# Costing breeding pipelines using the UQ Breeding Program Costing Tool

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David Rodgers

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# Breeding pipeline optimisation

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Breeding pipeline term used by product focused breeding programs to describe how genetic diversity moves through different stages of the breeding program towards a target (**product concept**)

**Key properties**

- Numbers of individuals reduce at most stages due to selection
- Pipeline produces a constant flow of new products
- New products should represent a real improvement over previous products

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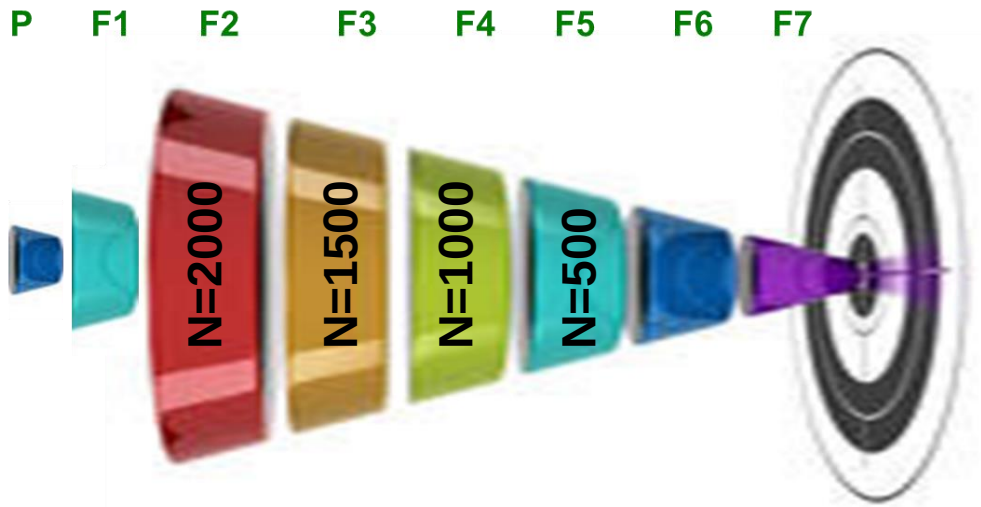


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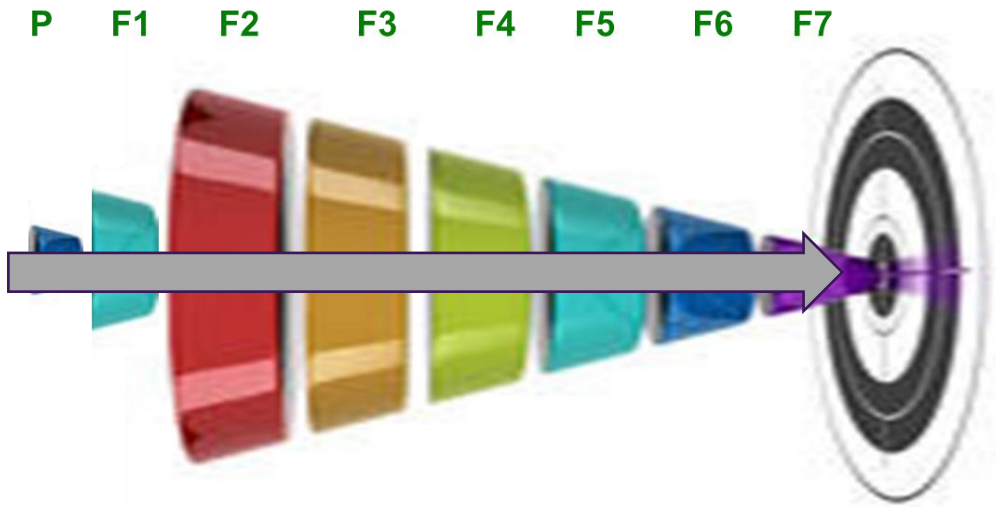


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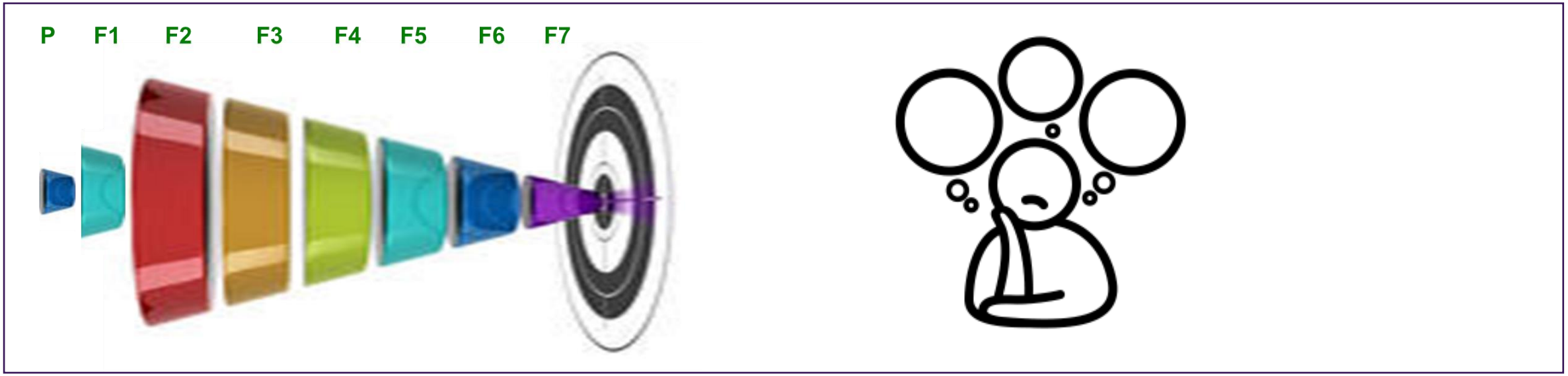

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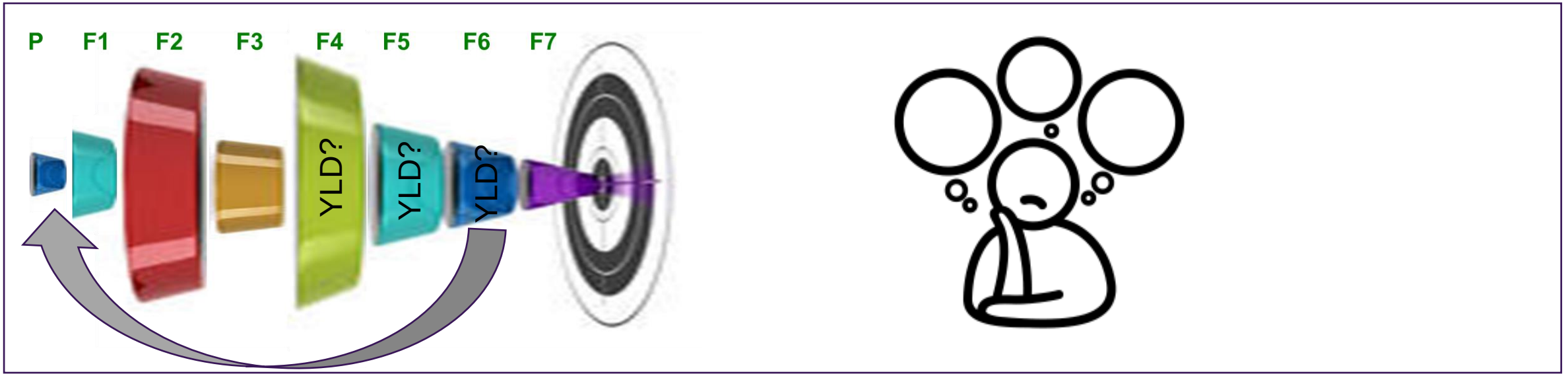
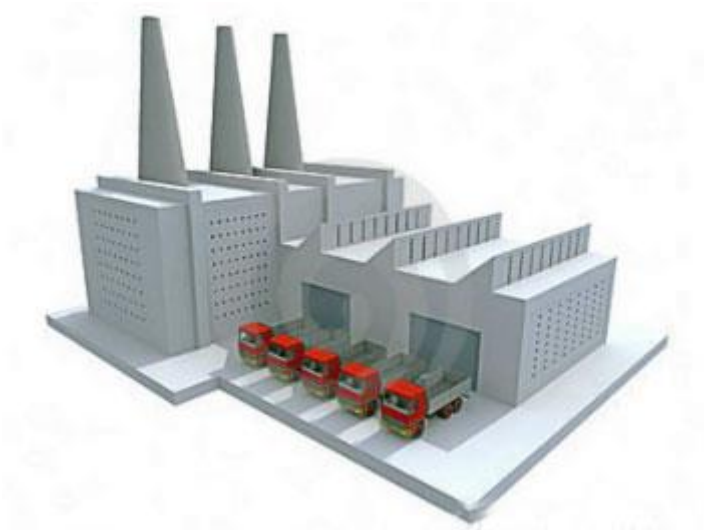


Plant breeding is a complex multi-stage process which involves using resources to generate new varieties that are superior to existing varieties.

Resources

- Genetic diversity
- Money
- Equipment
- Labour
- Land

Breeding pipeline



Product

- Improved lines
- Released varieties

## Plant breeding is a business

Efficient breeding programs use quantitative genetics principles encapsulated in the breeder's equation to maximise genetic gain within resource and time constraints.

Resources

Resource constraints

Maximising genetic gain

Product

- Genetic diversity
- Money
- Equipment
- Labour
- Land

$$\text{Response to selection} = \frac{\text{Phenotypic variance} \times \text{Selection Intensity} \times \text{Accuracy}}{\text{Generation interval}}$$

- Improved lines
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Resources

**Maximising genetic gain per $**

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## Plant breeding is a business

Efficient breeding programs use quantitative genetics principles encapsulated in the breeder's equation to maximise genetic gain within resource and time constraints.

Thus plant breeders are faced with a complex optimisation problem with multiple solutions, the best balance between rate of genetic gain and genetic gain per dollar is not necessarily obvious and will change with varying price of inputs, scale of the program, changes in breeding targets and the advent of new technologies.

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- Genetic diversity
- Money
- Equipment
- Labour
- Land

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Product

- Improved lines
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Making good decisions requires good decision support tools to enable breeders to evaluate alternative scenarios both from the point of view of genetic gain and cost.

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Product

- Improved lines
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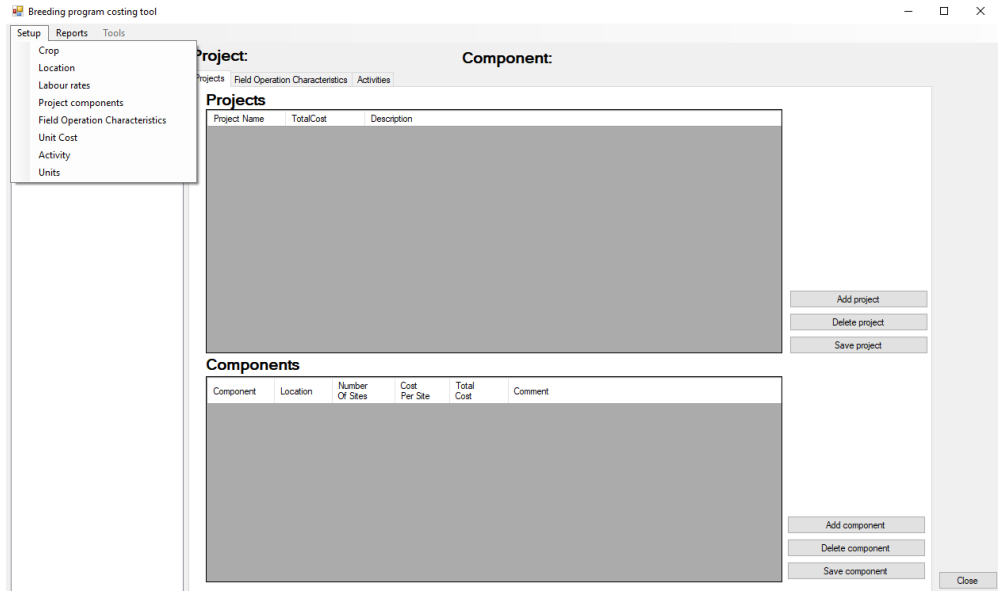
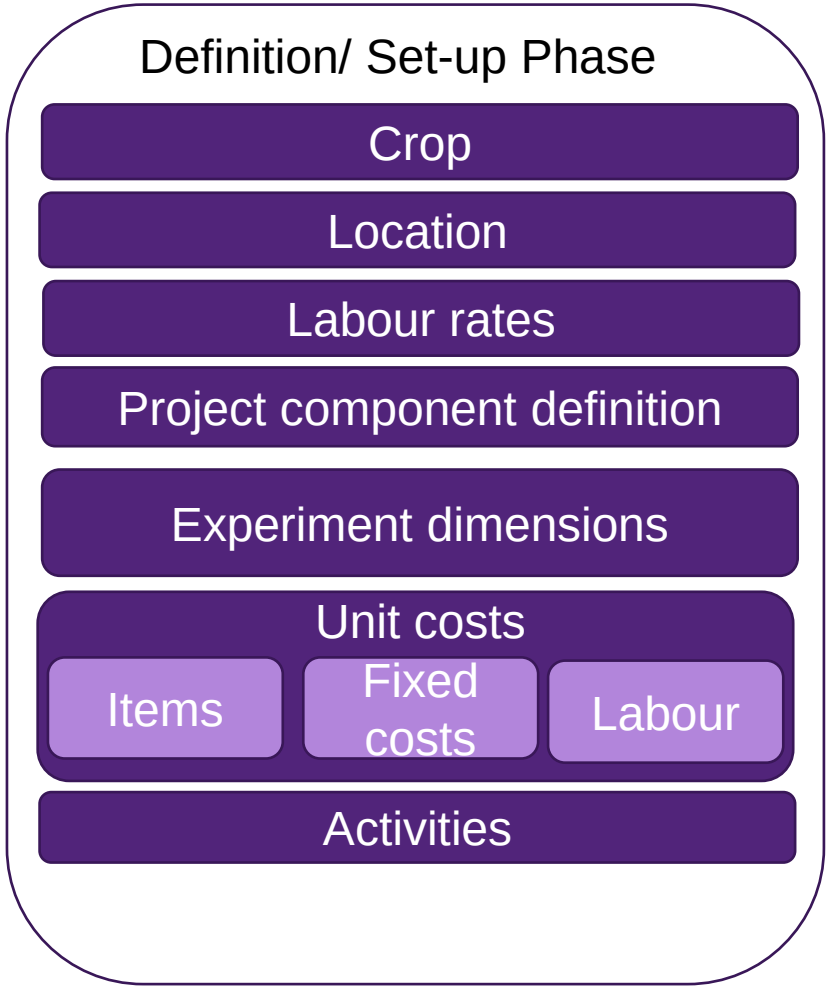
We have developed software to help breeders rapidly generate financial models of breeding programs which can be used to:

- **estimate costs of running their current breeding pipelines,**
- **modify the scale of elements of current breeding pipelines**
- **compare the costs of alternative breeding pipelines.**



The software develops financial models of breeding pipelines targeting specific product profiles using a modular framework incorporating unit costs multiplied by experimental dimensions within defined activities



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Definition/ Set-up Phase

- Crop
- Location
- Labour rates
- Project component definition
- Experiment dimensions
- Unit costs
  - Items
  - Fixed costs
  - Labour
- Activities

A project component is a distinct part of a project usually separated in time and made up of activities.

In a breeding program, this can be a generation.

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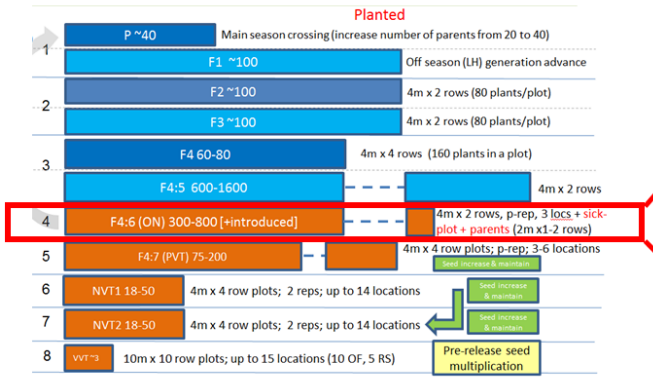
## Experiment dimensions define the scale of the project component




| | Type | Item | Value |
|---|---|---|---|
| 2 | Off-station | entries | 550.00 |
| 3 | Off-station | plots | 715.00 |
| 4 | Off-station | plot length | 4.00 |
| 5 | Off-station | row number | 2.00 |
| 6 | Off-station | row spacing | 0.30 |
| 7 | Off-station | Land area | 1716.00 |

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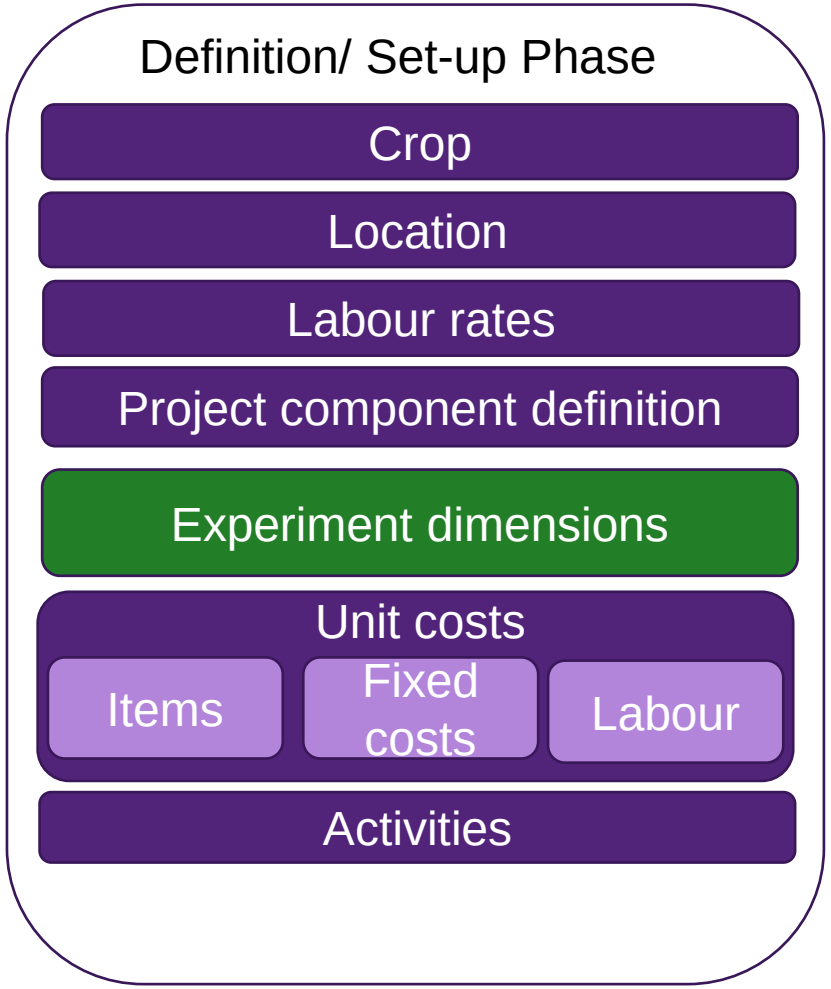


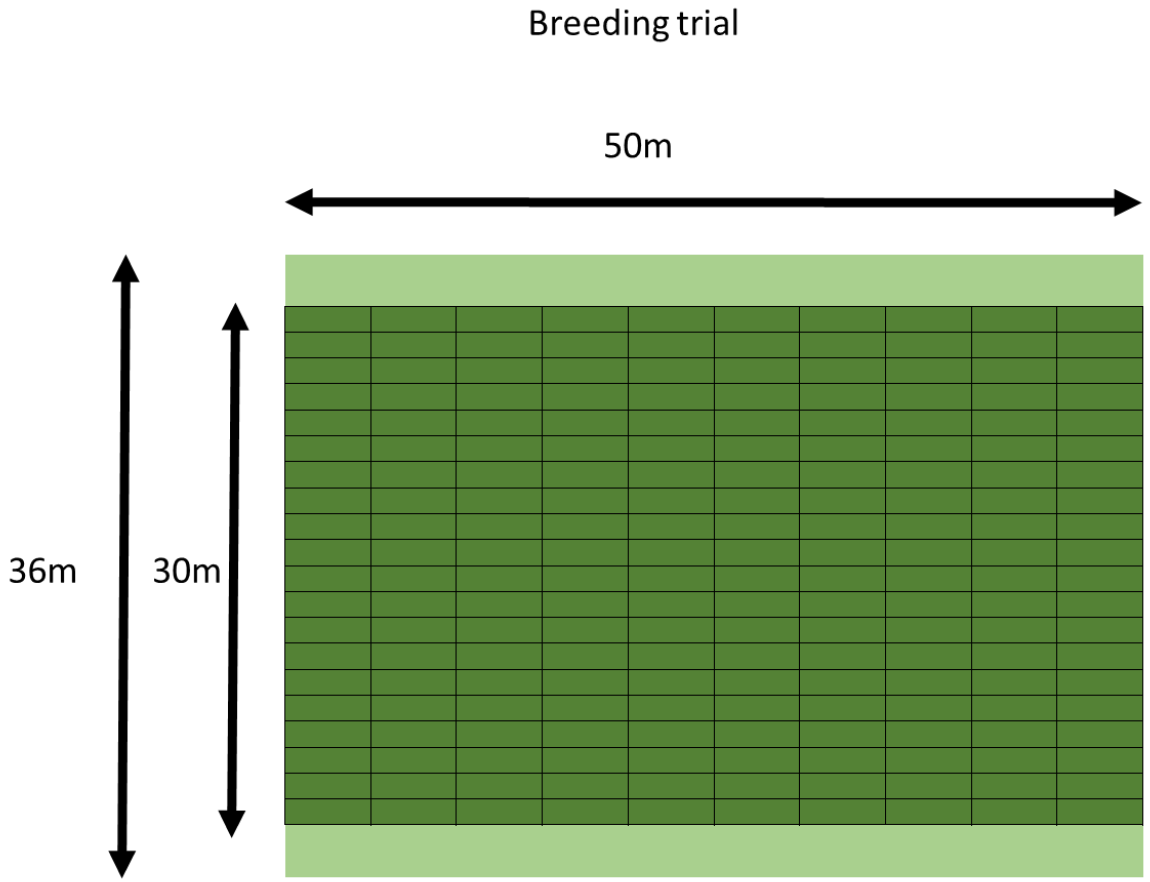

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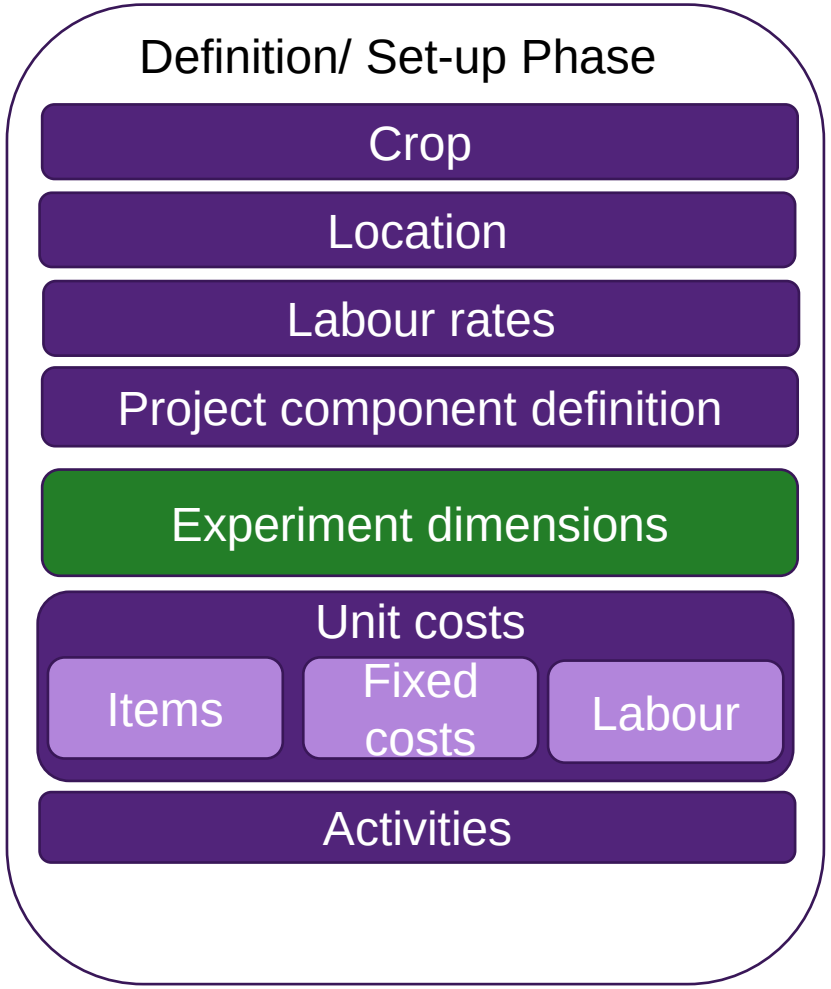


**NIR experiment**

Number of entries = 100
Number of biological reps = 3
Number of technical reps = 2
Number of samples = 500 samples

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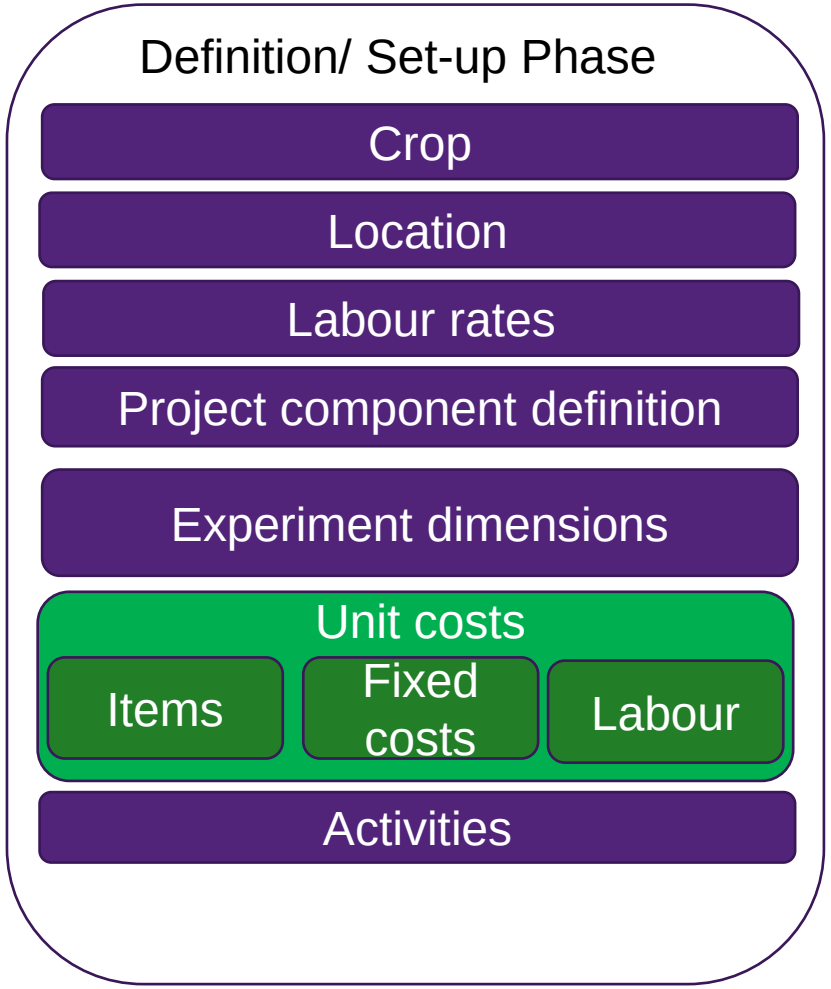
A unit cost is the cost of applying one input item (item, labour, or fixed cost) to one unit of an experiment (e.g. a plot, a $m^2$)

**Item Unit Cost**

The software develops financial models of breeding pipelines targeting specific product profiles using a modular framework incorporating unit costs multiplied by experimental dimensions within defined activities

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## Labour Unit Cost

**Cost of emasculation per flower**
Chickpea example: 30 emasculations per flower required
Rate: 1 flower/ 5 mins or 84 flowers per day (assuming a 7 hour working day)
Who does it: contract labour at 100Birr/day
Cost per flower = 1.19 i.e. (100/84)

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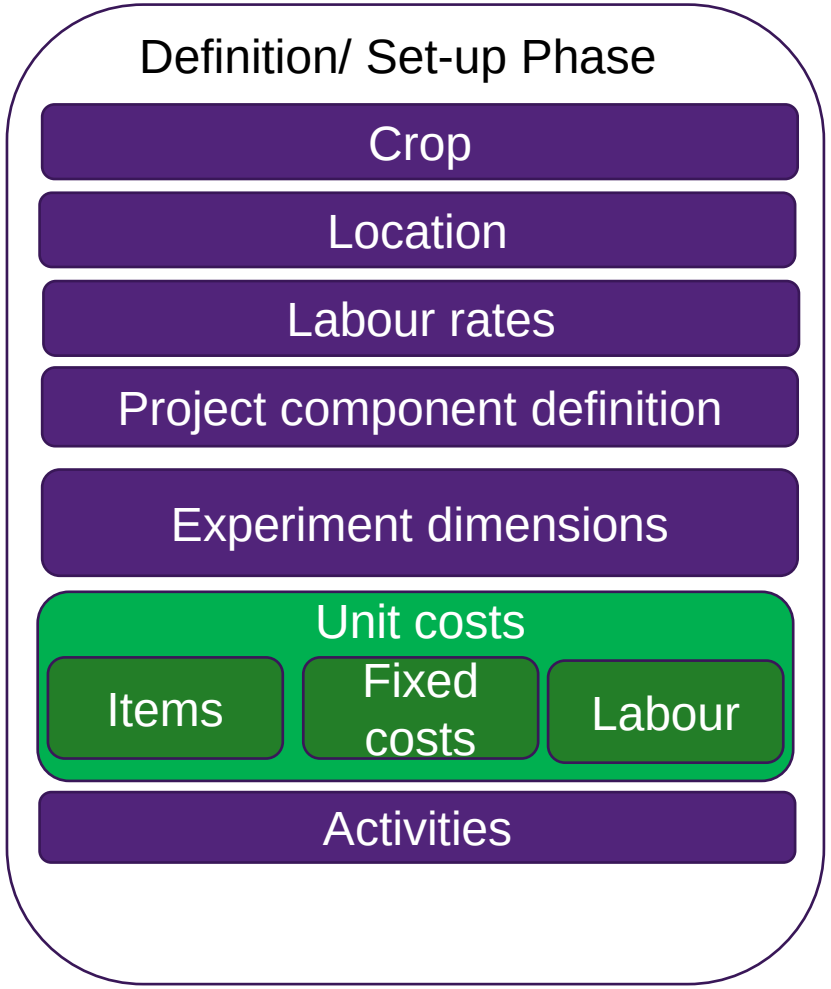


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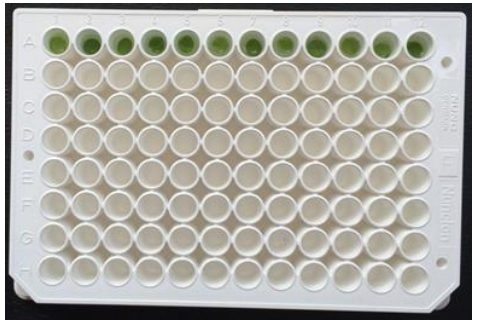

**Cost of leaf tissue sampling into a 96-well plate**
Rate: 1 plate/ 1 hour or 7 plates per day (assuming a 7 hour working day)
Who does it: Lab technician at 360Birr/day
Cost per plate = 51.43 Birr

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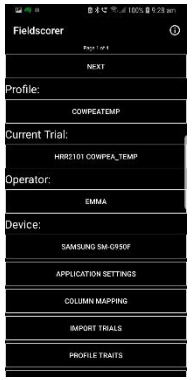
**Fixed Unit Cost**




Fixed costs for setting up FieldScorer files for digital data capture

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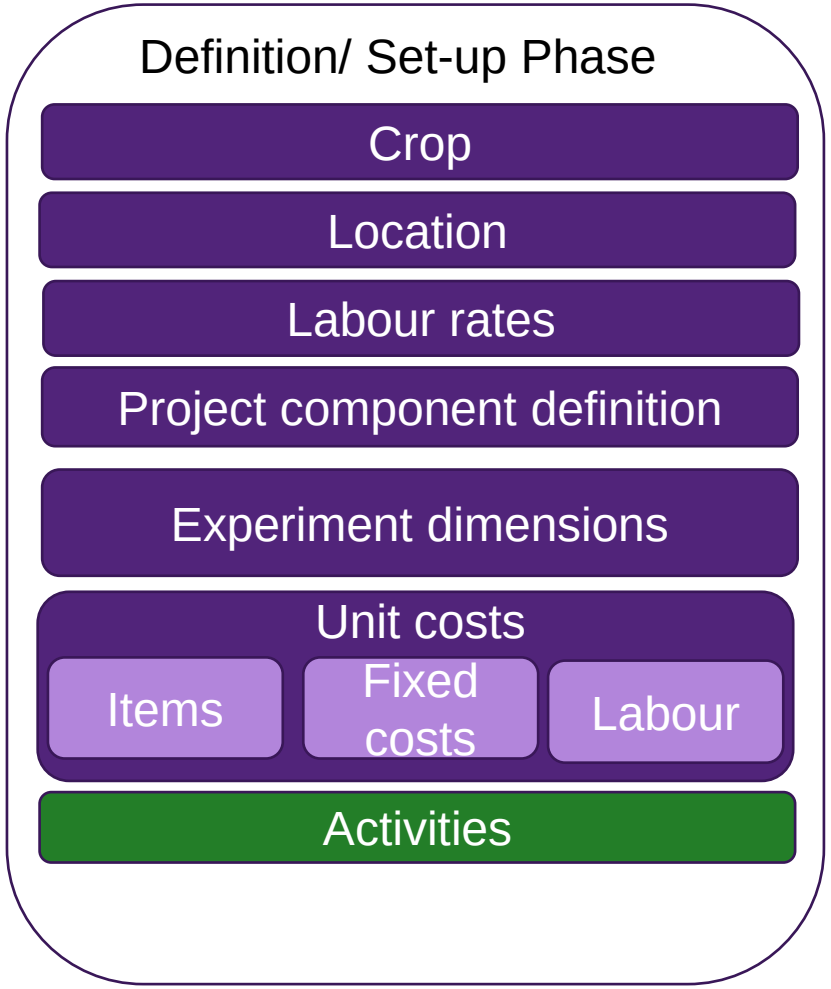


An activity is a collection of unit costs grouped together

**Activity: Trial planting**

- land preparation,
- trial design,
- seed packets,
- seed packeting,
- planting,
- weeding,
- thinning,
- cultivating,
- fertiliser
- fertiliser application

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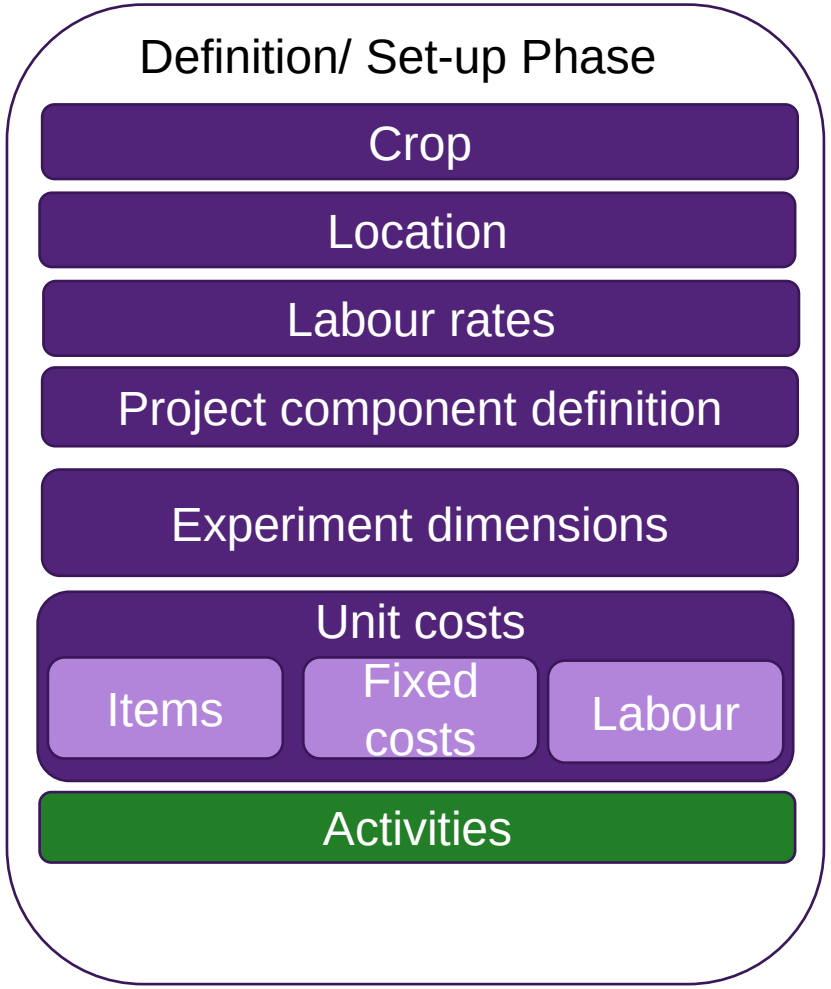


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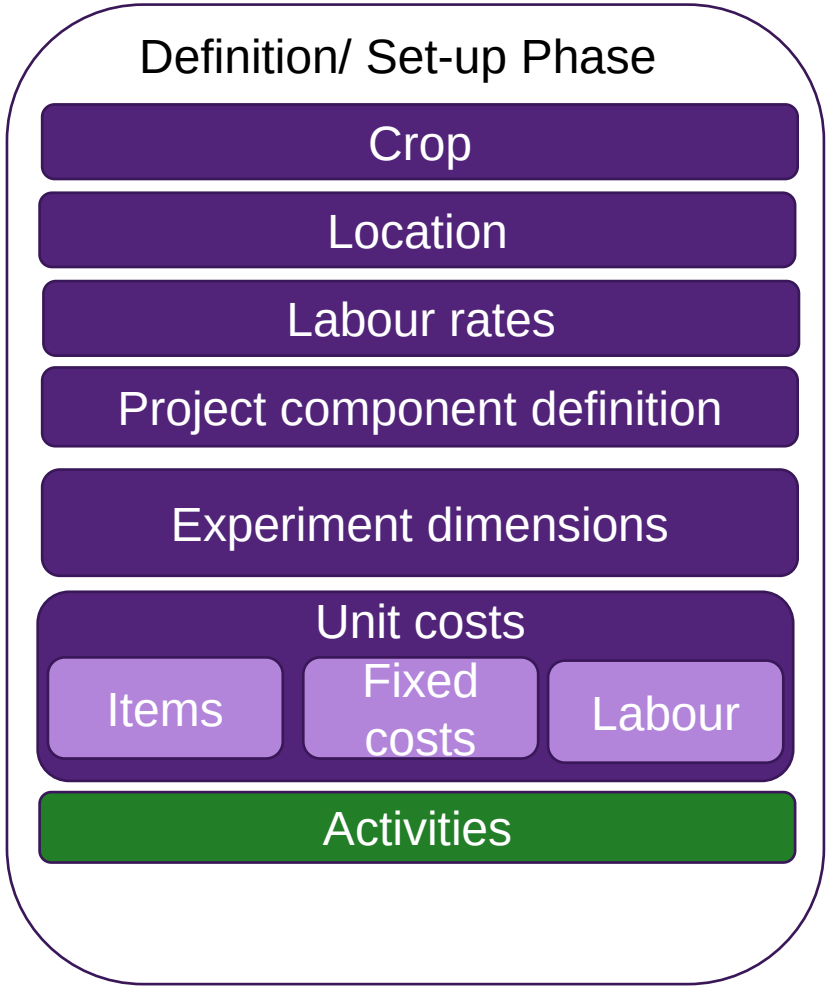


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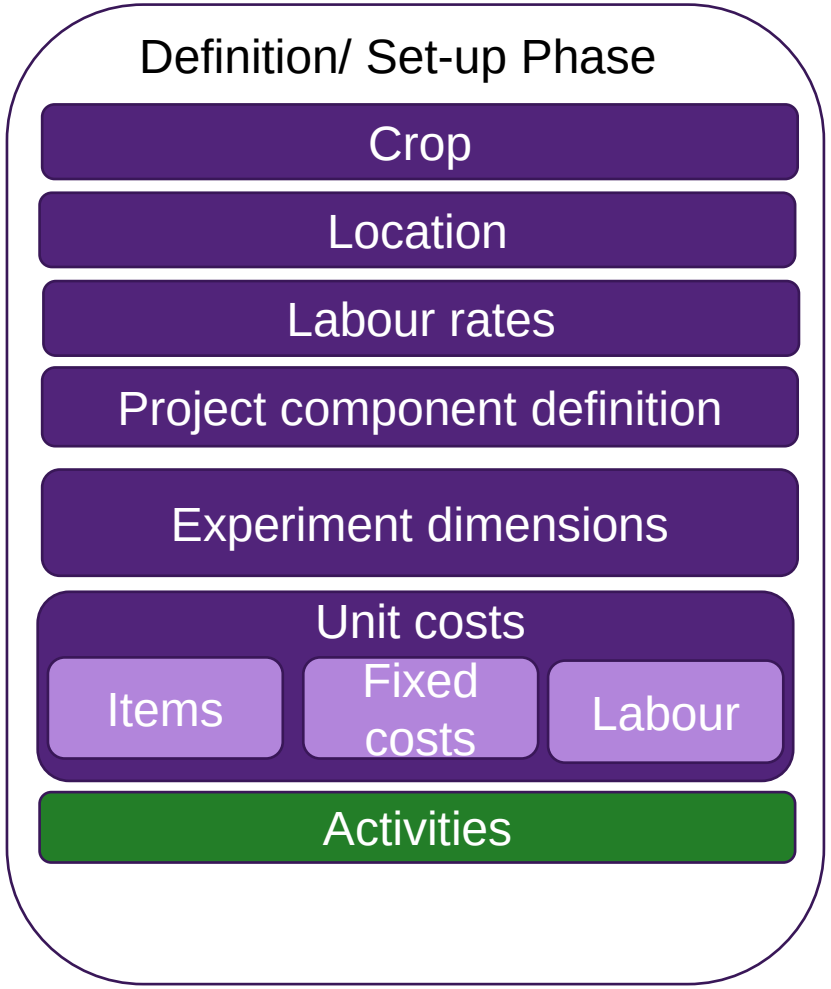


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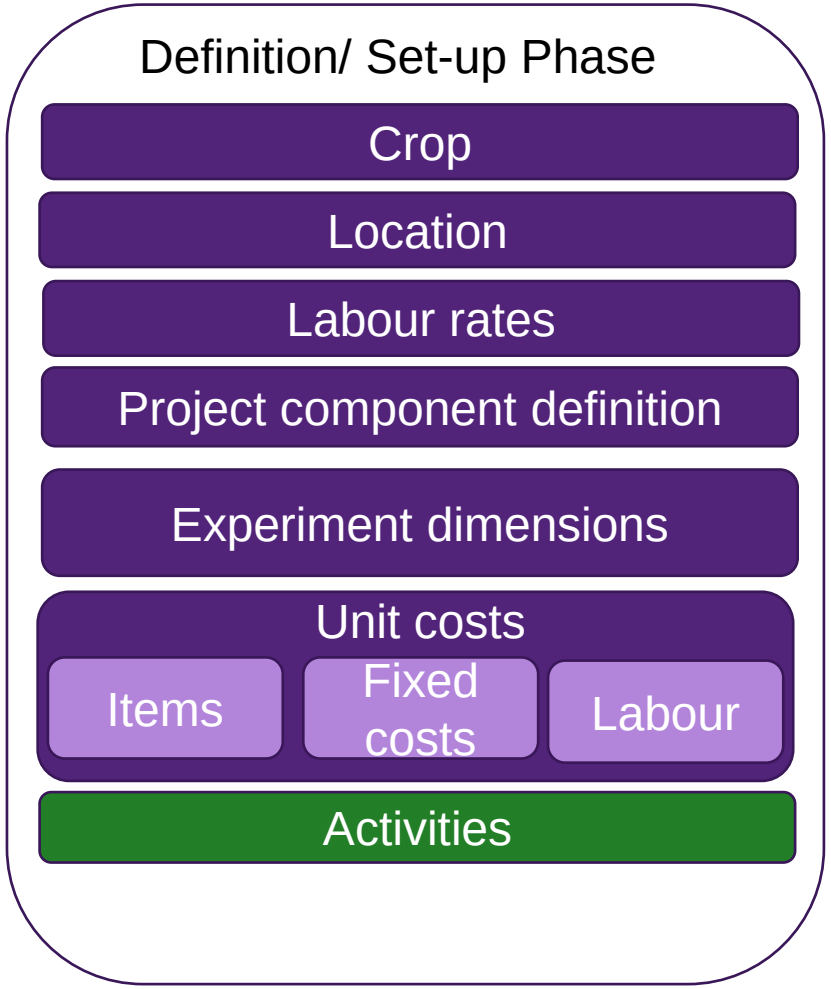



An activity is a collection of unit costs grouped together

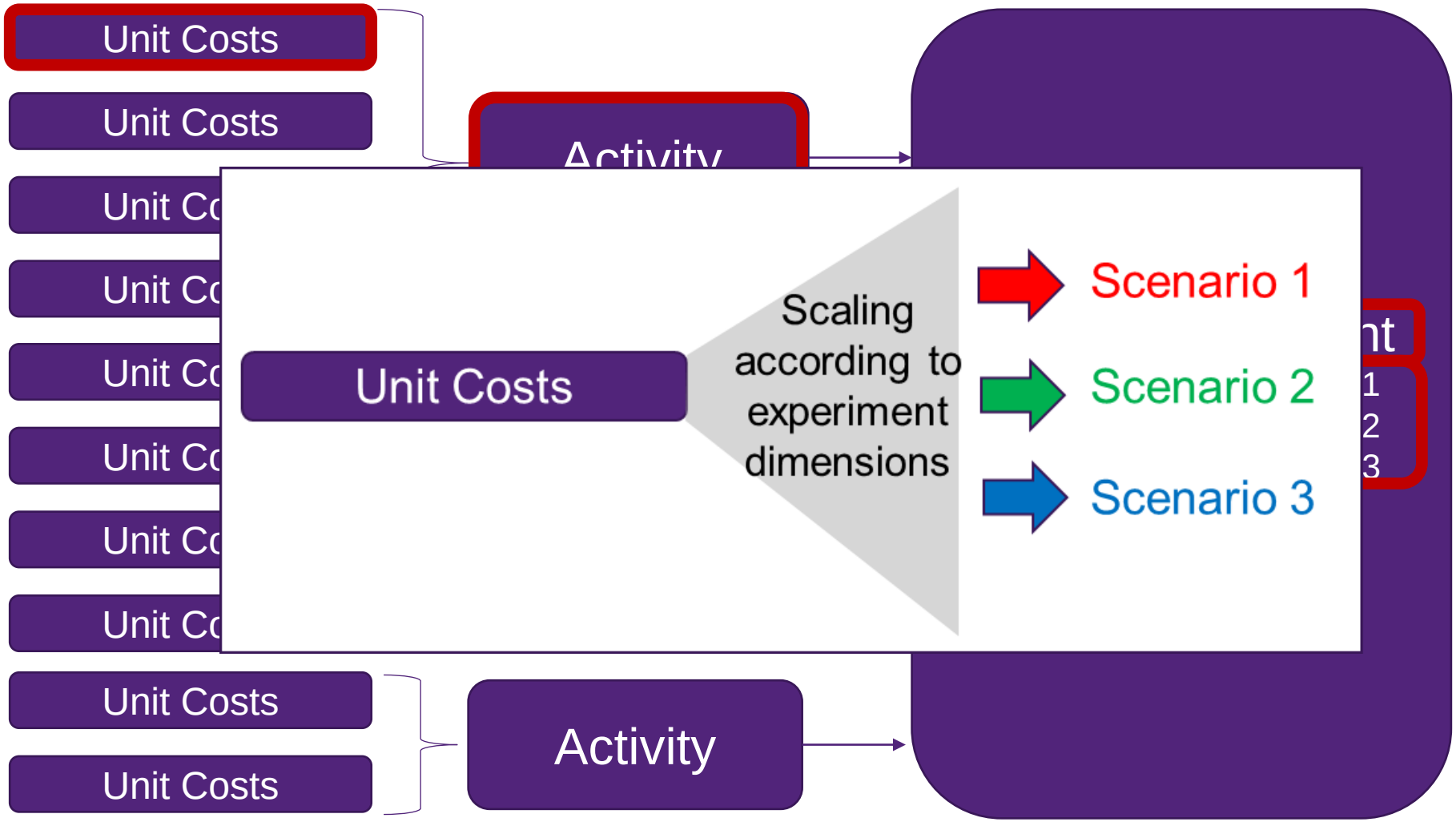
## Activity: Genotyping Advanced Entry Lines

- soil preparation and mixing,
- filling pots,
- planting seeds,
- watering pots,
- 96-well plates
- sampling leaf tissues into 96 well plate,
- inserting beads into plate,
- grinding leaf tissue,
- freeze-drying leaf tissue,
- paper work for sample submission,
- shipping samples,
- genotyping cost from service provider

Labour Unit Costs

Item Unit Costs

Fixed Unit Costs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Scaling according to experiment dimensions
Scenario 1
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Scenario 3
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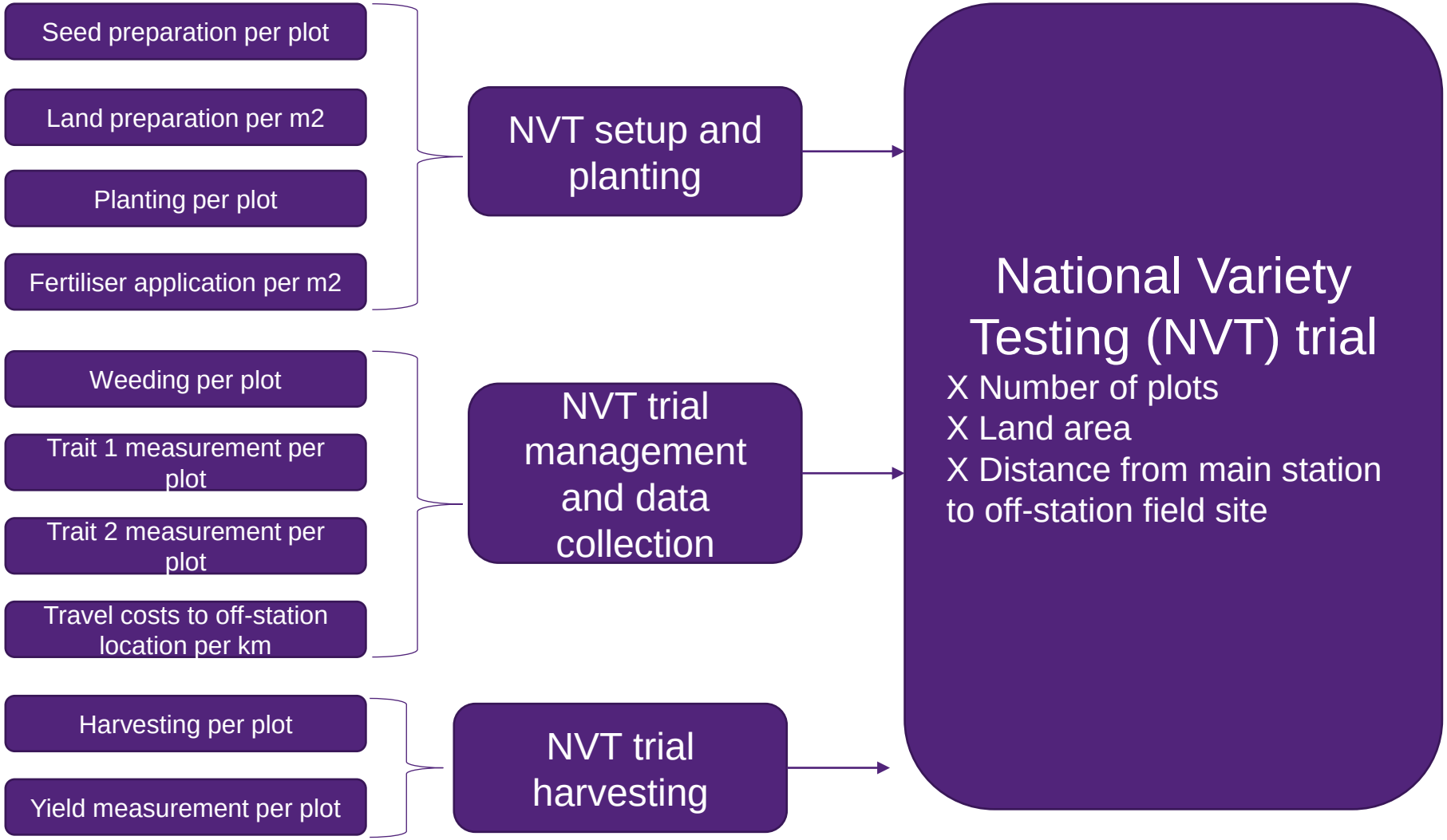
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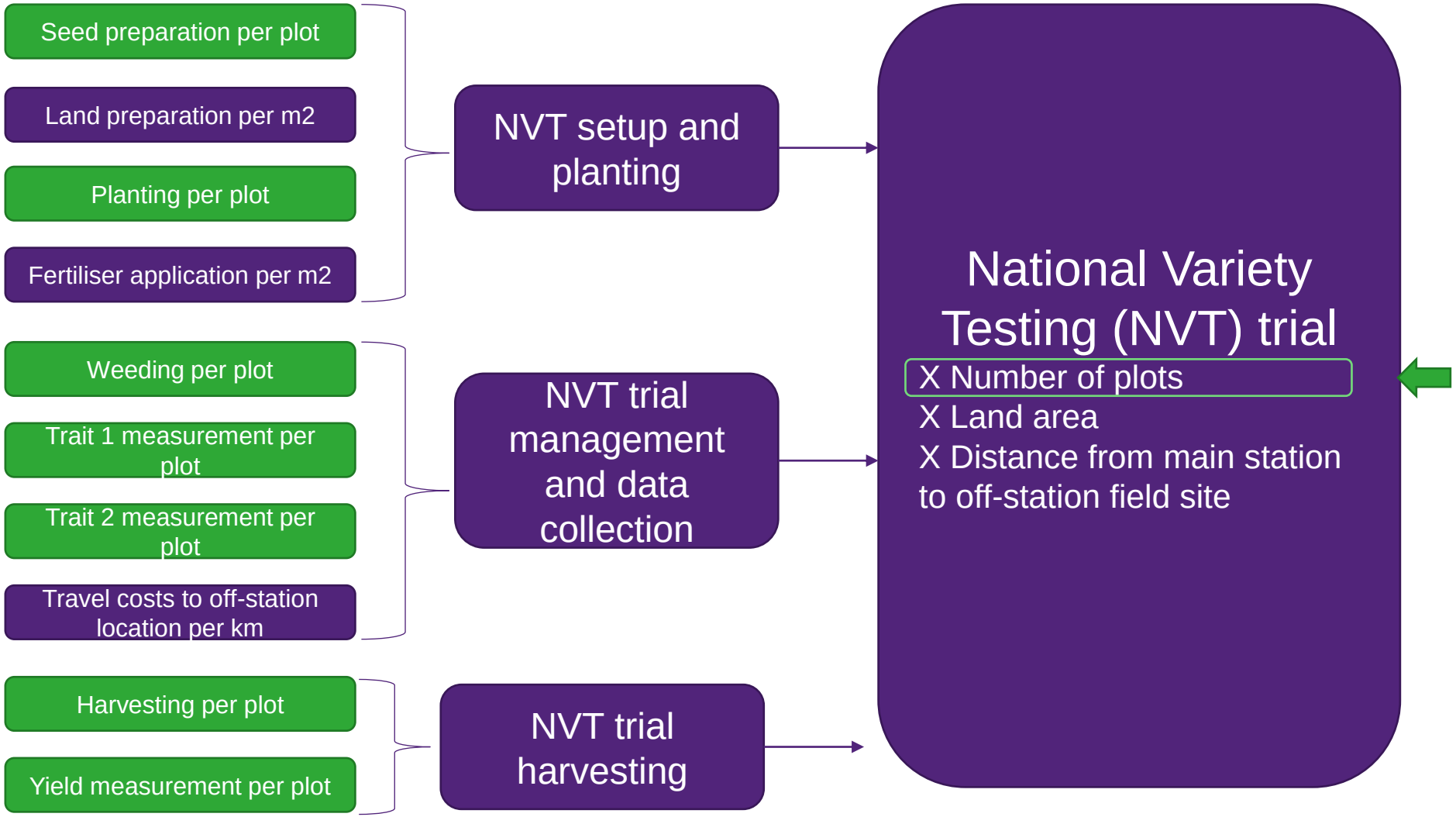
Land preparation per m2
Planting per plot
Fertiliser application per m2
NVT setup and planting
Weeding per plot
Trait 1 measurement per plot
Trait 2 measurement per plot
Travel costs to off-station location per km
NVT trial management and data collection
Harvesting per plot
Yield measurement per plot
NVT trial harvesting
National Variety Testing (NVT) trial
X Number of plots
X Land area
X Distance from main station to off-station field site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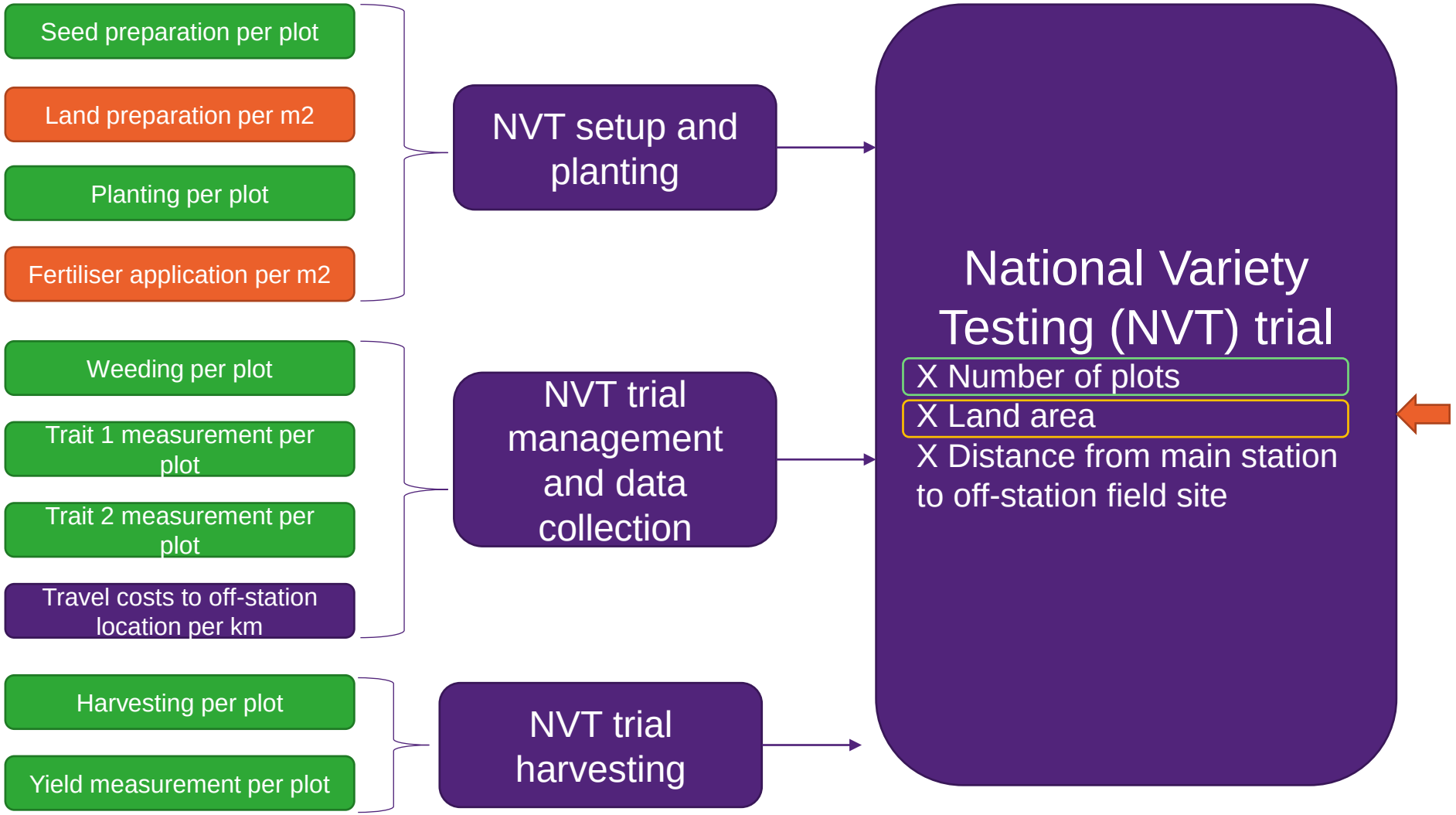
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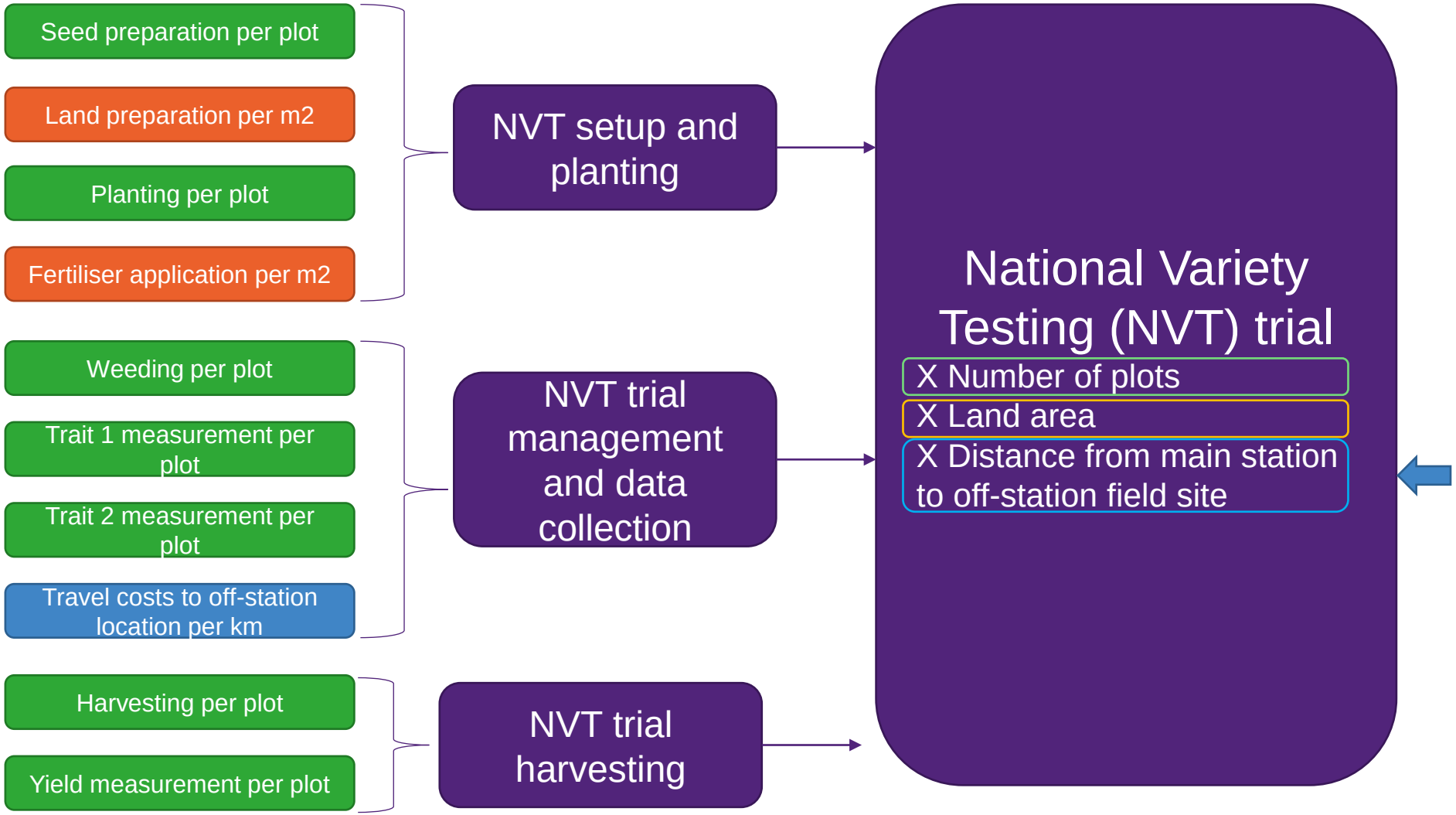
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Activity

Activity

P F1 F2 F3 F4 F5 F6 F7

ect component
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eriment dimension 2
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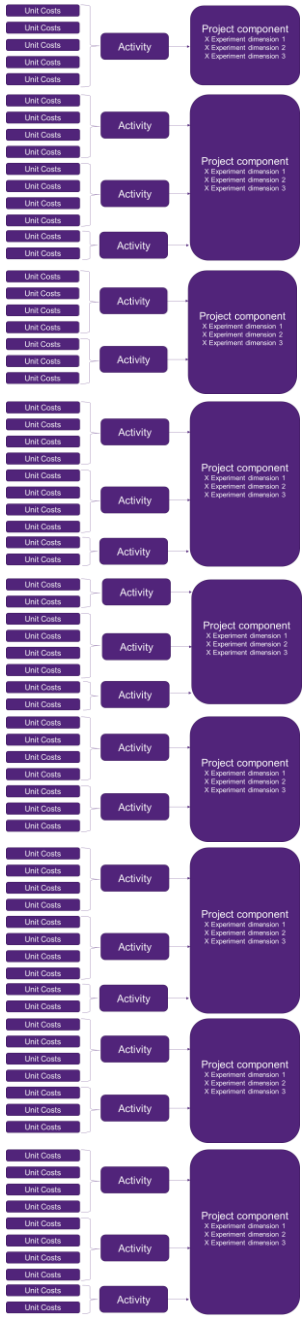



Crossing

F1

F2

F3

F4

ON

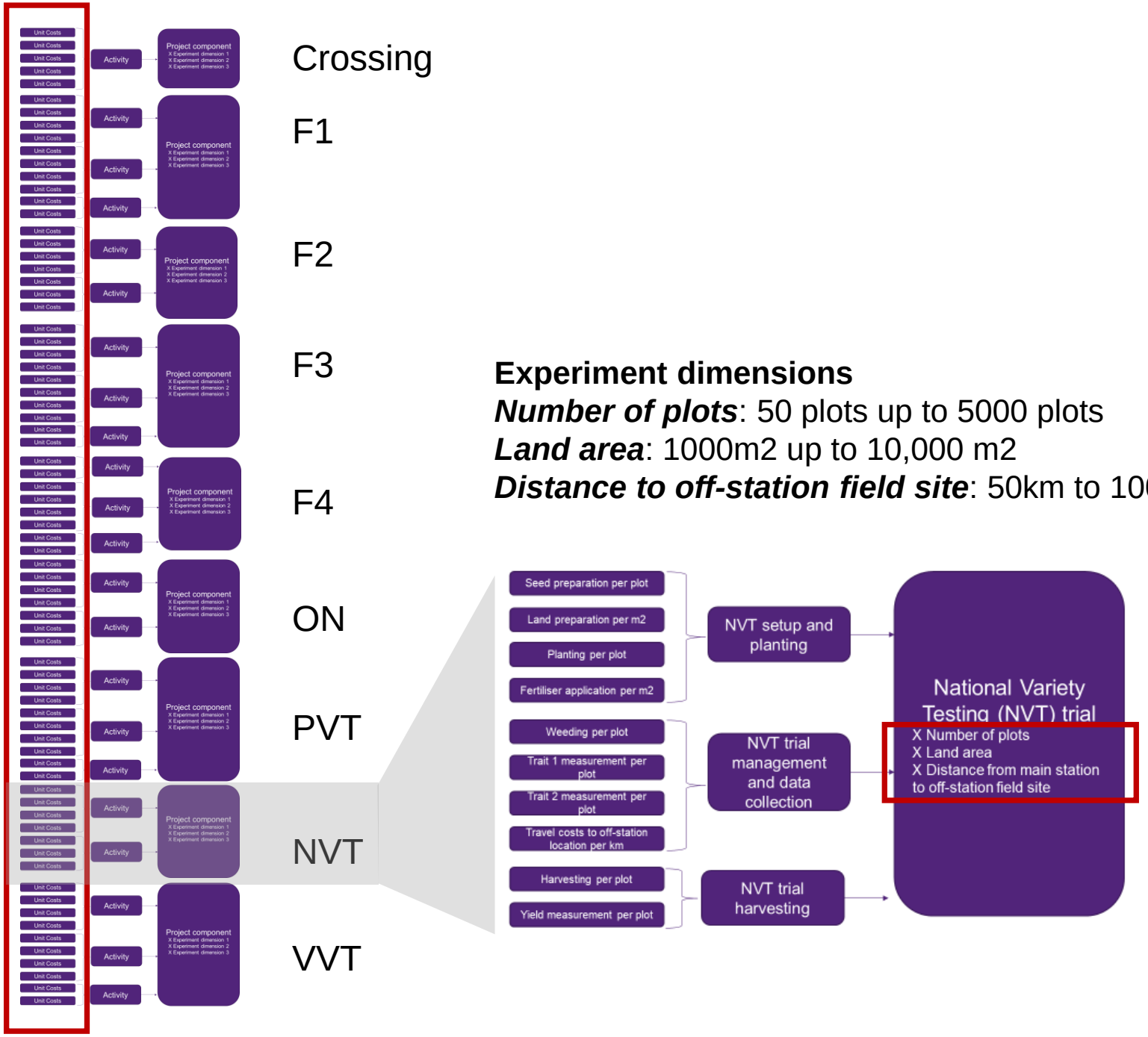
PVT

NVT

VVT

Project: product concept

**The unit cost definition in combination with the experiment dimensions that enables rapid re-scaling of activities**




**Experiment dimensions**

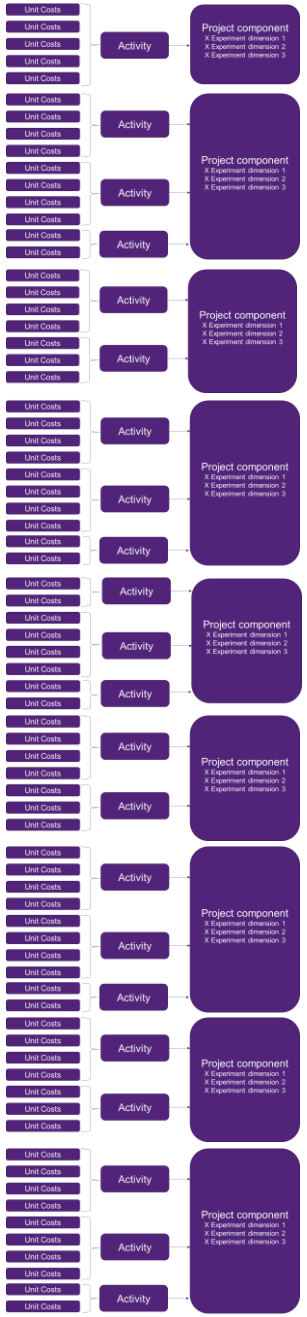
***Number of plots***: 50 plots up to 5000 plots

***Land area***: 1000m2 up to 10,000 m2

***Distance to off-station field site***: 50km to 1000 km

Reduce their budget by 10% in the next year?

Develop a business case to support procurement of a new capital item?

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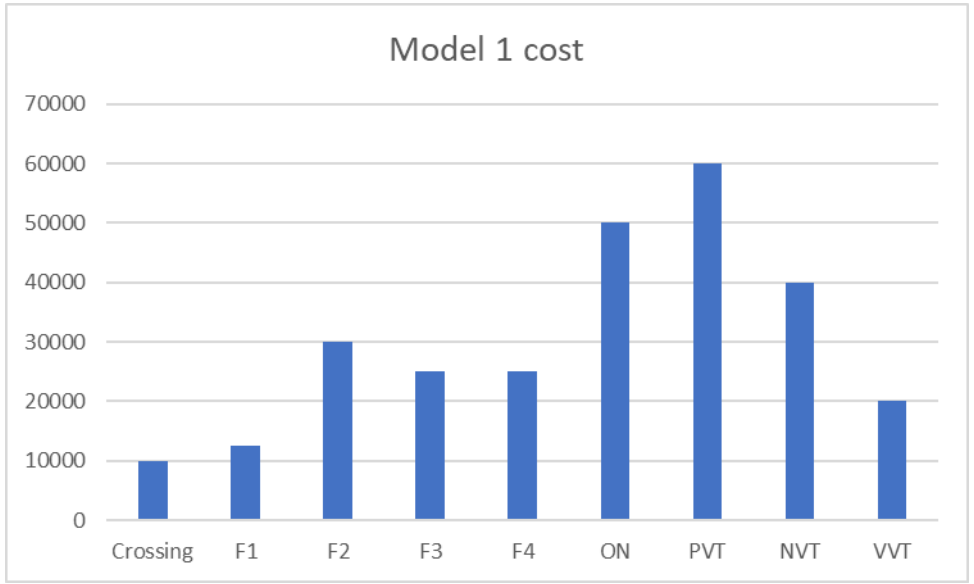
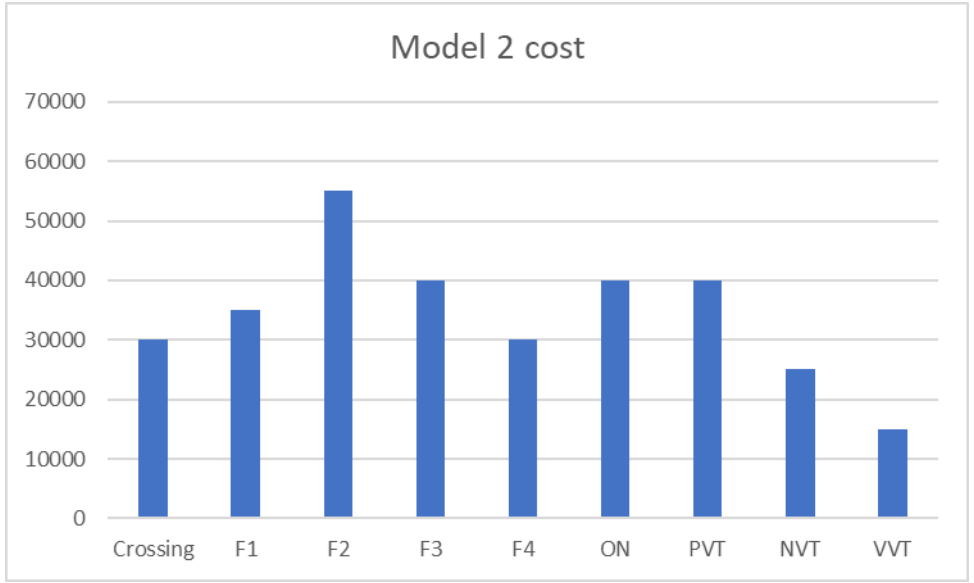
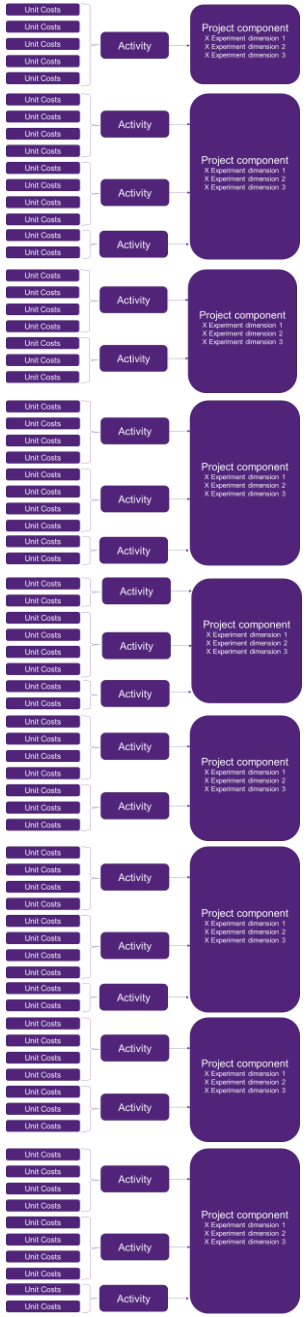





Crossing

F1

F2

F3

F4

ON

PVT

NVT

VVT

- **Estimate the costs of a current breeding pipeline**
- **Modify the scale of elements of current breeding pipelines**
- **Compare the costs of alternative breeding pipelines.**

# Estimate the costs of a current breeding pipeline

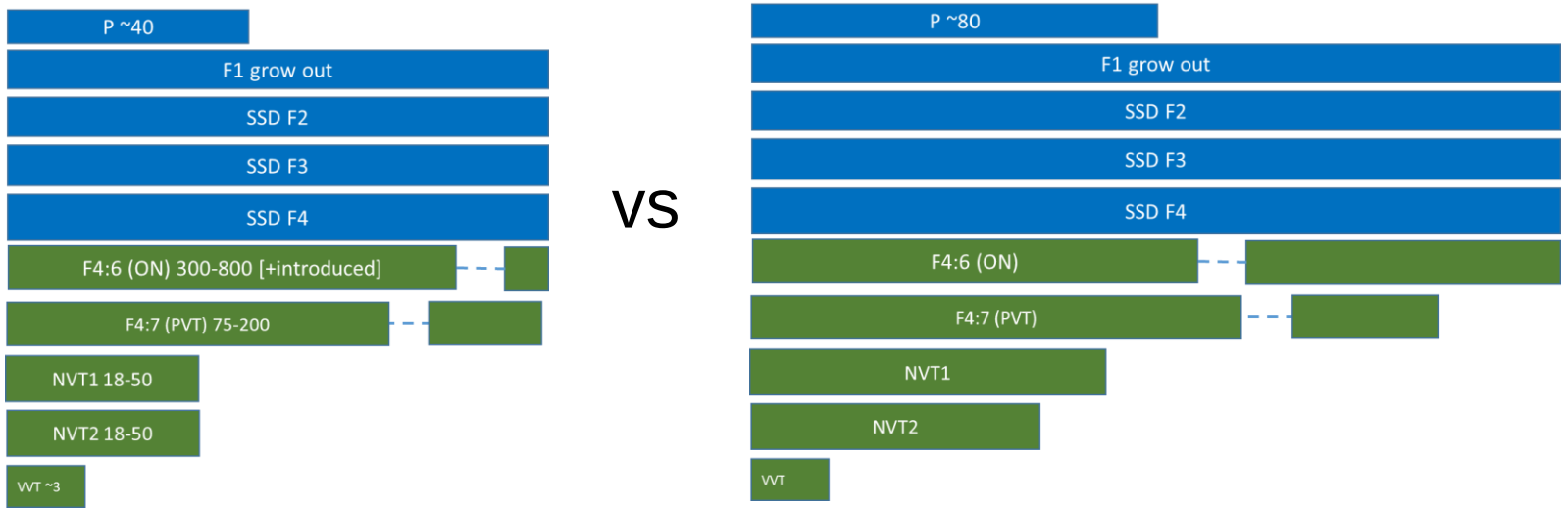
Accurate and scalable costs can be rapidly calculated for current breeding pipelines using modular functions that can be shared across project components, facilitating the

- accurate determination of the costs of running a particular activity
- identification of the activities and items that make the largest contribution to the cost of a breeding activity
- identification of likely purchasing requirements for consumables

# Modifying the scale of elements of an existing pipeline

The interactive project overview function enables rapid comparisons of various scenarios :

- Changing the number of entries per trial
- Changing the number of locations for each trial series
- Changing the replication rate.



Breeding program costing tool

Setup Reports Tools About

Crop Name: Generic

**Project: Product concept 1**

**Component: Crossing**

Project overview | Projects | Experiment Dimensions | Activities

| Component | Sites | Entries | Reps | Samples | Value | | |
|---|---|---|---|---|---|---|---|
| Crossing | 1 | 1 | 1 | 1 | 6,776.50 | Reload | Save |
| F2 grow-outs | 1 | 150 | 1 | 150 | 11,853.75 | Reload | Save |
| F3 rows | 1 | 1500 | 1 | 1500 | 37,909.75 | Reload | Save |
| F4 rows | 1 | 800 | 1 | 800 | 19,807.00 | Reload | Save |
| F5 rows | 1 | 450 | 1 | 450 | 12,695.13 | Reload | Save |
| Observation Nursery Site 1 | 1 | 450 | 1.3 | 585 | 14,710.94 | Reload | Save |
| Observation Nursery Site 2 | 1 | 450 | 1.3 | 585 | 18,429.02 | Reload | Save |
| Observation Nursery Site 3 | 1 | 450 | 1.3 | 585 | 11,566.65 | Reload | Save |
| PVT Trial 1 | 1 | 350 | 1.3 | 455 | 13,896.33 | Reload | Save |
| PVT Trial 2 | 1 | 350 | 1.3 | 455 | 13,896.33 | Reload | Save |
| PVT Trial 3 | 1 | 350 | 1.3 | 455 | 13,896.33 | Reload | Save |
| NVT Trial 1 | 1 | 200 | 2 | 400 | 9,592.00 | Reload | Save |
| NVT Trial 2 | 1 | 200 | 2 | 400 | 10,991.50 | Reload | Save |
| NVT Trial 3 | 1 | 200 | 2 | 400 | 12,592.00 | Reload | Save |
| NVT Trial 4 | 1 | 200 | 2 | 400 | 12,592.00 | Reload | Save |
| | | | | | | Reload | Save |

Project Total: 221,205.23

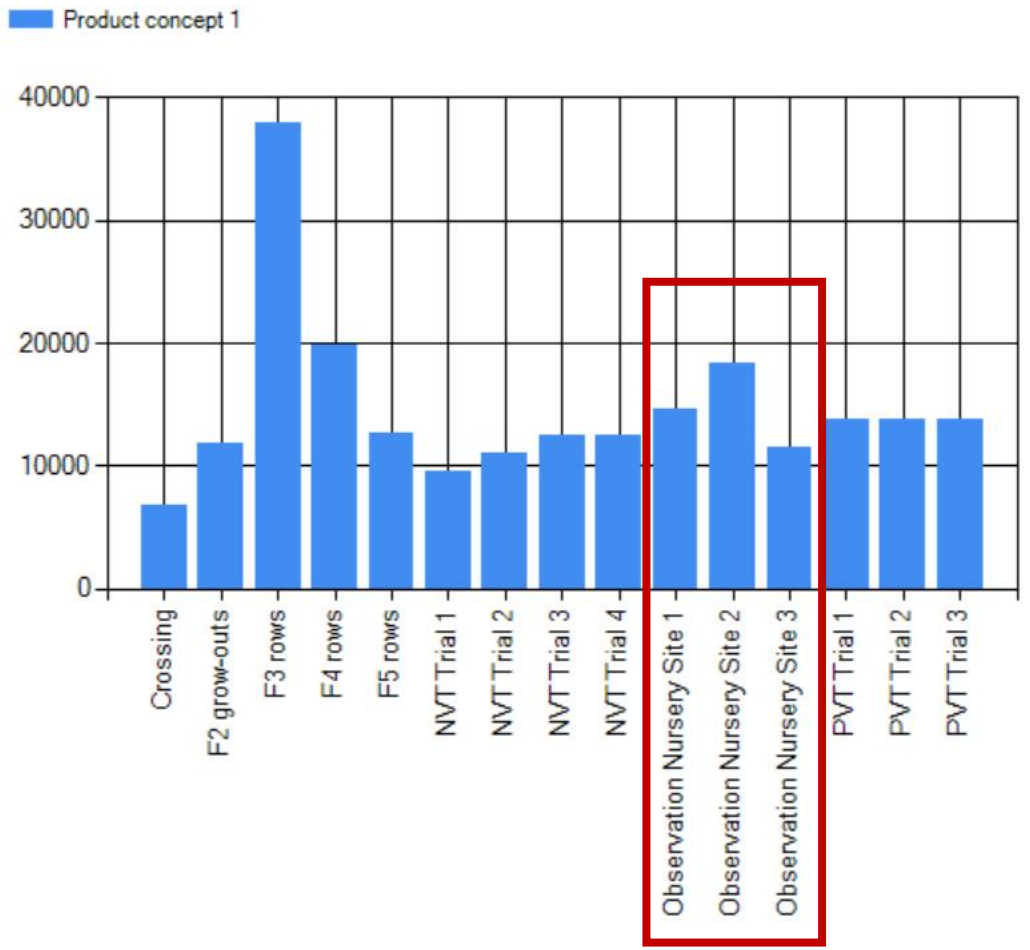



Chart by: (•) Selected Components ( ) Activity Costs for selected component | (•) Bar chart ( ) Pie chart

Close

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Breeding program costing tool

Setup Reports Tools About

Crop Name: Generic

# Project: Product concept 1

# Component: Crossing

Project overview | Projects | Experiment Dimensions | Activities

| Component | Sites | Entries | Reps | Samples | Value | | |
|---|---|---|---|---|---|---|---|
| Crossing | 1 | 1 | 1 | 1 | 6,776.50 | Reload | Save |
| F2 grow-outs | 1 | 150 | 1 | 150 | 11,853.75 | Reload | Save |
| F3 rows | 1 | 1500 | 1 | 1500 | 37,909.75 | Reload | Save |
| F4 rows | 1 | 800 | 1 | 800 | 19,807.00 | Reload | Save |
| F5 rows | 1 | 700 | 1 | 700 | 18055.75 | Reload | Save |
| Observation Nursery Site 1 | 1 | 700 | 1.3 | 910 | 21203.63 | Reload | Save |
| Observation Nursery Site 2 | 1 | 700 | 1.3 | 910 | 23229.51 | Reload | Save |
| Observation Nursery Site 3 | 1 | 700 | 1.3 | 910 | 21732.15 | Reload | Save |
| PVT Trial 1 | 1 | 350 | 1.3 | 455 | 13,896.33 | Reload | Save |
| PVT Trial 2 | 1 | 350 | 1.3 | 455 | 13,896.33 | Reload | Save |
| PVT Trial 3 | 1 | 350 | 1.3 | 455 | 13,896.33 | Reload | Save |
| NVT Trial 1 | 1 | 200 | 2 | 400 | 9612 | Reload | Save |
| NVT Trial 2 | 1 | 200 | 2 | 400 | 10,991.50 | Reload | Save |
| NVT Trial 3 | 1 | 200 | 2 | 400 | 12,592.00 | Reload | Save |
| NVT Trial 4 | 1 | 200 | 2 | 400 | 12,592.00 | Reload | Save |
| | | | | | | Reload | Save |

Project Total: 248,044.53

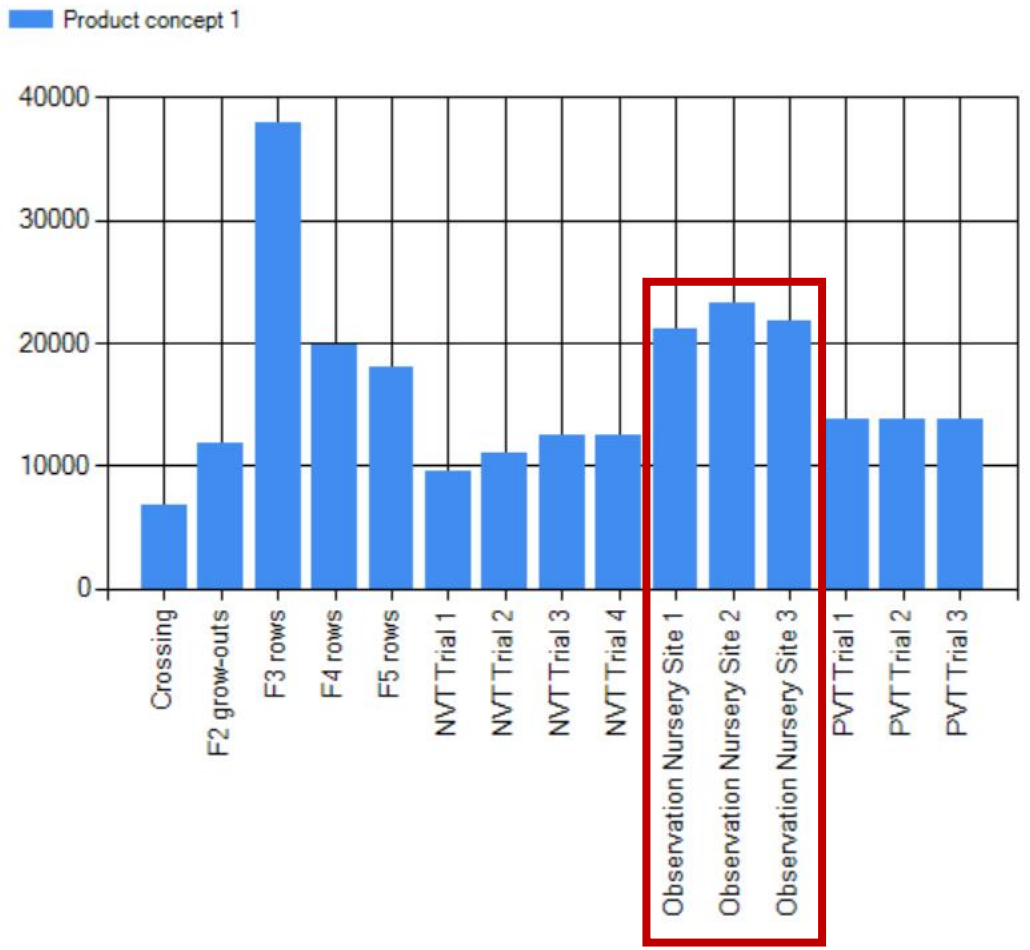


Chart by: Selected Components | Activity Costs for selected component | Bar chart | Pie chart

Close

Type here to search

ENG 1:12 PM 9/01/2020

Breeding program costing tool

Setup Reports Tools About

Crop Name: Generic

**Project: Product concept 1**

**Component: Crossing**

Project overview | Projects | Experiment Dimensions | Activities

| Component | Sites | Entries | Reps | Samples | Value | | |
|---|---|---|---|---|---|---|---|
| Crossing | 1 | 1 | 1 | 1 | 6,776.50 | Reload | Save |
| F2 grow-outs | 1 | 150 | 1 | 150 | 11,853.75 | Reload | Save |
| F3 rows | 1 | 1500 | 1 | 1500 | 37,909.75 | Reload | Save |
| F4 rows | 1 | 800 | 1 | 800 | 19,807.00 | Reload | Save |
| F5 rows | 1 | 700 | 1 | 700 | 18055.75 | Reload | Save |
| Observation Nursery Site 1 | 1 | 700 | 1.3 | 910 | 21203.63 | Reload | Save |
| Observation Nursery Site 2 | 1 | 700 | 1.3 | 910 | 23229.51 | Reload | Save |
| Observation Nursery Site 3 | 1 | 700 | 1.3 | 910 | 21732.15 | Reload | Save |
| PVT Trial 1 | 1 | 350 | 1.3 | 455 | 13,896.33 | Reload | Save |
| PVT Trial 2 | 1 | 350 | 1.3 | 455 | 13,896.33 | Reload | Save |
| PVT Trial 3 | 1 | 350 | 1.3 | 455 | 13,896.33 | Reload | Save |
| NVT Trial 1 | 1 | 200 | 2 | 400 | 9612 | Reload | Save |
| NVT Trial 2 | 1 | 200 | 2 | 400 | 10,991.50 | Reload | Save |
| NVT Trial 3 | 1 | 200 | 2 | 400 | 12,592.00 | Reload | Save |
| NVT Trial 4 | 1 | 200 | 2 | 400 | 12,592.00 | Reload | Save |
| | | | | | | Reload | Save |

Project Total: 248,044.53

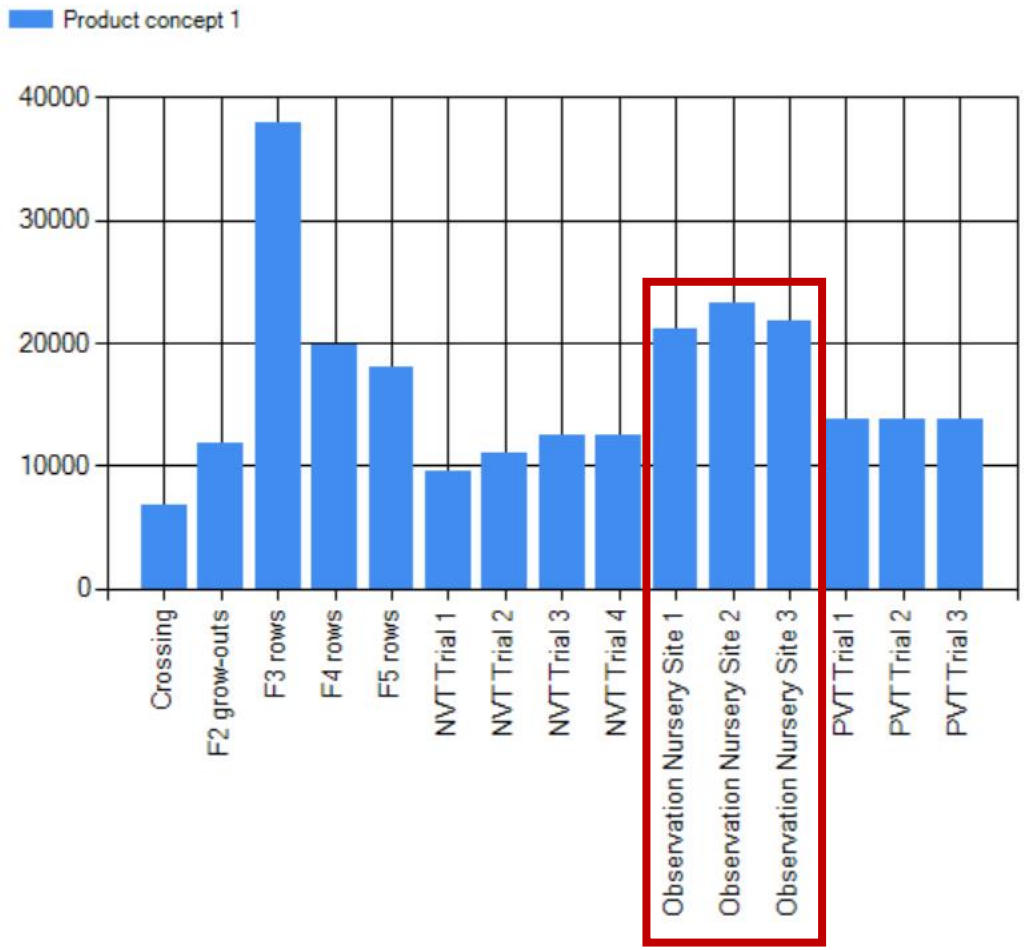


Chart by: Selected Components | Activity Costs for selected component | Bar chart | Pie chart

Close

Type here to search

ENG 1:12 PM 9/01/2020

Breeding program costing tool

Setup Reports Tools About

Crop Name: Generic

**Project: Product concept 1**

**Component: Crossing**

Project overview | Projects | Experiment Dimensions | Activities

| Component | Sites | Entries | Reps | Samples | Value | | |
|---|---|---|---|---|---|---|---|
| Crossing | 1 | 1 | 1 | 1 | 6,776.50 | Reload | Save |
| F2 grow-outs | 1 | 150 | 1 | 150 | 11,853.75 | Reload | Save |
| F3 rows | 1 | 1500 | 1 | 1500 | 37,909.75 | Reload | Save |
| F4 rows | 1 | 800 | 1 | 800 | 19,807.00 | Reload | Save |
| F5 rows | 1 | 700 | 1 | 700 | 18055.75 | Reload | Save |
| Observation Nursery Site 1 | 1 | 700 | 2 | 1400 | 30948.5 | Reload | Save |
| Observation Nursery Site 2 | 1 | 700 | 2 | 1400 | 34065.25 | Reload | Save |
| Observation Nursery Site 3 | 1 | 700 | 2 | 1400 | 33377 | Reload | Save |
| PVT Trial 1 | 1 | 350 | 1.3 | 455 | 13919.08 | Reload | Save |
| PVT Trial 2 | 1 | 350 | 1.3 | 455 | 13,896.33 | Reload | Save |
| PVT Trial 3 | 1 | 350 | 1.3 | 455 | 13,896.33 | Reload | Save |
| NVT Trial 1 | 1 | 200 | 2 | 400 | 9612 | Reload | Save |
| NVT Trial 2 | 1 | 200 | 2 | 400 | 10,991.50 | Reload | Save |
| NVT Trial 3 | 1 | 200 | 2 | 400 | 12,592.00 | Reload | Save |
| NVT Trial 4 | 1 | 200 | 2 | 400 | 12,592.00 | Reload | Save |
| | | | | | | Reload | Save |

Project Total: 280,292.74

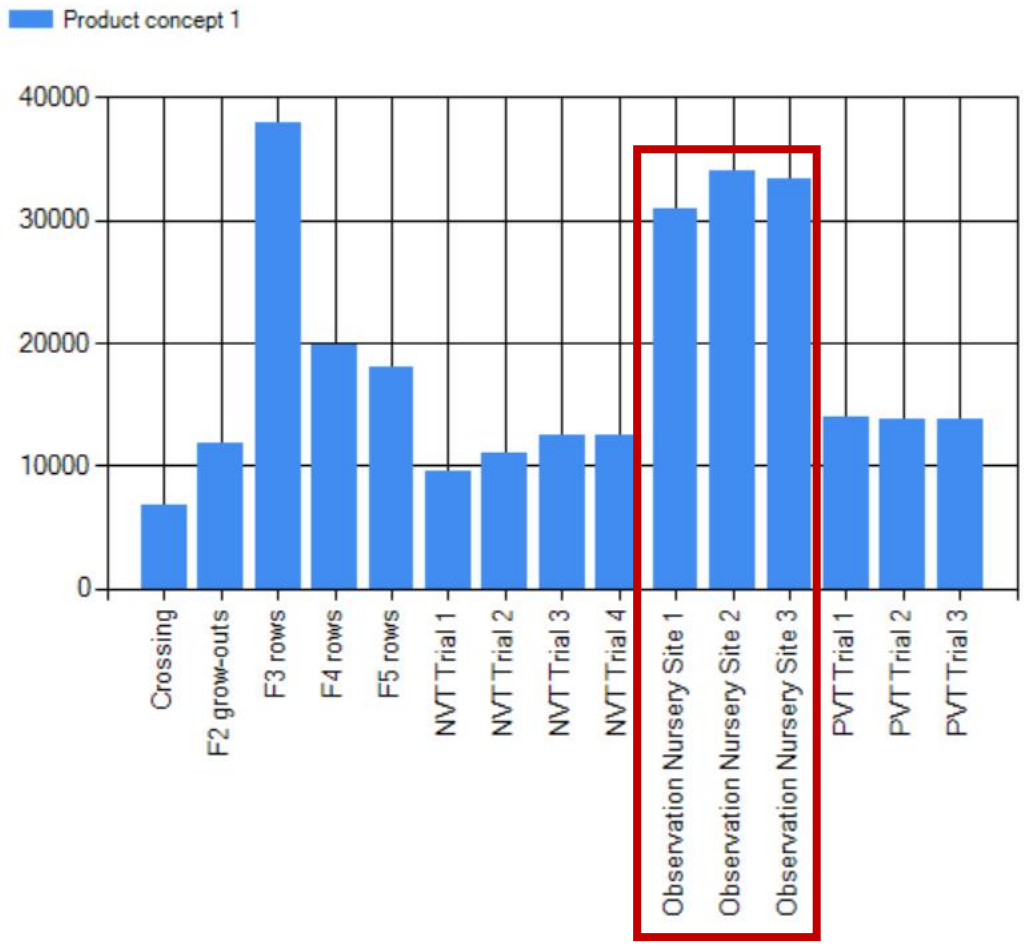


Chart by: Selected Components | Activity Costs for selected component | Bar chart | Pie chart

Close

Type here to search

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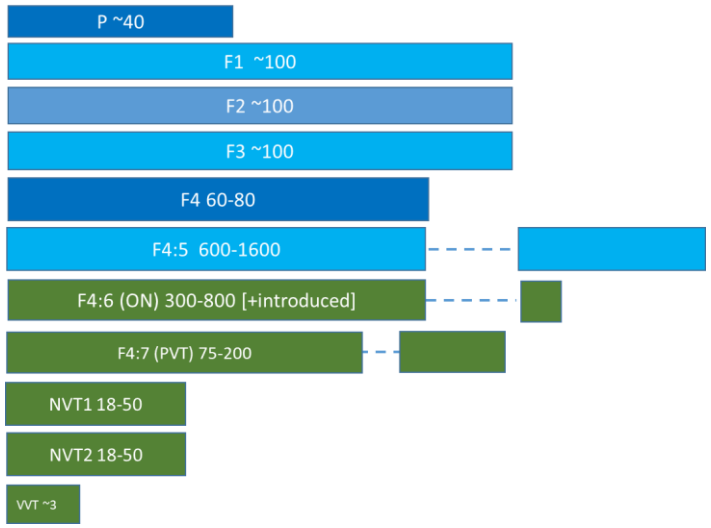
The interactive scale modification functionality allows users to conduct "***what if***" scenarios to explore the consequences of changing particular elements of the breeding activity or project including:

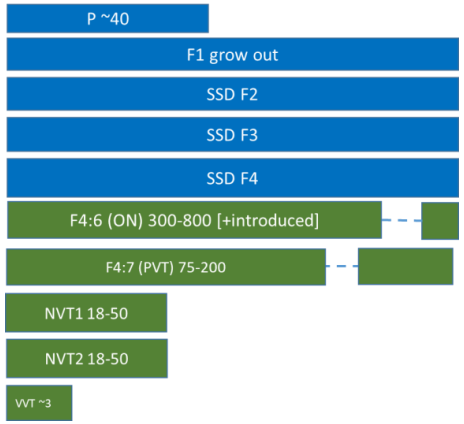
- Entry number versus replication level (e.g. including more genotypes in a partially-replicated design, versus a small number of genotypes in a 3 replicated RCB design)

- Increasing entry number at a limited number of sites versus reduced entries at more locations

# Comparing the costs of two alternative breeding pipelines




vs




The duplicate function for both project and project component, coupled with experiment dimensions and activity modification, enable the rapid build of financial models for comparison of alternative breeding pipelines.

# Comparing the costs of two alternative breeding pipelines

The rapid build of financial models for alternative pipelines enables the evaluation of the financial impacts of introducing new technologies, e.g.

- The introduction of rapid generation advance technologies comparing single seed descent, double haploids and/or genomic selection approaches with standard pedigree based approaches.

- The introduction of labour-saving technologies such as mechanisation (e.g. mechanised planting, harvesting and threshing, digital data capture)

Labour unit costs.

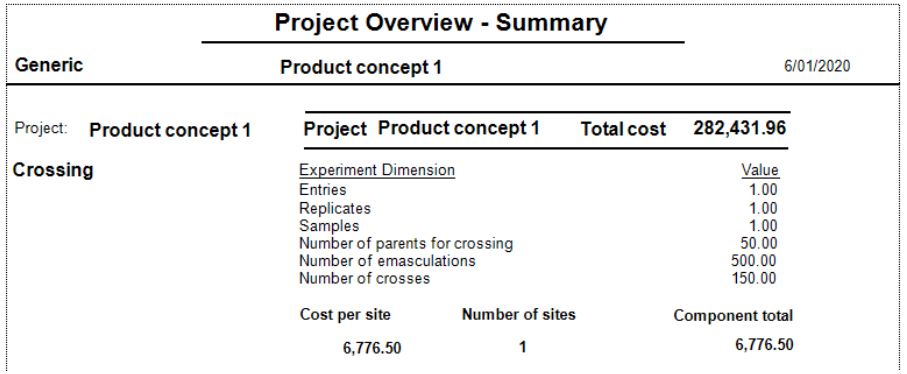
The cost of one unit of the item eg. one seed packet, one vehicle trip to remote site, cost of electricity for one project, ploughing one ha or the units specified for land area.

Item Costs | Labour Costs | Fixed Costs

| Labour Unit Cost | Location | Value | Experiment dimension | Permanent Labour | Defined Term Labour | Casual Labour | Unit | Comment |
|---|---|---|---|---|---|---|---|---|
| Hand threshing and cleaning/plot | All Locations | 3.81 | Samples | 0.00 | 0.00 | 3.81 | Birr | 1 plot/20 mins or 21 plots/day with casual labour on plot base (3m2) |
| Machine threshing/plot off-station | All Locations | 0.73 | Samples | 0.54 | 0.00 | 0.19 | Birr | 1 plot/1 mins or 420 plots/day (Operator + casual) |

# Reports

- The software is designed to calculate the cost of running a breeding activity, or an entire breeding pipeline operating at maximum capacity, using the prices, costs and salaries from a single year.
- The software generates a range of reports which can be used by the breeder to determine resource requirements and costs for a single year.
- In addition this data can be exported to a csv file and used to construct a multi-year budget assuming appropriate allowances were made for inflation and wage rises over time.



**Project Overview - Summary**

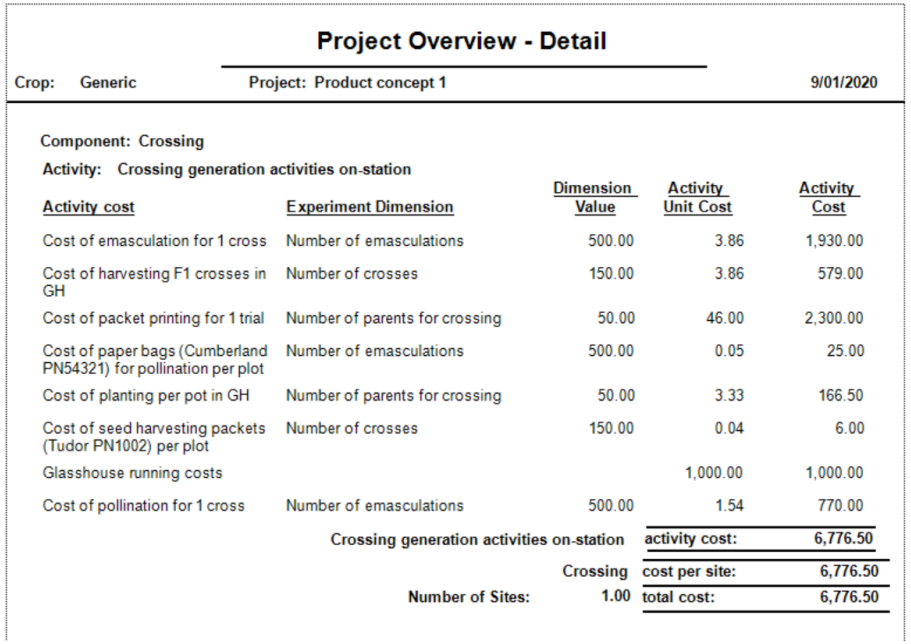
Generic — Product concept 1 — 6/01/2020

Project: **Product concept 1** — Project Product concept 1 — Total cost 282,431.96

**Crossing**

| Experiment Dimension | Value |
|---|---|
| Entries | 1.00 |
| Replicates | 1.00 |
| Samples | 1.00 |
| Number of parents for crossing | 50.00 |
| Number of emasculations | 500.00 |
| Number of crosses | 150.00 |

| Cost per site | Number of sites | Component total |
|---|---|---|
| 6,776.50 | 1 | 6,776.50 |



**Project Overview - Detail**

Crop: Generic — Project: Product concept 1 — 9/01/2020

**Component: Crossing**

**Activity: Crossing generation activities on-station**

| Activity cost | Experiment Dimension | Dimension Value | Activity Unit Cost | Activity Cost |
|---|---|---|---|---|
| Cost of emasculation for 1 cross | Number of emasculations | 500.00 | 3.86 | 1,930.00 |
| Cost of harvesting F1 crosses in GH | Number of crosses | 150.00 | 3.86 | 579.00 |
| Cost of packet printing for 1 trial | Number of parents for crossing | 50.00 | 46.00 | 2,300.00 |
| Cost of paper bags (Cumberland PN54321) for pollination per plot | Number of emasculations | 500.00 | 0.05 | 25.00 |
| Cost of planting per pot in GH | Number of parents for crossing | 50.00 | 3.33 | 166.50 |
| Cost of seed harvesting packets (Tudor PN1002) per plot | Number of crosses | 150.00 | 0.04 | 6.00 |
| Glasshouse running costs | | | 1,000.00 | 1,000.00 |
| Cost of pollination for 1 cross | Number of emasculations | 500.00 | 1.54 | 770.00 |

Crossing generation activities on-station — activity cost: 6,776.50

Crossing — cost per site: 6,776.50

Number of Sites: 1.00 — total cost: 6,776.50

# Access and implementation

The costing tool is currently being implemented in multiple breeding programs in Australia and Ethiopia.

The software and associated video help files are freely available via https://excellenceinbreeding.org/toolbox/tools/breeding-costing-tool and https://aussorgm.org.au/downloads/breeding-costing-tool/