Data Collection Procedures of Agronomic Crops

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Sampling

Sampling may be of following types:

- Simple Random Sampling***
- Stratified random sampling*
- Purposive sampling*
- Systematic sampling*
- Cluster sampling*
- Multistage sampling
- Double sampling
- Area sampling
- Quota sampling
- Mixed sampling

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Sample

A **sample** is a small represented part of a population.

Sample size

The number of elements selected for a sample is known as the sample size. A sample of size less than 30 is termed as a small sample and that having 30 or more elements is termed as a large sample.

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Objectives of sampling

- Sampling is more useful for taking **timely and quick** decision
- It save **money**
- It ensure the **accuracy** of results
- It **represent population** if can be properly done.
- It creates a **greater scope**.
- Large **population problems** can be avoided

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Data collection for Agronomic Research

Meteorological data

Latitude and altitude of the location of the study

Daily meteorological parameters

- Solar radiation
- Rainfall
- Maximum and minimum temperature
- Sunshine hours
- Wind speed
- Relative humidity

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Crop data

Phonological observation: Date of sowing, emergence, floral initiation, anthesis, physiological maturity.

Agronomic observations: The agronomic observations to be recorded at all the phonological stages of crop include plant population, number of leaves/plant, maximum leaf area of individual leaf, LAI, diurnal leaf water potential, diurnal leaf temperature, PAR, plant height, leaf weight, culm weight, dry matter, head/ear weight, grain weight, etc.

Final grain yield and yield components

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Soil and management Data

- **Soil data**

  Soil type, soil depth, structure, texture, water holding capacity, soil profile structure, bulk density, salinity, alkalinity, pH, EC, microbial content, soil fertility, soil productivity, available soil moisture, wilting point, permanent wilting point and available moisture at different stages of crop.

Management data

- Amount of irrigation, fertilizer quantity, herbicide quantity, date and mode of application, insecticide quantity and date of application, etc.

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Biometric observations in field crops

- It is important to collect data on various **growth and yield parameters** which may facilitate to interpret the results in a better way.
- Generally growth parameters such as **plant, height, tiller production, leaf area index and dry matter production** are recorded.
- In addition, yield parameters may also be recorded.
- The growth and yield parameters may be recorded at different growth stages viz. **tillering, primodial initiation, flowering and at harvest**. Observations can also be taken at 20, 40, 60, 80 and 100 days after planting or sowing. Appropriate **method** of sampling and proper **measurement** are important to get a valid data.

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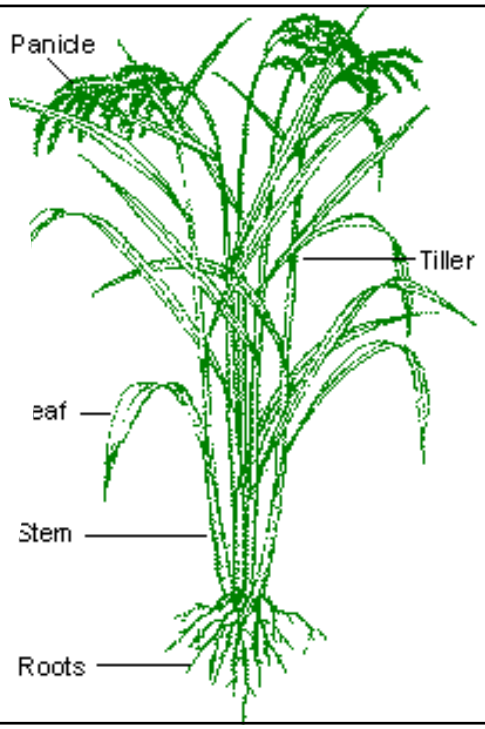
Rice



- Plant height
- Fresh weight and dry weight
- Leaf area
- Leaf area index (LAI)
- Number of effective and non-effective tillers
- Dry matter production
- Number of panicles per plants
- Panicle length
- Number of spikelets per panicle
- Number of filled per panicle
- Test grain weight
- Grain yield
- Straw yield

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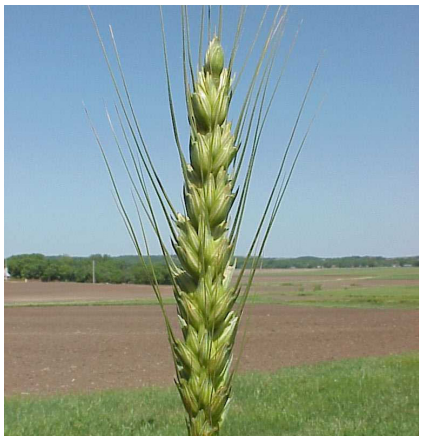
Wheat

Growth
- Germination percentage
- Plant population m^{-2}
- Plant height
- Number of tillers m^{-1} row length
- Effective tillers m^{-1} row length
- Leaf area / Leaf area index (LAI)
- Dry matter accumulation
- Crop growth rate (CGR)
- Relative growth rate (RGR)

Phenology
- Days to emergence
- Days to tillering
- Days to booting
- Days to heading
- Days to anthesis
- Days to maturity

Yield Components
- Spike length
- Number of spikelets $spike^{-1}$
- Number of grains $spike^{-1}$
- Grain weight $spike^{-1}$
- 1000-grain weight

Yield
- Grain yield
- Straw yield
- Biological yield
- Harvest index



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Maize

Growth
- Emergence percentage
- Plant height
- Stem diameter
- Number of leaves plant^{-1}
- Leaf area / LAI
- Dry biomass
- Root length and root biomass

Phenology
- Days to tasseling
- Days to silking
- Anthesis-silking interval (ASI)
- Days to physiological maturity

Yield Components
- Cob length
- Cob diameter
- Number of cobs plant^{-1}
- Number of kernel rows cob^{-1}
- Kernels row^{-1}
- Kernels cob^{-1}
- 1000-kernel weight

Yield
- Grain yield
- Stover yield
- Biological yield
- Harvest index

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Pulses

Growth
- Plant height
- Number of branches plant^{-1}
- Number of leaves plant^{-1}
- Leaf area / Leaf area index (LAI)
- Root length
- Root dry weight
- Shoot dry weight
- Total dry matter accumulation
- Crop growth rate (CGR)
- Relative growth rate (RGR)

Nodulation
- Number of nodules plant^{-1}
- Effective nodules plant^{-1}
- Nodule dry weight
- Nitrogen fixation efficiency

- **Phenology**
- Days to first flowering
- Days to 50% flowering
- Days to pod initiation
- Days to pod filling
- Days to physiological maturity
- Crop duration

Yield contributing Parameters
- Pods plant^{-1}
- Pod length
- Seeds pod^{-1}
- Filled pods plant^{-1}
- Unfilled pods plant^{-1}
- 100-seed weight / Test weight
- Seed weight plant^{-1}
-

Yield
- Seed yield
- Straw yield
- Biological yield
- Harvest index

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Rapeseed-mustard

Growth
- Plant height
- Number of primary branches
- Leaf area index
- Dry matter accumulation

Phenology
- Days to flowering
- Flowering duration
- Days to siliqua formation
- Days to maturity

Yield Components
- Number of siliquae plant^{-1}
- Siliqua length
- Seeds siliqua^{-1}
- 1000-seed weight

Yield
- Seed yield
- Stover yield
- Biological yield
- Harvest index
- Oil content
- Oil yield

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Sesame

Growth
- Plant height
- Branches plant^{-1}
- Leaf area
- Dry matter accumulation

Phenology
- Days to flowering
- Days to capsule formation
- Days to maturity

Yield Components
- Capsules plant^{-1}
- Seeds capsule^{-1}
- Capsule length
- 1000-seed weight

Yield
- Seed yield
- Stalk yield
- Biological yield
- Harvest index
- Oil content
- Oil yield

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Sunflower

Growth
- Plant height
- Stem diameter
- Number of leaves
- Leaf area
- Head diameter
- Dry matter production

Phenology
- Days to bud initiation
- Days to flowering
- Days to seed maturity

Yield Components
- Number of seeds head^{-1}
- Filled seeds head^{-1}
- Unfilled seeds head^{-1}
- 1000-seed weight

Yield
- Seed yield
- Biological yield
- Harvest index
- Oil content
- Oil yield

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Jute

Growth
- Germination percentage
- Plant population
- Plant height
- No. of branches/plant
- Basal stem diameter
- Number of leaves
- Leaf area*
- Dry matter accumulation

Phenology
- Days to flowering
- Days to harvest

Yield parameters
- Green biomass yield
- Stick yield
- Fiber yield
- Fiber recovery percentage
- Fiber strength
- Fiber fineness

- Total capsules/plant**
- Diameter of capsule**
- Seeds/capsule**
- Test weight of seed**
- Seed yield**

*data for fiber purpose

** data for seed purpose

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Potato

Growth
- Emergence percentage
- Plant height
- Number of stems hill^{-1}
- Number of leaves
- Leaf area index
- Dry matter accumulation

Phenology
- Days to emergence
- Days to tuber initiation
- Days to flowering
- Days to maturity

Yield components
- Tubers plant^{-1}
- Average tuber weight
- Marketable tubers
- Non-marketable tubers
- Tuber size grading

Yield parameters
- Tuber yield
- Biological yi
- Harvest ind
- Dry matter
- Specific gra
-

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Cotton

Growth
- Plant population
- Plant height
- Number of monopodial branches plant^{-1}
- Number of sympodial branches plant^{-1}
- Number of leaves plant^{-1}
- Leaf area / Leaf area index (LAI)
- Stem diameter
- Root length and root biomass
- Total dry matter accumulation
- Crop growth rate (CGR)
- Relative growth rate (RGR)

Phenology
- Days to emergence
- Days to first square initiation
- Days to first flowering
- Days to 50% flowering
- Days to boll formation
- Days to boll opening
- Days to maturity

Reproductive and yield contributing parameters
- Number of fruiting branches plant^{-1}
- Number of squares plant^{-1}
- Number of flowers plant^{-1}
- Boll number plant^{-1}
- Boll retention percentage
- Boll shedding percentage
- Boll weight
- Seeds boll^{-1}
- 100-seed weight
- Ginning outturn (GOT %)
- Lint index

Yield
- Seed cotton yield
- Lint yield
- Seed yield
- Stalk yield
- Biological yield
- Harvest index

Fiber Quality
- Fiber length
- Staple length
- Fiber strength
- Fiber fineness (micronaire value)
- Fiber uniformity
- Fiber elongation
- Maturity ratio

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Sugarcane

Growth Parameters
- Plant height / Cane height
- Stem diameter / Cane girth
- Number of tillers
- Number of millable canes
- Internode length
- Number of internodes cane^{-1}
- Leaf number plant^{-1}
- Leaf area / Leaf area index (LAI)
- Dry matter accumulation
- Root length and root biomass
- Crop growth rate (CGR)
- Relative growth rate (RGR)

Phenological Parameters
- Days to germination
- Days to tillering
- Days to grand growth phase
- Days to maturity

Yield-Contributing Parameters
- Number of millable canes hectare^{-1}
- Single cane weight
- Cane length
- Cane diameter
- Cane volume
- Internodal characteristics

Yield Parameters
- Cane yield
- Trash yield
- Biological yield
- Harvest index

Juice Quality Parameters
- Juice brix (%)
- Sucrose content (%)
- Purity percentage
- Commercial cane sugar (CCS %)
- Juice extraction percentage
- Reducing sugar content
- Pol percentage
- Fiber percentage

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Common Agronomic Measurements Across All Crops

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Stand Establishment

- Germination/emergence percentage
- Plant population
- Survival percentage

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Biomass and growth analysis

- Fresh weight
- Dry weight
- Root-shoot ratio
- LAI
- CGR
- RGR
- Net assimilation rate (NAR)

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Method for measuring plant fresh weight

- Carefully uproot or collect the plant sample at the desired growth stage.
- Remove soil and debris gently using water or tissue paper.
- Blot the plant material with paper towels to remove surface moisture without drying the tissues.
- Separate plant parts if required (root, shoot, leaf, etc.).
- Immediately weigh the sample using a digital balance.
- Record the weight in grams (g) as the fresh weight (FW).

Note: Fresh weight should be measured immediately after harvesting to avoid moisture loss.

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Method for measuring plant dry weight

- Collect plant samples and clean them to remove soil and debris.
- Separate plant parts if necessary (root, shoot, leaf, etc.).
- Place the samples in labeled paper bags or envelopes.
- Dry the samples in a hot-air oven at 65–70 °C until constant weight is achieved (usually 48–72 h).
- Remove the samples from the oven and cool them in a desiccator.
- Weigh the dried samples using a digital balance.
- Record the weight in grams (g) as the dry weight (DW).

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Method for measuring leaf area

- Collect fully expanded leaves from the plant sample.
- Measure leaf area using a leaf area meter or digital image analysis method.
- If a leaf area meter is unavailable, measure leaf length and maximum width and calculate using an appropriate correction factor:

$$\text{Leaf } area = Length \times Width \times k$$

where k is the crop-specific correction factor.

- Record the leaf area and express it in cm² or m² per plant.

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Crop-specific correction factors (*k* values) for major agronomic crops

Crop	Approximate Correction Factor (k)
Rice	0.75
Wheat	0.75
Maize	0.75
Barley	0.75
Sorghum	0.72–0.75
Millet	0.70–0.75
Sugarcane	0.70–0.75
Soybean	0.68–0.72
Groundnut/peanut	0.65–0.70
Mungbean	0.70
Blackgram	0.70
Cowpea	0.70–0.75
Chickpea	0.65–0.70
Lentil	0.65
Mustard/canola	0.75
Sunflower	0.73–0.75
Cotton	0.75–0.80
Sesame	0.70–0.75
Potato	0.65–0.70
Jute	0.75
Tobacco	0.72–0.75

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Method for measuring leaf area index (LAI)

- Measure the total leaf area of plants using a leaf area meter or by image analysis.
- Determine the ground area occupied by the plants.
- Calculate leaf area index using the following formula:

$$\text{LAI} = \frac{\textit{Total leaf area}}{\textit{Ground area covered by the plant}}$$

- Express LAI as a dimensionless value.

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Method for Measuring Crop Growth Rate (CGR)

- Collect plant samples from a known ground area at two different time intervals (T_1 and T_2 .(
- Dry the plant samples in an oven at 65–70 °C until constant weight is obtained.
- Record the dry weight at each sampling time (W_1 and W_2 .(
- Calculate crop growth rate using the following formula:

$$\text{CGR} = \frac{W_2 - W_1}{(T_2 - T_1) \times A}$$

Where:

$W_1$and W_2 =dry weight at times $T_1$and T_2

$T_2 - T_1$ =time interval (days)

A= ground area occupied by the crop

- Express CGR as g m^{-2} day^{-1}.

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Method for measuring relative growth rate (RGR)

- Collect plant samples at two different growth stages or time intervals (T_1 and T_2 .(
- Dry the samples in a hot-air oven at 65–70 °C until constant weight is achieved.
- Record the dry weights at the two sampling times (W_1 and W_2 .(
- Calculate relative growth rate using the following formula:

$$\text{RGR} = \frac{\ln W_2 - \ln W_1}{T_2 - T_1}$$

Where:

W_1 and W_2 =plant dry weights at times T_1 and T_2

$T_2 - T_1$ =time interval (days)

- Express RGR as g g^{-1} day^{-1} or mg g^{-1} day^{-1}.

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Method for measuring net assimilation rate (NAR)

- Collect plant samples at two different time intervals (T_1 and T_2).
- Measure total leaf area (L_1 and L_2 (and plant dry weight (W_1 and W_2 (at each sampling time.
- Dry plant samples in a hot-air oven at 65–70 °C until constant weight is achieved.
- Calculate net assimilation rate using the following formula:

$$\text{NAR} = \frac{(W_2 - W_1)(\ln L_2 - \ln L_1)}{(T_2 - T_1)(L_2 - L_1)}$$

Where:

W_1 and W_2 =plant dry weight at times T_1 and T_2

L_1 and L_2 =leaf area at times T_1 and T_2

$T_2 - T_1$ =time interval (days)

- Express NAR as g m^{-2} day^{-1}.

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Yield contributing characters and yield

- Harvest the crop from a predetermined net plot area at physiological maturity.
- Thresh, clean, and dry the harvested produce to standard moisture content.
- Record the economic yield (grain, seed, tuber, fiber, etc.) using a digital balance.
- Convert the yield to unit area basis using the following formula:

$$\text{Yield } (kg\ ha^{-1}) = \frac{Plot\ yield\ (kg) \times 10{,}000}{Net\ harvested\ area\ (m^2)}$$

- Express the result as kg ha^{-1} or t ha^{-1} depending on the crop and study.

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Biological yield

- Harvest the entire crop biomass from the net plot area at maturity.
- Dry and weigh total above-ground plant material.
- Express as kg ha^{-1} or t ha^{-1}.

Biological *Yield* = *Economic Yield* + *Straw/Stover Yield*

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Straw/stover yield

- Separate grain or economic parts from the remaining biomass after threshing.
- Dry and weigh the remaining plant material.
- Convert to unit area basis.

$$\text{Straw } \textit{Yield} = \textit{Biological Yield} - \textit{Economic Yield}$$

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Harvest index (HI)

- Measure economic yield and biological yield.
- Calculate harvest index using the following formula:

$$\text{HI } (\%) = \frac{\textit{Economic Yield}}{\textit{Biological Yield}} \times 100$$

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Seed yield per plant

- Harvest and thresh individual plants separately.
- Weigh the cleaned seeds.
- Express as g plant^{-1}.

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Shelling percentage

Common in maize, groundnut, etc.

$$\text{Shelling } (\%) = \frac{\textit{Weight of grains/seeds}}{\textit{Weight of unshelled produce}} \times 100$$

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Grain filling percentage

- Count filled and unfilled grains.
- Calculate using:
- Filled *Grain (%)* $= \frac{Number\ of\ filled\ grains}{Total\ grains} \times 100$

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Crop productivity

$$\text{Crop } Productivity = \frac{Economic\ Yield}{Crop\ Duration}$$

Expressed as kg ha^{-1} day^{-1}.

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Resource use efficiency

- Water use efficiency (WUE)
- Nutrient use efficiency (NUE)
- Radiation use efficiency (RUE)

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Method for measuring water use efficiency (WUE)

- Record the total amount of water applied to each plant or pot during the experimental period.
- Measure the plant biomass at harvest, usually as dry weight.
- Calculate water use efficiency using the following formula:

$$\text{WUE} = \frac{\textit{Plant dry weight (g)}}{\textit{Total water used (L)}}$$

or

$$\text{WUE} = \frac{\textit{Economic yield}}{\textit{Total water used}}$$

- Express WUE as g L^{-1} or kg m^{-3} depending on the study.

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Method for measuring nutrient use efficiency (NUE)

- Apply a known amount of nutrient fertilizer to each treatment.
- Grow plants under controlled experimental conditions until harvest.
- Measure plant growth, biomass, or yield at harvest.
- Determine nutrient uptake or total biomass/yield produced.
- Calculate nutrient use efficiency using the following formula:

$$\text{NUE} = \frac{\textit{Plant yield or biomass}}{\textit{Amount of nutrient applied}}$$

- Express NUE as g g^{-1}, kg kg^{-1}, or similar units depending on the parameter measured.

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Other parameter related to growth

- Stem diameter
- Number of leaves per plant
- Specific leaf weight, SLW (g m^{-2}) = leaf DW/leaf area
- Leaf weight ratio, LWR = leaf DW/plant DW
- Leaf area ratio, LAR (cm^2 g^{-1}) = leaf area/plant DW
- Shoot/root weight ratio, SRR = shoot DW/root DW

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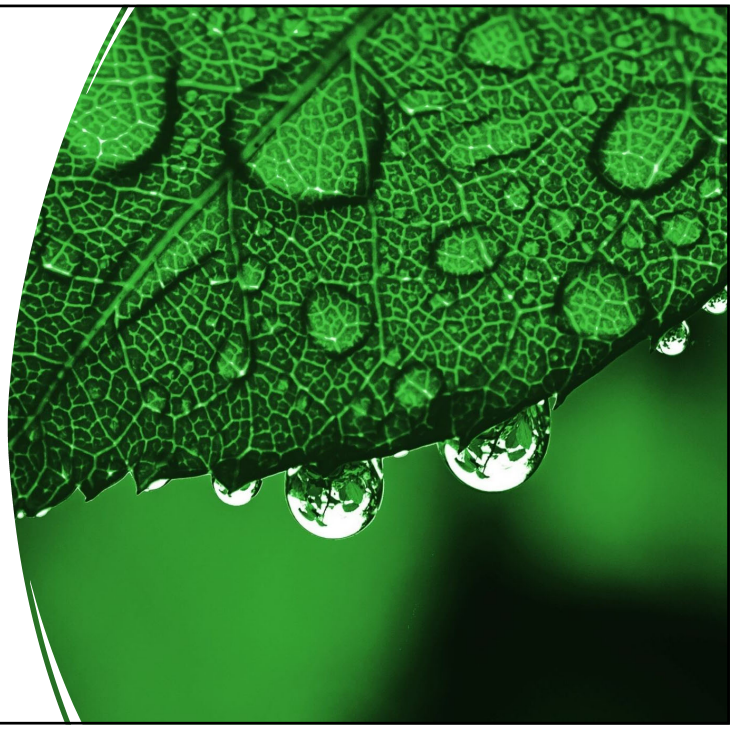
Physiological parameters

- Relative water content, RWC=RWC (%) = (FW – DW)/(TW – DW) × 100
- Leaf exudate rate
- Chlorophyll content
- Electrolyte leakage



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Method for measuring SPAD value

- Select fully expanded healthy leaves from each plant.
- Turn on the SPAD chlorophyll meter and calibrate if necessary.
- Place the leaf gently between the sensor clamps of the SPAD meter, avoiding the midrib.
- Record the SPAD reading displayed on the screen.
- Take multiple readings from different positions of the leaf and from several plants per treatment.
- Calculate the average value and express it as SPAD units.

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Method for measuring chlorophyll content

- Collect fresh leaf samples and cut them into small pieces.
- Homogenize a known weight of leaf tissue in 80% acetone or suitable extraction solvent*.
- Centrifuge the homogenate and collect the clear supernatant.
- Measure absorbance of the extract at 663 nm and 645 nm using a spectrophotometer.
- Calculate chlorophyll content using standard equations.

$$\text{Chlorophyll } a = (12.7 \times A_{663}) - (2.69 \times A_{645})$$
$$\text{Chlorophyll } b = (22.9 \times A_{645}) - (4.68 \times A_{663})$$
$$\text{Total } chlorophyll = (20.2 \times A_{645}) + (8.02 \times A_{663})$$

- Express chlorophyll content as mg g^{-1} fresh weight (FW).

*Solvent may be ethanol, methanol, *N*,*N*-Dimethylformamide (DMF), etc.

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Method for measuring electrolyte leakage (EL)

- Collect fresh leaf discs or plant tissue samples of uniform size.
- Wash the samples gently with distilled water to remove surface-adhered electrolytes.
- Place the samples in test tubes containing a known volume of deionized water.
- Incubate the tubes at room temperature for a fixed period (usually 12–24 h).
- Measure the initial electrical conductivity (EC_1 (of the solution using a conductivity meter.
- Autoclave or boil the samples to completely release all electrolytes and cool to room temperature.
- Measure the final electrical conductivity (EC_2)
- Calculate electrolyte leakage using the following formula:

$$\text{Electrolyte } Leakage\ (\%) = \frac{EC_1}{EC_2} \times 100$$

- Express the result as percentage (%).

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Method for measuring leaf exudation rate

- Select healthy, fully expanded leaves from the plant.
- Excise the leaf or cut the leaf tip/petiole using a sharp blade under water to avoid air embolism.
- Gently blot the cut surface and attach a pre-weighed absorbent cotton or collection tube to collect exudates.
- Allow exudation for a fixed period under controlled conditions.
- Measure the amount of exudate collected by weight or volume.
- Calculate leaf exudation rate using the following formula:

$$\text{Leaf } \textit{exudation rate} = \frac{\textit{Amount of exudate collected}}{\textit{Time}}$$

- Express the result as mg h^{-1}, mL h^{-1}, or on a leaf area basis if required.

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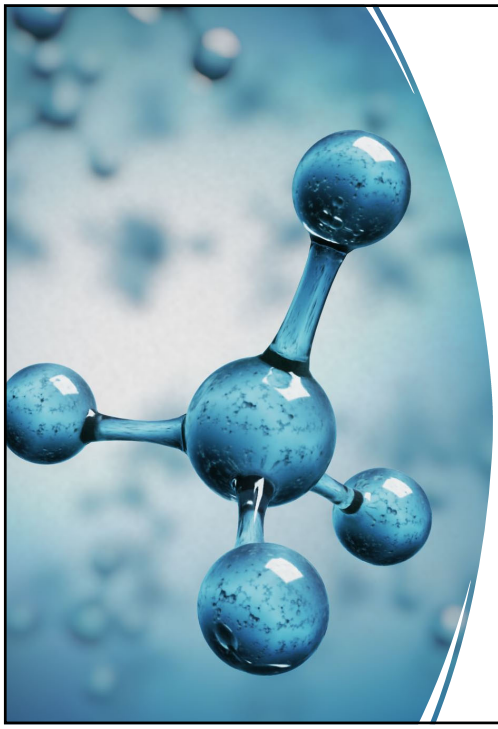

Biochemical parameters

- Enzymes
- Secondary metabolism
- Hormones

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Quality Parameters

- Carbohydrate contents
- Protein contents
- Oil/fatty acid contents
- Ash contents
- Vitamin contents
- Mineral contents
- Specific gravity
- Color/flavor etc.

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Economic parameters

Gross return

Net return

Benefit-cost ratio (BCR)

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Method for calculating gross return

- Record the total yield obtained from each treatment or unit area.
- Determine the market price of the harvested produce at the time of analysis.
- Multiply the total yield by the market price.
- Calculate gross return using the following formula:

  Gross *return* = *Total yield* × *Market price*
- Express the result as monetary value per unit area (e.g., Tk ha^{-1}).

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Method for calculating net return

- Calculate the gross return from the crop yield.
- Record all production costs, including land preparation, seed, fertilizer, irrigation, labor, pesticides, and other management expenses.
- Sum all expenses to obtain the total cost of cultivation.
- Calculate net return using the following formula:

  Net *Return* = *Gross Return* – *Total Cost of Cultivation*
- Express the result as monetary value per unit area (e.g., Tk ha^{-1}).

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Method for calculating benefit–cost ratio (BCR)

- Calculate the gross return obtained from crop production.
- Determine the total cost of cultivation, including all input and management costs.
- Calculate the benefit–cost ratio using the following formula:

$$\text{BCR} = \frac{\textit{Gross return}}{\textit{Total cost of cultivation}}$$

- Express the result as a ratio or decimal value.

BCR > 1 indicates profitable production.
BCR < 1 indicates economic loss.

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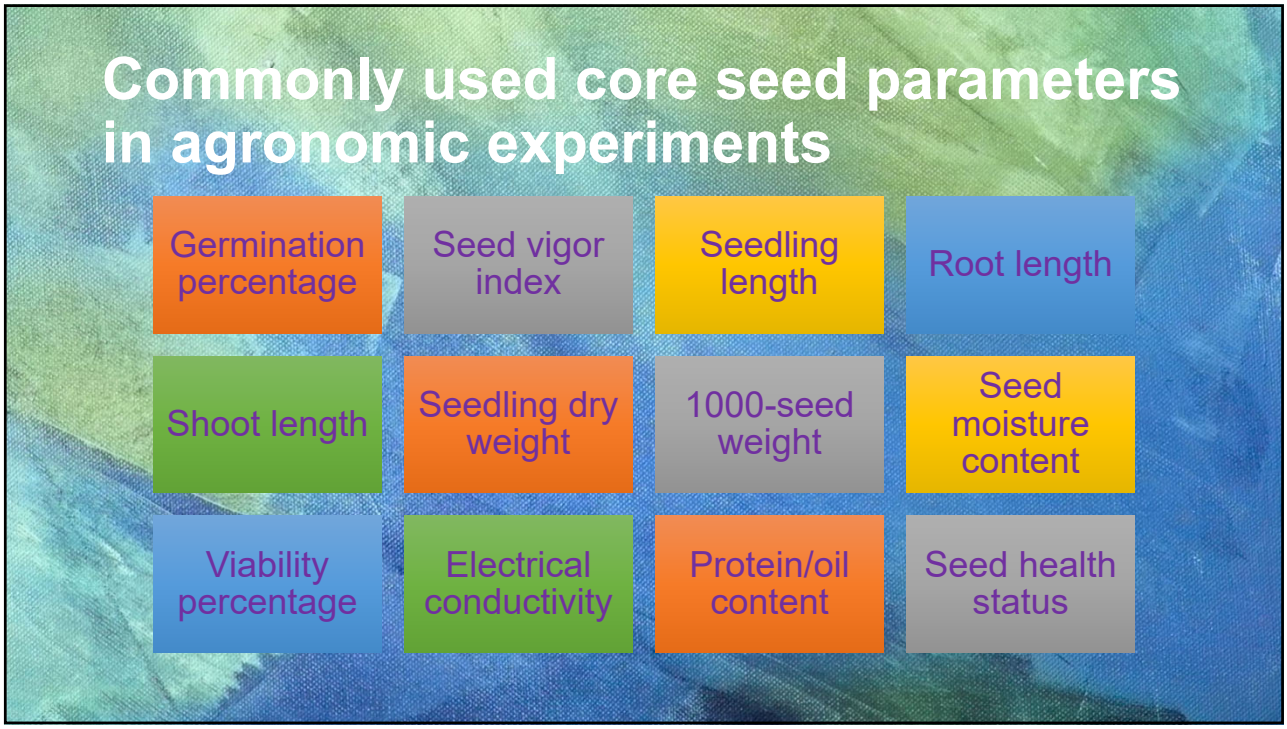

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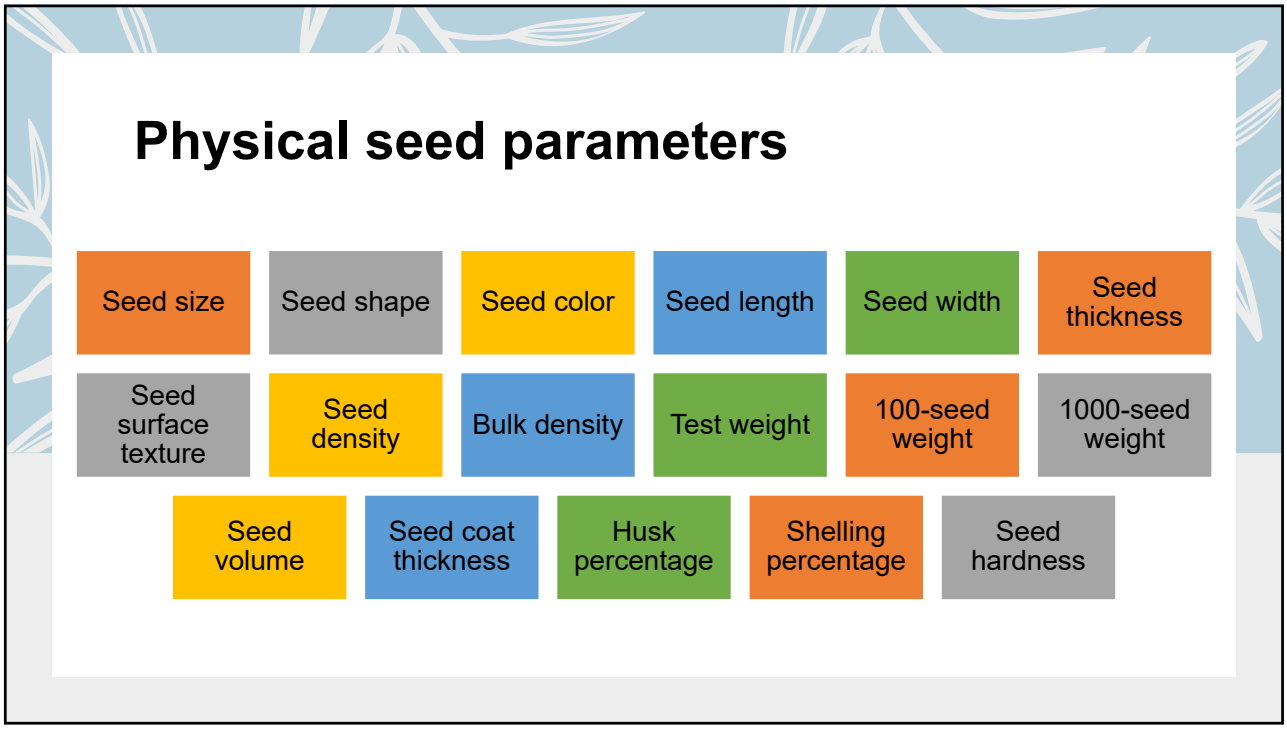

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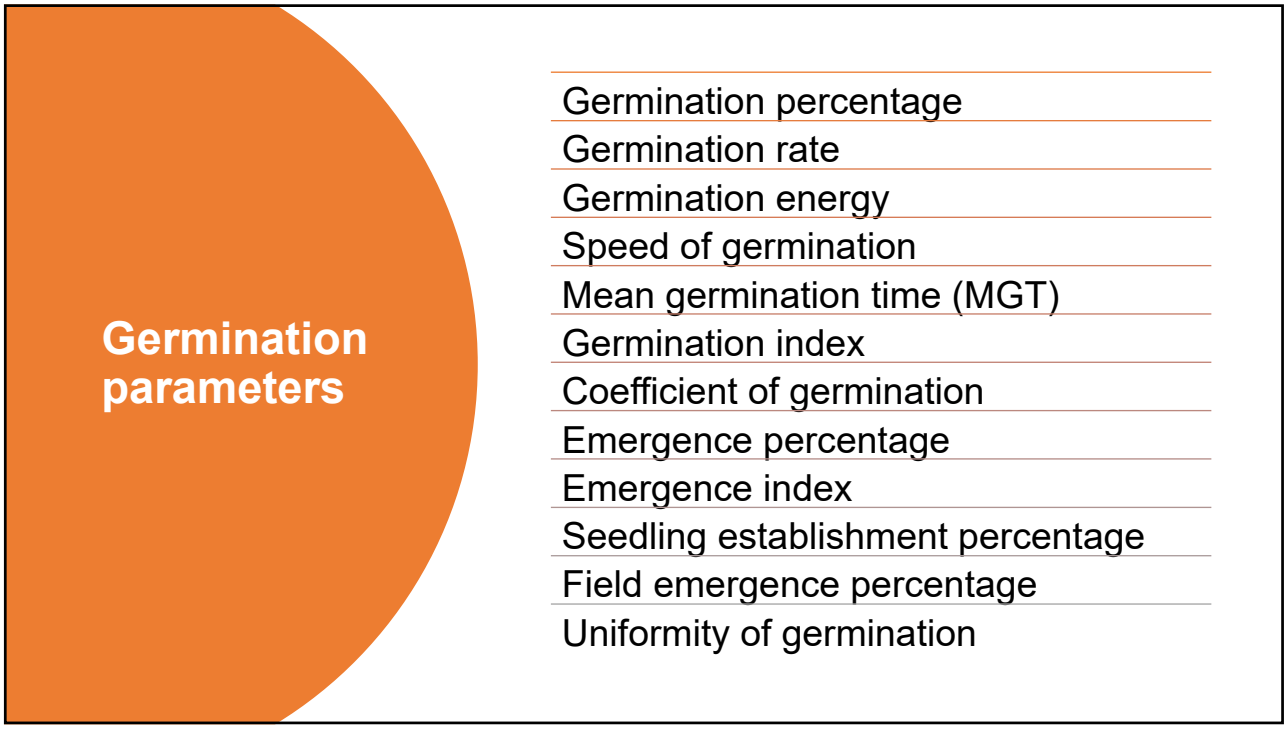

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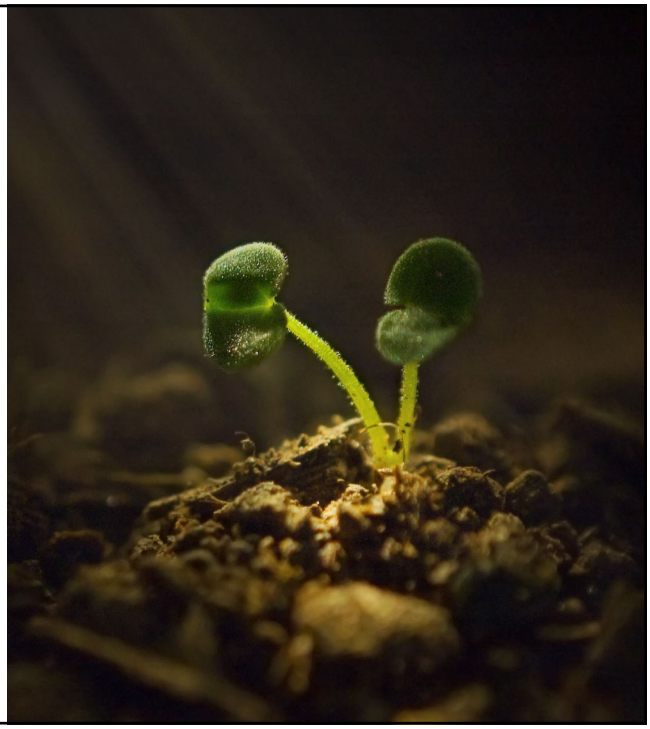
Seedling growth parameters

- Root length
- Shoot length
- Seedling length
- Root-shoot ratio
- Fresh weight of seedlings
- Dry weight of seedlings
- Seedling vigor index-I
- Seedling vigor index-II
- Seedling growth rate
- Plumule length
- Radicle length



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