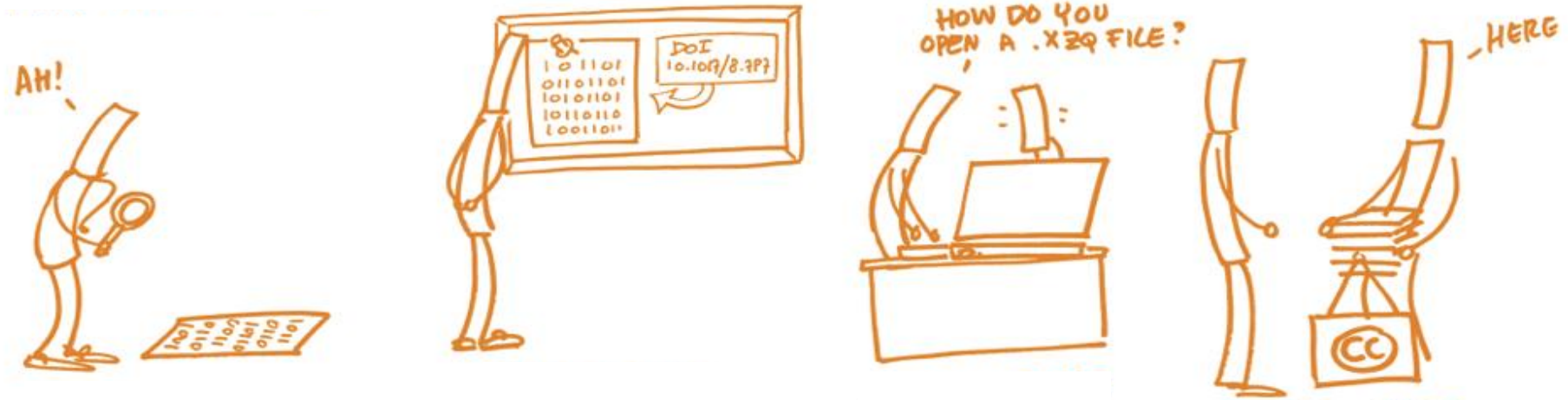
Progressing towards FAIR and Open Data requires a multidisciplinary cooperation :

- Biologists
- Bioinformaticians
- Specialists of ontologies/semantics



# ➤ FAIR Data Principles

Wilkinson et al., **The FAIR Guiding Principles for scientific data management and stewardship.**  
*Scientific Data 3 (2016)*



**FINDABLE**

Unique identifiers and metadata are used to allow data to be located quickly and efficiently

**Ids  
Metadata  
Index**

**ACCESSIBLE**

Data is open, free and universally available for research discovery efforts

**Open Protocols  
Perennial  
Metadata**

**INTER-OPERABLE**

A common programming language is used to allow use in a broad range of applications

**Semantics  
Linked Data  
Vocabularies**

**REUSABLE**

All data is clearly described and outlines associated data-use standards

**License  
Well described  
Provenance  
Standards**

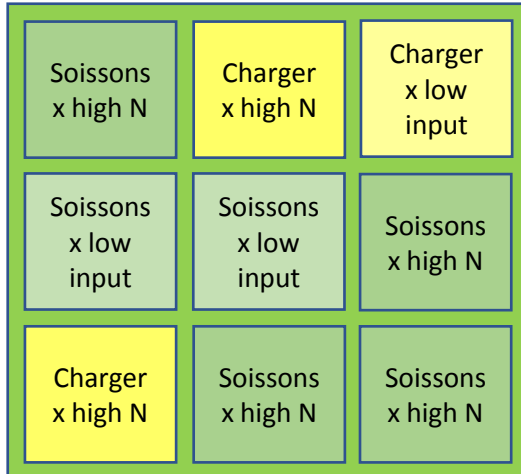


## ➤ Plant phenomics Data

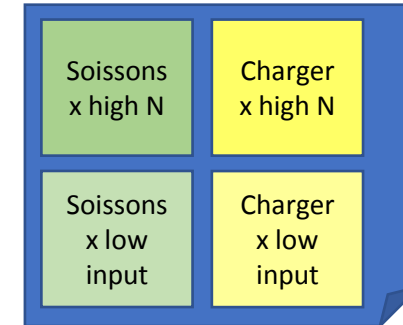
- Heterogenous data
- Different spatial scales
  - Metabolites
  - organ (leaf)
  - group of group of plants
  - whole experimental field
- Different time scales
  - Single measure
  - Time series : every 15 minutes
- Environment
- Complex life cycle

# ➤ Phenotyping data life cycle

Raw data

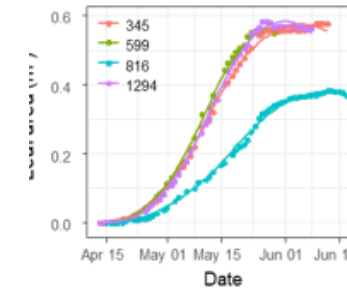


Elaborated data



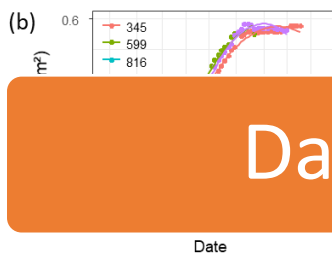
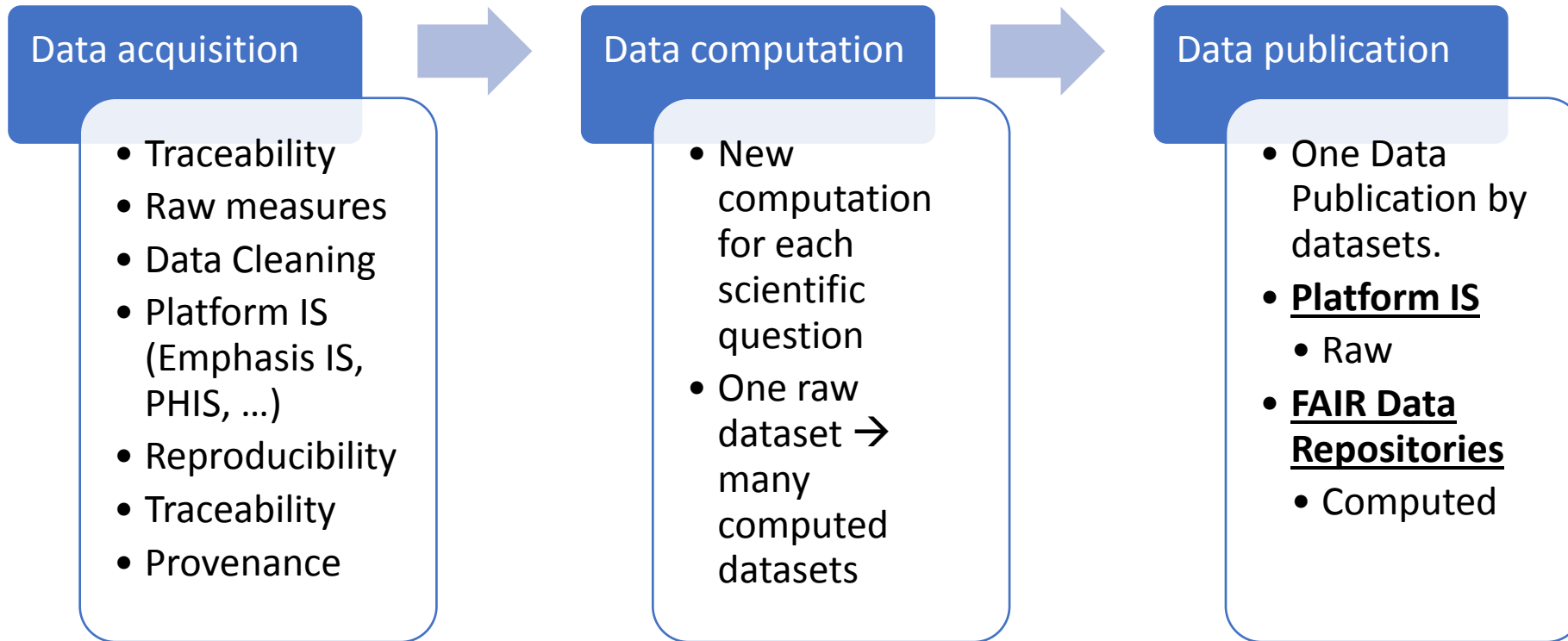
Genotype	Treatment	N input	Date	Rep	Fusariose
Soissons	low input	15,32253129	15/11/2011	1	5
Soissons	low input	15,31430556	16/11/2011	2	7

Genotype	Treatment	Fusariose
Soissons	low input	6



# ➤ Plant Phenotyping Life cycle

## Raw data long term conservation



**Data**

Genotype	traitement	Fusariose
Charger	low input	5
Charger	high N	2
Charger	low input	1
Charger	high N	2

Variety charger  
**Knowledge**  
intensive cultural practice



# ➤ Challenges for phenomics data



## Findable

- Distributed model: no central phenomic data archive
- Agreed or compatible ID and Metadata policy



## Accessible

- Complex life cycle
- Different types of data
- Complex DMP



## Interoperable

- Compatible standards
- Issues in relation with big data



## Reusable

- Phenotype = Genotype x Environment x Cultural practice => different silos of metadata definition
- Provenance is complex

### Data portals



### Data Archives



### Platform IS



...

## ➤ PLANT DATA STANDARDS : WHO

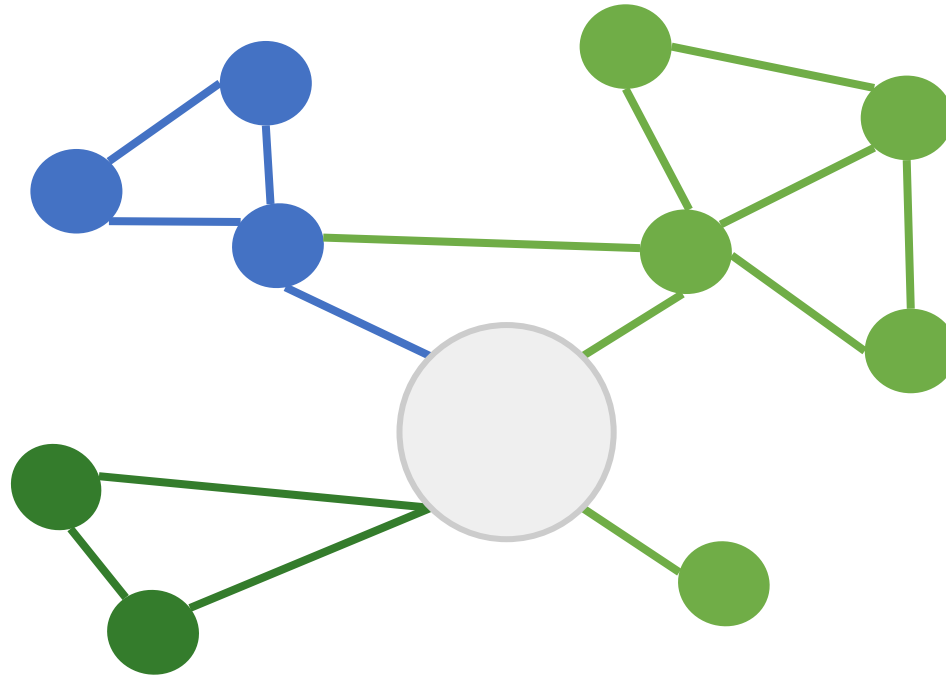


# ➤ Interoperability in International network

## National Networks



## Global Networks



## European Networks



## International data standards





## ➤ Plant data standards contributors

Gathered to solve interoperability standard problem

- ELIXIR

- European Infrastructure for life sciences
- Germany, France, Belgium, Italy, Portugal, UK, Netherland, Slovenia, ...
- <https://elixir-europe.org/communities/plant-sciences>

- CGIAR

- Consortium of International Agricultural Research Centers
- <https://www.cgiar.org/>

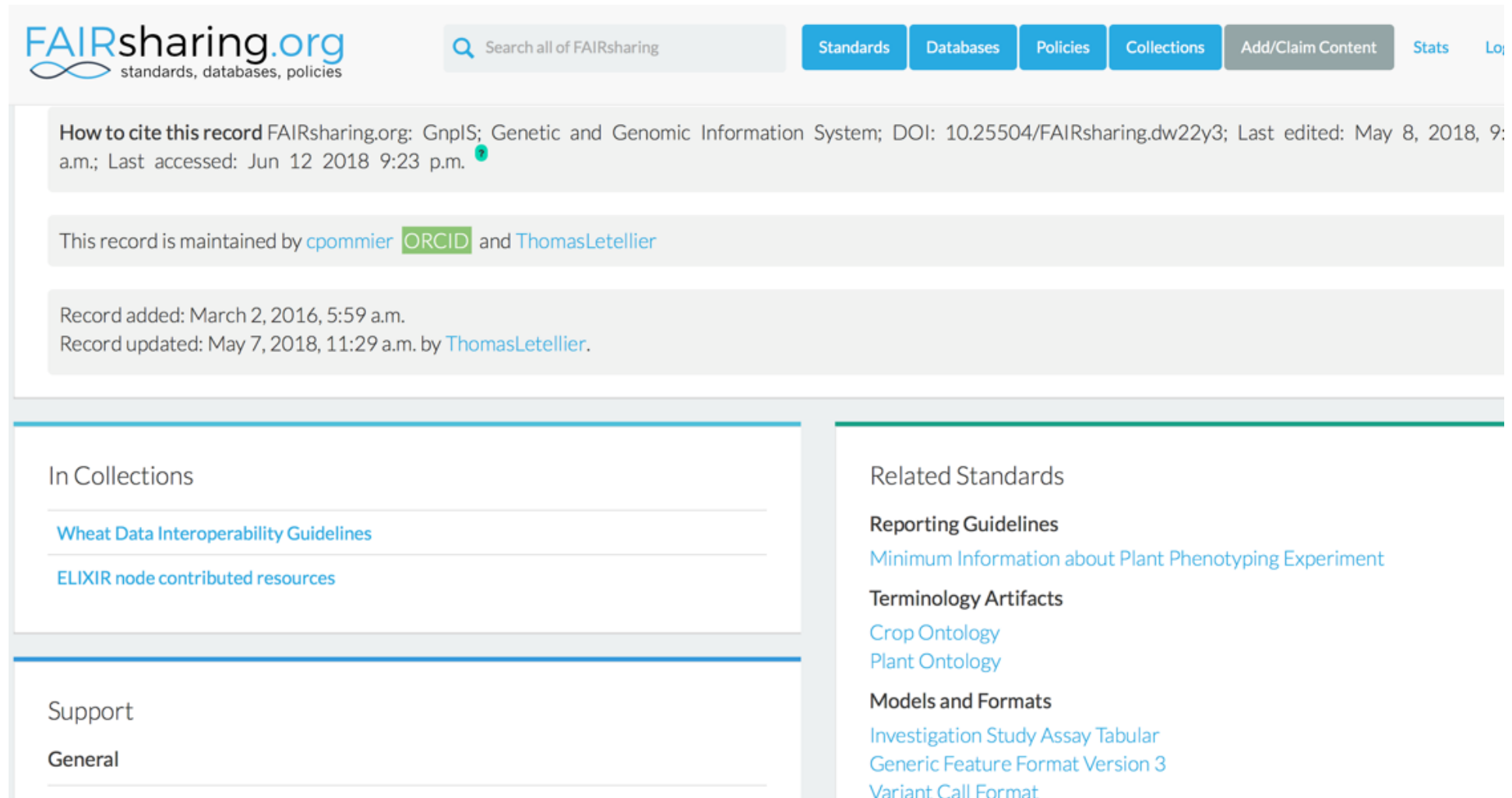
- EMPHASIS

- European Infrastructure for Plant Phenotyping
- France, Germany, Belgium, UK, ...
- <https://www.plant-phenotyping.eu>

- NAPPN

- North American Plant Phenotyping Network
- <https://nappn.plant-phenotyping.org/>

## > Sharing standards: standards registries



**FAIRsharing.org** standards, databases, policies

Search all of FAIRsharing

Standards Databases Policies Collections Add/Claim Content Stats Log

**How to cite this record** FAIRsharing.org: GnpIS; Genetic and Genomic Information System; DOI: 10.25504/FAIRsharing.dw22y3; Last edited: May 8, 2018, 9: a.m.; Last accessed: Jun 12 2018 9:23 p.m.

This record is maintained by [cpommier](#) [ORCID](#) and [ThomasLetellier](#)

Record added: March 2, 2016, 5:59 a.m.  
Record updated: May 7, 2018, 11:29 a.m. by [ThomasLetellier](#).

**In Collections**

- [Wheat Data Interoperability Guidelines](#)
- [ELIXIR node contributed resources](#)

**Support**

**General**

**Related Standards**

**Reporting Guidelines**

- [Minimum Information about Plant Phenotyping Experiment](#)

**Terminology Artifacts**

- [Crop Ontology](#)
- [Plant Ontology](#)

**Models and Formats**

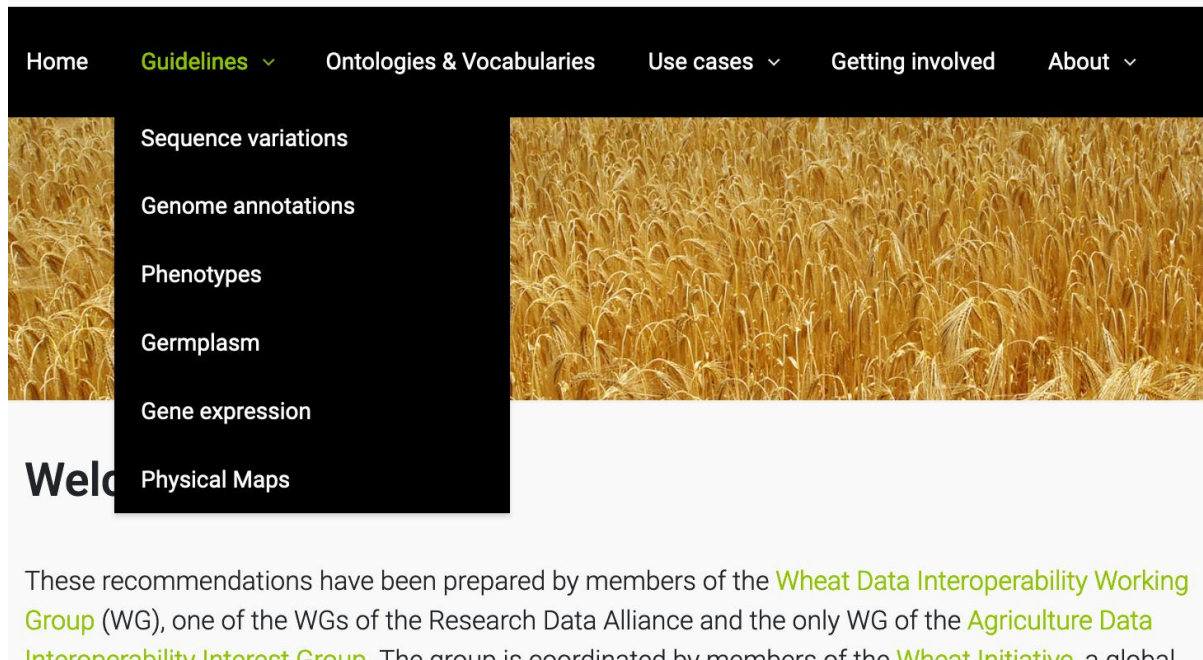
- [Investigation Study Assay Tabular](#)
- [Generic Feature Format Version 3](#)
- [Variant Call Format](#)



# ➤ Community driven recommendations

- WheatIS:  
<http://wheatis.org/DataStandards.php>

## Wheat Data Interoperability Guidelines



Home Guidelines ▾ Ontologies & Vocabularies Use cases ▾ Getting involved About ▾

- Sequence variations
- Genome annotations
- Phenotypes
- Germplasm
- Gene expression
- Physical Maps

Welc

These recommendations have been prepared by members of the [Wheat Data Interoperability Working Group](#) (WG), one of the WGs of the Research Data Alliance and the only WG of the [Agriculture Data Interoperability Interest Group](#). The group is coordinated by members of the [Wheat Initiative](#), a global

- Community story



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OPINION ARTICLE

**REVISED** Developing data interoperability using standards:  
A wheat community use case [version 2; referees: 2 approved]

Esther Dzale Yeumo<sup>1</sup>, Michael Alaux <sup>2</sup>, Elizabeth Arnaud<sup>3</sup>, Sophie Aubin<sup>1</sup>, Ute Baumann<sup>4</sup>, Patrice Buche<sup>5</sup>, Laurel Cooper <sup>6</sup>, Hanna Ćwiek-Kupczyńska<sup>7</sup>, Robert P. Davey <sup>8</sup>, Richard Allan Fulss<sup>9</sup>, Clement Jonquet <sup>10,11</sup>, Marie-Angélique Laporte<sup>3</sup>, Pierre Larmande <sup>12,13</sup>, Cyril Pommier <sup>2</sup>, Vassilis Protonotarios <sup>14</sup>, Carmen Reverte <sup>15</sup>, Rosemary Shrestha<sup>9</sup>, Imma Subirats<sup>16</sup>, Aravind Venkatesan <sup>12</sup>, Alex Whan<sup>17</sup>,  Hadi Quesneville <sup>2</sup>

+ Author details

 This article is included in the [Global Open Data for Agriculture and Nutrition gateway](#).



## ➤ PLANT DATA STANDARDS



# ➤ Data standards for FAIR

## Semantic

- ◆ Description of the data
- ◆ Controlled vocabularies: term name and definitions
- ◆ Ontologies: semantic links between terms
- ◆ *Biologist driven*



## Persistent Unique Identifiers

URI, gene ID, accessions ID, Trait ID, DOI,...

## Structure

- Formatting and Organizing the data
- Data Models
- Standards : CSV, VCF, GFF, MIAPPE ([www.miappe.org](http://www.miappe.org)) , etc...
- *Biologist & Computer scientist driven*



## Technical

- Data integration and sharing
- Interoperability : tools and systems
  - GA4GH
  - Breeding API [www.brapi.org](http://www.brapi.org)
- *Computer scientist driven*



## > Phenotype Semantic Standard: Ontologies

- Describing traits/features in specific plant species
- Crop Ontology Trait + Method + Scale Semantic model
- Dedicated presentation





# ➤ Phenotype Structure Standard



## Minimal Information About Plant Phenotyping Experiment : version 1.1 (Jan 2019)

[www.miappe.org](http://www.miappe.org)

- Many stakeholders
  - ◆ Elixir, Emphasis, Bioversity, North American PPN
- Open Community:
  - ◆ Request for comments
  - ◆ Github Feature requests
  - ◆ Mailing lists
  - ◆ Meetings & Workgroups
- Crops and woody plants

MIAPPE				
line #	MIAPPE Check list	Definition	Example	Cardinality
DM-1	<b>Investigation</b>	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
DM-2	<b>Investigation unique ID</b>	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.	EBI12345678	0-1
	<b>Investigation title</b>	Human-readable string summarising the investigation.	Adaptation of Maize to Temperate Climates: Mid-Density Genome-Wide Association Genetics and Diversity Patterns Reveal New Genomic Regions. with	1
Environment				
ENV-1	Non-exhaustive list of Environment Parameters.			
Environment parameters				
ENV-2	Environment parameters	Definition	Example	Format
Growth facility				
ENV-4	<b>Air temperature</b>	List of hourly air temperature throughout the experiment.	22 °C	Numeric
ENV-5	<b>Organ temperature</b>	List of hourly organ temperatures throughout the experiment.	18 °C	Numeric
Experimental Factors				
TR-1	Non-exhaustive list of Experimental Factors that can be applied.			
Experimental Factors				
TR-2	Factor type	Definition	Example factor values	Format
TR-3	<b>Seasonal environment</b>	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	<b>Air treatment regime</b>	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	<b>Soil temperature regime</b>	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'





# ➤ Phenotype Structure Standard : MIAPPE

Minimum Information for Biological and Biomedical Investigations

A collection of the historical MIBBI foundry reporting guidelines. The minimum information standard is a set of guidelines for reporting data derived by relevant methods in biosciences. If followed, it ensures that the data can be easily verified, analysed and clearly

- Biologist Friendly
- Minimal and sufficient list of metadata:
  - The objective of the experiment
  - Who contributed to the experiment
  - What were the experimental procedures
  - What was the biological material experimented
  - ...

# ➤ Phenotype Structure Standard



Computer scientist friendly :

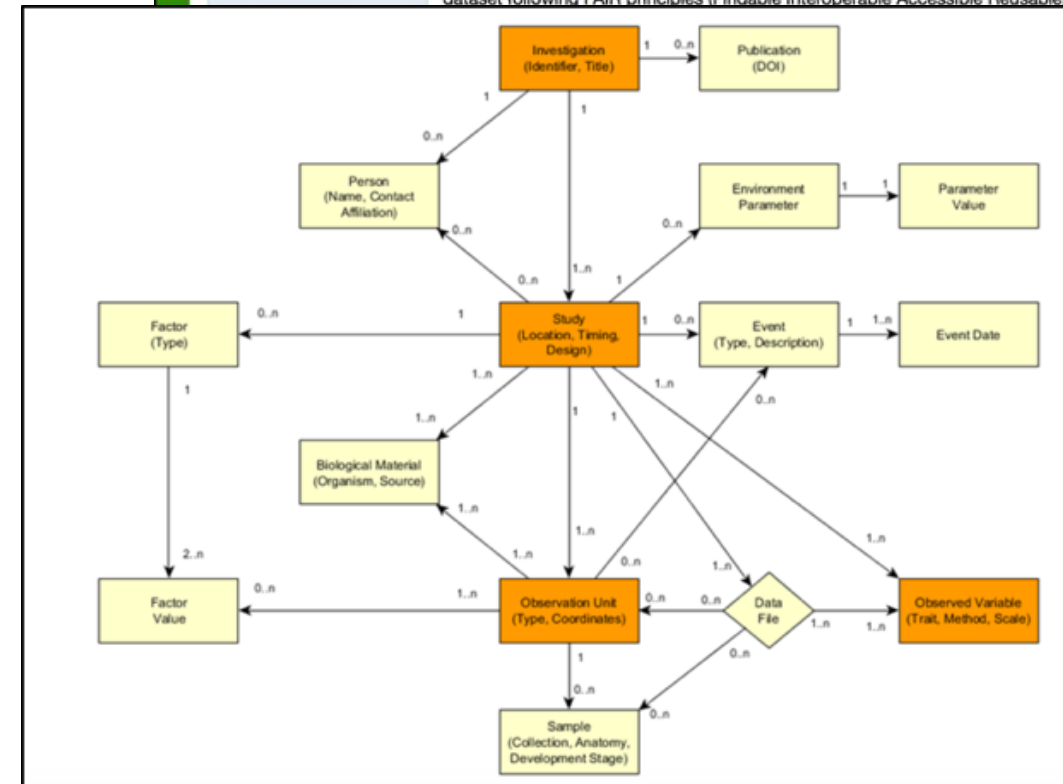
- Explicit Data Model: ISA-Tools and Breeding API (BrAPI) compatibility.
- Validation framework and toolbox
- Semantic representation in OWL: Phenotyping Experiment Ontology (PPEO) using OWL (<http://agroportal.lirmm.fr/ontologies/PPEO> )

Biologist friendly

- Clear definitions and examples
- Excel templates
- Trainings

Specification with multiple implementations

- File Archive: ISA Tab
- Semantic: Plant Phenotyping Experiment Ontology
- Web Service: Breeding API



Papoutsoglou *et al.* (2020) Enabling reusability and interoperability of plant phenomic datasets with MIAPPE 1.1. *New Phytol*, 227:260-273; <https://doi.org/10.1111/nph.16544>

## ➤ Phenotype Technical Standard

- Breeding API <http://brapi.org/>
- International collaboration
  - ◆ Standard Open Web Service API
  - ◆ Information Exchange, Main target: Breeding
  - ◆ Excellence in Breeding platform (CGIAR, Peter Selby)
- Major Elixir, Emphasis Contribution
  - ◆ Phenotyping specification
- Connect data repositories and tools:
  - ◆ Genotype visualization (Flapjack)
  - ◆ Studies graph preview and filtering
    - ◆ BrAPPS : Tools integrable in any BrAPI compliant System
    - ◆ <https://www.brapi.org/brapps.php>
  - ◆ R analysis environment
  - ◆ Field data capture
  - ◆ FAIR Data discovery → Elixir FAIDARE



Selby *et al. Bioinformatics* (2019),  
[doi.org/10.1093/bioinformatics/btz190](https://doi.org/10.1093/bioinformatics/btz190)

A screenshot of a web browser window displaying the 'BrAPI Study Comparison' interface. The window title is 'BrAPI Study Comparison'. Below the title, it says 'Requires: D3, jQuery'. The main heading is 'Study Comparison BrApp Example'. There are several input fields: 'BrAPI Server Address' with the value 'yambase.org', 'Username' with 'John\_Doe', and 'Password' with a masked field. Below these are 'Study IDs' with '19,20,21', 'Unit Type' with a dropdown menu, 'Group By Accession' with a radio button, and a 'Load' button. At the bottom, there are 'Select Variable' and 'Compare Variable' buttons.

## > Questions

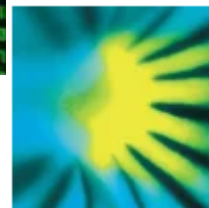
Plant Phenotyping standards : why and who

**MIAPPE overview through Crop & Forest use case**

Crop ontology

MIAPPE tools & web services: BrAPI, PPEO Ontology

## ➤ MINIMUM INFORMATION ABOUT A PLANT PHENOTYPING EXPERIMENT



# New Phytologist

Methods | Open Access |

### Enabling reusability of plant phenomic datasets with MIAPPE 1.1

Evangelia A. Papoutsoglou , Daniel Faria, Daniel Arend, Elizabeth Arnaud, Ioannis N. Athanasiadis, Inês Chaves, Frederik Coppens, Guillaume Cornut, Bruno V. Costa, Hanna Ćwiek-Kupczyńska, Bert Droesbeke, Richard Finkers, Kristina Gruden, Astrid Junker, Graham J. King, Paweł Krajewski, Matthias Lange, Marie-Angélique Laporte, Célia Michotey, Markus Oppermann, Richard Ostler, Hendrik Poorter, Ricardo Ramírez-Gonzalez, Živa Ramšak, Jochen C. Reif, Philippe Rocca-Serra, Susanna-Assunta Sansone, Uwe Scholz, François Tardieu, Cristobal Uauy, Björn Usadel, Richard G. F. Visser, Stephan Weise, Paul J. Kersey, Célia M. Miguel, Anne-Françoise Adam-Blondon, Cyril Pommier ... [See fewer authors](#) ^

First published: 14 March 2020 | <https://doi.org/10.1111/nph.16544> | Citations: 10

## MIAPPE Overview and use cases



## ➤ Capturing important information about phenotyping experiments using the MIAPPE standard

### Two examples to illustrate how to capture important information about the phenotyping experiments:

- **MAIZE:** [1] Millet *et al.* 2019 (<https://doi.org/10.15454/IASSTN>): A multi-site experiment in a network of European fields for assessing the maize yield response to environmental scenarios.
- **POPLAR:** [2] Monclus *et al.* 2012 (<http://dx.doi.org/10.1186/1471-2229-12-173>): Integrating genome annotation and QTL position to identify candidate genes for productivity, architecture and water-use efficiency in *Populus* spp

# Millet et al 2019 [1] - Material&methods section on phenotyping experiments

- A panel of **256 maize hybrids** was grown with **two water regimes** (irrigated or rainfed).
- **Location**: seven fields in 2012 and 2013, plus one site in Chile in 2013
- This resulted in 29 experiments defined as the combination of one year, one site and one **water regime**, with two and three **repetitions** for rainfed and irrigated treatments, respectively.
- A detailed **environmental characterisation** was carried out, with hourly records of micrometeorological data and soil water status, and associated with precise measurement of phenology.
- « **grain.yield** »: yield adjusted at 15% grain moisture, in ton per hectare (t ha<sup>-1</sup>). « **grain.number** »: number of grain per square meter. « **grain.weight** »: individual grain weight (mg). « **anthesis** »: male flowering (pollen shed), in thermal time cumulated since emergence (d20°C). « **silking** »: female flowering (silking emergence), in thermal time cumulated since emergence (d20°C). « **plant.height** »: plant height, from ground level to the base of the flag leaf (highest) leaf (cm). « **tassel.height** »: plant height including tassel, from ground level to the highest point of the tassel (cm). « **ear.height** »: ear insertion height, from ground level to ligule of the highest ear leaf (cm).

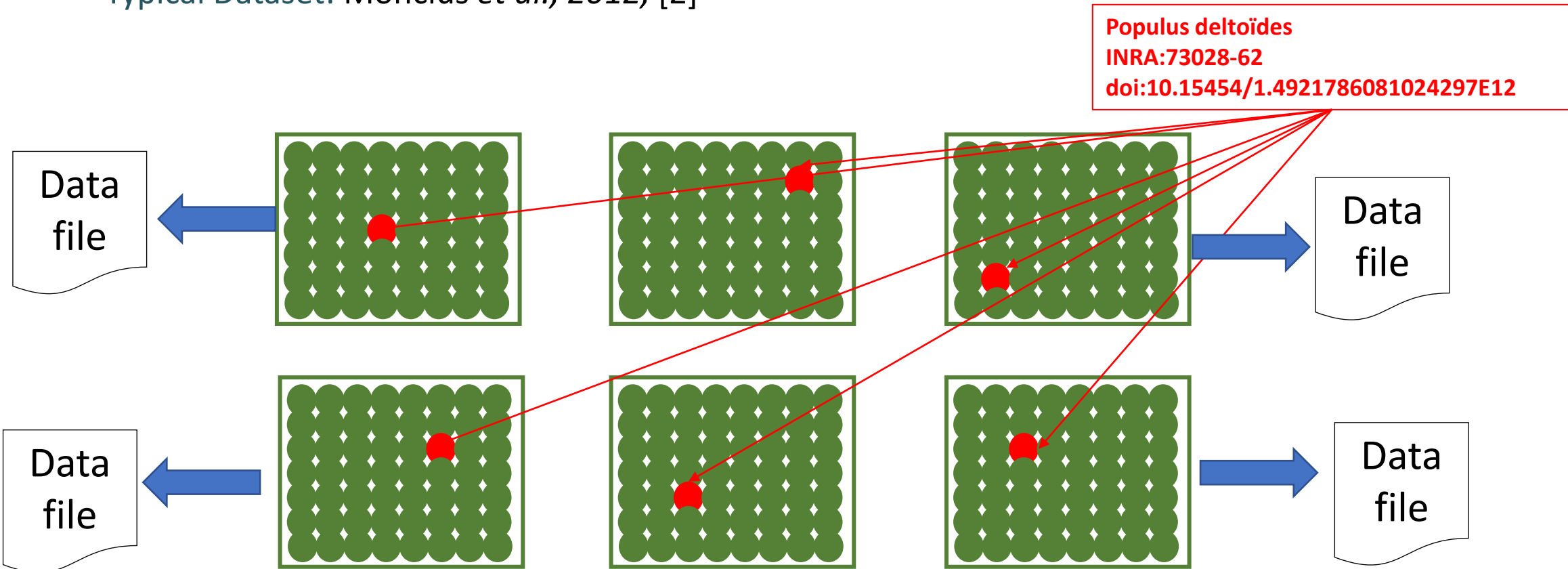


# Monclus et al 2012 [2] - Material&methods section on phenotyping experiments

- **3 Field trial** established in April 2003 **located** in France (Ardon, 47°49'41"N, 1°54'39"E, 110 m), Italy Cavallermaggiore ((44° 43' 0" N) , (7° 41' 0" E)), UK Headley ((51° 7' 0" N) , (-1° 10' 0" W) )
- The **biological material** consisted of a cloned 336 F1 progeny from an interspecific cross between the female *Populus deltoides* (Bartr. Ex Marsh.) '73028-62' from Illinois and the male *P. trichocarpa* (Torr. and Gray) '101-74' from Washington State.
- The **trial was established** from 25 cm- homogenous hardwood cuttings planted at a plant density of 6670 trees per ha. The trial was and consisted in 6 randomized complete blocks where each F1 genotype and each parent was represented by one replicate.
- **Circumference and stem height** were measured at the end of the first (winter 2003–2004) and second (winter 2004–2005) as described in Dillen et al. Forest Ecol Manag. 2007, 252 (1–3): 12-23). Growth increment in height and circumference during the second growing season were calculated.
- **Leaf traits** were measured in 2003: one fully illuminated mature leaf was collected on each tree according to Monclus et al. <http://doi.org/10.1111/j.1469-8137.2005.01407.x> ). Six calibrated discs of lamina were cut from this leaf, dried at 50 °C during 48 h and weighed, and specific leaf area (SLA, cm<sup>2</sup> g<sup>-1</sup>) was computed. Leaf discs were ground to fine powder for analysis of leaf carbon isotope composition ( $\delta^{13}\text{C}$ ), carbon ( $C_M$ ) and nitrogen ( $N_M$ ) contents. One-milligram subsamples of ground material were used for measuring the CO<sub>2</sub> produced by combustion and its <sup>13</sup>CO<sub>2</sub>/<sup>12</sup>CO<sub>2</sub> ratio by a continuous flux isotope ratio mass spectrometer. The discrimination between atmospheric CO<sub>2</sub> and plant material was calculated.

# ➤ MIAPPE 1.1 Overview

Typical Dataset: Monclus *et al.*, 2012, [2]



6 randomized blocks

1 observation unit = one tree

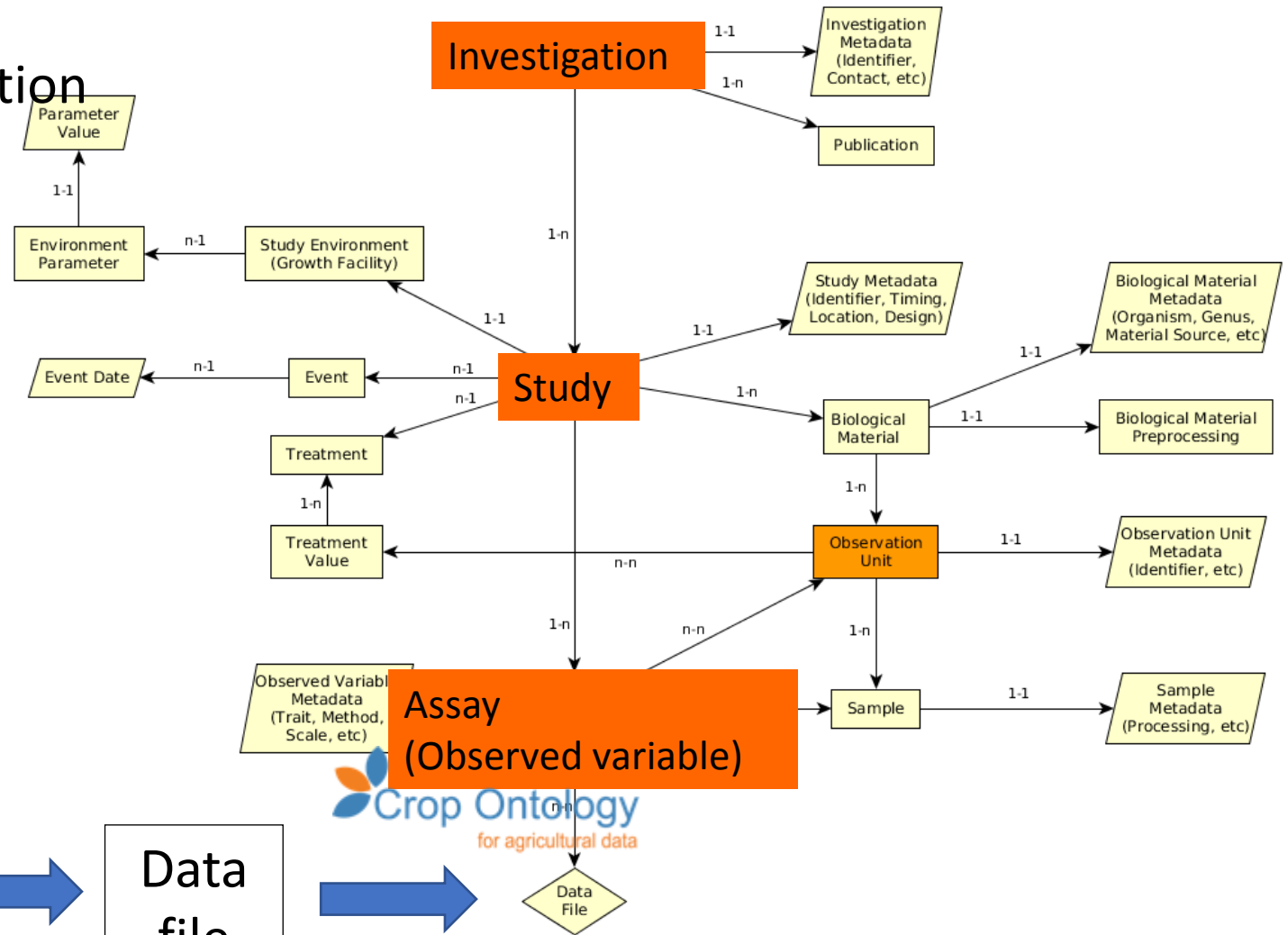
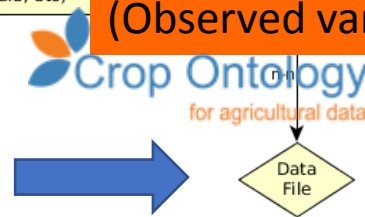
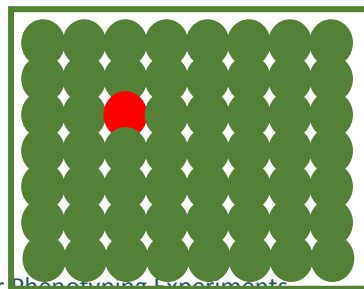
No treatment

6 replicates defined by their position in each block: row and column



# ➤ MIAPPE V1.1 Overview the (ISA) backbone

- **Investigation:** whole dataset
- **Study** : one experiment in one location for one to several year
- **Assay:** Level + Trait + Method + Scale/Unit
- **Level:**
  - Plant
  - Microplot
  - Block
  - Trial
  - ...



# ➤ MIAPPE V1.1 Overview

## Data file content

- Any format (Near Infra Red Spectrum, Images, Image Archives references, ....)
- Mostly tabular
- Metadata on each column header

A	B	C	D	E	F	G	H	I
Accession Number	Trial Site	Campaign	Circum1: Tree circumference at 1 year	Date [Circum1]	Height1: Tree total height at 1 year	Date [Height1]	Shoots3: Number of resprouts at 3 years	Date [Shoots3]
661300270	Ardon	2004	45.645632645603683	12/01/2004	284.3	12/01/2004		
661300270	Ardon	2005					14.630625	12/05/2005
661300444	Ardon	2004	38.96112577281653	12/01/2004	228.8	12/01/2004		
661300444	Ardon	2005					8.5030559999999991	12/05/2005
661300312	Cavallermaggiore	2004	52.4	01/01/2004	249.9	01/01/2004		
661300312	Cavallermaggiore	2005					12.9816090000000001	01/05/2005
661300371	Cavallermaggiore	2004	45.74	01/01/2004	230.2	01/01/2004		
661300371	Cavallermaggiore	2005					10.3041	01/05/2005
661300487	Cavallermaggiore	2004	72.52	01/01/2004	309.8	01/01/2004		
661300487	Cavallermaggiore	2005					10.6798239999999998	01/05/2005
661300585	Cavallermaggiore	2004	71.739999999999995	01/01/2004	305.7	01/01/2004		
661300585	Cavallermaggiore	2005					10.9561000000000001	01/05/2005
661300468	Headley	2004	45.27	01/01/2004		247	01/01/2004	
661300468	Headley	2005					15.8881960000000002	01/05/2005
661300469	Headley	2004	70.9300000000000007	01/01/2004		313	01/01/2004	
661300469	Headley	2005					13.2714489999999999	01/05/2005
661300533	Headley	2004	57.67	01/01/2004	258.8	01/01/2004		



## ➤ MIAPPE main sections – Investigation

- **Investigations are research programmes with defined aims.** They can exist at various scales: e.g. grant-funded programme of work with various published components; a single experiment.
- One investigation holds one to many studies.
- **Metadata**
  - ◆ **Similar to Archive deposition**
  - ◆ **DOI, title, description, associated publications/people, ...**
- **Examples Investigation :**
  - **MAIZE [1]: the whole set of multilocal and pluriannual phenotyping experiments**
  - **POPLAR [2]: the whole set of multilocal measurements over three years**



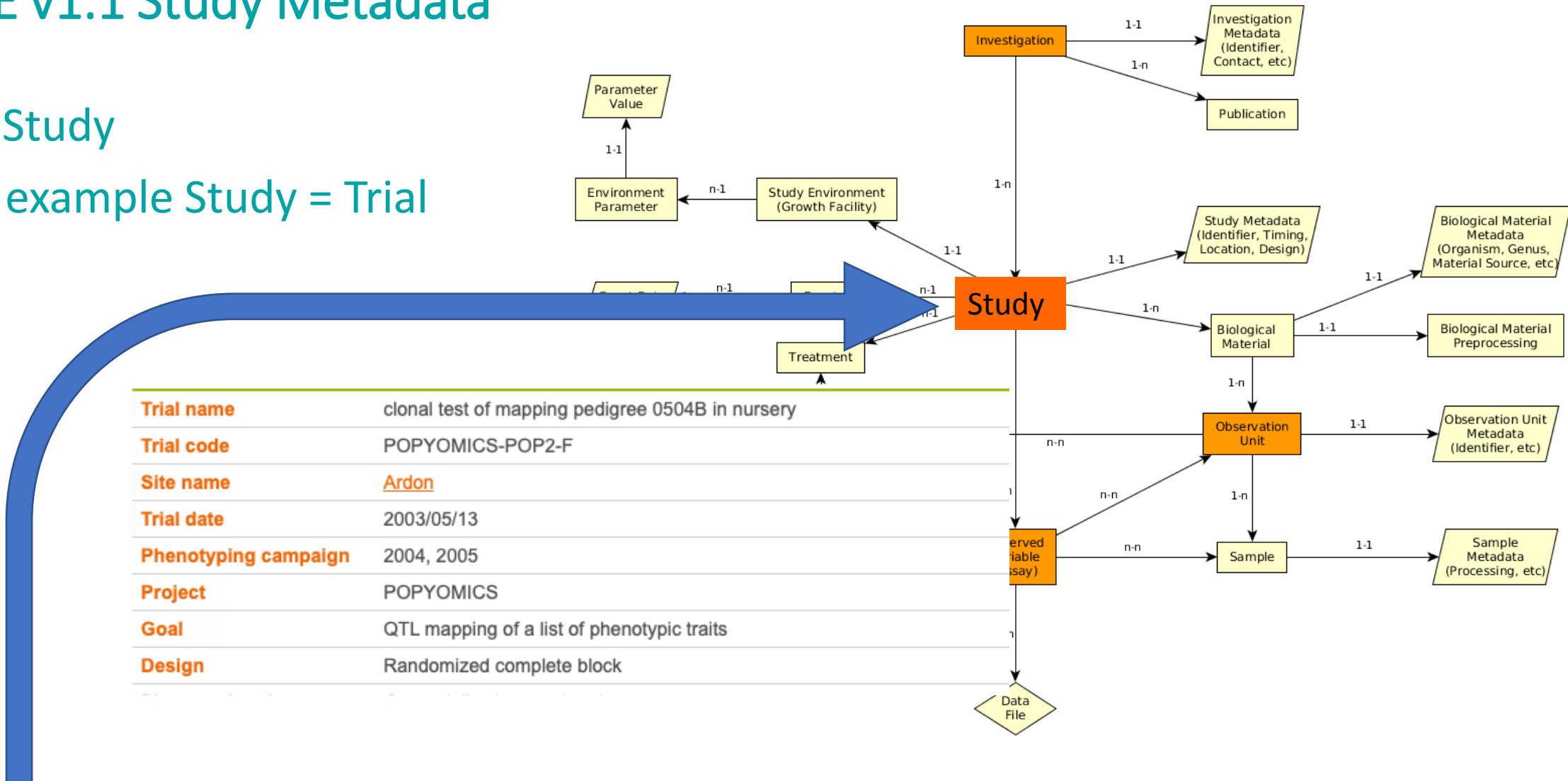
## > MIAPPE main sections – Study

- **A "study" (or experiment)**
  - ◆ One study = one location
  - ◆ comprises a series of assays (or measurements) undertaken to answer a particular biological question.
  
- **Metadata**
  - ◆ **experiment as a whole**
  - ◆ **timing, location, statistical design, cultural practices (but not event lists), etc...**
  
- **Examples of Studies:**
  - **MAIZE [1] : 37 studies: year x location x treatment (Gaillac 2012 rain, Gaillac 2013 watered, ...)**
  - **POPLAR [2] : 3 locations over one to several years (Ardon\_2003) (Ardon\_2003-2005)**



# MIAPPE v1.1 Study Metadata

- Poplar Study
- In that example Study = Trial



<b>Trial name</b>	clonal test of mapping pedigree 0504B in nursery
<b>Trial code</b>	POPYOMICS-POP2-F
<b>Site name</b>	<u>Ardon</u>
<b>Trial date</b>	2003/05/13
<b>Phenotyping campaign</b>	2004, 2005
<b>Project</b>	POPYOMICS
<b>Goal</b>	QTL mapping of a list of phenotypic traits
<b>Design</b>	Randomized complete block

A	B	C	D	E	F	G	H	I
Accession Number	Trial Site	Campaign	Circum1: Tree circumference at 1 year	Date [Circum1]	Height1: Tree total height at 1 year	Date [Height1]	Shoots3: Number of resprouts at 3 years	Date [Shoots3]
661300270	Ardon	2004	45.645632645603683	12/01/2004	284.3	12/01/2004		
661300270	Ardon	2005					14.630625	12/05/2005
661300444	Ardon	2004	38.96112577281653	12/01/2004	228.8	12/01/2004		
661300444	Ardon	2005					8.5030559999999991	12/05/2005



## ➤ MIAPPE main sections – Biological material

- **Biological material being studied**
- Plus its source (stock center, gen bank, etc...).
- **Crucial** for integrating phenotyping data with genomic or genetic data.

### • Metadata

- ◆ Minimal fields from Multicrop Passport Descriptor (MCPD) standard
- ◆ GPS location for forest tree / in situ material provenance

**Source of the material used:**  
accession, cultivar/variety, region  
of provenance, laboratory cross, ...



**Biological material used in the study:** seed lot, cuttings...



**Plant Samples used in the study:** detached leaves, ...

#### MCPD identification system:

- Genebank/Lab + Species + accession number (mandatory)
- DOI

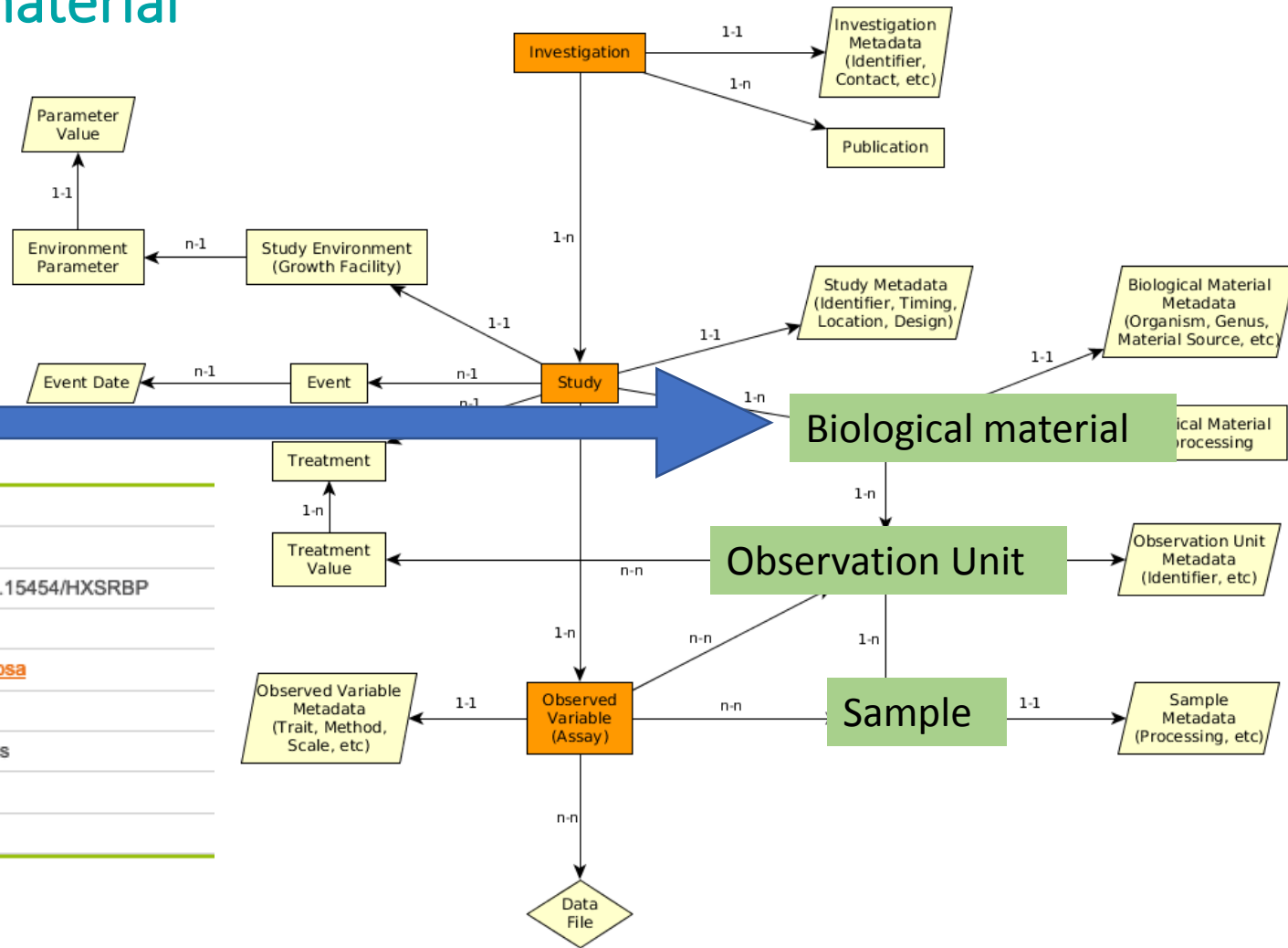
- Lab + internal accession number (mandatory)
- URI

- Lab + internal accession number (mandatory)
- BioSample ID



# MIAPPE main sections – Biological material

- Plant Material
  - Identification
  - Description
- Multi Crop Passport Descriptor



## IDENTIFICATION

<b>Accession number</b>	661300333
<b>Accession name</b>	661300333
<b>Permanent Unique Identifier</b>	<a href="https://doi.org/10.15454/HXSRBP">https://doi.org/10.15454/HXSRBP</a>
<b>Synonyms</b>	0054B115
<b>species</b>	<u><a href="#">Populus x generosa</a></u>
<b>Pedigree</b>	-
<b>Biological status</b>	Interspecific cross
<b>Genetic nature</b>	Clone
<b>Comment</b>	-

## HOLDING

<b>Holding stock center</b>	<u><a href="#">Forest BRC (I)</a></u>
<b>Presence status</b>	

A	B	C	F	G	H	I		
Accession Number	Trial Site	Campaign	Circum1: Tree circumference at 1 year	Date [Circum1]	Height1: Tree total height at 1 year	Date [Height1]	Shoots3: Number of resprouts at 3 years	Date [Shoots3]
661300270	Ardon	2004	45.645632645603683	12/01/2004	284.3	12/01/2004		
661300270	Ardon	2005					14.630625	12/05/2005
661300444	Ardon	2004	38.96112577281653	12/01/2004	228.8	12/01/2004		
661300444	Ardon	2005					8.5030559999999991	12/05/2005

# ➤ MIAPPE main sections – Observed Variable (Assay)

- **An Observed Variable (assay)**
  - ◆ specific measurement.
  - ◆ Targets a trait
  - ◆ with a method and a scale.
  - ◆ Trait: Phenotype or Environment
- **Metadata**
  - ◆ Crop Ontology Trait Dictionary:
  - ◆ **trait, method, scale**
- **Example:**
- In each study of Millet *et al.* [1] :
  - ◆ Plant level: 20 variables
  - ◆ Genotype/ Study level: 19 variable both phenotype and environment
  - ◆ Plot level: 9 variables
  - ◆ *E.g. Female flowering days to silking D20deg*
  - ◆ *E.g. Plant height (cm)*

**FFLW\_D20deg: Female flowering days to silking D20deg** VARIABLE

<b>Synonyms</b>	Female flowering days to silking D20deg FFLW
<b>Growth stage</b>	Flowering
<b>Crop</b>	Maize

**Silking time** TRAIT

<b>Identifier</b>	CO_322:0000031
<b>Name</b>	Silking time
<b>Description</b>	Silking time
<b>Synonyms</b>	Female flowering time
<b>Main abbreviation</b>	Silk
<b>Alternative abbreviations</b>	S FFW
<b>Entity</b>	Flower
<b>Attribute</b>	Silking time
<b>Class</b>	Phenological

**Thermal time between emergence and silking – Computation** METHOD

<b>Identifier</b>	MIPO:0000027
<b>Name</b>	Thermal time between emergence and silking – Computation
<b>Description</b>	Calculated as equivalent days at 20 °C unit between emergence and 50% anthesis.
<b>Reference</b>	B. Parent, O. Turc, Y. Gibon, M. Stitt and F. Tardieu (2010) Modelling temperature-compensated physiological rates, based on the co-ordination of responses to temperature of developmental processes. Journal of Experimental Botany
<b>Class</b>	Computation

**D20deg: days equivalent time at 20 °C** SCALE

<b>Identifier</b>	MIPO:0000030
<b>Name</b>	D20deg: days equivalent time at 20 °C
<b>Data type</b>	Numerical

**PTHT: Plant height (cm)** VARIABLE

<b>Ontology name</b>	Maize Traits
<b>Identifier</b>	MIPO:0000006
<b>Name</b>	PTHT
<b>Synonyms</b>	Plant height (cm)
<b>Xref</b>	CO_322:0000994
<b>Crop</b>	Maize

**Plant height** TRAIT

<b>Identifier</b>	CO_322:0000994
<b>Name</b>	Plant height
<b>Description</b>	Plant height from the base to the top part (in reproductive stages to the top of the tassel).
<b>Main abbreviation</b>	PH
<b>Entity</b>	Plant
<b>Attribute</b>	height
<b>Class</b>	Agronomical

**PH - Measurement** METHOD

<b>Identifier</b>	CO_322:0000995
<b>Name</b>	PH - Measurement
<b>Description</b>	Recommended to take multiple plants and measure the height from the base of a plant to the top of the tassel, enter the data individually in the FieldBook and calculate the average.
<b>Reference</b>	DTMA drought phenotyping protocol. 2009. CIMMYT. Magorokosho et al. 2010. Characterization of maize germplasm grown in eastern and southern Africa: Results of the 2009 regional trials coordinated by CIMMYT. Zimbabwe



# MIAPPE v1.1 Metadata

## Observed Variable: Trait + Method + Scale

### Traits, methods and scales

English

HT: Tree total height **VARIABLE**

Search terms...

- Terminal bud diameter **TRAIT**
- Tree circumference **TRAIT**
- Tree diameter **TRAIT**
- Tree flexuosity **TRAIT**
- Tree height **TRAIT**
- HT: Tree total height **VARIABLE**
- HTm: Tree total height in m **VARIABLE**
- Tree ring width **TRAIT**
- Tree shape **TRAIT**
- Tree status **TRAIT**
- Type cépée **TRAIT**
- Volume **TRAIT**
- Whorl defects **TRAIT**
- Wood axial parenchyma high **TRAIT**
- Wood axial parenchyma thickness **TRAIT**
- Wood density **TRAIT**

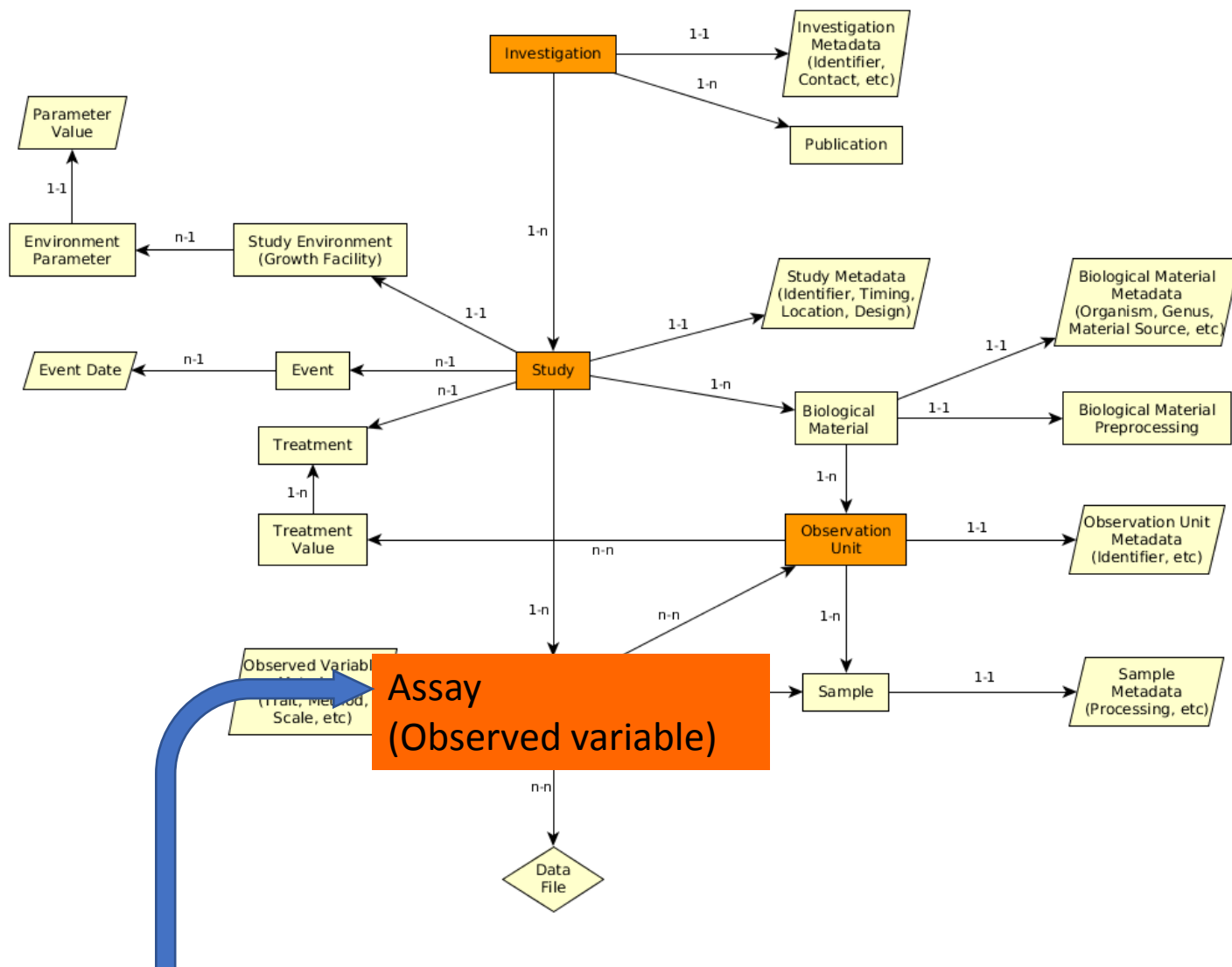
**Ontology name** Woody Plant Ontology  
**Identifier** CO\_357:0000048  
**Name** HT

**Tree height **TRAIT****  
**Identifier** CO\_357:1000037  
**Name** Tree height  
**Description** Total height of the tree, from the ground to the tallest part of the crown  
**Main abbreviation** HT  
**Alternative abbreviations** Height, HP, HPL, h, H, TH, Height.F, Height.LUK, Height.I

**Entity** tree  
**Attribute** height  
**Status** Standard for INRA & GenTree project  
**Class** Morphological

**Tree height protocol **METHOD****  
**Identifier** CO\_357:2000027  
**Name** Tree height protocol  
**Description** Measured from soil to basis of the apical meristem or bud (depending of time in season) with a pole or a clinometer  
**Reference** GenTree\_protocols\_0.99.pdf page 16, [https://en.wikipedia.org/wiki/Tree\\_measurement#Height](https://en.wikipedia.org/wiki/Tree_measurement#Height)  
**Class** Measurement

**cm **SCALE****  
**Identifier** CO\_357:3000107  
**Name** cm



A	B	C	D	E	F	G	H	I
Accession Number	Trial Site	Campaign	Circum1: Tree circumference at 1 year	Date [Circum1]	Height1: Tree total height at 1 year	Date [Height1]	Shoots3: Number of resprouts at 3 years	Date [Shoots3]
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661300270	Ardon	2005					14.630625	12/05/2005
661300444	Ardon	2004	38.96112577281653	12/01/2004	228.8	12/01/2004		
661300444	Ardon	2005					8.5030559999999991	12/05/2005

## ➤ MIAPPE main sections – Observation Unit, Samples

- **Observation units**

- ◆ objects in the study
- ◆ Observations/measures are made on observation units
- ◆ Treatments values are made on observation units
- ◆ Also used for environmental variables.

- **Metadata are specific to MIAPPE: identifiers, location, replication, treatments, ...**

- **A sample**

- portion of plant tissue extracted from an observation unit
- sub-plant observations and/or molecular studies.

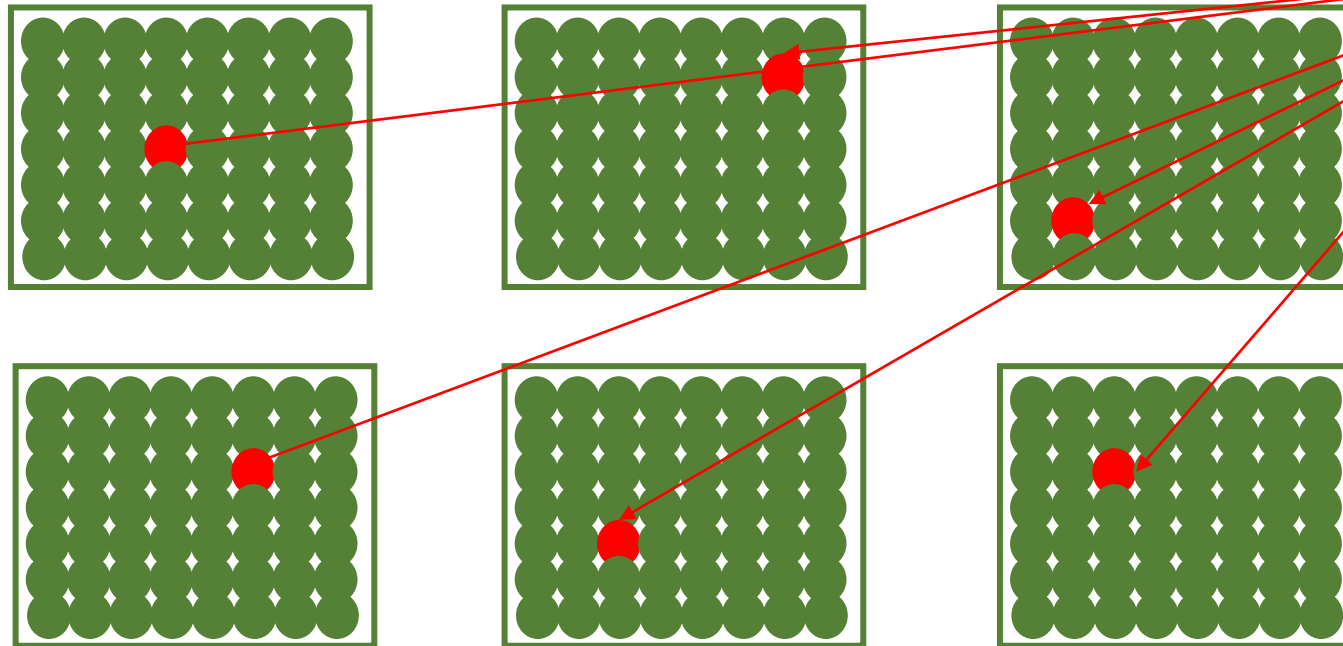
- **Metadata : identifiers, information about processing, ...**



## ➤ MIAPPE main sections – Observation Unit, Samples

**Example:** Monclus *et al.*, 2012, [2]

**Populus deltoïdes**  
INRA:73028-62  
doi:10.15454/1.4921786081024297E12



6 randomized blocks

1 observation unit = one tree

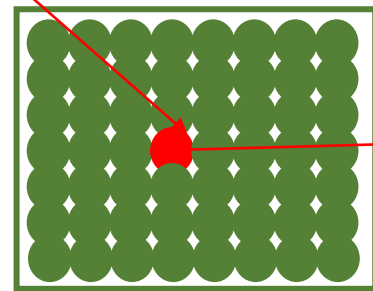
No treatment

6 replicates defined by their position in each block: row and column

## ➤ MIAPPE main sections – Observation Unit, Samples

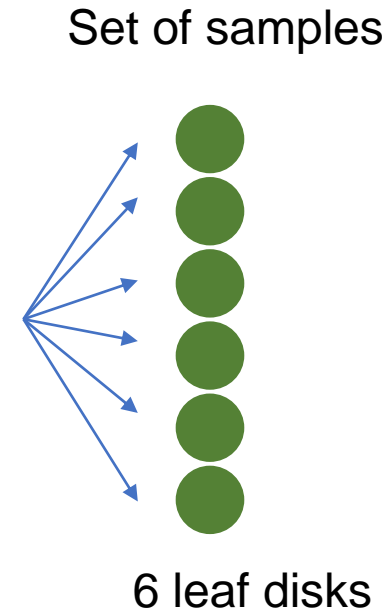
**Example:** Monclus *et al.*, 2012, [2]

**Populus deltoïdes**  
 INRA:73028-62  
 doi:10.15454/1.4921786081024297E12  
 [observation unit] : Block1-Row4-Col4



For each tree of each block  
 = for each observation unit

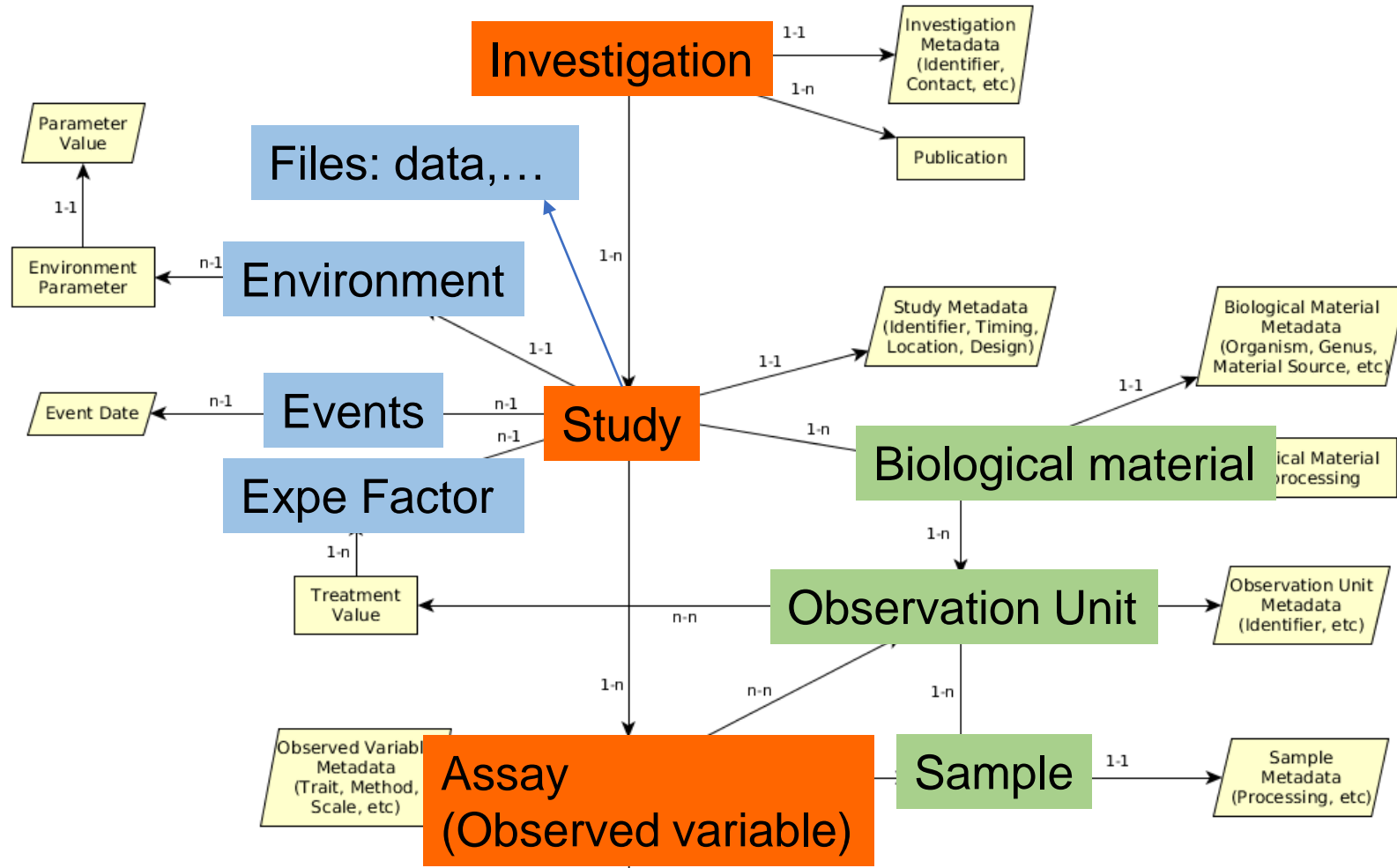
One leaf



Different types of processing of the leaf disks depending on the measurement: can be captured by different sets of samples (e.g. if subsampling generates repetitions) or in the method of the observed variable.



# ➤ MIAPPE V1.1 data model – Other Important sections



## ➤ MIAPPE main sections – Experimental Factor

- **Biotic or abiotic experimental factor**
  - ◆ Its effects are evaluated in the study.
  - ◆ Takes different values in the observation units
- **Metadata: name, description and value**
- **Example : Maize dataset [2]**
  - ◆ Two Experimental factors/treatments: Rainfed, Watered
  - ◆ Identified by dedicated metadata
  - ◆ Block organisation
  - ◆ Study the effect of Environment/Drought on the Biological material



GENOTYPE ID		TREATMENT	Trial Name	Trial Site	LEVEL	LEVEL	LEVEL
Accession Number	Accession Name	water_regime			BLOCK	PLOT	REPLICATE
FR19_H	FR19_H	rainfed	<a href="#">KWS Karlsruhe 2011</a>	Karlsruhe	5	124	1
FR19_H	FR19_H	rainfed	<a href="#">KWS Karlsruhe 2011</a>	Karlsruhe	10	250	3
FR19_H	FR19_H	rainfed	<a href="#">KWS Karlsruhe 2013</a>	Karlsruhe	11	401503	2
FR19_H	FR19_H	watered	<a href="#">KWS Karlsruhe 2012</a>	Karlsruhe	23	400353	1
FR19_H	FR19_H	watered	<a href="#">KWS Karlsruhe 2011</a>	Karlsruhe	2	6	1
FR19_H	FR19_H	rainfed	<a href="#">KWS Karlsruhe 2012</a>	Karlsruhe	16	401451	2

## ➤ MIAPPE main sections – Event

- **Event**

- ◆ Discrete occurrence at a particular time
- ◆ Natural, e.g. rain, unwanted pathogen attack
- ◆ Cultural practice, e.g. planting, watering, etc.
- ◆ **Whole study level** or at **the observation unit level**
- ◆ It is not the studied Factor but an additional information

- **Metadata: name, description, time/date**

- **Examples:** In Poplar, [2]

- the field establishment date, 2003.
- the orchard was subjected to 15mm of rain on March 15, 2012 (fiction).



Study	Event		
	Name	Description	Date
Monclus <i>et al.</i> , 2012	Rain	15mm of rain on the orchard	2012-03-15

## ➤ MIAPPE main sections – Environment

- **Environment parameters**

- ◆ Constant throughout the study
- ◆ Did not change between observation units or assays.
- ◆ Environment characteristics that vary over time, i.e. environmental variables, should be recorded as Observed Variables

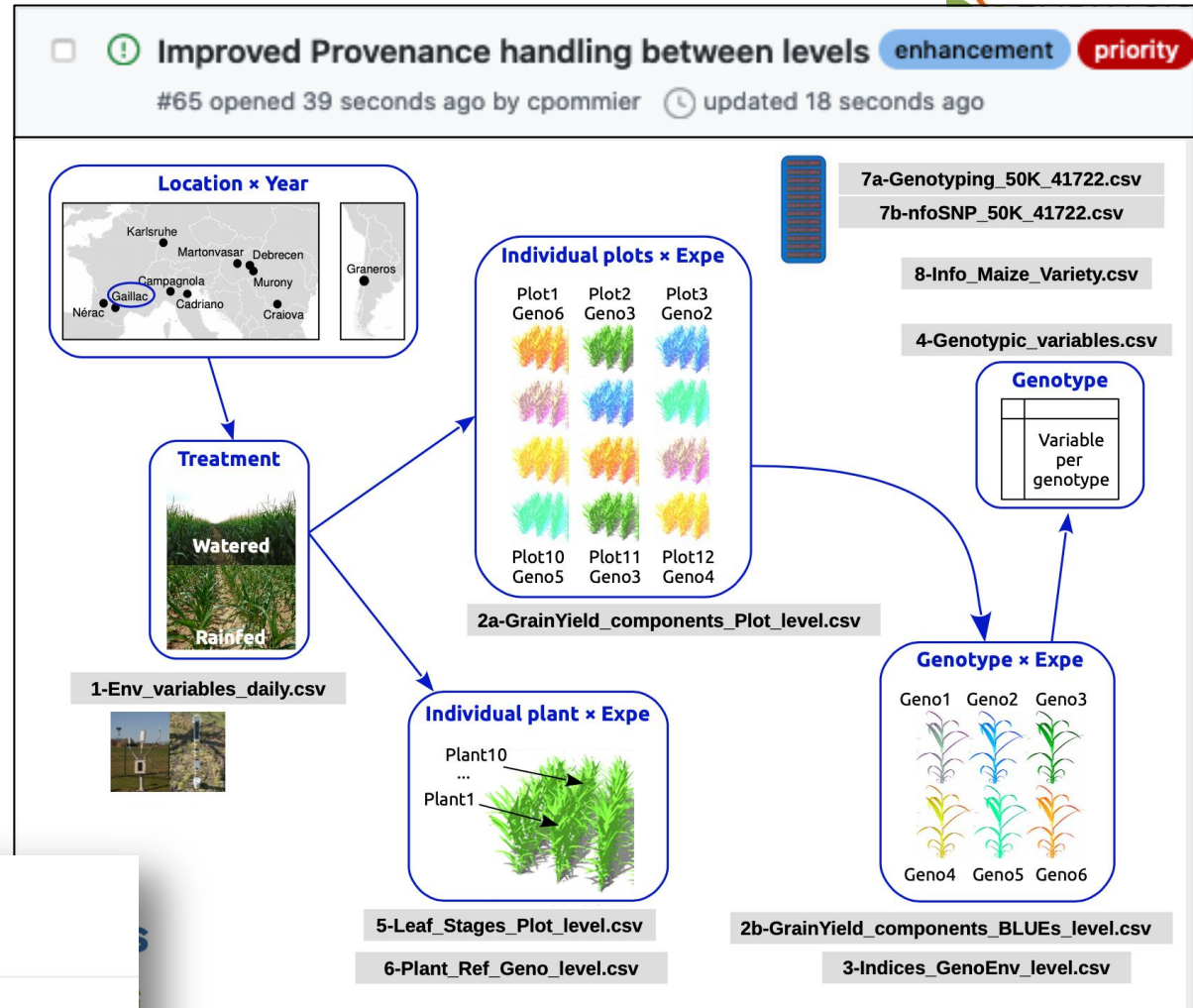
- **Metadata :name, value**

- **Example:**

Environment parameter	Environment parameter Value
Sowing density	20 seeds/m <sup>2</sup>
Rooting medium composition	Ca (XEO:00058): 5 mg/L; ...

# ➤ Perspectives

- Open community
  - ◆ Github
  - ◆ Mailing list
- Outreach
- Training
- Elixir Service bundles



- 📌 **Experimental Factor should allow a single modality/level** enhancement priority  
 #51 opened on 3 May 2019 by cpommier ⌚ updated 6 hours ago 🔗 V2
- 📌 **Genotypes can be given in the material ID fields** enhancement priority  
 #61 opened on 5 Feb by PapoutsoglouE ⌚ updated 6 hours ago
- 📌 **Missing filed for biological material other IDs** enhancement priority  
 #64 opened on 12 Nov by cpommier ⌚ updated 6 hours ago
- 📌 **Feedback on MIAPPE for low throughput long-term agricultural experiments**  
 #4 opened on 18 Jun 2018 by cpommier ⌚ updated on 30 Oct 2019 🔗 V2

## ➤ Questions

Plant Phenotyping standards : why and who  
MIAPPE overview through Crop & Forest use case

### **Crop ontology**

MIAPPE tools & web services: BrAPI, PPEO Ontology

## ➤ CROP ONTOLOGY





## > Context

### • Need

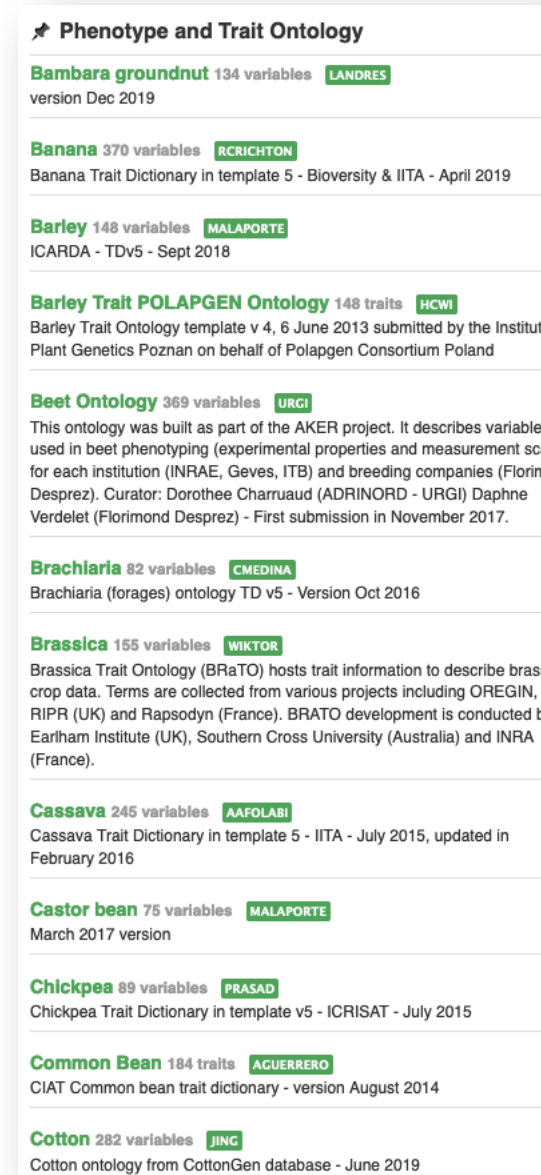
- ◆ Importance of controlled vocabularies and ontologies for data annotation and FAIRness
- ◆ Must respect crop specificities

Study	Genotype	CIR	HT	SUR
Domaine de Valcros	6579	600	17	1
Domaine de Valcros	6580	482	14	1

Study	Genotype	H	CIR
La Nerthe	6579	23	650
La Nerthe	6580	28	514

### • Answer

- ◆ Development of a standard to build ontologies to annotate phenotypes: “Crop Ontology”
  - ◆ Crop-specific vocabulary established by its community
- ⇒ 31 ontologies crop-specific available (including woody plants):  
[www.cropontology.org](http://www.cropontology.org)



Crop	Variables/Traits	Ontology Name	Version
Bambara groundnut	134 variables	LANDRES	version Dec 2019
Banana	370 variables	RCRICHTON	Banana Trait Dictionary in template 5 - Bioversity & IITA - April 2019
Barley	148 variables	MALAPORTE	ICARDA - TDv5 - Sept 2018
Barley Trait	148 traits	HCWI	Barley Trait Ontology template v 4, 6 June 2013 submitted by the Institut Plant Genetics Poznan on behalf of Polapgen Consortium Poland
Beet	369 variables	URGI	This ontology was built as part of the AKER project. It describes variable used in beet phenotyping (experimental properties and measurement sc for each institution (INRAE, Geves, ITB) and breeding companies (Florin Desprez). Curator: Dorothee Charruaud (ADRINORD - URGI) Daphne Verdelet (Florimond Desprez) - First submission in November 2017.
Brachiaria	82 variables	CMEDINA	Brachiaria (forages) ontology TD v5 - Version Oct 2016
Brassica	155 variables	WIKTOR	Brassica Trait Ontology (BRaTO) hosts trait information to describe brassica crop data. Terms are collected from various projects including OREGIN, RIPR (UK) and Rapsodyn (France). BRATO development is conducted by Earlham Institute (UK), Southern Cross University (Australia) and INRA (France).
Cassava	245 variables	AAFOLABI	Cassava Trait Dictionary in template 5 - IITA - July 2015, updated in February 2016
Castor bean	75 variables	MALAPORTE	March 2017 version
Chickpea	89 variables	PRASAD	Chickpea Trait Dictionary in template v5 - ICRISAT - July 2015
Common Bean	184 traits	AGUERRERO	CIAT Common bean trait dictionary - version August 2014
Cotton	282 variables	JING	Cotton ontology from CottonGen database - June 2019

## > Standard model

**Variable** = trait + method + scale

Trial	Genotype	CIR	HT	SUR
Domaine de Valcros	6579	600	17	1
Domaine de Valcros	6580	482	14	1

## The phenotypic observation

Variable	<b>Variable ID</b>
	Variable name
	Variable synonyms
	Context of use
	Growth stage
	Variable status
	Variable Xref
	Institution
	Scientist
	Date
	Language
	Crop

## > Standard model

Variable = **trait** + method + scale

Trial	Genotype	CIR	HT	SUR
Domaine de Valcros	6579	600	17	1
Domaine de Valcros	6580	482	14	1

Circumference of the tree

Total height of the tree

Survival state of the tree

What is the studied character?

Trait	<b>Trait ID</b>
	Trait
	Trait class
	Trait description
	Trait synonyms
	Main trait abbreviation
	Alternative trait abbreviations
	Entity
	Attribute
	Trait status
Trait Xref	

## > Standard model

Variable = trait + **method** + scale

Trial	Genotype	CIR	HT	SUR
Domaine de Valcros	6579	600	17	1
Domaine de Valcros	6580	482	14	1

Measured at breast height with a graduated ribbon

Measured from soil to crown with a pole or a clinometer

Visual assessment with a reference scoring scale

How is it observed?

Method	<b>Method ID</b>
	Method
	Method class
	Method description
	Formula
	Method reference



## > Standard model

Variable = trait + method + **scale**

Trial	Genotype	CIR	HT	SUR
Domaine de Valcros	6579	600	17	1
Domaine de Valcros	6580	482	14	1

cm

mm

0 = Alive  
1 = Dead  
2 = Doubtful

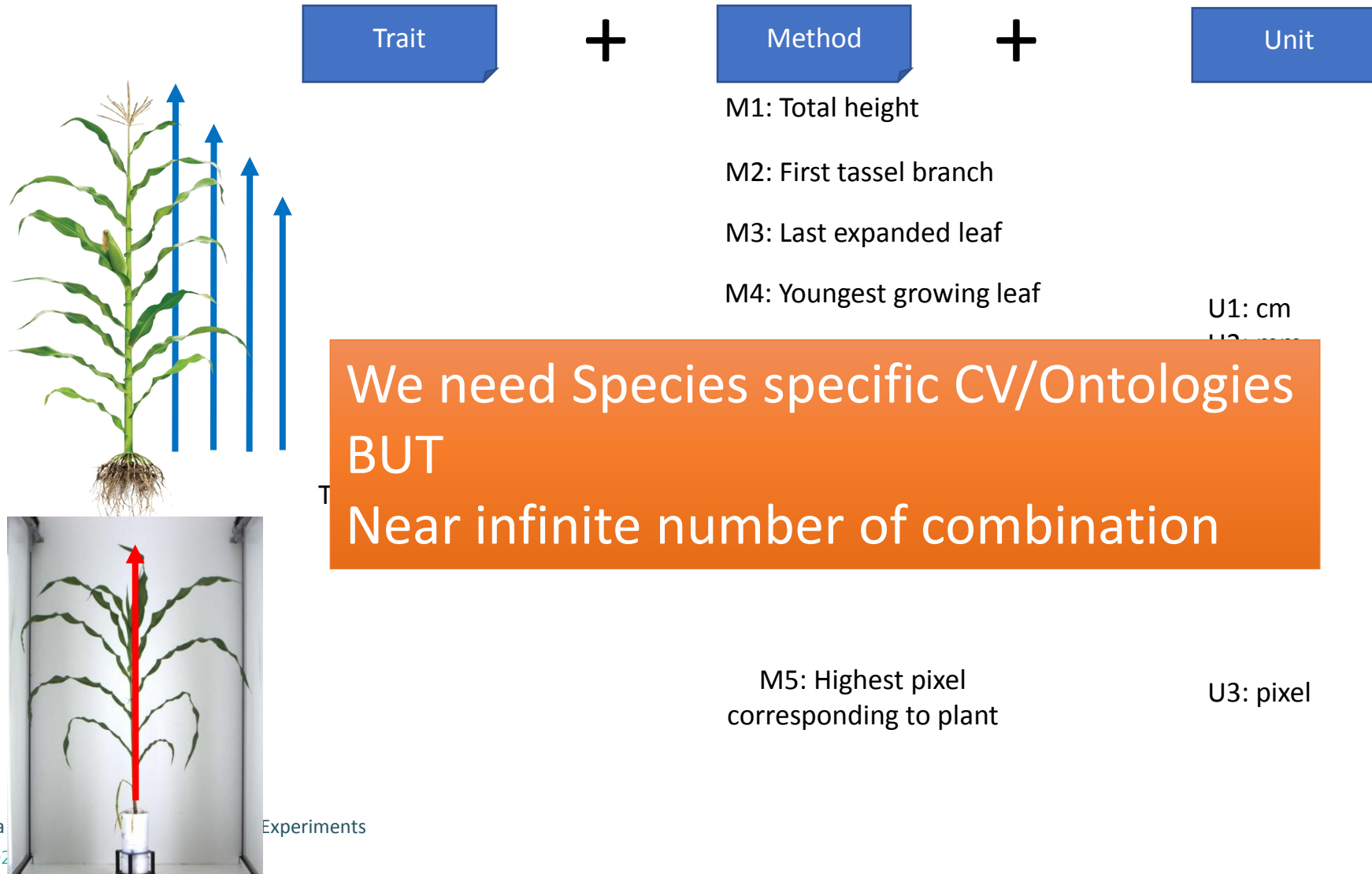
How is it expressed (unit or scale)?

Scale	Scale ID
	Scale name
	Scale class
	Decimal places
	Lower limit
	Upper limit
	Scale Xref
	Category 1
	Category 2
	...
Category n	



# > Controlled Vocabulary Challenge

Phenotyping/environment variable = *Trait + Method + Unit/Scale*



# ➤ Controlled Vocabulary Challenge

Variable annotation

- Using MIAPPE for minimal variable description
  - Optional reference to existing crop ontology
  - Ad hoc Trait or Method or Scale in MIAPPE dataset
  - Focus on Trait for interoperability



# ➤ Controlled Vocabulary Challenge

## Variable annotation Example 1

Trait	Trait description
L98AR1	Latent Period for strain 98AR1
L93CV1	Latent Period for strain 93CV1
Canker_LL	Canker lesion length

**Traits, methods and scales** English

Latent period

- Woody Plant Ontology **ONTOLOGY**
  - Biotic stress **TRAIT CLASS**
    - Latent Period **TRAIT**
      - LD: Latent Period** **VARIABLE**

### LD: Latent Period **VARIABLE**

Ontology name	Woody Plant Ontology
Identifier	CO_357:0000220
Name	LD
Synonyms	Latent Period LD[Adonis]
Context of use	QTL analysis
Status	Standard for INRA
Institution	INRA
Scientist	Célia Michotey
Date	20/02/2018
Crop	WoodyPlant

### Latent Period **TRAIT**

Identifier	CO_357:1000183
Name	Latent Period
Description	Latency measured against a given rust strain
Main abbreviation	LD
Alternative abbreviations	LP
Entity	tree
Attribute	latency
Status	Standard for INRA
Class	Biotic stress

### Latent period protocol **METHOD**

Identifier	CO_357:2000083
Name	Latent period protocol
Description	Duration in half-day scale between date of inoculation and first sporulating uredia.
Class	Measurement

### Half-day **SCALE**

Identifier	CO_357:3000068
Name	Half-day
Data type	Duration



# ➤ Controlled Vocabulary Challenge

## Variable annotation Example 2

Trait	Trait description
L98AR1	Latent Period for strain 98AR1
L93CV1	Latent Period for strain 93CV1
<b>Canker_LL</b>	Canker lesion length

VARIABLE	VARIABLE
<b>Canker length.1: Bacterial canker lesion length 1 year after inoculation</b>	<b>Canker length.2: Bacterial canker lesion length 2 years after inoculation</b>

Traits, methods and scales English

canker\_ll

Woody Plant Ontology **ONTOLOGY**

Biotic stress **TRAIT CLASS**

Canker lesion length **TRAIT**

CHALCOL: Collar Chalara **VARIABLE**

**Canker\_LL: Canker lesion length** **VARIABLE**

Canker\_LL.C: Canker cumulative length

### Canker\_LL: Canker lesion length **VARIABLE**

Ontology name	Woody Plant Ontology
Identifier	CO_357:0000088
Name	Canker_LL
Synonyms	Canker lesion length canker_length Canker.length CLL[Adonis]
Context of use	Research-intensive characterization Trial evaluation Breeding criterion
Status	Standard for INRA
Institution	INRA/BET
Scientist	Célia Michotey
Date	13/03/2017
Crop	WoodyPlant

### Canker lesion length **TRAIT**

Identifier	CO_357:1000076
Name	Canker lesion length
Description	Lesion length (longitudinal extent) of a canker lesion, an area of dead tissue which grow slowly and is caused by bacteria or fungus
Main abbreviation	Canker_LL
Alternative abbreviations	canker_length Canker.length LCH LCHA LCHAN
Entity	trunk
Attribute	lesion

### Canker lesion length protocol **METHOD**

Identifier	CO_357:2000037
Name	Canker lesion length protocol
Description	Measured in millimeters with a measuring tape at the inoculation point. Most protocol are using 2 or 3 inoculation points per tree.
Reference	<a href="https://forqemia.inra.fr/urqi-is...">https://forqemia.inra.fr/urqi-is...</a>
Class	Measurement

### mm **SCALE**

Identifier	UO:0000016
Name	mm
Data type	Numerical
Decimal places	0
Xref	<a href="http://purl.obolibrary.org/obo/">http://purl.obolibrary.org/obo/...</a>



## ➤ Controlled Vocabulary Challenge

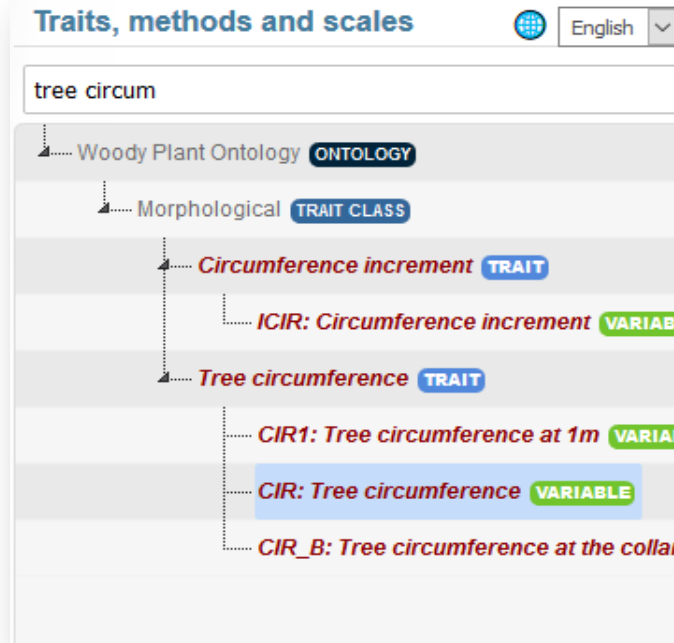
Trait decomposition to Entity/Attribute

- Trait = Leaf Area → Entity = Leaf, Attribute = Area
- Enables ad hoc controlled vocabulary + Trait Interoperability
- Formalized by Mungal et al 2009
- Existing in crop ontology
- EMPHASIS proposition : Use for easy Variable creation and interoperability

# ➤ Tree Variable example1

[https://urgi.versailles.inra.fr/ontologyportal#termIdentifier=CO\\_357:0000019](https://urgi.versailles.inra.fr/ontologyportal#termIdentifier=CO_357:0000019)

- 1 Trait
- 3 Variables
- 3 methods



Tree circumference <b>TRAIT</b>	
Identifier	CO_357:1000012
Name	Tree circumference
Description	Circumference of the tree main stem
Synonyms	Tree girth
Main abbreviation	CIR
Alternative abbreviations	CIRC Circ CI Girth
Entity	trunk
Attribute	circumference
Status	Standard for INRA
Class	Morphological

## CIR: Tree circumference **VARIABLE**

Ontology name	Woody Plant Ontology
Identifier	CO_357:0000019
Name	CIR
Synonyms	Tree circumference Tree girth C130 Ci130 CIR[Adonis]
Context of use	Research-intensive characterization Trial evaluation Breeding criterion
Status	Standard for INRA
Institution	INRA
Scientist	Célia Michotey
Date	13/03/2017
Crop	Woody Plant

## Ribbon 130cm protocol **METHOD**

Identifier	CO_357:2000017
Name	Ribbon 130cm protocol
Description	Measured at 130cm from the ground (approximately breast height) with a graduated ribbon
Class	Measurement

## mm **SCALE**

Identifier	UO:0000016
Name	mm
Data type	Numerical
Xref	<a href="http://purl.obolibrary.org/obo/">http://purl.obolibrary.org/obo/...</a>



# ➤ Tree Variable example2

[https://urgi.versailles.inra.fr/ontologyportal#termIdentifier=CO\\_357:0000082](https://urgi.versailles.inra.fr/ontologyportal#termIdentifier=CO_357:0000082)

Traits, methods and scales English

survival

Woody Plant Ontology **ONTOLOGY**

Stress **TRAIT CLASS**

Survival **TRAIT**

ESDET: Detailed health status **VARIABLE**

**SUR: Survival** **VARIABLE**

SUR\_Rate: Survival rate **VARIABLE**

Terminal bud status **TRAIT**

Withered leaves **TRAIT**

## SUR: Survival **VARIABLE**

**Ontology name** Woody Plant Ontology  
**Identifier** CO\_357:0000082  
**Name** SUR  
**Synonyms** Survival  
 Health status  
 ES  
 S  
 MOR  
 SUR[Adonis]  
**Context of use** Trial evaluation  
**Status** Standard for INRA  
**Institution** INRA/BET  
**Scientist** Célia Michotey  
**Date** 13/03/2017  
**Crop** WoodyPlant

### Survival **TRAIT**

**Identifier** CO\_357:1000070  
**Name** Survival  
**Description** Assessment of the survival state of the tree  
**Synonyms** Health status  
**Main abbreviation** SUR  
**Alternative abbreviations** S  
 SR  
 Survival  
 Survie  
 Etat sanitaire  
 ES  
 Vivants  
 MOR  
**Entity** tree  
**Attribute** survival  
**Status** Standard for INRA  
**Class** Stress

### Visual scoring **METHOD**

**Identifier** CO\_357:2000003  
**Name** Visual scoring  
**Description** Visual assessment with a reference scoring scale  
**Class** Estimation

### Survival scoring scale **SCALE**

**Identifier** CO\_357:3000036  
**Name** Survival scoring scale  
**Data type** Nominal  
**Decimal places** 0  
**Min** 0  
**Max** 2

**Categories** 0 = Alive  
 1 = Dead  
 2 = Doubtful



# ➤ Environmental Variable example

Traits, methods and scales

English

Tnight: Night temperature **VARIABLE**

Search terms...

- Environmental Traits **ONTOLOGY**
  - Experimental practice **TRAIT**
    - Check: microplot altered by environmental meas
  - Maximal temperature **TRAIT**
    - Tmax: Maximum air temperature **VARIABLE**
  - Night temperature **TRAIT**
    - Tnight: Night temperature **VARIABLE****
  - Soil water potential **TRAIT**
    - Psi: Soil water potential **VARIABLE**
  - Solar radiation **TRAIT**
    - Ri: Solar radiation **VARIABLE**
- GAFI Trait Ontology **ONTOLOGY**
- IPGPAS **ONTOLOGY**

**Ontology name** Environmental Traits  
**Identifier** EIPO:0000001  
**Name** Tnight  
**Synonyms** Night temperature  
**Scientist** Melanie Buy  
**Crop** Maize

## Variable annotation

Night temperature **TRAIT**

**Identifier** EIPO:0000006  
**Name** Night temperatur  
**Description** Air night tempera  
**Entity** Air  
**Attribute** Temperature

	<b>VARIABLE</b>	<b>VARIABLE</b>	<b>VARIABLE</b>
	<u>Tnight_Early: between panicle initiation and panicle appearance.</u>	<u>Tnight_Fill: between abortion limit stage and physiological maturity.</u>	<u>Tnight_Flo: between panicle appearance and abortion limit stage.</u>
	20.6817422225	17.2676313374	18.910907588
	20.3843729319	17.6469314405	18.9795167231
	16.7446952482	13.4769056245	19.7126400686

Night temperature measurement **METHOD**

**Identifier** EIPO:0000011  
**Name** Night temperature measurement  
**Description** Average night temperature. Temperature should be recorded in a weather station close to the field.  
**Class** Measurement

Celsius degrees **SCALE**

**Identifier** EIPO:0000016  
**Name** Celsius degrees  
**Data type** Numerical



# ➤ Crop Variable example

Traits, methods and scales



English

TKW: Thousand kernel weight (g) **VARIABLE**

Search terms...

Agronomical **TRAIT CLASS**

Ear height **TRAIT**

Ear husk cover **TRAIT**

Ear number **TRAIT**

Grain number **TRAIT**

Grain row number **TRAIT**

Grain weight **TRAIT**

TKW: Thousand kernel weight (g) **VARIABLE**

Grain yield **TRAIT**

GY\_Adj\_tha: Grain yield **VARIABLE**

KW: Kernel weight per plant (g) **VARIABLE**

Plant height **TRAIT**

PTHT: Plant height (cm) **VARIABLE**

Seedling Vigor **TRAIT**

Standard germination **TRAIT**

Seedling Vigor **TRAIT**

Standard germination **TRAIT**

**Ontology name** Maize Traits  
**Identifier** MIPO:0000012  
**Name** TKW  
**Synonyms** Thousand kernel weight (g)  
**Growth stage** After harvest  
**Xref** CO\_322:0000133  
**Crop** Maize

Ad Hoc Variable

**Grain weight** **TRAIT**  
**Identifier** CO\_322:0000133  
**Name** Grain weight  
**Description** Grain weight of mature kernels.  
**Synonyms** Grain weight  
**Main abbreviation** GW  
**Alternative abbreviations** KW, TKW  
**Entity** Grain  
**Attribute** Weight  
**Class** Agronomical

Trait: reference Crop Ontology  
Maize

**GW DW - Measurement** **METHOD**  
**Identifier** CO\_322:0000341  
**Name** GW DW - Measurement  
**Description** Count and weigh grains randomly selected from the total grains.  
**Reference** IMIS (International Maize Information System; <http://imis.cimmyt.org/>) Database, CIMMYT.  
**Class** Measurement

**g/1000grain** **SCALE**  
**Identifier** CO\_322:0000722  
**Name** g/1000grain  
**Data type** Numerical




# ➤ Crop Ontology repositories and workflow



**GitHub**

Version History



[Trait Dictionary Template v5](#)



**Crop Ontology**  
for agricultural data

Repository, some crop ontologies



**AgroPortal**  
LIRMM

Repository, some other crop ontologies



**OLS**  
EMBL-EBI

Search over several ontologies



**BrAPI**



**URGI**

Plant scientist friendly browser

<https://urgi.versailles.inra.fr/ontologyportal>



## ➤ Questions

Plant Phenotyping standards : why and who  
MIAPPE overview through Crop & Forest use case  
Crop ontology

**MIAPPE tools & web services: BrAPI, PPEO Ontology**

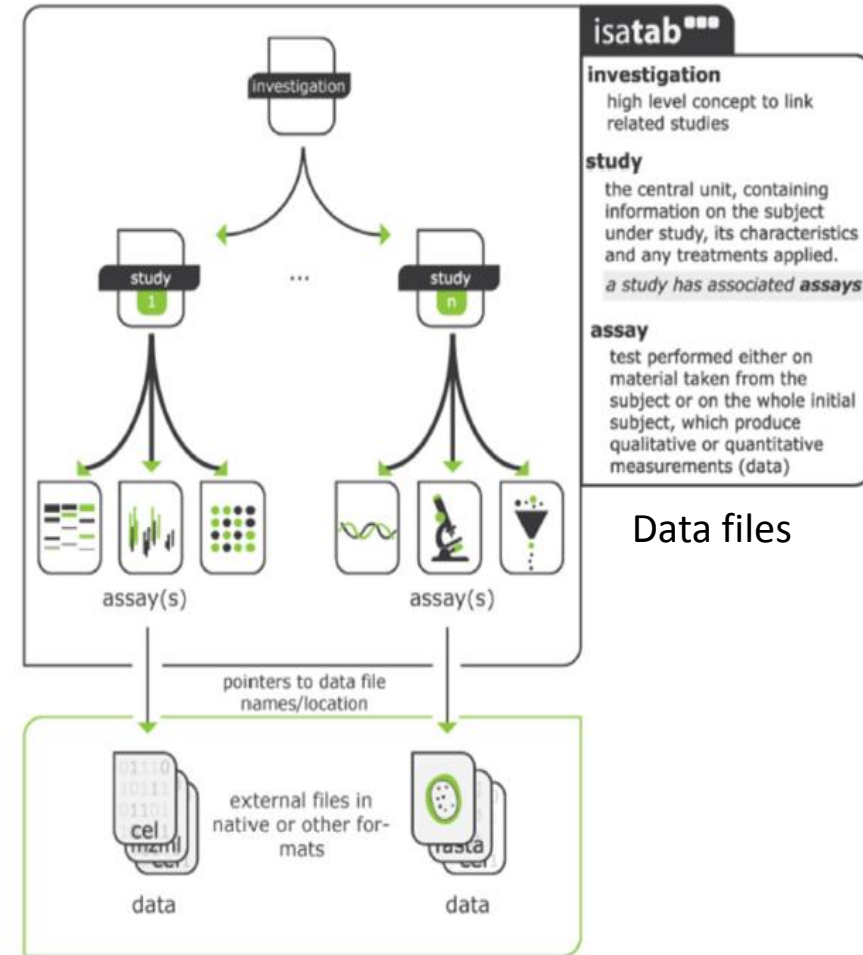
## ➤ MIAPPE TOOLS & WEB SERVICES: BRAPI, PPEO ONTOLOGY



- File Archive: ISA Tab
- Semantic representation in OWL: Phenotyping Experiment Ontology (PPEO) using OWL (<http://agroportal.lirmm.fr/ontologies/PPEO> )
- Web Service: Breeding API

# MIAPPE File Archive

- ISA Tab for Phenotyping
  - ◆ Investigation/Study/Assay
  - ◆ Zip Archive
    - MIAPPE Metadata
    - Raw data
      - CSV
      - Images or binary files
      - Reference to image archive (URI/URL)
    - Elaborated data
      - CSV
      - Provenance
- Training and improvements
  - ◆ File and metadata curation
    - Elixir
    - Célia Miguel & Anne Françoise Adam Blondon
  - ◆ BrAPI to IsaTab portable tool
    - Elixir implementation study for MIAPPE Validation



# MIAPPE File: Poplar Phenology dataset

- Zip archive
- 1 investigation
  - **i\_Investigation.txt** : initial file
- 3 Studies
  - **3 s\_\*.txt** file
- 1 level per study
  - **3 a\_\*.txt**
- 3 trait definition file
  - **Crop ontology format**
  - **T\_\*.txt** files
- 3 data files
  - **D\_\*.txt** file



- a\_dXJuOIVSR0kvc3R1ZHkvUE9QWU9NSUNTLVBPUDItRg==\_virtual\_trial.txt
- a\_dXJuOIVSR0kvc3R1ZHkvUE9QWU9NSUNTLVBPUDItSQ==\_virtual\_trial.txt
- a\_dXJuOIVSR0kvc3R1ZHkvUE9QWU9NSUNTLVBPUDItVUs=\_virtual\_trial.txt
- d\_dXJuOIVSR0kvc3R1ZHkvUE9QWU9NSUNTLVBPUDItRg==\_virtual\_trial.txt
- d\_dXJuOIVSR0kvc3R1ZHkvUE9QWU9NSUNTLVBPUDItSQ==\_virtual\_trial.txt
- d\_dXJuOIVSR0kvc3R1ZHkvUE9QWU9NSUNTLVBPUDItVUs=\_virtual\_trial.txt
- i\_investigation.txt
- s\_dXJuOIVSR0kvc3R1ZHkvUE9QWU9NSUNTLVBPUDItRg==.txt
- s\_dXJuOIVSR0kvc3R1ZHkvUE9QWU9NSUNTLVBPUDItSQ==.txt
- s\_dXJuOIVSR0kvc3R1ZHkvUE9QWU9NSUNTLVBPUDItVUs=.txt
- t\_dXJuOIVSR0kvc3R1ZHkvUE9QWU9NSUNTLVBPUDItRg==.txt
- t\_dXJuOIVSR0kvc3R1ZHkvUE9QWU9NSUNTLVBPUDItSQ==.txt
- t\_dXJuOIVSR0kvc3R1ZHkvUE9QWU9NSUNTLVBPUDItVUs=.txt

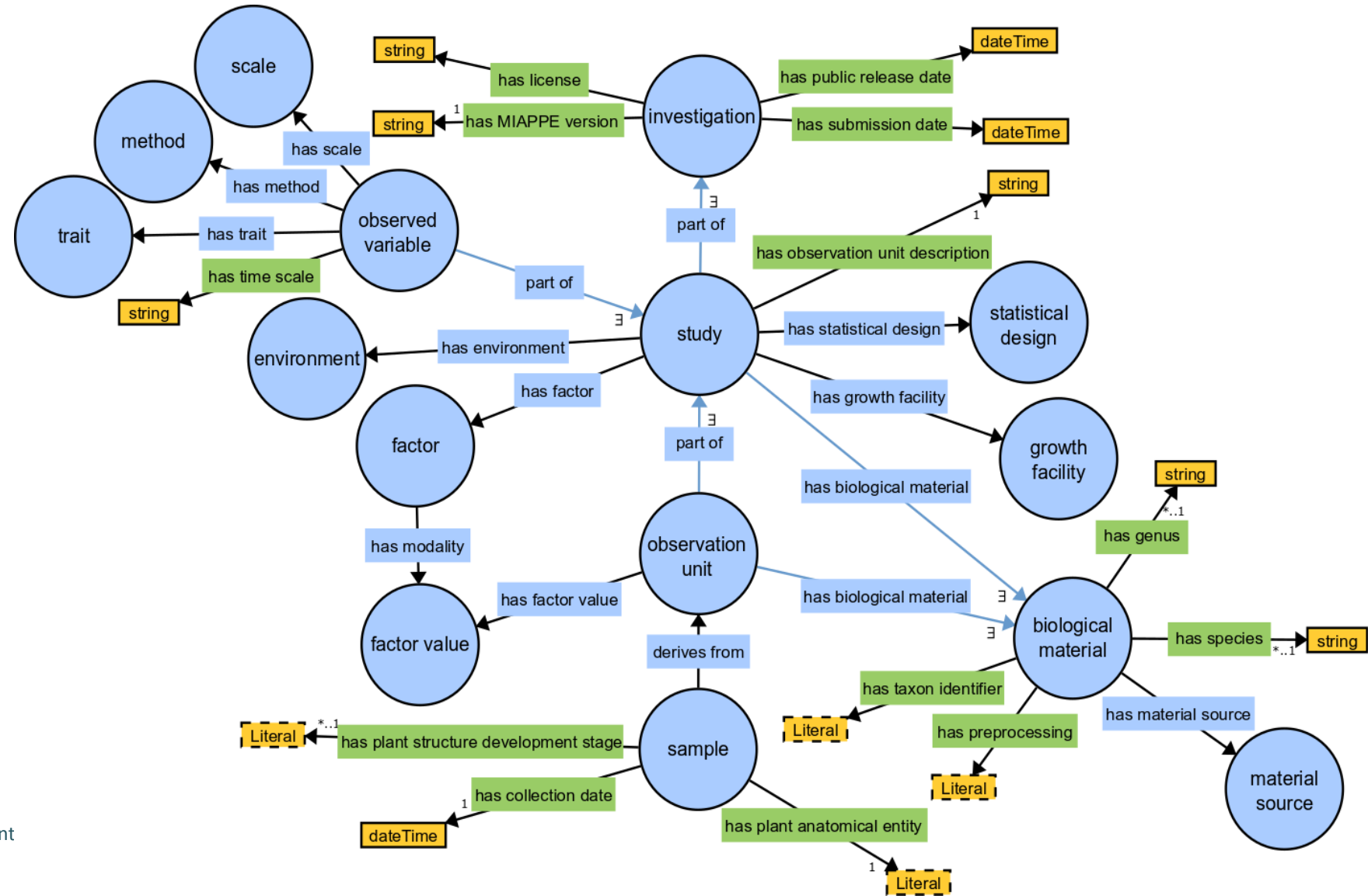
# ➤ MIAPPE Semantic: PPEO

## • MIAPPE OWL Implementation

- ◆ <https://github.com/MIAPPE/MIAPPE-ontology>
- ◆ [www.MIAPPE.ORG](http://www.MIAPPE.ORG)

## • Data model representation

## • Formal concepts and constraints



# ➤ MIAPPE Semantic: PPEO

## • Brapi 2 MIAPPE RDF workflow

- ◆ <http://ist.blogs.inra.fr/wdi/phenotypes-as-rdf/> ([www.wheatIS.org](http://www.wheatIS.org) data standards)
- ◆ JSON LD based
- ◆ Plant BrAPI ETL FAIDARE: needs update to BrAPI v1.3
- ◆ <https://github.com/elixir-europe/plant-brapi-etl-faidare>

## • Wheat dataset

- ◆ <http://dx.doi.org/10.15454/1.4489666216568333E12>

### Wheat Data Interoperability Guidelines

Home Guidelines ▾ Ontologies & Vocabularies Use cases ▾ Getting involved About ▾

Home / Phenotypes as RDF

#### Phenotypes as RDF

## Phenotypes to Semantic web publication

The sharing and especially the reusability of complex data like phenotypes is a good use case for a publication following the semantic web principles. This page describes how to generate a Phenotype RDF dataset from a [Breeding API](#) MIAPPE compliant endpoint. The growing adoption of this API will facilitate the reusability of such a transformation process.

### Recommendations

The RDF publication relies among other things on the correct identification of different resources through Permanent Unique Identifier (PUI), either URIs or DOIs. Therefore, adding a correct set of URI's to the key

### Virtuoso SPARQL Query Editor

Default Data Set Name (Graph IRI)

#### Query Text

```
PREFIX brapi: <https://brapi.org/rdf/>
SELECT ?network ?study ?attribute ?value
FROM <urn:urgi:pheno-brapi-inra-small-grain-cereals-network>
WHERE {?study a brapi:Study;
        ?attribute ?value.
        ?trial a brapi:Trial;
        brapi:hasName ?network.}
ORDER BY ?network ?study
```

(Security restrictions of this server do not allow you to retrieve remote RDF data, see [details](#).)

Results Format:

HTML

Execution timeout:

0 milliseconds (values less than 1

Options:

Strict checking of void variables  Log debug int

(The result can only be sent back to browser, not saved on the server, see [details](#))

Run Query Reset

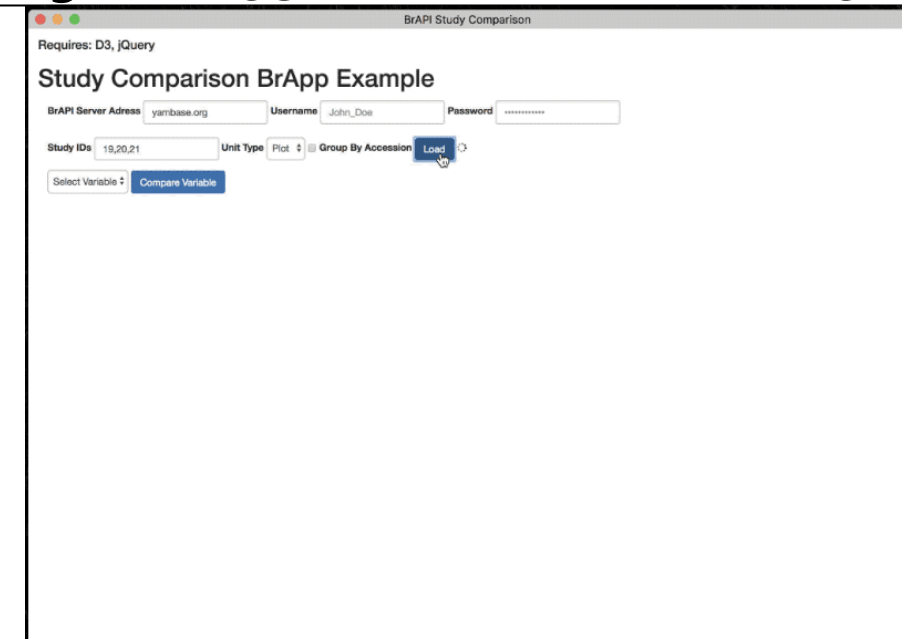


## ➤ Phenotype Technical Standard

- Breeding API <http://brapi.org/>
  - Connect data repositories and tools:
    - Genotype visualization (Flapjack)
    - Studies graph preview and filtering
      - BrAPPS : Tools integrable in any BrAPI compliant System
      - <https://www.brapi.org/brapps.php>
    - R analysis environment
    - Field data capture
    - FAIR Data discovery → Elixir
- FAIDARE

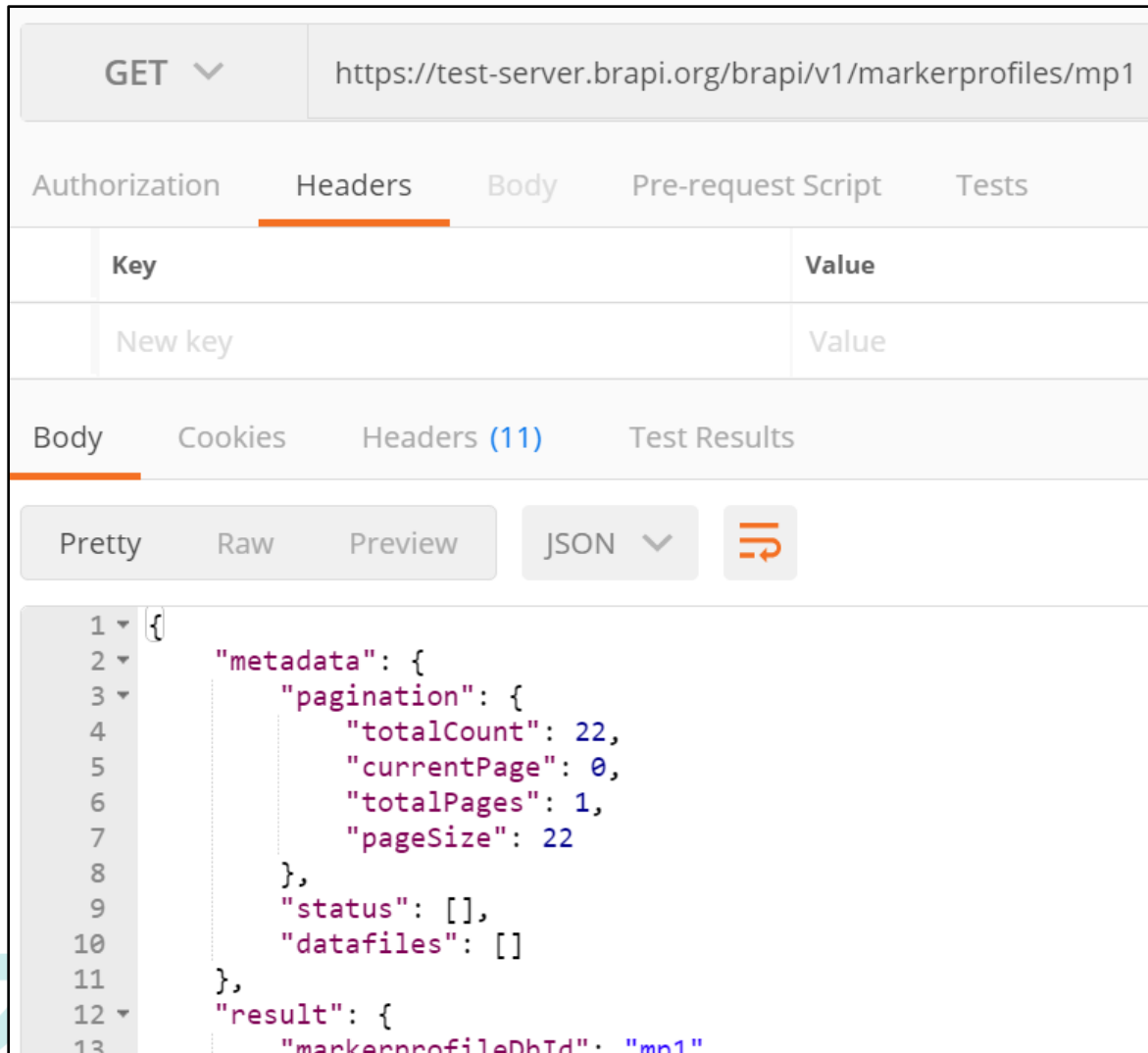


Selby *et al. Bioinformatics* (2019),  
[doi.org/10.1093/bioinformatics/btz190](https://doi.org/10.1093/bioinformatics/btz190)



# ➤ REST - Representational State Transfer

- REST is an architecture design for creating Web Services using the well known HTTP standard
- Requests are made with URLs
- Data is represented with JSON



The screenshot shows a REST client interface with the following details:

- Method: GET
- URL: https://test-server.brapi.org/brapi/v1/markerprofiles/mp1
- Selected tab: Headers
- Body tab selected, showing JSON response:

```
1 {
2   "metadata": {
3     "pagination": {
4       "totalCount": 22,
5       "currentPage": 0,
6       "totalPages": 1,
7       "pageSize": 22
8     },
9     "status": [],
10    "datafiles": []
11  },
12  "result": {
13    "markerprofileDbId": "mn1"
```

## > Standardized **Specification**

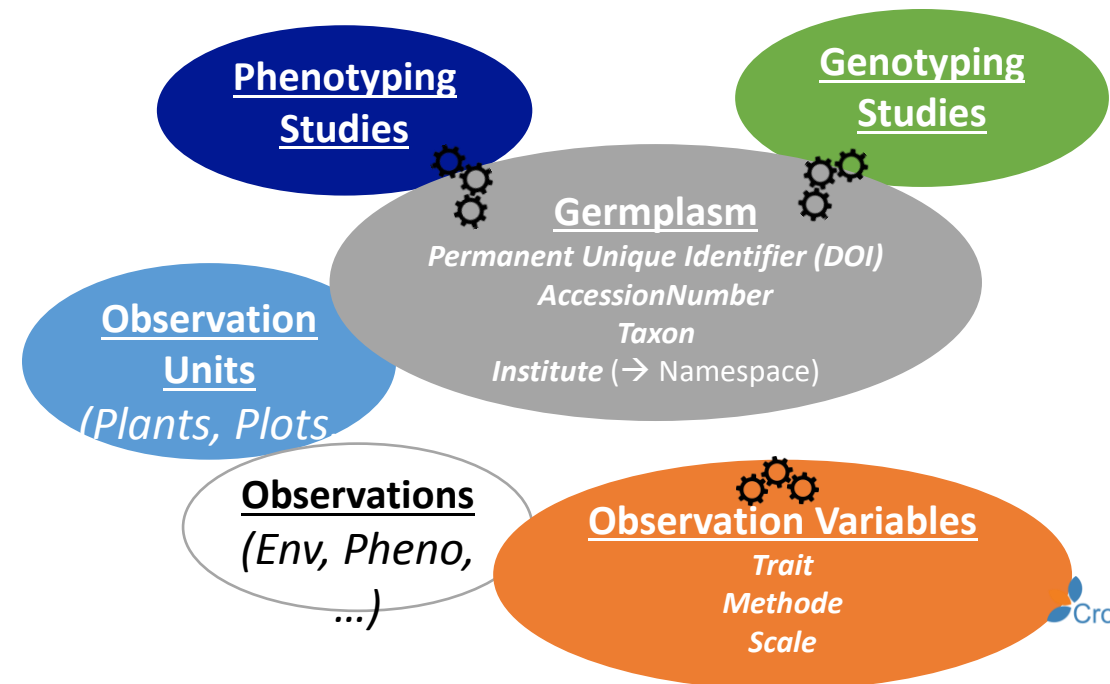


- BrAPI has defined a Standardized set of data model structures to communicate the basic information of plant breeding
- BrAPI is a technical **Specification** which software developers can easily turn into code which communicates using the Standard.



## ➤ BrAPI data model

- MIAPPE compliant
- MIAPPE Investigation → BrAPI Trial
- MIAPPE Study → BrAPI Study
- Biological Material Germplasm MCPD dedicated BrAPI calls
- Observation variable BrAPI calls
- Datafile or Observation Unit



## ➤ Data repositories & Data portals

- National data repositories opened for collaborators
  - ◆ GnpIS/data.inrae.fr
    - <https://urgi.versailles.inra.fr/Data/Phenotyping/Data-submission>
  - ◆ eDal!-PGP
    - <https://edal-pgp.ipk-gatersleben.de/>
  - ◆ BrAPI compliant databases
    - <https://www.brapi.org/servers>
  - ◆ Emphasis databases
    - PHIS, PIPPA, ...
- Data portals
  - ◆ Search over repositories all over the world
  - ◆ <https://urgi.versailles.inra.fr/faidare/>
  - ◆ <http://wheatis.org/Search.php>



➤ Take Home message

Standardizing your data is

- Good for you
- Good for others
- Getting easier
- Contribution Welcomed !

Thank you!

