Sir Brian's Review and Tutorial Center
Crop Science Face-to-Face Review
Summary Notes
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Agriculture

- "*Ager*" = field
- "*Cultura*" = cultivation or growing
- **Systematic** raising of **useful plants and animals** under the **management of man**
- The **science and art** of cultivating useful plants and raising livestock to **meet human needs**
- Agriculture involves the **provision of agricultural supplies and service**

State of agriculture in the world

- Total land area in the world: **150 million sq. km.**
    - 1% or 1.5 million sq. km is for permanent crops
    - 10% or 15 million sq. km is considered arable land
    - 24% or 36 million sq. km is for meadows and pastures
    - 31% or 46.5 million sq. km are forests and woodlands
    - 34% or 51 million sq. km supports little to no vegetation
- Population data
    - Global population in 2025: 8.2 billion
    - FAO predicted population to reach 9.1 billion in 2050
    - Percentage increase in population peaked at 2.3% in 1963 but currently sits at 9%
    - Percentage increase in food supply per year sits at 1.7% but is set to decline down to 0.8% by 2050
- How to increase food supply according to FAO
    - **Solution #1:** Increase importation (not sustainable)
    - **Solution #2:** Increase agricultural land use (not sustainable)
    - **Solution #3:** Higher yield and cropping intensity (sustainable)

State of Philippine agriculture

- Threats faced by Philippine agriculture
    - **Threat #1:** Rapid population growth
    - **Threat #2:** Agricultural land conversion
    - **Threat #3:** Smaller farm sizes
    - **Threat #4:** Lower share in GDP and employment versus other sectors
    - **Threat #5:** Climate change
- Government laws in line with agriculture
    - **RA 11203:** Rice Tariffication Law
    - **RA 11901:** The Agriculture, Fisheries and Rural Development Financing Enhancement Act of 2022
    - **RA 8435:** Agriculture and Fisheries Modernization Act of 1997
    - **RA 6657:** Comprehensive Agrarian Reform Law of 1988
    - **RA 3844:** Agricultural Land Reform Code
    - **RA 8175:** Revised Charter of the Philippine Crop Insurance Corporation Act of 1995
    - **RA 7900:** High-Value Crops Development Act of 1995
    - **RA 7308:** Seed Industry Development Act of 1992
    - **RA 7607:** Magna Carta of Small Farmers

- **RA 10068:** Organic Agriculture Act of 2010
- **RA 10845:** Anti-Agricultural Smuggling Act of 2016
- **RA 10659:** Sugarcane Industry Development Act of 2015
- **RA 10816:** Farm Tourism Development Act of 2016
- **RA 10089:** Philippine Rubber Research Institute Act of 2010
- **RA 10601:** Agriculture and Fisheries Mechanization (AFMech) Law
- **RA 12215:** Philippine Agriculturists Act (former Senate Bill 2535)

- Government programs and initiatives to support Philippine agriculture
  - Rice Competitiveness Enhancement Fund (RCEF)
  - Adapting Philippine Agriculture to Climate Change (APA) Project
  - National Farm to Market Road Network Plan 2023-2028 (NFMRNP)
  - Adaptation and Mitigation Initiative in Agriculture (AMIA)
  - National Rice Program
  - National Corn Program
  - National High Value Crops Development Program
  - National Urban and Peri-Urban Agriculture Program

Crop Science

- **Plant:** Any organism belonging to the kingdom plantae that is capable of photosynthesizing and producing its own food (broader term)
- **Crop:** A specialized category of plants that is cultivated and harvested for economic and subsistence purposes; typically grown in large quantities
- **Crop production as a science, art, and business**
  - **Science:** It is a science based on the basic sciences of chemistry, mathematics, physics, breeding, and genetics
  - **Art:** It is an art because it requires skills to produce crops even with little to no scientific training
  - **Business:** It is a business because plants are grown not only to satisfy the needs of man but to realize some profits
- Disciplines:
  - **Agronomy**
    - **Definition:** Focus on soil management, large-scale field crop production for food, feed, fiber
    - **Focus:** Cereals, legumes, forage crops, fiber crops, sugar crops, oilseeds, soil science
    - **Scale:** Large-scale production and open fields
  - Horticulture:
    - **Definition:** Focuses on the small-scale cultivation of crops often in an enclosure
    - **Focus:** vegetables, fruits, ornamentals, landscape gardening
    - **Scale:** smaller-scale production, gardens, greenhouse, nurseries, flower farms
    - Subcategories:
      1. Olericulture
      2. Pomology
      3. Floriculture
      4. Nursery management

5. Landscape gardening

Classification of crops

- Different systems of classification
  - **Artificial system**
    - Carolus Linnaeus
    - Looks at the easily observable structures or features as a basis for grouping
  - **Natural system**
    - George Bentham and Joseph Dalton Hooker
    - Looks at the most prominent or peculiar morphological structure of the plant to group them according to the most familiar number of features
  - **Phylogenetic system**
    - Groups plants according to their evolutionary history
- According to growth habit
  - Herbs – succulent with self-supporting stems
  - Trees – woody with central stem
  - Shrubs – woody without central stem but has several branches
  - Vines – succulent or woody without self-supporting stem
- According to life cycle
  - Annuals
  - Biennials
  - Perennials
- According to mode of reproduction
  - Sexual
  - Asexual
- According to temperature tolerance
  - Tropical
  - Subtropical or semi-temperate
  - Temperate
- According to photoperiodic response
  - Long-day – requires light exposure longer than a critical length
  - Short-day – requires light exposure shorter than a critical length
- According to moisture regime
  - Mesophyte – most economically important crops
  - Xerophyte – crops adapted to grow on arid environments
  - Hydrophyte – crops adapted to grow on wet or flooded environments
- According to sunlight requirement
  - Heliophytes – sun-loving crops
  - Sciophytes – shade-loving crops
- Special types
  - Parasites – Relies completely on host for survival (parasitism)
  - Saprophytes – Typically relies on host for physical anchorage without causing any harm or benefit (commensalism)
  - Epiphytes – Consumes decaying matter for survival
- According to purpose

- Cereals or grain crops
- Legumes
- Root crops
- Tubers
- Fiber crops
- Oil crops
- Sugar crops
- Pasture or forage crops
- Beverage crops
- Spices, condiments, essences
- Latex and resins
- Medicinal and poison crops
- Fruits
- Vegetables
  - Root
  - Leafy
  - Stem
  - Flowers
  - Fruit
- Ornamentals
  - Cut-flowers
  - Flowering pot plants
  - Landscape plants
  - Foliage plants
  - Cut-foliage
  - Turf
- Special groups
  - Green manure
  - Companion crops
  - Cover crops
  - Catch crops
  - Trap crops
  - Soilage
  - Silage
  - Refuge crops

Top produced crops and top producers in the Philippines

Crop	National Vol. of Production 2024 (in MT)
Palay	19,087,135.43
Corn	8,138,177.93
Banana	8,690,496.11
Sugarcane	18,731,276.01

Coconut	14,075,126.82

PALAY	
Region	Volume of Production 2024 (in MT)
National Production	19,087,135.43
1. Region III (Central Luzon)	3,482,484.4
2. Region II (Cagayan Valley)	2,922,716.55
3. Region I (Ilocos Region)	1,967,134.45
4. Region VI (Western Visayas)	1,891,368.12
5. Region XII (SOCCSKSARGEN)	1,213,670

PALAY	
Province	Volume of Production 2024 (in MT)
National Production	19,087,135.43
1. Nueva Ecija	1,772,448.7
2. Isabela	1,468,910
3. Pangasinan	1,213,670
4. Cagayan	1,063,403
5. Ilo-Ilo	831,333.77

CORN	
Region	Volume of Production 2024 (in MT)
National Production	8,138,177.93
1. Region II (Cagayan Valley)	1,956,155.67
2. Region X (Northern Mindanao)	1,536,376.4
3. BARMM (Bangsamoro Autonomous Region in Muslim Mindanao)	1,228,127.83
4. Region XII (SOCCSKSARGEN)	1,002,518.02
5. Region I (Ilocos Region)	581,738.37

CORN

Province	Volume of Production 2024 (in MT)
National Production	8,138,177.93
1. Isabela	1,091,772.79
2. Bukidnon	1,072,234.16
3. Maguindanao	717,018.1
4. Cagayan	614,425
5. Lanao del Sur	450,748.73

COCONUT

Region	Volume of Production 2024 (in MT)
National Production	14,075,126.82
1. Region XI (Davao Region)	1,950,251.44
2. Region X (Northern Mindanao)	1,800,795.31
3. Region IX (Zamboanga Peninsula)	1,741,410.99
4. Region IV-A (CALABARZON)	1,445,850.18
5. BARMM (Bangsamoro Autonomous Region in Muslim Mindanao)	1,256,569.59

COCONUT

Province	Volume of Production 2024 (in MT)
National Production	14,075,126.82
1. Quezon	1,267,558.15
2. Zamboanga del Norte	843,182.03
3. Maguindanao	673,426.53
4. Zamboanga del Sur	645,427.06
5. Davao Oriental	626,228.64

SUGARCANE

Region	Volume of Production 2024 (in MT)
National Production	18,731,276.01
1. Region VI (Western Visayas)	11,278,255.86

2. Region X (Northern Mindanao)	3,067,766.69
3. Region VII (Central Visayas)	1,689,565.03
4. Region XII (SOCCSKSARGEN)	751,401.61
5. Region IV-A (CALABARZON)	481,700.85

SUGARCANE

Province	Volume of Production 2024 (in MT)
National Production	18,731,276.01
1. Negros Occidental	10,058,030.8
2. Bukidnon	3,067,764.7
3. Negros Oriental	1,666,876.06
4. Ilo-Ilo	910,779.11
5. Cotabato	570,402.61

BANANA

Province	Volume of Production 2024 (in MT)
National Production	8,690,496.11
1. Region XI (Davao Region)	3,190,178.49
2. Region X (Northern Mindanao)	1,968,560.51
3. Region XII (SOCCSKSARGEN)	1,086,462.92
4. BARMM (Bangsamoro Autonomous Region in Muslim Mindanao)	507,260.76
5. Region II (Cagayan Valley)	324,712.8

BANANA

Province	Volume of Production 2024 (in MT)
National Production	8,690,496.11
1. Davao del Norte	1,441,001.73
2. Bukidnon	1,386,301.07
3. Davao de Oro	717,651.54
4. Davao del Sur	704,387.56

5. Cotabato	456,142.92

Plant cells

- The smallest structure in the universe capable of growth and reproduction. It is the basic unit of every living organism.
- Plant cells vs animal cells:

Cellular part	Plant cell	Animal cell
Chloroplast	✅	❌
Vacuole	✅	❌
Cell wall	✅	❌
Lysosome	❌	✅
Centriole	❌	✅

- Cellular parts:
  - Cell wall
    - Parts of the cell wall:
      1. Middle lamella – made of pectin; cements adjacent cells
      2. Primary cell wall – thin, not rigid; rich in plasmodesmata
      3. Secondary cell wall – rigid and thick
    - Concepts relevant to the cell wall:
      1. Plasmodesmata
      2. Apoplastic pathway – movement of water through cell wall
      3. Symplastic pathway – movement of water through cytoplasm
  - Cytoplasm
    - Not an organelle but a collective term for all living matter inside the cell besides the nucleus
    - Cytosol – aqueous liquid where cell organelles are suspended
    - Cyclosis – flowing movement of cytoplasm brought about by the microfilament
  - Plasmalemma
    - Flexible outer layer of the cell
    - Controls entry and exit of cellular substances
    - Exhibits selective permeability
  - Endoplasmic reticulum
    - Divided into two:
      1. Smooth ER – Lipid synthesis
      2. Rough ER – Protein synthesis due to ribosomes
  - Golgi bodies
    - Works with the endoplasmic reticulum
    - Glycosylates proteins and lipids, turning them into glycoproteins and glycolipids

- Delivers modified compounds to cell wall or externally
- Mitochondria
  - Main ATP generating organelle
  - Site of cellular respiration
- Plastids
  - Play unique function based on the plant's needs
  - Types:
    1. Proplastid
    2. Etioplast
    3. Chloroplast
    4. Chromoplast
    5. Leucoplast
    6. Amyloplast
    7. Proteinoplast
    8. Elaioplast
- Cytoskeleton
  - Microtubules: made of protein "tubulin" and supports cell division and cellulose alignment in cell wall
  - Microfilaments: made of protein "actin" and helps with cyclosis
- Vacuole
  - Stores water, neutralizes toxic products, and breaks down macromolecules
  - Turgor pressure
- Peroxisome
  - Essential for photorespiration
  - Recovers glycerate from glycolate
- Glyoxysome
  - Converts fats to carbs during seed germination
- Nucleus
  - Contains all genetic material passed from generation to generation

Plant tissues

- Group of typically similar cells performing life processes
- Tissues systems found in plants:
  - Ground tissues – majority of tissues
  - Dermal tissues – tissues found on the surface of the plants
  - Vascular tissues – tissues involved in the plant's vascular system
- Meristematic tissues
  - Young tissues where cell division occurs
  - Three types:
    1. Apical meristem – vertical growth
       - Shoot apical meristem
       - Root apical meristem –
       - Axillary meristem – branches
    2. Lateral meristem – lateral growth
       - Cork cambium – periderm

- Vascular cambium – xylem and phloem

3. Intercalary meristem – stem elongation; monocots only

- Permanent tissues
  - Meristems that have achieved physiological maturity
  - Two types:
    1. Simple tissues – composed of similar cell types
       - Parenchyma
       - Collenchyma
       - Sclerenchyma
    2. Complex tissues – composed of multiple cell types
       - Xylem
         - Water and mineral transport from root to shoot
         - Main parts:
           - Tracheids
           - Vessel elements
           - Xylem fiber
           - Xylem parenchyma
       - Phloem
         - Photosynthate transport from source to sinks
         - Main parts:
           - Sieve tube element
           - Companion cells
           - Phloem fiber
           - Phloem parenchyma

Plant organs

- Plant parts made up of several tissues working together to perform specific functions: growth, survival, and reproduction
- Types of plant parts:
  - **Roots**
    - Anchorage and absorption
    - Parts:
      1. Region of cell division
      2. Region of elongation
      3. Region of maturation
    - Types:
      1. Adventitious or fibrous – monocot
      2. Taproot – dicot
  - **Stem**
    - Structural support and conduct
    - Parts:
      1. Bark
      2. Pith
      3. Wood
  - **Leaves**

- Food manufacturing, storage, and gas exchange
- Types:
    1. Simple
    2. Compound
- Venation:
    1. Reticulate
    2. Parallel

- **Flowers**
    - Reproduction
    - Parts:
        1. Petals
        2. Sepals
        3. Stamen
        4. Pistil
    - Types:
        1. Complete – has all 4 parts
        2. Incomplete – missing at least 1 part
        3. Perfect – has both male and female organs
        4. Imperfect – has either male or female organ
- **Seed**
    - Ripened ovules that shed from mother plant
    - Parts:
        1. Embryo – developing plant within the seed
        2. Endosperm – food source of monocots
        3. Cotyledon – embryonic leaves; food source of dicots
        4. Epicotyl – (along with apical meristem) embryonic shoot
        5. Hypocotyl
        6. Radicle – embryonic root
        7. Seed coat
    - Types of germination:
        1. Epigeal
            - Dicots
            - Hypocotyl extends
            - Cotyledon emerge
        2. Hypogeal
            - Monocots
            - Epicotyl extends
            - Cotyledons remain undergroun
    - Types of seeds:
        1. Orthodox
        2. Intermediate
        3. Recalcitrant
- **Fruits**
    - Ripened ovaries that contain the ripened ovules
    - Types of fruits:
        1. Simple – one flower, one ovary

2. Aggregate – one flower, multiple ovaries
3. Multiple – one inflorescence, multiple flowers

- Types of fruits:
  1. Fleshy
     - Berry
     - Hesperidium
     - Pepo
     - Drupe
     - Pome
  2. Dry
     - Indehiscent
       - Achene
       - Caryopsis
       - Nut
       - Samara
       - Utricle
     - Dehiscent
       - Legume
       - Follicle
       - Capsule
       - Pyxis

Photosynthesis

- $CO_2 + H_2O + Sunlight \rightarrow (CH_2O)_n + O_2$
- Main organ involved: Leaves
- Main organelle involved: Chloroplast
- Main pigment involved: Chlorophyll
- Divided into two phases:
  1. Light-dependent reaction
     - Requires light
     - Main products are ATP and NADPH
     - Types:
       A. Cyclic photophosphorylation
          - Generation of ATP
       B. Non-cyclic photophosphorylation
          - Generation of ATP
          - Production of NADPH
          - Photolysis of water
          - Release of oxygen
  2. Light-independent reaction
     - Does not require light
     - Inorganic carbon is converted to sugars
     - Pathways:
       A. C3
          - Initial CO_2 acceptor: ribulose-1,5-bisphosphate

- Initial CO_2 fixing enzyme: ribulose-1,5-bisphosphate carboxylase oxygenase
- First stable product: 3-phosphoglycerate

B. C4

- Presence of kranz anatomy
- Divided in space: mesophyll and bundle sheath cells
- Mesophyll
  - Initial CO_2 acceptor: phosphoenolpyruvate
  - Initial CO_2 fixing enzyme: phosphoenolpyruvate carboxylase
  - First stable product: oxaloacetate
- Bundle sheath cells
  - Initial CO_2 acceptor: ribulose-1,5-bisphosphate
  - Initial CO_2 fixing enzyme: ribulose-1,5-bisphosphate carboxylase oxygenase
  - First stable product: 3-phosphoglycerate

C. CAM

- Separated in time: day and night
- Night
  - Initial CO_2 acceptor: phosphoenolpyruvate
  - Initial CO_2 fixing enzyme: phosphoenolpyruvate carboxylase
  - First stable product: oxaloacetate
- Day
  - Initial CO_2 acceptor: ribulose-1,5-bisphosphate
  - Initial CO_2 fixing enzyme: ribulose-1,5-bisphosphate carboxylase oxygenase
  - First stable product: 3-phosphoglycerate

Photorespiration

- Occurs when RuBisCO fixes O_2, instead of CO_2, to RUBP
- Initial product is phosphoglycolate (unnecessary for photosynthesis)
- Peroxisome and mitochondria recovers glycerate from phosphoglycolate

Respiration

- $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + ATP$ (aerobic respiration)
- $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + CO_2 + ATP$ (anaerobic respiration)
- Main organelle involved: Mitochondrion
- Divided into three phases:
  1. Glycolysis
     - Occurs in the cytoplasm
     - Each glucose molecule yields:
       - Two 3-carbon pyruvate
       - 2 net ATPs

    - Divided into phases: energy investment phase (plants spend 2 ATPs) and energy payoff phase (plants earn 4 ATPs)
2. Krebs cycle
    - Occurs in the mitochondrial matrix
    - Each 3-C pyruvate molecule gets converted to 2-C acetyl-CoA before entering the mitochondrion
    - Each acetyl-CoA undergoes a series of processes, yielding:
        - 3 NADH
        - 1 FADH2
        - 1 ATP
3. Electron Transport System
    - Occurs in the inner mitochondrial membrane
    - NADH and FADH2 from the Krebs cycle are oxidized, releasing H+ to the intermembrane space
    - H+ gradients powers up the ATP synthase producing ATP
    - Some H+ ions combine with O2 releasing water

Transpiration

- Loss of moisture from the plants in the form of water vapor
- Xylem is the main tissue involved
- Unidirectional – root to shoot
- Types:
    1. Stomatal – Stomates
    2. Cuticular – Cuticle
    3. Lenticular – Lenticel
- Guttation
    - Loss of water in the form of droplets
    - Hydathodes

Translocation

- Movement of photosynthates from the source to the sink
- Sucrose is the main translocated sugar
- Phloem is the main tissue involved
- Bi-drectional
- Translocation depends on several factors:
    1. Sink strength
    2. Proximity of sink to source
    3. Stage of development
    4. Nature of vascular connections

Concepts of Development

- **Development** – Attainment of size by virtue of growth and architectural style by the concomitant process of morphogenesis

- Has three interrelated concepts:
    1. Growth – Irreversible increase in size
    2. Differentiation – Attainment of cellular specialization
    3. Organization – Arrangement of differentiated cells

Plant Growth Regulators

Function	Auxin (IAA)	Gibberellin (GA)	Cytokinin	Ethylene	Abscisic Acid (ABA)
Cell elongation	✅	❌	❌	❌	❌
Cell division	✅	❌	✅	❌	❌
Vascular development	✅	❌	❌	❌	❌
Sex determination	✅ *(female)*	✅ *(male)*	❌	✅ *(female)*	❌
Tropic/nastic movements	✅ *(tropic bending)*	❌	❌	❌	✅ *(epinasty)*
Apical dominance	✅	❌	❌ *(fights)*	❌	❌
Axillary dominance	❌ *(fights)*	❌	✅	❌	❌
Leaf senescence	❌ *(delays)*	❌	❌ *(delays)*	✅	✅ *(promotes)*
Fruit development	✅	✅	✅	❌	❌
Fruit ripening	❌	❌	❌	✅	❌
Seed/bud dormancy	❌	❌	❌	❌	✅
Seed germination	❌	✅	❌	✅	❌ *(inhibits)*
Root initiation	✅	❌	❌	✅ *(adventitious roots)*	❌
Flowering	❌	✅ *(bolting)*	❌	✅	❌
Stomatal movement	❌	❌	✅ *(opening)*	❌	✅ *(closing)*
Stress responses	❌	❌	❌	✅	✅

Chloroplast/phyll dev't	❌	❌	✅	❌	❌

Genetics

- P = G + E + (G x E)
  - Phenotype – observable characteristic or outward expression of plants
  - Genotype – genetic design; sets ultimate limit for plant variation
  - Environment – external factors that influence phenotype; may be biotic or abiotic
  - G x E – interaction between the plant's genotype and the environment
- Phenotype in action
  - A high-yielding variety grown in optimum or ideal environment will have a high yield
  - A high-yielding variety grown in under a poor environment will have a low yield
  - A low-yielding variety grown in optimum or ideal environment will still have a low yield

Abiotic factors affecting crop production

- Divided into **climatic** and **edaphic** factors
- **Climatic factors – weather-based elements**
  - Climate – average seasonal pattern in a place (long-term)
  - Weather – momentary state of the atmosphere (short-term)
  - Climatic elements
    1. Precipitation – solid or liquid water falling from the atmosphere to the earth
       - ➢ Factors affecting:
         - Topography
         - Proximity to bodies of water
         - Air circulation patterns
       - ➢ Drought – state of insufficiently low rainfall or moisture
         - Absolute – 29 consecutive days without rainfall of ≥ 0.25 mm
         - Partial – 15 consecutive days without rainfall of ≥ 0.25 mm
    2. Temperature – relative coldness or hotness of the atmosphere
       - ➢ Cardinal temperature:
         - Minimum – enzymes deactivate
         - Optimum – highest rate of enzymatic activity
         - Maximum – enzymes denature
    3. Wind – horizontal movement of air
       - ➢ Act as agents of pollination
       - ➢ Pushes away boundary layer, increasing transpiration rate
       - ➢ Too strong can destroy canopy and cause lodging
       - ➢ Too strong can reduce CO_2 concentration
    4. Solar radiation – energy given out by sun through radiation
       - ➢ Three aspects:
         - Light intensity – brightness
         - Daylength – length of sunlight exposure
         - Wavelength – specific colors that plants respond to

- ➢ Effect of solar radiation:
  - Photoenergetic – effect of light on photosynthesis
  - Photocybernetic – effect of light on plant behavior
  - Photoperiodic – effect of light on flowering based on daylength

5. Relative humidity – concentration of moisture in the air
   - ➢ ↑ RH + ↑ temperature = ↓ evapotranspiration
   - ➢ ↓ RH + ↑ temperature = ↑ evapotranspiration
   - ➢ ↑ RH + ↓ temperature = ↓ evapotranspiration
   - ➢ ↓ RH + ↓ temperature = ↓ evapotranspiration

- **Edaphic factors – soil-based elements**
  - Soil – mixture of both organic (from decomposed living matter) and inorganic (from weathering of rocks) materials that developed on the earth's surface
  - Edaphic properties:
    1. Soil texture – relative proportion of sand, silt, and clay
       - ➢ Loam – ideal soil texture; equal proportion of sand, silt, and clay
    2. Soil structure – clustering or aggregation of soil particles which influences water infiltration and aeration
       - ➢ Granular or friable – ideal soil structure
       - ➢ Platy or massive – ideal soil structure for rice; hard pan
    3. Soil chemical properties
       - ➢ Soil organic matter
       - ➢ Soil pH – relative acidity or alkalinity of the soil
       - ➢ CEC – ability of the soil to adsorb and exchange cations with plant roots
       - ➢ Soil nutrition/fertility – ability of the soil to supply nutrients to the plants
         - Essential nutrients
           i. Required for life cycle completion
           ii. Constituent of plant metabolites
           iii. Not replaceable
         - Beneficial nutrients
           i. Can compensate for the toxic effect of other elements
           ii. Can replace mineral nutrients in some less specific function
         - Macronutrient – C, H, O, N, P, K, Ca, Mg, S
         - Micronutrient – Fe, Mn, Cu, Zn, Mo, B, Cl, Ni, Co
         - Mobile elements – N, P, K, Mg, Cl, Ni, S, Mn
           - If limited, deficiency is shown in older leaves
         - Immobile elements – Ca, Fe, Mo, B, Cu, Zn, Co
           - If limited, deficiency is shown in younger leaves

Biotic factors affecting crop production

- All living matter in the environment affecting crop production
- May be external (outside of the plant) or internal (inherent to the plant)
  - Internal biotic factors
    - Genotype
    - Phytohormones

        - Physiological processes
    - External biotic factors
        - Beneficial organisms
        - Pollinators
        - Decomposers
        - Natural pest enemies
        - Pests

Plant breeding

- Science, art, and business of crop improvement for human benefit
- Always directional (purpose-driven)
- Plant breeding can be divided into 6 activities:
    1. Creation of variability – generating differences among parental lines to provide material for selection
        A. Naturally existing variability – naturally-occurring in the environment
            i. Domestication
            ii. Germplasm collection
            iii. Introduction
        B. Creation of new variability
            - Breeding methods
                i. Hybridization
                - Production of F1
                - Hybrid – products of hybridization; exhibits heterosis
                - Heterosis – superior performance of hybrids
                    - Mid-parent heterosis
                    - Standard heterosis
                    - Heterobeltiosis

                ii. Inbreeding
                - Inbreds – products of inbreeding
                - Leads to eventual homozygosity
                - May result in inbreeding depression or poor performance due to deleterious recessive alleles

                iii. Topcrossing – inbred x OPV
                iv. Backcrossing
                - Recurring parent x donor parent
                - F1 x recurring parent (multiple generations)

                v. Test cross
                - line with dominant traits but unknown genotype x homozygous recessive individual
                - To see if line is homozygous dominant or heterozygous

                vi. Polycross – selected lines are allowed to randomly mate in a controlled environment
                vii. Reciprocal cross
                - Mating of two plants in which each is used as male parent in one cross and female in another

- Looks at maternal inheritance

viii. Wide or distant cross – crossing distantly related individuals
ix. Introgressive hybridization – modified backcrossing between interspecific hybrids to one parental species

- Other ways to create variability:
  i. Mutation – heritable change in DNA
  ii. Chimera – individual with different genotype along its body
  iii. Polyploidization – organism with ploidy level beyond diploid
- Combining ability – ability to transfer desirable traits to progeny
  - ➢ General combining ability – looks at the average or expected performance of offsprings for a targeted trait (additive gene effects)
  - ➢ Specific combining ability – looks at the specific interaction of parents in a cross resulting in deviatory performance of offsprings versus expected values or GCA (non-additive gene effects)

2. Selection – identifying superior individuals with more desirable traits
   - Types:
     - Natural selection – Natural change in gene frequencies where desirable individuals survive and reproduce more successfully
     - Artificial selection – Change in gene frequency brought about by humans through selective breeding
   - Modes:
     - Disruptive
     - Directional
     - Stabilizing
   - Traits selected for:
     - Qualitative traits
       - ➢ monogenic/oligogenic traits
       - ➢ Less influenced by the environment
       - ➢ Shows non-continuous variation
     - Quantitative traits
       - ➢ Polygenic traits
       - ➢ More influenced by environment
       - ➢ Measurable; shows continuous variation
   - Additional concepts to familiarize:
     - Heritability – portion of phenotypic variance due to genotypic variance
       - ➢ Broad sense heritability – ratio between genotypic variance and phenotypic variance
       - ➢ Narrow sense heritability – ratio between additive gene effects and phenotypic variance
     - Selection intensity – percentage of individuals selected in a population
     - Selection differential – difference in mean performance of selected individuals versus the population mean
     - Gain in selection – increase in mean performance of a population after each cycle of selection

3. Evaluation – assessment of performance of newly developed lines through appropriate multi-location trials and tests
    - Sequence of yield tests:
        I. Observational yield tests
            - ➢ Testing of experimental lines
            - ➢ Uses incomplete block or triple lattice design
            - ➢ 2-3 reps in one location

        II. Preliminary yield tests
            - ➢ Evaluating experimental lines against a check variety
            - ➢ Uses incomplete block or triple lattice design
            - ➢ 2-3 reps in >2 locations

        III. General yield tests
            - ➢ Uses randomized complete block design
            - ➢ 3 reps in >3 locations

        IV. Advanced yield tests
            - ➢ Evaluating elite lines selected from general yield tests
            - ➢ Uses randomized complete block design
            - ➢ 4 reps in 6-10 locations
4. Multiplication
    - Done on strains identified for varietal release
        - Called "stock seeds" before varietal release
        - Called "breeder seeds" after release as variety
5. Distribution
    - Seed classes
        - **Breeder seeds** – White tag; produced by breeding institutions; highest purity
        - **Foundation seeds** – Red tag; progeny of breeder seeds; produced by trained agriculturists in conformity with regulated national standard
        - **Registered seeds** – Green tag; progeny of foundation seeds grown by selected farmers in in conformity with regulated national standard; undergoes field and seed inspections
        - **Certified seeds** – Blue tag; progeny of foundation, registered, or certified seeds; grown by selected farmers in conformity with regulated national standard; undergoes field and seed inspections
6. Germplasm conservation
    - Germplasm – sum total of available material for crop improvement
    - Germplasm storage
        - Seed storage – commonly used for orthodox seeds, dried and kept in storage
        - Field gene banks – used for recalcitrant seeds that are planted and maintained in the field
        - In vitro storage – for vegetatively produced or tissue culture crops

Crop Biotechnology

- Science-driven application of biological knowledge, techniques, and tools to improve the genetic makeup of crops
- Conventional vs non-conventional breeding
    - Conventional – improvement of crops using natural or controlled sexual reproduction
    - Non-conventional – improvement of crops using modern biotechnology

Category	Conventional breeding	Non-conventional breeding
Basis for improvement	Phenotype or observable traits	Genotypic information
Speed	Slow; requires several generations	Faster; requires fewer generations
Limitation	Limited to sexually compatible species	Can cross interspecific barriers
Precision	Less; may include undesirable genes	High' specific genes can be modified
Cost	Typically low but time-consuming	High upfront costs but saves resources
Public perception	Widely accepted	Mixed perception especially with GMOs

- Examples of crop biotechnology
    - Marker Assisted Selection (MAS) – use molecular markers to determine quantitative trait loci (QTL)
    - Genetic engineering – Introduces foreign genes into a plant's genome to express new traits (used for BT)
    - Gene editing (CRISPR-Cas9) – Precisely modifies specific DNA sequences in a plant's genome to improve traits without introducing foreign DNA.
    - RNA Interference (RNAi) – Silences specific gene expression using double stranded RNA.
    - Double Haploid Technology – Produces completely homozygous lines by doubling haploid gametes.
    - Tissue culture – Growing of true-to-type plants in vitro in a sterile environment using plant tissues.
    - Bioinformatics – Analyzes genetic and genomic data to identify genes and markers useful for plant breeding.
    - Protoplast fusion – Combines cells from different species or varieties by fusing their protoplasts to create hybrids with novel traits.

Sustainable agriculture

- Integrated system of plant and animal production that aims to:
    - satisfy human food and fiber needs
    - preserve/enhance the environment and its natural resources

- Efficiently use non-renewable resources
- Integrate biocon

- Characteristics of SA
  1. Flexible
  2. Experiential
  3. Participatory
  4. Proactive
- Features/dimensions/attributes of SA
  - Continuously evolving – non-permanent, dynamic
  - Gender sensitive
  - Ecologically sound and friendly
  - Culturally appropriate
  - Economically viable
  - Location-specific
  - Resource-based not input based or capital-intensive
  - Socially equitable
  - Holistic
- Types:
  1. Biodynamic farming
     - ➢ Rudolf Steiner
     - ➢ Pseudoscientific and esoteric
     - ➢ Recognizes the spirituality in nature and sees farm as a living organism
  2. Ecological farming
     - ➢ Emphasizes natural processes
     - ➢ Avoids GMOs, agricultural inputs, GMOs
  3. Natural farming
     - ➢ Minimal human intervention
     - ➢ No tillage, fertilizers, pesticides, weeding, pruning
     - ➢ Polyculture
  4. Kyusei Nature
     - ➢ Terou Higa
     - ➢ Uses effective microorganisms (EM) to improve the diversity of soil microorganisms, improve soil structure, and protect crops from diseases
  5. Permaculture
     - ➢ Bill Mollison
     - ➢ Applies human-designed structures to farm
     - ➢ Integrates plant, animals, people, and structure to mimic natural ecosystems
  6. Organic farming
     - ➢ First used by Lord Northbourne in his 1940 book, *Look to the Land*
     - ➢ Avoids synthetic soil amendments and agricultural inputs
     - ➢ Prioritizes environmentally friendly inputs
     - ➢ Shuns GMOs
  7. Regenerative agriculture – focuses on regeneration renewable resources
  8. Precision farming
     - ➢ Leverages technology like computers, GPs, telecoms for site-specific information on which practices and inputs are most pertinent on the field

➢ Most efficient

Farming systems

- Describes the manner how farm the interrelated and interdependent farm resources are assembled, integrated, and used for agricultural production while recognizing the influence of natural, social, political, and economic forces
- Resources in the farming system
    1. Farm household – labor, capital, decision-making
    2. Natural resources – biophysical resource base
    3. Physical and material resources – farm infrastructure and inputs
    4. Institutional and support systems – external entities influencing farming system
- Classification of FS
    1. Based on enterprise mix – monoculture, polyculture, livestock, *etc*.
    2. Based on dominant crop – rice-based, coconut-based
    3. Based on agro-evironment – moisture regime (rainfed/irrigated), topography (lowland, upland, hilly)
    4. Based on use of farm inputs – high external input, low external input
    5. Based on central or unique farm feature
    6. Evolving or modern farming system types – recreational or hobby farms, agrotourism
    7. Specialized farming system – production of high-value cutflowers, production of fingerlings
- General Types of FS
    1. Lowland
    2. Upland
    3. Highland
    4. Agro-forestry
    5. Dryland

Cropping system

- **Cropping System:** Refers to the pattern or arrangement of crops in time and space (cropping pattern), as well as the process of growing them (management practices)
- **Cropping Pattern:** The yearly sequence (temporal or time) and spatial arrangement (space) of crops or of crops and fallows on a given area
- Types of cropping systems:
    1. Monocropping – one crop is grown on the same piece of land year-after-year
        - Monoculture – one crop is grown on the same piece of land at a given time
        - Types of monoculture
            A. Annual crop monoculture
            B. Perennial monoculture
    2. Multiple cropping – growing of multiple crops on the same land within a year
        - Types of multiple cropping
            A. Sequential cropping – the succeeding crop is planted after the preceding crop is harvested; denoted by a hyphen (–)

B. Intercropping – the succeeding crop is planted before the flowering stage of the preceding crop; denoted by a plus (+)
C. Relay cropping – the succeeding crop is planted after the flowering stage or before the harvesting of the preceding crop; denoted by a slash (/)

- Other types of cropping system:
    1. Sorjan cropping system – developed in Indonesia, has deep sinks, raised beds, and pond refuge
    2. Alley cropping – alternate succession of strips, hedgerow cropping, annuals, and perennials to prevent soil erosion (example is SALT)
    3. Low External Input Sustainable Agriculture (LEISA) – minimal use of agricultural input and maximizing use of on-farm resources

Land preparation and planting practices

- Land preparation is done to provide a favorable soil for germination and growth
    - Done through the process of tillage
    - Varies depending on the crop in question and the available soil regime and other physical elements in the farm
- Tillage
    - Lowland
        - soaking, plowing, harrowing, levelling
        - done on predominantly clayey soils
        - Creates hardpan and bunds to retain moisture inside the field
        - Only macropores are retained in the soil
    - Upland
        - plowing, harrowing/rotavation, levelling
        - done on predominantly loamy soils
        - Soil is granular and friable, aerated soils
        - Macropores and micropores are retained on the soil
- Tillage and planting equipment
    1. Plow – turn over soil into large clods called peds; primary tillage (most aggressive)
    2. Harrow (disc, comb-tooth, spike-tooth) – break peds into smaller pieces
    3. Rotavator (powered tool) – break peds into smaller pieces
    4. Furrower – create furrows and ridges on the soil
    5. Leveler – ensure soil is level
- Forms of tillage operations
    - Conventional tillage – results in a residue-free soil; done in commercial farms
    - Conservation tillage – some residue is left to conserve moisture; not that aggressive
        - Types of conservation tillage:
            i. No tillage or zero tillage – crops are seeded in the seedbed that haven't been tilled since the harvest of previous crop
            ii. Mulch tillage – crop residue is left to serve as mulch
            iii. Strip tillage or strip till or zone tillage – tillage is done only on stripes where seeding is done
            iv. Minimum tillage – like conventional tillage but to a lesser extent

v. Ridge tillage – the ridge is tilled and the soil is incorporated with crop residue

Planting materials, selection, preparation

Population density (plants per hectare) = total area / (row space)*(hill space)

Seeding rate (kilograms per hectare)
= (planting density)*(**1000-seed weight in g**) / (germination rate)*(emergence rate)*(**1000**)*(**1000**)

Notes:

- *Emergence rate may be provided or not*
- *One of the **1000**s in the denominator depends on the number of seeds, if 300-seed weight or 500-seed weight is given, then the denominator will be 300 or 500, respectively*
- *The other **1000** depends if the given seed weight is in grams or kilograms, if grams, 1000 is added in the denominator, if kilograms, one of the 1000s is removed*

I. Seeds
   - Sexual propagation (involves fertilization of ovule)
   - Most common and efficient method of cultivation
   - Low germination rate
   - Seed germination – series of events where viable quiescent seeds initiate seedling from the embryo
     1. Water imbibition
     2. Rehydration of enzymes
     3. Breakdown of reserve food
     4. Translocation and metabolism of assimilates
     5. Seedling emergence and growth
   - Concepts related to seed germination:
     - Seed quiescence – viable seed cannot germinate because of unfavorable conditions
     - Seed dormancy – physiological or physical barriers that prevent viable seeds from germination despite the availability of favorable conditions
       - ➢ Types of seed dormancy:
         A. Primary dormancy
            i. Exogenous – seed-coat related dormancy
            ii. Endogenous – factors within the embryo itself
         B. Secondary dormancy – caused by factors external to the seed
       - ➢ Types of bud dormancy
         A. Paradormancy – caused by factors outside of the bud but from other plant parts
         B. Endodormancy – caused by factors within the bud itself
         C. Ecodormancy – caused by external or environmental factors

- ➢ How to break seed dormancy
  - A. Scarification – treatment that removes or alters the seed coat
    - i. Physical scarification – involves use of physical elements
    - ii. Mechanical scarification – involves use of tools or equipment
    - iii. Chemical scarification – involves use of chemicals
  - B. Stratification – placement of dormant seeds to layers of moist sand, soil, sawdust to mimic environmental cues and stimulate germination
    - i. Cold stratification – for temperate seeds
    - ii. Warm stratification – for tropical/subtropical seeds
    - iii. Double stratification – warm → cold → germination
  - C. Embryo culture – removing the embryo from the seed and growing it on a culture medium
- ➢ Vernalization – treatment of vegetative plant parts to cold temperature to break flowering dormancy and initiate flowering

■ Seed viability testing
- ➢ Standard germination tests
  - A. Ragdoll method or rolled-towel method – seeds are arranged in rows in a moist cloth or paper towel and then rolled
  - B. Seedbox method – seeds are sown in sterilized soil
  - C. Petri dish method – seeds are placed in absorbent material, typically filter paper, on a petri dish
- ➢ **Tetrazolium Test (TTZ)** – colorimetric test where biochemical reaction changes the color of test solution under certain conditions
  - ○ If seeds are respiring and viable, they will change color to **RED**
  - ○ If seeds are dead, they will remain **COLORLESS**

○ Seeding methods

1. **Direct seeding**
   - ➢ Economical, less labor intensive, unsatisfactory germination rate
   - ➢ Ideal for crops that experience transplanting shocks
   - ➢ Methods of direct seeding:
     - A. Broadcasting – Even spreading of seeds; may be done manually or mechanically (rotary seeder)
     - B. Drilling – mechanical way of direct seeding with greater seeding precision; typically done in cereals
     - C. Dibbling – typically done in hilly areas; no land prep except holes are made where the seeds are sown
2. **Transplanting**
   - ➢ Growing seeds to seedlings in nursery; better land-use efficiency; assures complete and uniform crop stand
   - ➢ Methods of rice transplanting
     - A. Wetbed – done in puddled raised beds; transplant in 15-21 days
     - B. Drybed – done in dry raised beds; transplant in 15-21 days

C. Dapog – done on banana leaves or plastic sheets covered with paddy husk; transplant in 9-14 days

II. Vegetative propagules
- Asexual propagation (involves somatic reproduction)
- Uses vegetative plant parts and is possible because the organ has the capacity for regeneration
- Types of asexual propagation:
  1. Separation and division
     - ➢ Separation – separating naturally detachable organs from the mother plant
     - ➢ Division – cutting vegetative structures into sections
     - ➢ Examples:
       A. Bulb – small underground stem with basal plate and overlapping fleshy leaves
       B. Bulbil – aerial plantlet formed on the leaf axil
       C. Corm – vertical underground starchy stem; grows cormels
       D. Offset – short, thickened, succulent lateral shoots
       E. Stolon/runners – long horizontal aboveground stem
       F. Rhizome – horizontal underground stem
       G. Suckers – shoots arising from an underground stem
       H. Slips – shoots originating from the peduncle just below the fruit
       I. Tuber – starchy modified underground stem with buds (eyes)
       J. Tuberous roots – starchy modified roots
  2. Cutting
     - ➢ Root cutting
     - ➢ Stem cutting
     - ➢ Leaf cutting
     - ➢ Leaf-bud cutting
  3. Layering – Propagation method where adventitious roots are grown on the stem while still attached to mother plant
     - ➢ Simple layering
     - ➢ Air layering or marcotting
     - ➢ Serpentine layering
     - ➢ Mound layering
     - ➢ Trench layering
  4. Grafting – connecting plant parts together where they unity and continue to grow as one plant
     - ➢ Scion – becomes the new shoot system
     - ➢ Rootstock – becomes the new root system
     - ➢ Interstock – inserted between the scion and rootstock to overcome incompatibility issues
     - ➢ Types:
       A. Inarching
       B. Topworking
       C. Splice grafting
       D. Cleft grafting

E. Bark grafting
F. Side grafting

5. Budding – like grafting, except the scion is reduced to only one bud
   - ➢ Patch budding
   - ➢ Shield budding or T budding
   - ➢ Chip budding
6. Tissue culture – growing of crops derived from plant tissues (called explants) on a culture medium in an aseptic environment and allowed to regenerate into complete plant

Harvesting and Post-harvest

- Harvesting – Separation of economic yield (whether plant part or whole plant biomass) when the plant has reached its physiological or commercial maturity
- Post-harvest handling – movement of farm products through which the commodity undergo from harvest to the consumer
- Post-production technology – practices and operations implemented on the harvest prior to sale and consumption
  - Primary processing – basic handling and processing to keep produce fresh and usable
  - Secondary processing – conversion of produce into more stable, consumer-ready forms
  - Types of crops based on post harvest characteristics
    A. Durables
    B. Perishables
       - ➢ Ways to prolong lifespan of perishables
         i. Cold storage
         ii. Evaporative cooling
         iii. Modified Atmosphere Storage (MAS)
         iv. Controlled Atmosphere Storage (CAS)
  - Kinds of packages used
    A. Flexible
       - ➢ Burlap
       - ➢ Gunny sacks
       - ➢ Polyethylene bags
       - ➢ Palm leaves

    B. Rigid/semi-rigid
       - ➢ Bamboo
       - ➢ Rattan baskets
       - ➢ Wooden crates
       - ➢ Cartons
       - ➢ Wood Paper laminated container
       - ➢ Plastic crates
       - ➢ Foamed plastic baskets
  - Classification of crops based on ripening behavior
    A. Climacteric – capable of ripening even after harvest
    B. Non-climacteric – no burst of respiration at postharvest which means they must be harvested at the right maturity stage

- Maturity indices:
    - Phenological – age-related, based on observed phenomenon or distinct phases in the plant's life cycle
    - Morphological – based on observable characteristics or tell-tale signs of maturity

Site Selection and Characterization

- **Site selection** – analytical assessment of the importance, effectiveness, and worth of a site, which affect future decisions related to production, farm operation, transportation, *etc*.
- Factors to consider:
    - **Socio-economic factors** – relating to social, economic, and political elements prevalent in the place, including peace and order, existing facilities, land tenure, *etc*.
    - **Biological factors** – relating to the biological elements available in the location, including crop pests and diseases, available pollinators, existing vegetation
    - **Physical factors** – relating to the physical elements on the place, including soil condition, land area/shape/topography, farm-to-market road availability, climatic condition