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Protocol for Designing and Conducting Potato Field Experiments for Modeling Purposes

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Protocol for Designing and Conducting Potato Field Experiments for Modeling Purposes

The following document summarizes the minimum information required to obtain the parameters for a simplified potential growth model. The experiments developed for this purpose should be conducted under optimal conditions; that is, without water or nutrient limitations and without damage from diseases, pests or weed competition.

General Information

- Leader
- Collaborators
- Institution

Location

Register the geographical coordinates of the experimental site. Use the spherical coordinate system and express coordinates in sexagesimal degrees (Degrees:Minutes:Seconds). Otherwise, specify the coordinate system and datum used. Make use of a GPS or a National Map at the scales 1:25000 or 1:100000.

Minimun data

- Country
- Administrative Division 1
- Administrative Division 2
- Administrative Division 3
- Site
- Latitude (Degrees:Minutes:Seconds)
- Longitude (Degrees:Minutes:Seconds)
- Elevation (m.a.s.l.)
- Ecological classification or agro-ecological zone

Experimental Design

More information

- Steel, R., J. Torrie, D. A. Dickey. 1997. Principles and procedures of statistics: a biometrical approach. McGraw-Hill. 666 pages
- Kuehl, R. O. 2000. Design of Experiments: Statistical Principles of Research Design and Analysis. Duxbury/Thomson Learning. 666 pages.

Scope

It is recommended to select a homogeneous experimental field for implementing modeling trials of potential growth. A varietal trial in the field may be blocked to lessen effects of soil fertility differences between locations. The completely randomized block design can be used when the experimental units can be meaningfully grouped. Such a group is called a block or replication. The object of grouping is to have the units in a block as uniform as possible. Variability among units in different blocks will be greater, on the average, than variability among units in the same block. Ideally the variability among experimental units is controlled so that the variation among

blocks is maximized while the variation within is minimized (Steel and Torrie 1997).

Genotypes will be assigned to blocks. In order to implement destructive samplings in the field, each block will include 6 small randomized sub-plots, by 20 plants (Appendix 1). Considering 20 plants per sub-plot, 6 destructive samplings and 3 blocks, approximately 360 tuber-seeds will be required and approximately 250 m^2 of land per each genotype.

Data for experimental design

- Experiment type
- Experimental design
- Number of blocks
- Treatments
- Experiment total area (m^2)

Data of genotype

More information

- International Potato Center (CIP). Genetics and Crop Improvement; Integrated IT & Computational Research. 2013. Catalogue of potato varieties and advanced clones [CD-ROM]. Lima (Peru). CIP. ISBN 978-92-9060-382-5. https://research.cip.cgiar.org/redlatinpapa/pages/home.php

Minimum data

- Number of genotypes to be tested
- Variety name, clone code or CIP number
- Growing cycle: short (<120 days), intermediate (120-150 days), long (>150 days)
- Response to photoperiod: short (N<13), intermediate (N=13-15), long (N>15)

Desirable data

- Tolerance or resistance to biotic and abiotic factors
- Parental material

Agronomic data

Minimum data

- Planting date
- Planting method
- Tuber-seed type: basic, pre-basic, commercial, botanic seed, cutting
- Tuber-seed mean size: weight (gr), diameter (mm)
- Sprout mean length at planting (mm)

- Planting density (plant/m^2)
- Distance between rows (m)
- Distance between plants (m)
- Planting depth (cm)
- Harvest date

Desirable data

- Dates and volume of water applied (m^3/ha)
- Irrigation type
- Sources and doses of fertilization
- Fertilizers application dates
- Organic matter application (t/ha)
- Pests and diseases control

Meteorological data

More information

- World Meteorological Organization. 2008. Guide to Meteorological Instruments and Methods of Observation. WMO-No. 8. Seventh edition. Geneva http://www.wmo.int/pages/prog/gcos/documents/gruanmanuals/CIMO/CIMO_Guide-7th_Edition-2008.pdf
- World Meteorological Organization. 2011. Guide to Climatological Practices. WMO-No. 100. Geneva http://www.wmo.int/pages/prog/wcp/ccl/documents/WMO_100_en.pdf

Scope

It is required to install an automatic weather station in the experimentation site in order to record daily meteorological data (Figure 1). For that purpose, consider the World Meteorological Organization (WMO) procedures. If you do not have a weather station, try to identify the closest one. It is advisable to check the continuous operation of sensors and data loggers.

Minimum data

- Location of the weather station
- Latitude (Degrees:Minutes:Seconds)
- Longitude (Degrees:Minutes:Seconds)
- Altitude (m.a.s.l.)
- Daily records of Minimum temperature (ºC)
- Daily records of Maximum temperature (ºC)
- Daily records of Solar radiation or sunshine hours (MJ. m^{-2}.day^{-1})

Recommended data

- Daily records of Rainfall (mm.day^{-1})
- Daily records of Relative humidity (%)
- Daily records of Reference evapotranspiration (mm.day^{-1})
- Daily records of Dew point temperature (ºC)
- Daily records of Wind speed and direction (km.$hour^{-1}$)

Figure 1. Meteorological Weather Station

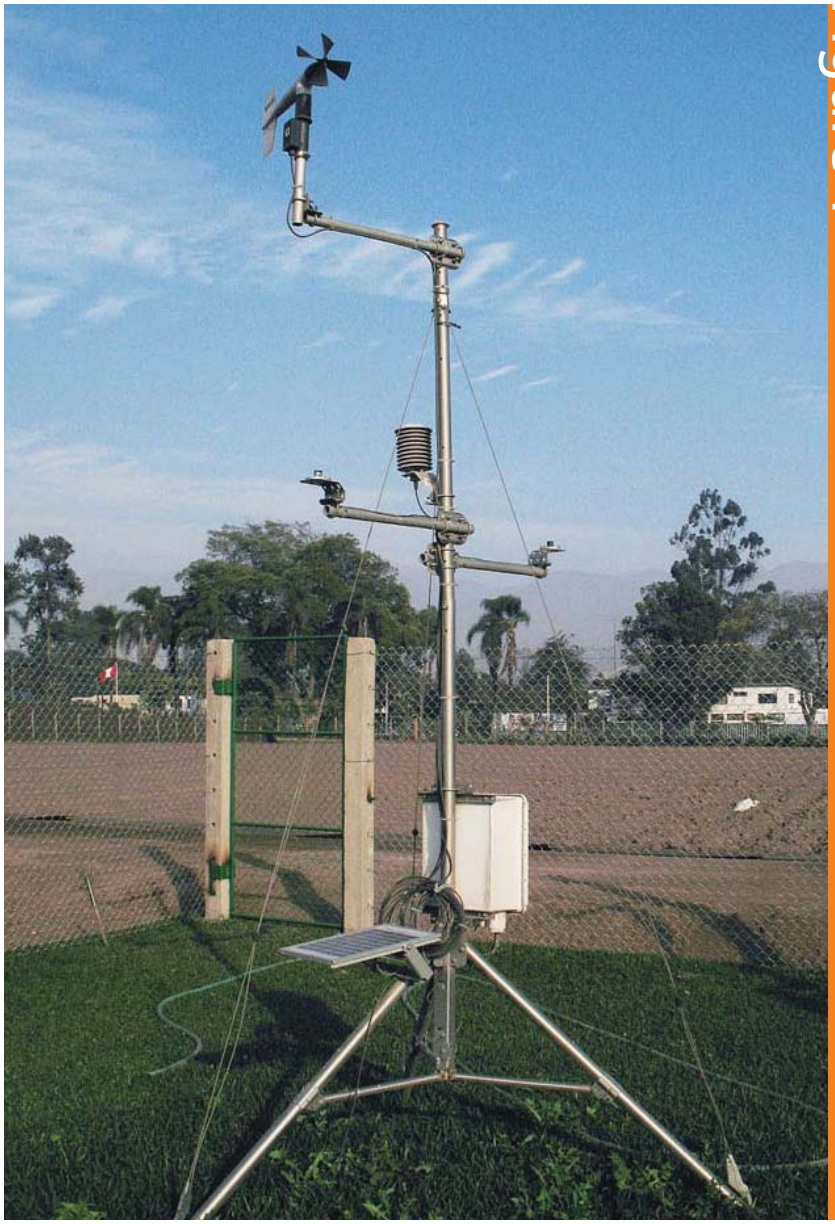


Figure 1

Soil data

Minimum data

- Texture classification
- Sand (%)
- Silt (%)
- Clay (%)

Recommended data

- Soil characterization LAB ANALYSIS by soil profile.
- Field capacity and wilting point (%vol)
- Daily records of Soil temperature (ºC) and Soil water content (%vol), by soil profile

Phenology

More information

- Haverkort, A.J., MacKerron, D.K.L. (eds.). 1995. Potato ecology and modeling of crops under conditions limiting growth: Proceedings. Dordrecht (Netherlands). Kluwer Academic Press.
- Federal Biological Research Centre for Agriculture and Forestry. 2001. Growth stages of mono-and dicotyledonous plants. BBCH Monograph. Edited by Uwe Meier. Second Edition. http://www.bba.de/veroeff/bbch/bbcheng.pdf

Scope

Crop phenology characterization contributes to many scientific disciplines from biodiversity, agriculture, agrometeorology and forestry to human health. Potato phenology stages include: emergence, tuber initiation, tuber filling and senescence (Haverkort & MacKerron 1995).
Identification of these phases brings important information about the effect of climate on the growth and development of the crop (Figure 2).

Basic Principle

The first ideas about the quantitative study of the relationship between plant growth and temperature were proposed by Reaumur in 1730. The concept of heat units or degree days, as the summation of temperatures above a certain threshold value, will be used for the assessment of physiological time scales in potato. Degree day calculation, has vastly improved the description and prediction of phenological events.

Equipment

Weather station for daily records of Minimum and Maximum temperature

Procedure

In order to determine the emergence day, it is necessary to perform daily monitoring of the number of plants that emerge per plot and repetition. The percentage of emergence is calculated by comparing the number of plants emerged with the total number of plants per plot and repetition. The emergence onset is considered once this ratio reaches 50%. It is possible to express the emergence initiation using thermal time units (GDD). The other phenological stages will be estimated from the canopy cover and dry matter periodic data.

Calculation

$$GDD = \left[\frac{(T_{MAX} + T_{MIN})}{2} \right] - T_{BASE}$$

Where:
GDD Growing degree days
TMAX Maximum temperature
TMIN Minimum temperature
TBASE Threshold temperature for which plant growth begins

Figure 2. Potato phenology stages

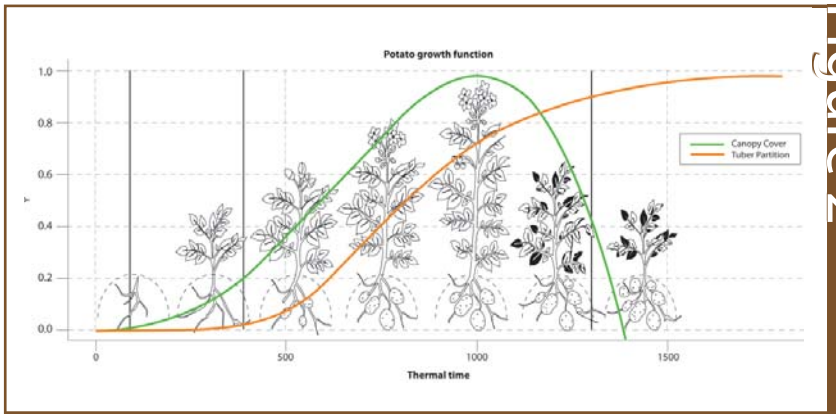


Figure 2

Canopy cover

More information

- Haverkort, A.J., Uenk, D., Veroude, H., Waart, M. van de. 1991. Relationships between ground cover, intercepted solar radiation, leaf area index and infrared reflectance of potato crops. Potato Research. (Netherlands). 34(2):113-121.

Scope

Canopy structure is essential to understand the influence that structure has on plant-environment interactions. Canopy cover measurements bring an indirect estimation of the crop's light interception capacity.

Basic Principle

Coupling digital photography and computer software applied in a strict monitoring protocol enabled rapid sampling and recording of quantitative canopy cover values. Image segmentation techniques can be used to separate healthy green vegetation from the other components of the scene.

Equipment

1. A digital camera (point and shoot camera or single-lens reflex (SLR) camera) with a standard lens (approximate focal length of 50 mm, if available).
2. Bubble level.
3. Measuring tape.
4. Software for data processing

Sampling intensity

For monitoring purposes, take pictures of the canopy cover every fifteen days at 25, 40, 55, 70, 85, 100 and 115 days after planting (dap). We can select different sampling periods taking into account the growing cycle of an early or late variety. Establish preferably a fixed hour to take the photographs considering the time with the best lighting during the day. It is recommended to take 16 canopy cover photos per sub-plot and repetition.

Procedure

1. Set up the camera in automatic mode considering the following features:

a. No zoom
b. No flash
c. Iso 100 (if available)
d. Maximum image resolution

2. Estimate the frame covered by your camera at different altitudes (Use Table 1 as a reference).

3. Select the appropriate height according to the crop distance. It is recommended to include two plants per picture.

4. Place the camera with its lens oriented directly to the top of the plant, using the selected altitude from the top of the plant (e.g.: 1 meter from the top of the plant to the camera's lens). Put the long side of the camera along the row distance and the short side along the plant distance of the crop. See Figure 3a.

5. Make use of the bubble level to locate the camera parallel to the ground.

6. Use the previous settings to take a single picture of an object with a known distance. A retractable tape measure could be used. See Figure 3b.

7. Take pictures of canopy cover, after having verified the altitude, level and the frame position of the camera. See Figure 3c.

8. If available, make use of a tripod and a remote control or a cable and a laptop for shooting to avoid being part of the image.

9. The desirable number of photographs should be a function of the local variability. As a rule of thumb, we recommend at least 15% of the total number of plants. If infeasible, as many pictures as you can take, provided you sample the heterogeneity of the plots.

10. Download the images and use software to estimate canopy cover area and percentage.

Table 1. Area covered by the camera Canon A640 (10 MPx)

Altitude (cm)	Length (cm)	Width (cm)
50	49	36
60	59	44
70	69	51
80	79	59
90	89	66
100	97	71
110	111	83
120	119	89
130	129	95
140	139	104

Figure 3. Taking Canopy Cover photographs

Figure 3a

Figure 3c

Figure 3b

Calculation

Image processing software will be used to count the number of pixels covered by healthy green vegetation and estimate the area and percentage of canopy cover (Figure 4).

Figure 4. Canopy Cover Photograph and Classification Results

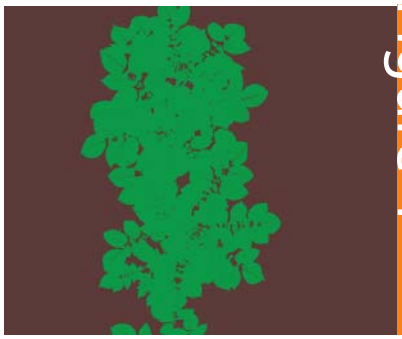


Figure 4

Units

Canopy cover (%), percentage
Days after planting (dap)
Days after emergence (dae)

Dry weight by organs

More information

- Undersander D., Mertens D., Thiex N. 1993. Forage Analyses Procedures. National Forage Testing Association. http://www.foragetesting.org/files/Laboratory Procedures.pdf

Scope

Use this procedure in order to study the crop growth dynamics. Total dry-matter protocol should be used in order to determine the dry matter content of leaves, stems and tubers on potato individual plant samples. Total dry weight of leaves, stems and tubers is based on the dry matter content estimation and the total fresh weight by organs. Samples dried by this procedure are not appropriate for subsequent fiber, lignin, or acid detergent insoluble nitrogen analysis.

Basic Principle

The functional method of growth analysis allows us to describe the crop growth in a continuous way, adapting mathematical functions or other functions to the original growth data. Moisture is evaporated from sample by oven drying. Total dry matter is determined gravimetrically as the residue remaining after drying. Weighing may be done on hot samples.

Equipment

- Digging fork and shovel
- Pruning shears
- Vegetable cutting machine or cutting board and a knife
- Paper bags and labels
- Top loading electronic balance, accurate to 0.1 mg
- Forced-air drying oven at 100ºC, capable of maintaining temperature at ±2ºC.

Sampling intensity

Sequential destructive sampling of a group of complete individual plants will be carried out for growth monitoring. Dry weight of leaves, stems and tubers is recorded every 15 days at 40, 55, 70, 85 and 100 days after planting (dap). Reserve the last sub-plot for the harvest sampling.

Minimum 6 complete plants should be sampled per plot, selecting them from the central part. In this way, 18 plants are collected per genotype, at each sampling. Selected plants should be representative of the average condition of the plot. Any plant showing anomalous growth should be not considered for the sampling.

Procedure

- Before start the sampling at field, dry the paper bags at 55 ºC for 8 hours. Weigh paper bags on a top loading balance and record weight to nearest 0.01 g.
- Extract and transfer each selected plant to a processing area. It is recommended to identify plants using codes. Prevent the loss of weight of plant material.
- Clean or rinse the tubers and stems if necessary and let them aerate or drain for a few minutes to air then separate by organ, leaves, stems and tubers.
- Record the total fresh weight (TFW) of leaves, stems and tubers separately.
- Reserve an individual sub-sample of approx. 150 g. of leaf, stem and tuber per each individual plant sample. Cut up the sub-samples in uniform pieces.
- Place the sub-samples in previously dried paper bags and label.
- Tare empty bags to zero and weigh constant volume of coarse leaves, stems and tubers and register the fresh weight (SFW), recording weight to nearest 0.01 g.
- Place sub-samples into an oven which has been preheated to 100 ºC (or 105 ºC) for at least 3 hours. Oven should return to temperature within 1 hour after samples have been placed into it.
- Leave samples in oven for 24 hrs. at 100 ºC.
- Individually remove paper bags from the oven and immediately weigh to obtain the dry weight of the sub-samples (SDW). Record weight to nearest 0.1 mg.

Comments

- Use a forced-air oven so that drying is more rapid and uniform and temperature drop is minimized during weighing.
- Samples should be placed in drying oven in such a way that air can circulate freely. Samples should not touch each other.

- The balance must be located next to the oven; carrying samples any distance will allow cooling and absorption of moisture.
- Samples should be removed from oven one at a time and immediately weighed.
- Use of computer software to electronically record weight can reduce variance in weights due to operator differences in determining minimum weight.

Calculation

Total dry weight by leaves, stems and tubers can be calculated using this equation:

$$TDW = (TFW*SDW)/SFW$$

Where:
TDW Total dry weight (g/plant)
TFW Total fresh weight (g/plant)
SDW Sub-sample dry weight (g/plant)
SFW Sub-sample fresh weight (g/plant)

Dry matter content of tubers

At harvest, register the total fresh weight of tuber per plant and perform a commercial quality selection.
Select a sub-sample of the tuber yield to calculate dry matter content of tubers by genotype. Use the previous procedure to estimate dry matter content of tubers.

Calculation

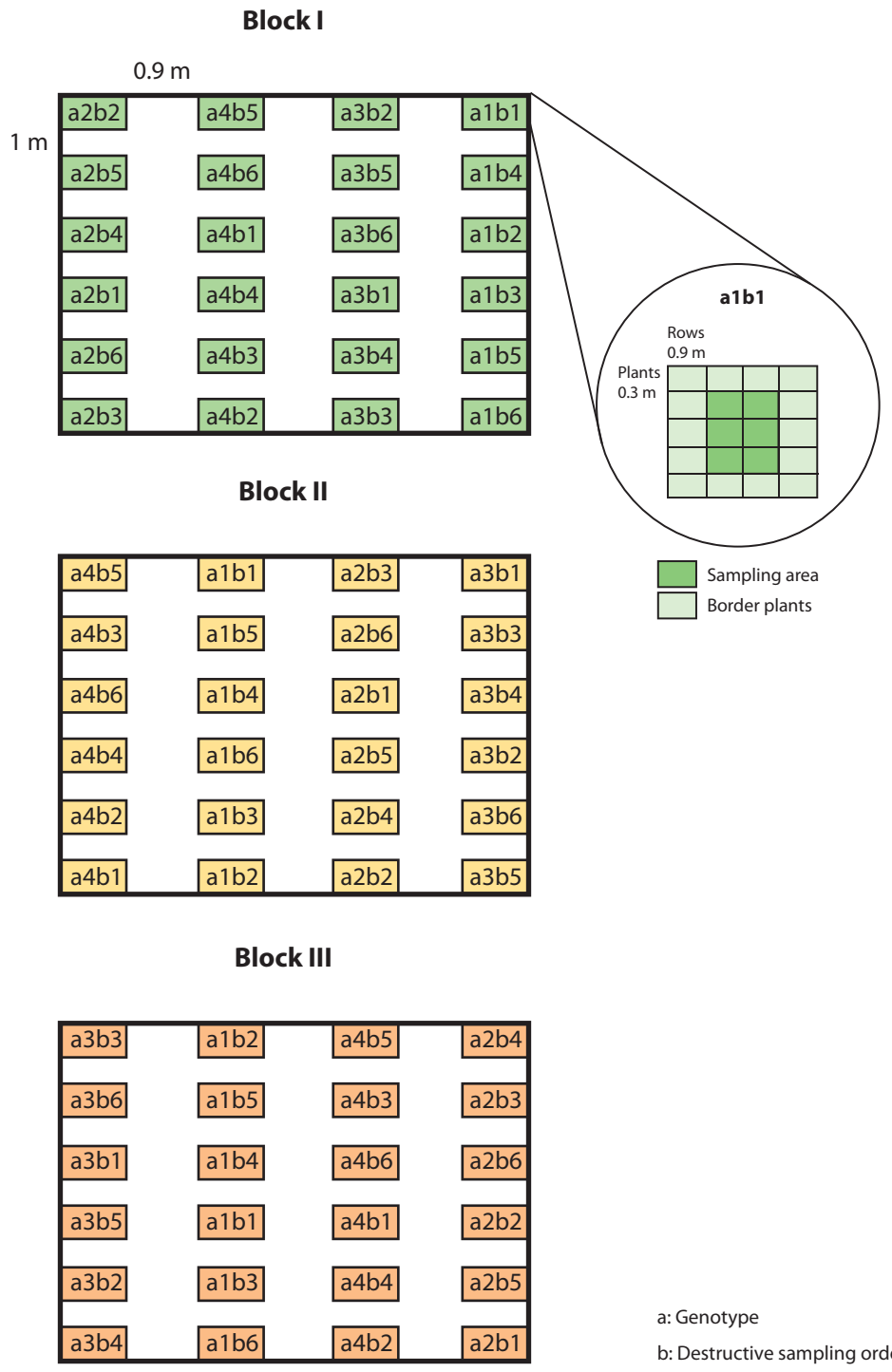
Total dry matter content of tubers, can be estimated using this equation:

$$DMC_t = (DW_t / FW_t)*100.$$

Where
DMC_t Dry matter content of tubers
DW_t Dry weight of tubers
FW_t Fresh weight of tubers

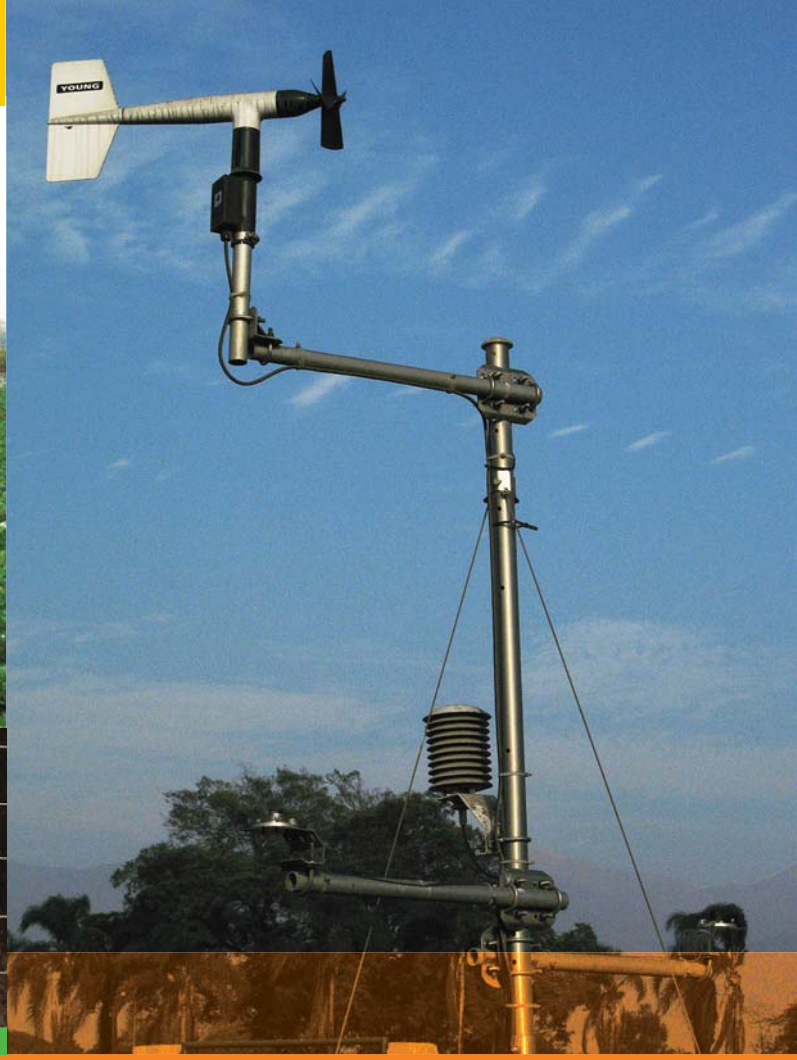
Appendix 1

Layout for field experiments
Complete Randomized Block Design



a: Genotype

b: Destructive sampling order



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