La-Net

AGE 207

TECHNIQUES OF VEGETABLE CROP PRODUCTION

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Course code: AGE 207

Course title: Techniques of Vegetable Crop Production

Course credit load: 2 Units

Series 1: Vegetable Crop Production Basics

- **Part 1.1: Vegetables, Mankind, and Gardening**
    - Sub Part 1.1.1: Definition and importance of vegetables to mankind
    - Sub Part 1.1.2: Types of gardening
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- **Part 1.2: Classification of Vegetables and Fruits**
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Introduction

Vegetable crop production is one of the most important branches of horticulture and a cornerstone of nutrition and food security in Nigeria and across the tropics. Vegetables provide essential vitamins, minerals, dietary fibre, and phytochemicals that protect human health, and they generate income for millions of smallholder farmers in urban and peri-urban areas. Understanding the basics of vegetable production, from classification and gardening systems to nursery practices, land preparation, and post-harvest handling, is the foundation on which all advanced study of vegetable crop techniques is built.

This opening Series introduces vegetables and their importance to mankind; surveys the types of gardening and the classification of common vegetables and fruits; covers nursery establishment and transplanting; and describes the basic principles of land preparation, planting, crop management, and harvesting. The knowledge acquired here is applied and extended in all the subsequent Series of AGE 207.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 1.1** define vegetables, explain their importance to mankind, and describe the types of gardening and consumer vegetable growing (Linked to Part 1.1),
- **SLO 1.2** classify vegetables and fruits and describe the types and classes of common tropical fruits and vegetables (Linked to Part 1.2),
- **SLO 1.3** describe the importance of the nursery, types of seedbed, and transplanting practices in vegetable production (Linked to Part 1.3), and
- **SLO 1.4** describe the basic principles of land preparation, planting, crop management, and harvesting in vegetable production (Linked to Part 1.4).

1.1 Vegetables, Mankind, and Gardening

1.1.1 Definition and importance of vegetables to mankind

A vegetable is any herbaceous plant or part of a plant (root, stem, leaf, flower, fruit, or seed) that is consumed by humans as food, either raw or cooked. Vegetables differ from fruits in common usage: fruits are the mature ripened ovary of a flowering plant (often sweet and eaten raw), while vegetables are the non-sweet parts or unripe fruits used in savoury cooking. In botanical terms, however, many commonly called vegetables (tomato, pepper, cucumber, garden egg) are technically fruits. Examples of Nigerian vegetables include tomato (Lycopersicon esculentum), pepper (Capsicum annuum and C. chinense), okra (Abelmoschus esculentus), garden egg (Solanum melongena), fluted pumpkin (Telfairia occidentalis, ugu), waterleaf (Talinum triangulare), amaranth (Amaranthus species), jute mallow (Corchorus olitorius, ewedu), bitter leaf (Vernonia amygdalina), and onion (Allium cepa).

Vegetables are important to mankind for several reasons: nutritional value (vegetables are the primary dietary source of vitamins A, C, K, and B-complex; minerals such as iron, calcium, potassium, and zinc; dietary fibre; and protective phytochemicals including antioxidants, flavonoids, and carotenoids that reduce the risk of cancer, cardiovascular disease, and other non-communicable diseases); economic value (vegetable farming provides income and employment for millions of Nigerian smallholder farmers, market women, and traders; vegetables are sold in local, regional, and export markets); food security (vegetables are calorie-dense relative to their cost and space requirements; home gardens and peri-urban vegetable plots contribute directly to household food security); and medicinal value (many vegetables have ethnomedicinal uses: bitter leaf is used for fever and diabetes; fluted pumpkin seeds for male fertility; moringa for anaemia and malnutrition).

Fill in the blank: A ________ is any herbaceous plant or part of a plant (root, stem, leaf, flower, fruit, or seed) consumed by humans as food; vegetables are important for their nutritional, economic, food security, and medicinal value.

1.1.2 Types of gardening

Gardening is the practice of growing plants (vegetables, fruits, herbs, ornamentals) in a defined, managed area. The major types of gardening practised in Nigeria and the tropics are: home garden (kitchen garden; a small plot adjacent to the house, cultivated mainly by women and children for family consumption; typically less than 0.1 ha; highly diversified with many species grown in a small space; uses household waste water and kitchen compost; important for nutritional diversity and food security); market garden (commercial vegetable production; typically 0.1-2 ha; located near urban markets; uses intensive management; irrigated; aims at a marketable surplus for sale rather than household consumption; the most economically important type in Nigerian peri-urban agriculture).

Allotment garden: a small plot of land rented from a local authority or institution for personal food production; common in urban areas; important for urban food security. School garden: a vegetable and crop demonstration plot attached to a school; used for agricultural education (similar to the school farm discussed in AGE 201); teaches students practical vegetable production skills. Community garden: a shared garden managed collectively by a group of community members or a cooperative; allows people without land to grow food; builds community cohesion and food sovereignty. Container gardening (urban gardening): growing vegetables in pots, bags, tyres, or containers on rooftops, balconies, and yards; increasingly important in Nigerian urban environments where land is scarce; suitable for herbs, tomato, pepper, leafy vegetables, and small-fruited crops.

Fill in the blank: A market ________ is a commercially oriented vegetable growing operation typically of 0.1-2 ha located near urban markets; it uses intensive management and irrigation and aims at a marketable surplus rather than family consumption.

1.1.3 Consumer vegetable growing

Consumer vegetable growing refers to the production of vegetables by individuals or households primarily for their own consumption rather than for sale. It encompasses home gardens, allotment gardens, school gardens, and container gardens. Consumer vegetable growing is gaining increasing importance in Nigeria and globally as concerns about food safety (pesticide residues on commercially produced vegetables), food cost, and urban food security grow. A consumer who grows their own vegetables can control the inputs used (avoiding excessive pesticide and chemical fertiliser), harvest at peak freshness, and access varieties not available in local markets.

The principles and practices of consumer vegetable growing are essentially the same as commercial production but scaled down: selecting suitable varieties for the available space (compact, high-yielding varieties for small spaces; dwarf tomato and pepper varieties for containers); preparing a small seedbed or container with good quality, well-drained growing medium (compost-enriched topsoil or commercial potting mix); planting at the correct spacing and time; irrigating regularly with household water; applying small amounts of organic fertiliser (compost, worm castings); managing pests with non-chemical methods (handpicking, soap sprays, neem extract); and harvesting frequently to encourage continued production. Consumer vegetable growing also has social and psychological benefits, including stress relief, physical activity, connection with nature, and community building.

Fill in the blank: Consumer vegetable ________ refers to the production of vegetables by households primarily for their own consumption; it is growing in importance in Nigerian cities because of concerns about food safety (pesticide residues), food cost, and urban food security.

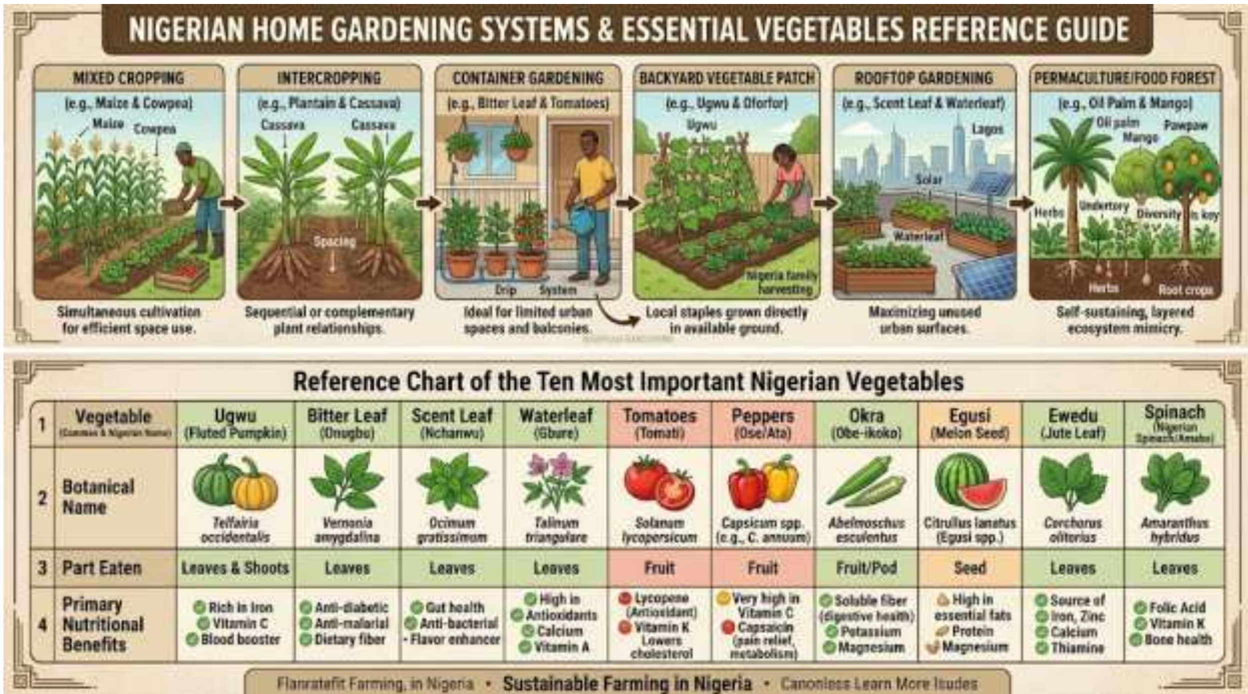

Figure 1.1: Types of gardening and vegetables important to Nigerians

Pilot questions 1.1

1. Define a vegetable and state four reasons why vegetables are important to mankind.
2. Name six types of gardening and state one characteristic of each.
3. Explain what consumer vegetable growing is and state three reasons why it is important.
4. Name five Nigerian vegetables and state the part of the plant eaten in each case.
5. Distinguish between a home garden and a market garden.

1.2 Classification of Vegetables and Fruits

1.2.1 Classification of vegetables

Vegetables are classified in several ways. By botanical part eaten: leaf vegetables (the leaves are the edible part; e.g. spinach/amaranth, fluted pumpkin/ugu, bitter leaf, waterleaf, jute mallow/ewedu, cabbage, lettuce); stem vegetables (the stem or modified stem is eaten; e.g. Irish potato, onion bulb, celery, kohlrabi); root vegetables (the root is the edible part; e.g. carrot, radish, beetroot, turnip); flower vegetables (the flower or flower head is eaten; e.g. cauliflower, broccoli, pumpkin flower); fruit vegetables (the fruit, technically a botanically defined fruit, is the edible part; e.g. tomato, pepper, okra, cucumber, garden egg, bitter tomato); and seed vegetables (the seed is eaten; e.g. cowpea, green peas, garden beans, sweet corn).

By life cycle: annual vegetables (complete their life cycle in one growing season; e.g. tomato, okra, cowpea, pepper, maize); biennial vegetables (require two growing seasons to complete their life cycle; e.g. carrot, cabbage, onion in temperate climates); perennial vegetables (live and produce for many years; e.g. fluted pumpkin, bitter leaf, moringa, garden egg). By use: salad vegetables (consumed raw; e.g. lettuce, cucumber, tomato, carrot, cabbage); cooking vegetables (cooked before eating; e.g. okra, garden egg, cowpea, pumpkin); dual-purpose vegetables (eaten raw or cooked; e.g. tomato, pepper, carrot). By climatic adaptation: tropical vegetables (grow best in hot, humid conditions; most Nigerian vegetables); temperate vegetables (grow best in cool conditions; e.g. cabbage, carrot, Irish potato; grown in the Jos Plateau and similar highlands in Nigeria).

Fill in the blank: Vegetables classified by the botanical part eaten include leaf vegetables (amaranth, ugu), stem vegetables (Irish potato, onion), ________ vegetables (carrot, radish), fruit vegetables (tomato, okra), flower vegetables (cauliflower), and seed vegetables (cowpea, green peas).

1.2.2 Types and classes of common fruits

A fruit, in the botanical sense, is the mature ripened ovary of a flowering plant, containing the seeds. Fruits are classified by structure: simple fruits (develop from a single ovary of one flower; e.g. drupe/stone fruit: mango, avocado, plum, coconut, olive; berry: tomato, banana, grape, garden egg, guava; pome: apple, pear; legume: cowpea, soybean; capsule: okra, cotton); aggregate fruits (develop from a single flower with many separate pistils; e.g. strawberry, blackberry, soursop); multiple fruits (develop from the fusion of many flowers of an inflorescence; e.g. pineapple, breadfruit, fig, mulberry); and accessory fruits (the edible part develops partly from non-ovarian tissue; e.g. cashew apple, which develops from the swollen receptacle/peduncle).

Common tropical fruits grown in Nigeria are classified into: citrus fruits (orange, tangerine/mandarin, grapefruit, lemon, lime; family Rutaceae; important for vitamin C); other tropical tree fruits (mango, avocado, pawpaw/papaya, guava, pineapple, banana/plantain, breadfruit, soursop, jackfruit, star apple, African star apple/agbalumo); palm fruits (oil palm, coconut, raffia palm); minor fruits (tamarind, jujube/igi ofi, velvet tamarind/awin, African breadfruit/ukwa); and temperate fruits adapted to highlands (apple, pear, peach, plum; grown on the Jos Plateau and Mambilla Plateau). Nigeria's most economically important fruits by production volume are banana, plantain, mango, citrus (orange), pineapple, and pawpaw.

Fill in the blank: A ________ fruit develops from a single ovary of one flower; examples include drupe (mango, avocado), berry (tomato, banana), and pome (apple, pear); it is distinguished from aggregate fruits (soursop, strawberry) and multiple fruits (pineapple, breadfruit).

1.2.3 Fruits and vegetables in the tropics

The tropical climate (characterised by high temperatures year-round, distinct wet and dry seasons, high solar radiation, and high biodiversity) is highly favourable for the production of a wide range of fruits and vegetables. The tropics extend between the Tropics of Cancer (23.5 degrees N) and Capricorn (23.5 degrees S) and include most of sub-Saharan Africa, South and Southeast Asia, and Central and South America. In the tropics: temperatures of 25-35 degrees Celsius support rapid vegetable growth; high solar radiation promotes photosynthesis and fruit sugar accumulation; the wet season provides natural rainfall for rain-fed crops; and year-round warmth allows perennial fruit trees to produce continuously or in multiple seasonal flushes.

Challenges of vegetable and fruit production in the tropics include: high humidity and temperature promote rapid development of fungal diseases (early and late blight, powdery mildew, anthracnose) and insect pests (aphids, whiteflies, thrips, stem borers, fruit flies); high temperatures during the dry season cause heat stress and flower drop in tomato and pepper; the absence of winter cold limits the production of temperate fruits; heavy tropical rains cause soil erosion on bare seedbeds and splash pathogens onto leaves; and rapid post-harvest deterioration is accelerated by heat. Successful tropical vegetable and fruit production requires varieties adapted to heat, humidity, and local pest pressure; management practices that reduce waterlogging and erosion; and post-harvest handling methods that extend shelf life in the absence of refrigeration.

Fill in the blank: The ________ climate, with year-round high temperatures, high solar radiation, and distinct wet and dry seasons, is highly favourable for vegetable and fruit production but also creates challenges of high pest and disease pressure, heat stress, and rapid post-harvest deterioration.

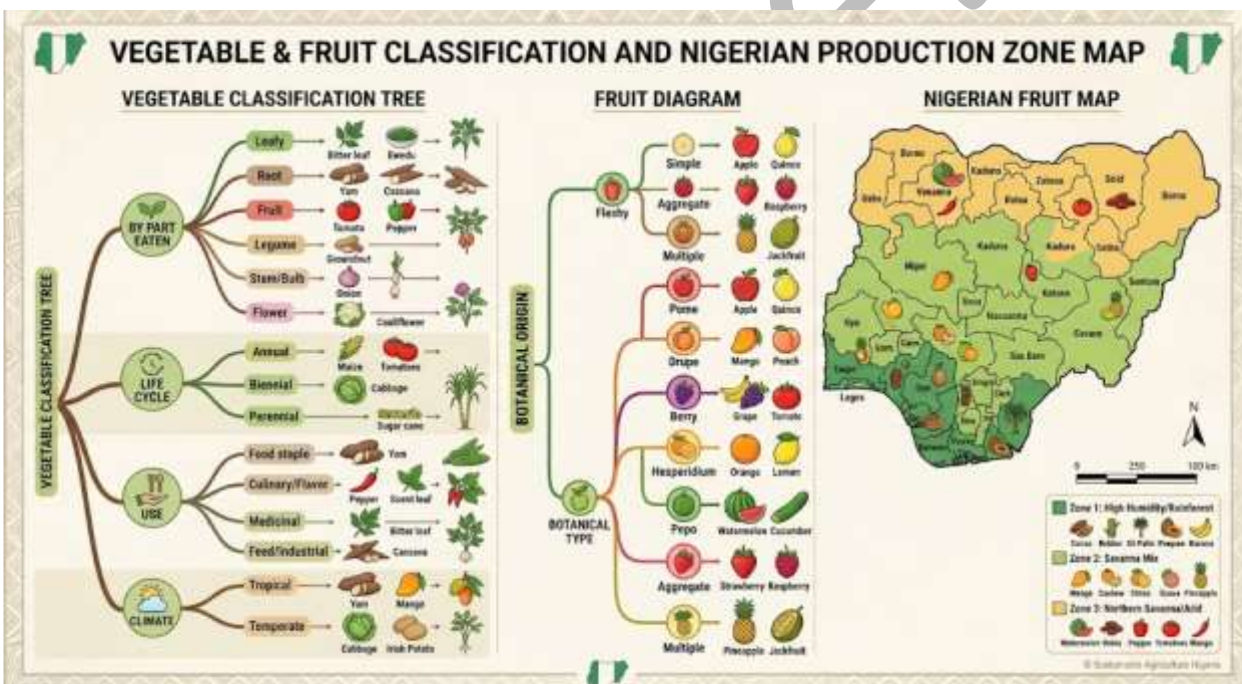

Figure 1.2: Classification of vegetables and fruits

Pilot questions 1.2

1. Classify vegetables by the botanical part eaten and give two Nigerian examples of each class.
2. Distinguish between annual, biennial, and perennial vegetables with one example each.

3. Define a fruit in the botanical sense and distinguish between simple, aggregate, and multiple fruits.
4. Name six common tropical fruits grown in Nigeria and state one nutritional benefit of each.
5. State three challenges of vegetable and fruit production in the tropical climate.

1.3 Nursery Practices in Vegetable Production

1.3.1 Importance of the nursery

A nursery is a place where seeds are germinated and seedlings are raised under controlled conditions before being transplanted to the permanent field. In vegetable production, the nursery stage is critically important for several reasons: it protects delicate seedlings from harsh field conditions (heavy rain, scorching sun, strong wind, pest and disease pressure) during the most vulnerable stage of plant growth; it allows closer monitoring of germination, watering, and pest management than is possible in the open field; it enables off-season production (seedlings can be raised in the nursery before the rains arrive and transplanted immediately when the field conditions are suitable); and it ensures a uniform, healthy stand of transplants for the field, saving expensive seed by only transplanting the strongest seedlings.

The nursery also allows the grower to stagger planting (starting new seedling batches every 2-3 weeks) to achieve a continuous supply of vegetables for the market rather than a single large harvest; this is known as succession planting. In Nigeria, nursery raising is standard practice for most vegetable crops that are small-seeded, slow to establish, or require a longer growing period than the rainy season allows (tomato, pepper, cabbage, onion, celery, broccoli, cauliflower). Direct seeding without a nursery is used for large-seeded, fast-growing vegetables that do not transplant well (cowpea, okra, cucumber, melon, beans, maize).

Fill in the blank: A ________ is a place where seeds are germinated and seedlings are raised under controlled conditions before transplanting to the field; it protects seedlings during the most vulnerable growth stage and enables succession planting for continuous vegetable supply.

1.3.2 Types of nursery and seedbed preparation

Types of nursery: open-air nursery (the most common type in Nigeria; seedlings are raised in raised beds or seed trays in the open; no permanent structure; shaded with palm fronds or shade net; low cost; suitable for most vegetables in the rainy season); protected nursery (a structure with shade netting, polythene covering, or a greenhouse; protects seedlings from heavy rain, direct sun, and insects; more expensive; used for high-value vegetables and dry-season production); container nursery (seeds are sown in polythene bags, seedling trays, or jiffy plugs filled with a growing medium; easy to transport; minimises transplanting shock because the root ball is intact; used for tomato, pepper, and tree crop seedlings).

Seedbed preparation: a well-prepared seedbed is essential for good germination and seedling growth. Steps: (1) Select a site that is slightly elevated, well-drained, and close to the water supply. (2) Clear and remove all vegetation and debris. (3) Dig and loosen the soil to a depth of 15-20 cm using a fork or hoe. (4) Incorporate well-decomposed compost or farmyard manure (4-6 kg per m2) to improve organic matter, water retention, and soil structure. (5) Form a raised bed (10-15 cm high; 1 m wide; any convenient length) to improve drainage and allow water to drain away from the seed zone during heavy rain. (6) Rake the surface to a fine, smooth, firm tilth free of large clods and stones. (7) Water the bed thoroughly one day before sowing to ensure moist conditions for germination. (8) Shade the seedbed with palm fronds or shade cloth (50% shade) to reduce temperature and moisture loss.

Fill in the blank: The seedbed for a vegetable nursery should be ________ (10-15 cm above the surrounding ground level) to ensure good drainage; it should be prepared to a fine, smooth tilth after incorporating well-decomposed compost at 4-6 kg per m2.

1.3.3 Transplanting practices

Transplanting is the operation of moving seedlings from the nursery to their permanent positions in the field. The timing of transplanting is critical: tomato and pepper seedlings are transplanted when they are 4-6 weeks old and have 4-6 true leaves; cabbage and cauliflower at 3-4 weeks old;

onion at 6-8 weeks. Transplanting too early (seedlings too small and weak) or too late (seedlings root-bound, stressed, and leggy) reduces establishment success. Hardening off: before transplanting, seedlings are gradually exposed to full sun and reduced watering over 5-7 days to acclimatise them to field conditions; sudden transfer from the shaded, well-watered nursery to the open field without hardening off causes transplanting shock and wilting.

Transplanting procedure: (1) Water the nursery bed or trays thoroughly 1-2 hours before lifting seedlings to keep the root ball intact. (2) Lift seedlings carefully with a trowel or dibber, keeping as much soil around the roots as possible. (3) Transplant into pre-prepared field beds or ridges; make a hole of the correct size and depth with a dibber or finger; place the seedling at the correct depth (root collar at soil level); firm the soil around the roots to eliminate air pockets. (4) Water each transplant immediately after planting to settle the soil around the roots. (5) Shade transplants with leaves or shade cloth for 3-5 days if transplanted in hot, sunny conditions. (6) Irrigate daily for the first 7-10 days until roots are established; then reduce irrigation frequency. Seedlings that fail to establish (more than 5-10% wilting or death) should be replaced (gap filling) within the first week.

Fill in the blank: ________ off is the process of gradually exposing nursery seedlings to full sun and reduced watering over 5-7 days before transplanting; it acclimatises seedlings to field conditions and prevents transplanting shock and wilting.

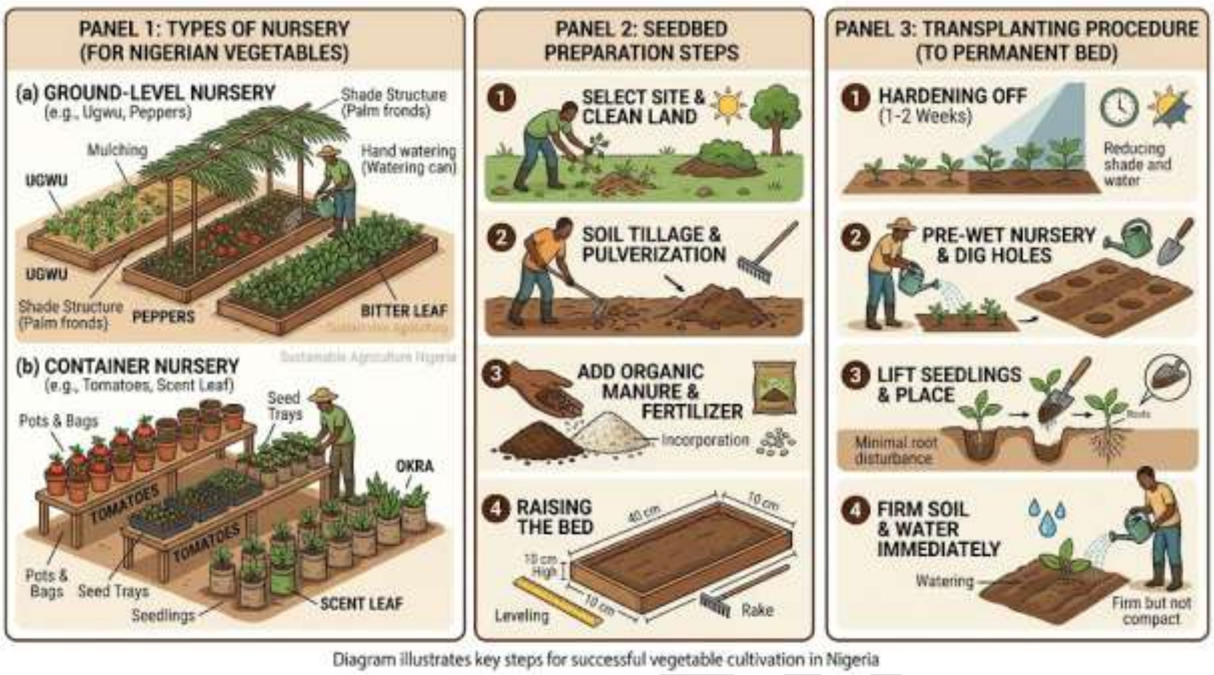

Figure 1.3: Nursery practices in vegetable production

Pilot questions 1.3

1. State five reasons why the nursery stage is important in vegetable production.
2. Name three types of nursery and state one advantage and one limitation of each.
3. Describe the eight steps in preparing a vegetable seedbed.
4. Explain what hardening off is and why it is necessary before transplanting.
5. Describe the procedure for transplanting tomato seedlings from nursery to field.

1.4 Basic Principles of Vegetable Crop Production

1.4.1 Land preparation for vegetable production

Land preparation for vegetable production is more intensive than for field crops because vegetables have shallow, fibrous root systems that require a friable, well-aerated, weed-free soil environment for rapid establishment and growth. Steps in land preparation: clearing (removal of crop residues, weeds, and debris from the previous crop; large residues are composted; fine residues may be incorporated); primary tillage (ploughing or deep digging to a depth of 25-30 cm using a mouldboard plough, disc plough, or garden fork; breaks up compacted layers; buries weeds; improves drainage); secondary tillage (harrowing or raking to break clods, level the surface, and create a fine, firm seedbed); and bed or ridge formation (raised beds or ridges 15-30 cm high improve drainage, allow intensive planting, and facilitate irrigation and weeding).

Soil amendment before planting: apply well-decomposed farmyard manure or compost (10-20 tonnes per hectare for vegetable production; much higher than for field crops) to improve soil organic matter, structure, water-holding capacity, and fertility; apply lime if pH is below 6.0-6.5 (the optimum range for most vegetables) to correct acidity and improve nutrient availability; apply basal fertiliser (NPK 15:15:15 at 200-400 kg/ha, depending on soil fertility and crop) at or just before planting. In Nigerian vegetable production, the most common form is bed production: raised beds 1-1.2 m wide and any convenient length, separated by 40-50 cm pathways, are the standard system for intensive vegetable farming in peri-urban areas.

Fill in the blank: Land preparation for vegetable production requires deeper and more intensive tillage than for field crops because vegetables have shallow, fibrous root systems that need a ________ , well-aerated, weed-free soil environment for rapid establishment and growth.

1.4.2 Planting, spacing, and crop management

Planting: vegetables are established either by direct seeding (sowing seeds directly in the field; used for okra, cowpea, cucumber, carrot, radish, beans; seeds sown at the correct depth and spacing) or by transplanting seedlings raised in the nursery (tomato, pepper, cabbage, onion, celery, broccoli). Correct plant spacing is critical for maximising yield per unit area while avoiding excessive competition for light, water, and nutrients. Typical spacings: tomato (60-90 cm between rows x 45-60 cm within row; 1 plant per hole); pepper (60 cm x 45 cm); cabbage (45-60 cm x 45 cm); onion (20-30 cm x 10-15 cm); okra (60-90 cm x 30-45 cm); amaranth (30 cm x 20 cm).

Crop management practices: irrigation (vegetables require regular, adequate water supply; drip irrigation is most efficient; furrow irrigation or overhead sprinkler irrigation also used; daily or every-other-day watering for leafy vegetables; 2-3 times per week for fruiting vegetables); fertilisation (top dressing with nitrogen fertiliser at 2-3 weeks and again at flowering to support vegetative growth and fruit set; split application reduces nitrogen loss; foliar micronutrient sprays correct deficiencies rapidly); staking and training (tomato, pepper, and climbing vegetables require stakes or trellis to support the plant, improve air circulation, and keep fruit off the soil; bamboo, wooden stakes, or wire are used); mulching (applying dry grass, rice straw, or black polythene mulch around plants to conserve soil moisture, suppress weeds, and moderate soil temperature; particularly important in the dry season).

Fill in the blank: Vegetables are established by direct ________ (for okra, cowpea, cucumber, carrot) or by transplanting nursery seedlings (for tomato, pepper, cabbage, onion); the method chosen depends on seed size, transplanting tolerance, and the crop's establishment requirements.

1.4.3 Harvesting and post-harvest handling of vegetables

Harvesting vegetables at the correct maturity stage is critical for quality, shelf life, and consumer acceptance. Each vegetable has distinct harvest indicators: tomato (when fruits change from green to pink-red; should be firm; not fully ripe for distant markets); pepper (green-mature for green pepper market; colour-changed for fresh red/yellow pepper market; fully dried for dried pepper); okra (when pods are 8-12 cm long and still tender; 3-5 days after flowering; over-mature pods become fibrous and inedible); leafy vegetables (amaranth, waterleaf, ugu: harvested when leaves are young and tender; multiple harvests by cutting stems above the lowest node); onion (when the tops fall over naturally and the necks dry; skins turn papery).

Post-harvest handling: fresh vegetables are highly perishable; they continue to respire after harvest, consuming their own sugars and nutrients, and losing water; without proper handling, losses of 30-50% are common between harvest and consumer in Nigeria. Key post-harvest practices: harvest in the early morning when temperature is lowest; sort and grade immediately after harvest (remove damaged, diseased, or over-mature produce); wash with clean water if required (leafy vegetables; tomato) and dry before packing; pack in ventilated wooden crates, bamboo baskets, or plastic crates (never in sealed polythene bags that trap heat and moisture); pre-cool if facilities are available; store in a cool, shaded, well-ventilated room; sell or distribute as quickly as possible. Evaporative coolers (zerodur coolers; charcoal coolers) can extend storage life by 2-5 days in Nigerian conditions at low cost.

Fill in the blank: Post-harvest ________ of vegetables includes sorting, grading, washing, packing in ventilated crates, pre-cooling, and selling quickly; without proper handling, post-harvest losses of 30-50% are common between harvest and consumer in Nigeria.

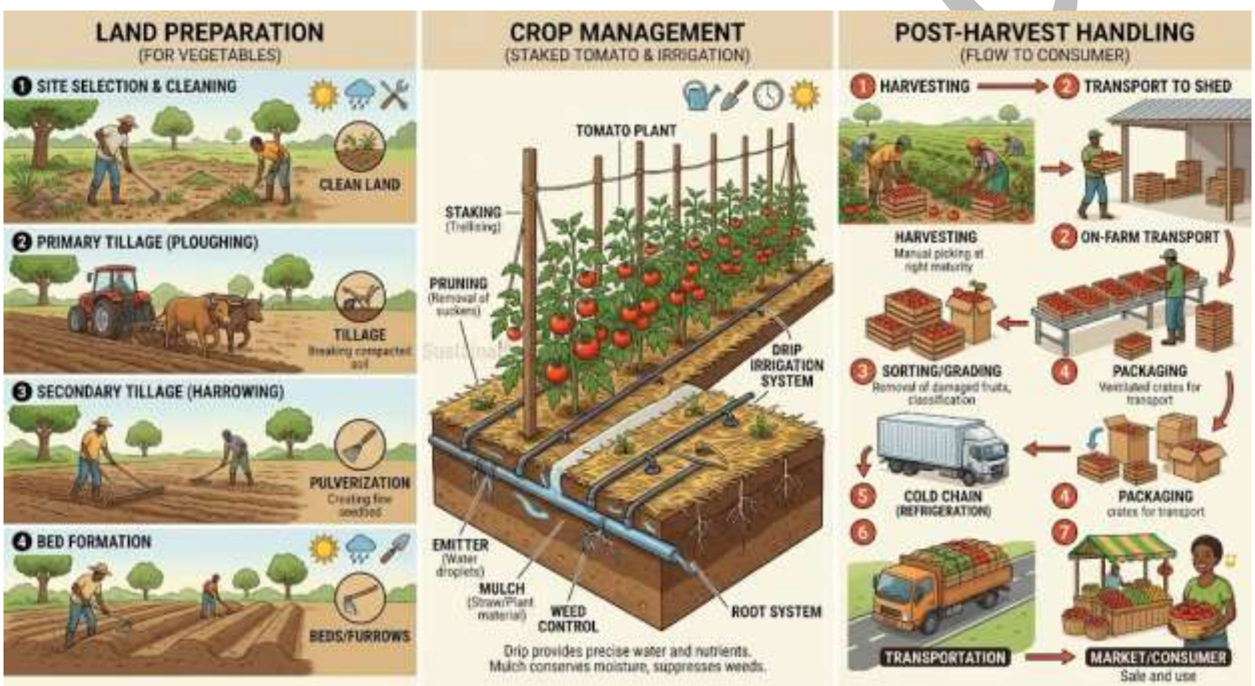

Figure 1.4: Land preparation, planting, and harvesting in vegetable production

Pilot questions 1.4

1. Describe the steps in land preparation for vegetable production.
2. State the recommended plant spacings for tomato, pepper, cabbage, and okra.
3. Explain the importance of mulching in vegetable crop management.
4. State the harvest indicators for tomato, okra, and onion.
5. Describe four post-harvest handling practices that reduce vegetable losses in Nigeria.

Series Summary

This Series examined vegetables and fruits, their classification, importance, and production. **A vegetable is an edible herbaceous plant or plant part consumed as food**, while fruits are classified as simple, aggregate, multiple, or accessory fruits. Vegetables support nutrition, income, food security, and health, and may be grown in home, market, allotment, school, community, or container gardens. Consumer vegetable growing refers to household production mainly for family use, providing fresh, affordable, and safer food. Vegetables may be classified by the part eaten, life cycle, use, or climatic requirement, while major Nigerian fruits include citrus, mango, banana, plantain, pawpaw, pineapple, guava, and avocado.

The Series also covered nursery establishment, land preparation, planting, crop management, harvesting, and post-harvest handling. **A nursery is a place where seedlings are raised and cared for before transplanting to the field.** Tomato, pepper, cabbage, and onion are commonly raised in nurseries, while okra, cowpea, and cucumber are usually direct-seeded. Good production requires proper seedbed preparation, hardening off, careful transplanting, suitable spacing, irrigation, fertiliser application, staking, mulching, and timely harvesting. Post-harvest losses can be reduced by harvesting in the morning, sorting, grading, cleaning, using ventilated crates, keeping produce cool and shaded, and marketing quickly. By completing this Series, students should achieve SLOs 1.1–1.4.

Glossary of Terms

- **Allotment garden:** a small plot of land rented from a local authority for personal food production; important for urban food security.
- **Biennial vegetable:** a vegetable that requires two growing seasons to complete its life cycle; e.g. carrot and cabbage in temperate climates.
- **Consumer vegetable growing:** vegetable production by households primarily for their own consumption; grows in importance in Nigerian cities for food safety, cost, and freshness.

- **Container nursery:** a nursery type in which seeds are sown in polythene bags, seedling trays, or plugs; easy to transport; minimises transplanting shock.
- **Drip irrigation:** a water-efficient irrigation system that delivers water directly to the root zone through emitters in a tube; reduces water use and weed growth between rows.
- **Evaporative cooler (charcoal cooler):** a low-cost post-harvest storage device that uses evaporating water from wet charcoal or bricks to lower the temperature inside and extend vegetable shelf life.
- **Fruit vegetable:** a vegetable whose edible part is the botanical fruit (the mature ovary); examples: tomato, okra, pepper, garden egg, cucumber.
- **Gap filling:** replacing seedlings that failed to establish after transplanting; done within the first week to maintain the target plant population.
- **Hardening off:** the process of gradually exposing nursery seedlings to full sun and reduced watering over 5-7 days before transplanting, to acclimatise them to field conditions.
- **Home garden:** a small, diversified plot adjacent to the house cultivated mainly for family consumption; typically less than 0.1 ha; managed by women.
- **Leaf vegetable:** a vegetable whose edible part is the leaf; examples include amaranth, fluted pumpkin (ugu), bitter leaf, waterleaf, jute mallow (ewedu), cabbage, and lettuce.
- **Market garden:** a commercial vegetable growing operation of 0.1-2 ha located near urban markets; uses intensive management and irrigation to produce a marketable surplus.
- **Mulching:** covering the soil surface around plants with dry grass, rice straw, or polythene to conserve moisture, suppress weeds, and moderate soil temperature.
- **Nursery:** a place where seeds are germinated and seedlings are raised under controlled conditions before transplanting to the permanent field.

- **Open-air nursery:** the most common Nigerian nursery type; seedlings are raised in raised beds in the open and shaded with palm fronds or shade netting; low cost; suitable for the rainy season.
- **Post-harvest handling:** operations carried out after harvest to maintain produce quality and reduce losses: sorting, grading, washing, packing, cooling, storing, and transporting.
- **Protected nursery:** a nursery enclosed by shade netting or polythene to protect seedlings from heavy rain, direct sun, and insects; used for high-value vegetables and dry-season production.
- **Raised bed:** a planting bed elevated 10-30 cm above the surrounding ground level to improve drainage, facilitate intensive planting, and ease crop management.
- **Root vegetable:** a vegetable whose edible part is the root; examples include carrot, radish, beetroot, and turnip.
- **Seedbed:** a prepared area of soil in which seeds are sown; must be fine, firm, moist, and well-drained.
- **Staking:** the practice of supporting vegetable plants (tomato, pepper, climbing vegetables) with bamboo stakes, wooden poles, or wire trellis to keep them upright, improve air circulation, and prevent fruit contact with the soil.
- **Succession planting:** starting new batches of seedlings every 2-3 weeks so that harvests are staggered and a continuous supply of fresh vegetables is available throughout the season.
- **Transplanting:** moving seedlings from the nursery to their permanent positions in the field; used for tomato, pepper, cabbage, and onion.
- **Vegetable:** any herbaceous plant or part of a plant consumed by humans as food; important for nutrition, economy, food security, and medicine.

Concept Check Questions [Series 1]

Objective Questions

1. A ________ is any herbaceous plant or part of a plant consumed by humans as food; vegetables are important for their nutritional, economic, food security, and medicinal value. (Linked to SLO 1.1)
2. A market ________ is a commercially oriented vegetable growing operation of 0.1-2 ha near urban markets that uses intensive management and irrigation to produce a marketable surplus. (Linked to SLO 1.1)
3. Vegetables classified by part eaten include leaf, stem, ________ , fruit, flower, and seed vegetables; carrot and radish are examples of the third category. (Linked to SLO 1.2)
4. A ________ is a place where seeds are germinated and seedlings are raised under controlled conditions before transplanting; it protects seedlings and enables succession planting. (Linked to SLO 1.3)
5. Post-harvest ________ of vegetables (sorting, grading, washing, packing, cooling, selling quickly) reduces losses from the typical 30-50% to 5-10% in Nigerian conditions. (Linked to SLO 1.4)

Short-Answer Questions

6. Define a vegetable and state four reasons why vegetables are important. (Linked to SLO 1.1)
7. Name five types of gardening and state one characteristic of each. (Linked to SLO 1.1)
8. Classify vegetables by part eaten and give one Nigerian example of each class. (Linked to SLO 1.2)
9. State five reasons why the nursery is important in vegetable production. (Linked to SLO 1.3)
10. State the harvest indicator for tomato, okra, and onion. (Linked to SLO 1.4)

Long-Answer Questions

11. Define vegetables and explain their importance; describe the types of gardening and explain consumer vegetable growing. (Linked to SLO 1.1)
12. Classify vegetables by four criteria; classify fruits; and describe fruits and vegetables in the tropical climate. (Linked to SLO 1.2)
13. Describe nursery importance, types, seedbed preparation, hardening off, and transplanting; describe land preparation, planting, crop management, harvesting, and post-harvest handling. (Linked to SLOs 1.3, 1.4)

Answers to Concept Check Questions [Series 1]

Objective Questions

1. Vegetable.
2. Garden.
3. Root.
4. Nursery.
5. Handling.

Short-Answer Questions

6. A vegetable is any herbaceous plant or part consumed by humans as food. Four reasons: nutritional (vitamins, minerals, fibre, phytochemicals); economic (income for farmers and traders); food security (calorie-dense; home garden contribution); medicinal (bitter leaf for fever; moringa for anaemia).
7. Home garden (small; family consumption; diversified); market garden (commercial; 0.1-2 ha; irrigated); allotment (rented plot; urban food security); school garden (educational demonstration); community garden (cooperative; shared by group); container garden (pots/bags; urban; leafy vegetables and herbs).
8. Leaf (amaranth, ugu); stem (Irish potato, onion); root (carrot, radish); fruit (tomato, okra); flower (cauliflower, broccoli); seed (cowpea, green peas).

9. Protects delicate seedlings; allows close monitoring; enables off-season production; ensures uniform healthy plant stand; enables succession planting for continuous supply.
10. Tomato: when fruit turns pink-red and is still firm. Okra: when pods are 8-12 cm long and still tender (3-5 days after flowering). Onion: when tops fall over and skins become papery.

Long-Answer Questions

11. A vegetable is any herbaceous plant or part (root, stem, leaf, flower, fruit, or seed) consumed by humans as food. Importance: nutritional (vitamins A, C, K; minerals; fibre; antioxidants; reduce non-communicable disease risk); economic (income and employment for millions of Nigerian smallholder farmers and traders); food security (home gardens and peri-urban plots contribute directly to household nutrition); medicinal (bitter leaf: fever and diabetes; fluted pumpkin seed: male fertility; moringa: anaemia). Types of gardening: home garden (adjacent to house; under 0.1 ha; diversified; family consumption; women-managed); market garden (commercial; 0.1-2 ha; near urban markets; irrigated; marketable surplus); allotment (rented plot; urban food security); school garden (educational; practical agricultural teaching); community garden (shared; cooperative; for people without land); container garden (pots, bags, tyres; rooftops/balconies; urban environments). Consumer vegetable growing: household production for own consumption; important for food safety (avoids pesticide residues), cost savings, freshness, and variety access; same principles as commercial production but scaled down with organic inputs.
12. Vegetables by part eaten: leaf (amaranth, ugu, bitter leaf, ewedu, cabbage); stem (Irish potato, onion, celery); root (carrot, radish, beetroot); fruit (tomato, okra, pepper, garden egg); flower (cauliflower, broccoli); seed (cowpea, green peas). By life cycle: annual (tomato, okra, cowpea); biennial (carrot, cabbage); perennial (bitter leaf, fluted pumpkin, moringa). By use: salad (lettuce, cucumber, tomato); cooking (okra, garden egg); dual-purpose (pepper, carrot). By climate: tropical (most Nigerian vegetables); temperate/highland (cabbage, carrot, Irish potato; Jos Plateau). Fruit classification: simple (drupe: mango, avocado; berry: banana, tomato; pome: apple; legume: cowpea); aggregate (soursop, strawberry); multiple (pineapple, breadfruit); accessory (cashew

apple). Tropical production: high temperatures (25-35 degrees Celsius) and solar radiation favour growth; challenges: high pest/disease pressure (fungi, insects); heat stress causes flower drop; heavy rains erode seedbeds; rapid post-harvest deterioration without refrigeration.

13. Nursery importance: protects seedlings from harsh conditions; allows close monitoring; enables off-season and succession planting; saves expensive seed; ensures uniform healthy stand. Types: open-air (most common; raised bed; palm frond shade; rainy season; low cost); protected (shade netting or polythene; dry season; higher cost); container (polythene bags or trays; minimal transplanting shock). Seedbed preparation: elevated site; loosen 15-20 cm; compost 4-6 kg/m2; raised bed 10-15 cm; fine tilth; water; shade. Hardening off: 5-7 days of gradual sun exposure and reduced watering before transplanting; prevents transplanting shock. Transplanting: water nursery first; lift carefully; plant at root collar depth; water immediately; shade 3-5 days; irrigate daily for 7-10 days. Land preparation: clear residues; primary tillage 25-30 cm; secondary tillage; raised beds (1-1.2 m wide; 15-30 cm high); compost 10-20 t/ha; lime if pH below 6.0; basal NPK. Planting: direct seed (okra, cowpea, cucumber) or transplant (tomato, pepper, cabbage). Spacings: tomato 60-90 x 45-60 cm; pepper 60 x 45 cm; okra 60-90 x 30-45 cm. Crop management: irrigation (daily for leafy; 2-3x/week for fruiting); top-dressing at 2-3 weeks and flowering; staking; mulching. Harvesting: tomato at pink-red firm; okra at 8-12 cm tender; onion when tops fall and skins papery. Post-harvest: morning harvest; sort and grade; wash and dry; ventilated crates; cool store; sell quickly; losses 30-50% without good practices.

Answers to Pilot Questions [Series 1]

Part 1.1

1. A vegetable is any herbaceous plant or part of a plant (root, stem, leaf, flower, fruit, or seed) consumed by humans as food, raw or cooked. Four reasons: (1) Nutritional (primary source of vitamins, minerals, dietary fibre, and protective phytochemicals). (2) Economic (provides income and employment for millions of Nigerian smallholder farmers, market women, and traders). (3) Food security (calorie-dense relative to cost; home and peri-urban gardens contribute directly to household food availability). (4) Medicinal (many vegetables have traditional medicinal uses: bitter leaf for fever and diabetes, fluted pumpkin for male fertility, moringa for anaemia and malnutrition).
2. Six types: (1) Home garden (small plot adjacent to the house; under 0.1 ha; diversified species; mainly for family consumption; typically managed by women). (2) Market garden (commercial; 0.1-2 ha; near urban markets; intensive management; irrigated; produces marketable surplus). (3) Allotment garden (small rented plot; urban food security; allocated by local authority). (4) School garden (educational; vegetable and crop demonstration attached to a school; teaches practical agricultural skills). (5) Community garden (shared plot managed collectively by a group or cooperative; provides access for people without land). (6) Container garden (vegetables grown in pots, bags, tyres; suitable for rooftops and balconies; used in Nigerian cities where land is scarce).
3. Consumer vegetable growing is the production of vegetables by households primarily for their own consumption rather than for commercial sale. Three reasons: (1) Food safety (consumers can avoid excessive pesticide and chemical residues common on commercially produced vegetables). (2) Cost savings (home-grown vegetables reduce household expenditure on food, especially in urban areas where fresh vegetables are expensive). (3) Freshness and variety access (vegetables can be harvested at peak freshness and at the time of need; unusual or traditional varieties not available in the local market can be grown).
4. Five Nigerian vegetables and part eaten: (1) Tomato (Lycopersicon esculentum): fruit (the botanical berry). (2) Okra (Abelmoschus esculentus): young fruit (pod). (3) Fluted

pumpkin/ugu (Telfairia occidentalis): leaves and seeds. (4) Bitter leaf (Vernonia amygdalina): leaves. (5) Onion (Allium cepa): bulb (modified stem and leaf bases).

5. Home garden: a small plot (under 0.1 ha) adjacent to the house; cultivated mainly by women and children; highly diversified with many species; grown primarily for family consumption; uses household waste water and kitchen compost; rarely generates a commercial surplus. Market garden: a commercial operation (0.1-2 ha) located near urban or peri-urban markets; cultivated by the farmer or hired labour; fewer, high-value species grown at larger scale; irrigated; intensive management; specifically aimed at producing a marketable surplus for sale; generates farm income.

Part 1.2

1. By part eaten: (1) Leaf vegetables: edible leaves; examples: amaranth (spinach), fluted pumpkin/ugu, bitter leaf, waterleaf. (2) Stem vegetables: edible stem or modified stem; examples: Irish potato (tuber), onion (bulb). (3) Root vegetables: edible root; examples: carrot, radish. (4) Fruit vegetables: edible botanical fruit; examples: tomato, okra, pepper, garden egg. (5) Flower vegetables: edible flower or flower head; examples: cauliflower, broccoli, pumpkin flower. (6) Seed vegetables: edible seed; examples: cowpea (black-eyed bean), garden peas.
2. Annual: completes life cycle in one growing season; example: tomato (planted and harvested within 3-4 months). Biennial: requires two growing seasons; example: carrot (grows vegetatively in the first season and flowers/seeds in the second, though usually harvested in the first season). Perennial: lives and produces for many years without replanting; example: fluted pumpkin (Telfairia occidentalis; established once from seed or stem cutting; harvested continuously for several years).
3. A fruit is the mature ripened ovary of a flowering plant, containing seeds. Simple fruit: develops from a single ovary of one flower; examples: drupe (mango, avocado; stony endocarp), berry (banana, tomato, garden egg; fleshy pericarp with seeds embedded), pome (apple, pear; fleshy receptacle). Aggregate fruit: develops from a single flower with many separate pistils that fuse or cluster together; example: soursop, strawberry. Multiple

fruit: develops from the fused ovaries of many flowers of an inflorescence; example: pineapple, breadfruit, fig.

4. Six tropical fruits and nutritional benefits: (1) Mango (Mangifera indica): rich in vitamins A, C, and B6; beta-carotene. (2) Citrus/orange (Citrus sinensis): rich in vitamin C (ascorbic acid); folate; flavonoids. (3) Banana/plantain (Musa species): energy source (carbohydrates); potassium; vitamin B6. (4) Pawpaw/papaya (Carica papaya): vitamins A and C; papain enzyme (digestive aid); lycopene. (5) Pineapple (Ananas comosus): vitamin C; bromelain enzyme; manganese. (6) Guava (Psidium guajava): very high vitamin C (4x more than orange); lycopene; dietary fibre.
5. Three challenges: (1) High pest and disease pressure (warm, humid tropical conditions favour year-round development of fungal diseases such as early blight, late blight, anthracnose, and powdery mildew; and insect pests such as aphids, whiteflies, thrips, and fruit flies; making pest and disease management more expensive and difficult than in temperate climates). (2) Heat stress (during the dry season, temperatures exceeding 35-38 degrees Celsius cause flower drop in tomato and pepper, reducing fruit set and yield; this is a major constraint on dry-season vegetable production in Nigeria). (3) Rapid post-harvest deterioration (high temperatures accelerate respiration, moisture loss, and microbial decay in harvested vegetables; without refrigeration, shelf life is reduced to 1-3 days for leafy vegetables and 3-7 days for fruiting vegetables, causing high losses between harvest and consumer).

Part 1.3

1. Five reasons: (1) Protects delicate seedlings from harsh field conditions (heavy rain, scorching sun, strong wind, and soil-borne pests) during the most vulnerable early growth stage. (2) Allows closer monitoring of germination, watering, and pest management than is possible in the open field. (3) Enables off-season production by starting seedlings in the nursery before field conditions are suitable and transplanting them immediately when conditions improve. (4) Ensures a uniform, healthy stand of transplants by selecting only the strongest seedlings from the nursery, saving expensive seed. (5) Enables succession

planting (starting new seedling batches every 2-3 weeks) to stagger harvests and maintain a continuous supply of vegetables for the market.

2. Three types: (1) Open-air nursery: advantage: low cost; no permanent structure needed; widely available materials (palm fronds for shade). Limitation: seedlings exposed to heavy rain and insects; less suitable for the dry season. (2) Protected nursery (shade netting or polythene structure): advantage: protects from heavy rain, direct sun, and insects; suitable for dry-season production and high-value vegetables. Limitation: higher initial capital cost for structure and shade netting. (3) Container nursery (polythene bags or seedling trays): advantage: easy to transport; minimises transplanting shock because root ball is intact at planting. Limitation: higher cost of bags/trays and growing medium; requires more frequent watering than field nursery beds.
3. Eight steps: (1) Select a slightly elevated, well-drained site close to the water supply. (2) Clear and remove all vegetation, debris, and large stones. (3) Dig and loosen the soil to 15-20 cm depth with a fork or hoe. (4) Incorporate well-decomposed compost or farmyard manure at 4-6 kg per m2. (5) Form a raised bed 10-15 cm high and 1 m wide (any convenient length). (6) Rake the surface to a fine, smooth, firm tilth free of large clods. (7) Water the bed thoroughly one day before sowing to ensure moist germination conditions. (8) Apply 50% shade cloth or palm fronds over the bed to reduce temperature and moisture loss.
4. Hardening off is the process of gradually exposing nursery seedlings to full sun and reducing watering over 5-7 days before transplanting to the field. It is necessary because seedlings raised in the sheltered, moist, shaded nursery environment are acclimatised to low light, high humidity, and regular watering; suddenly transferring them to the full sun, wind, and irregular watering of the open field causes transplanting shock (severe wilting, leaf scorch, and sometimes death). Hardening off gradually acclimatises the seedling's physiology (stomatal behaviour, cuticle thickness, root activity) to the harsher field conditions before permanent planting.
5. Transplanting procedure for tomato: (1) Water the nursery bed thoroughly 1-2 hours before lifting to keep the root ball intact. (2) Lift seedlings (4-6 weeks old; 4-6 true leaves) carefully with a trowel, keeping as much soil around the roots as possible. (3) Select only healthy, vigorous seedlings; discard any diseased, damaged, or leggy ones.

(4) In the pre-prepared field bed, make holes at the correct spacing (60-90 cm x 45-60 cm) with a dibber. (5) Place the seedling in the hole at root collar depth; firm the soil around the roots. (6) Water each transplanted seedling immediately to settle the soil and prevent air pockets around the roots. (7) Shade transplants with cut leaves or shade cloth for 3-5 days if conditions are hot and sunny. (8) Irrigate daily for the first 7-10 days until the roots are established; then reduce to regular watering schedule.

Part 1.4

1. Steps in land preparation: (1) Clearing (remove crop residues, weeds, and debris; large residues composted; fine residues incorporated). (2) Primary tillage (plough or deep-dig to 25-30 cm; breaks compacted layers; buries weeds; improves drainage). (3) Secondary tillage (harrow or rake to break clods, level the surface, and create a fine firm seedbed). (4) Bed or ridge formation (raised beds 15-30 cm high; 1-1.2 m wide; 40-50 cm pathways). (5) Soil amendment (apply compost or farmyard manure 10-20 t/ha; apply lime if pH below 6.0; apply basal NPK fertiliser 200-400 kg/ha at or just before planting).
2. Recommended spacings: tomato: 60-90 cm between rows x 45-60 cm within row; pepper: 60 cm x 45 cm; cabbage: 45-60 cm x 45 cm; okra: 60-90 cm x 30-45 cm.
3. Mulching is important in vegetable crop management for three main reasons: (1) Moisture conservation (a mulch layer of dry grass, rice straw, or polythene reduces evaporation from the soil surface; soil under mulch stays moist for longer, reducing irrigation frequency; particularly important in the dry season). (2) Weed suppression (mulch blocks light from reaching weed seeds and seedlings, reducing weed germination and growth; this reduces the cost and labour of hand weeding). (3) Soil temperature moderation (mulch insulates the soil, preventing extreme temperature fluctuations that can stress vegetable roots; it also prevents surface crusting by shielding the soil from rain impact).
4. Harvest indicators: Tomato: when the fruit changes from green to pink-red colour and is still firm (not soft); for distant markets, harvest at the pink (turning) stage before full colour. Okra: when pods are 8-12 cm long and still tender (approximately 3-5 days after

flowering); over-mature okra becomes fibrous and stringy, making it inedible and unmarketable. Onion: when the aerial tops naturally fall over and die back, and the outer skin of the bulb becomes dry and papery; harvested by carefully lifting the bulbs from the soil.

5. Four post-harvest practices: (1) Morning harvest (harvest in the early morning when temperatures are lowest; lower temperature reduces respiration rate and water loss, extending shelf life). (2) Sorting and grading (immediately remove damaged, diseased, or over-mature produce; grade remaining produce by size and quality; reduces pathogen spread from diseased to healthy produce during storage and transport). (3) Packing in ventilated containers (pack in open-weave bamboo baskets, wooden crates, or vented plastic crates; never in sealed polythene bags; ventilation removes heat and moisture, reducing decay rate). (4) Rapid marketing (transport and sell as quickly as possible after harvest; minimise the time between harvest and consumer; use evaporative charcoal coolers where refrigeration is unavailable to extend shelf life by 2-5 days).

References and Attributions

Textual References (Books and External Sources)

- FAO (Food and Agriculture Organization of the United Nations). (2025). Guidelines for sustainable agriculture. FAO.
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- Schippers, R. R. (2000). African indigenous vegetables: An overview of the cultivated species. Natural Resources Institute/ACP-EU Technical Centre for Agricultural and Rural Cooperation, Chatham, UK.
- Tindall, H. D. (1983). Vegetables in the tropics. Macmillan Press, London.

Figures, Plates, Tables, and Boxes

- Figure 1.1: Types of gardening and important Nigerian vegetables Attribution: AI generated. Suggested OER search string: "types gardening home garden market garden school garden container gardening Nigeria vegetables tomato okra pepper ugu OER".
- Figure 1.2: Classification of vegetables and fruits Attribution: AI generated. Suggested OER search string: "vegetable classification leaf stem root fruit flower seed annual perennial tropical temperate Nigeria fruits mango citrus banana pineapple OER".
- Figure 1.3: Nursery practices in vegetable production Attribution: AI generated. Suggested OER search string: "vegetable nursery raised bed seedbed preparation transplanting tomato pepper cabbage Nigeria OER".
- Figure 1.4: Land preparation, planting, and harvesting in vegetable production Attribution: AI generated. Suggested OER search string: "vegetable land preparation raised bed tillage transplanting staking drip irrigation mulching harvesting post-harvest handling Nigeria OER".

Series 2: Plant Growth and Reproductive Processes

- **Part 2.1: Vegetative Structures of Plants**
  - Sub Part 2.1.1: Roots and stems
  - Sub Part 2.1.2: Leaves and their functions
  - Sub Part 2.1.3: Modified vegetative structures
- **Part 2.2: Reproductive Structures of Plants**
  - Sub Part 2.2.1: Flowers: structure and function
  - Sub Part 2.2.2: Pollination and fertilisation
  - Sub Part 2.2.3: Fruit and seed development
- **Part 2.3: Basic Physiological Processes**
  - Sub Part 2.3.1: Photosynthesis
  - Sub Part 2.3.2: Respiration and transpiration
  - Sub Part 2.3.3: Vegetative growth and reproductive growth
- **Part 2.4: Plant Propagation in Vegetable Production**
  - Sub Part 2.4.1: Sexual propagation (seed propagation)
  - Sub Part 2.4.2: Asexual (vegetative) propagation
  - Sub Part 2.4.3: Factors affecting successful propagation

Introduction

A thorough understanding of plant structure and physiology is essential for any serious student of vegetable crop production. Knowing how roots anchor and feed the plant, how leaves capture sunlight and manufacture food, how flowers are pollinated and fruits develop, and how plants grow and reproduce enables the vegetable grower to make informed management decisions at every stage of production.

This Series covers the vegetative and reproductive structures of plants; the key physiological processes of photosynthesis, respiration, transpiration, and growth; and the methods of plant propagation used in vegetable production. The understanding built here underpins the study of orchard and garden layout, production factors, and pest and disease management in the remaining Series of AGE 207.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 2.1** identify and describe the major vegetative structures of plants and their functions (Linked to Part 2.1),
- **SLO 2.2** describe the reproductive structures of plants and explain pollination, fertilisation, and fruit and seed development (Linked to Part 2.2),
- **SLO 2.3** explain photosynthesis, respiration, transpiration, vegetative growth, and reproductive growth (Linked to Part 2.3), and
- **SLO 2.4** describe sexual and asexual propagation methods and explain the factors affecting successful propagation (Linked to Part 2.4).

2.1 Vegetative Structures of Plants

2.1.1 Roots and stems

The root is the underground organ of the plant that performs three main functions: anchorage (holds the plant firmly in the soil against wind and mechanical forces); absorption (absorbs water and dissolved mineral nutrients from the soil through root hairs on the young root surface); and storage (some roots store food reserves; e.g. carrot, radish, beetroot, cassava, sweet potato). Types of root systems: taproot system (one main primary root with smaller lateral roots; e.g. carrot, radish, tomato, pepper; associated with dicotyledonous plants); fibrous root system (no main root; many fine, branching roots of similar size radiating from the stem base; e.g. maize, rice, onion, grasses; associated with monocotyledonous plants). Root hairs are thin-walled extensions of epidermal cells just behind the root tip; they greatly increase the absorptive surface area of the root.

The stem is the above-ground axis of the plant that connects the roots to the leaves and other organs. Functions of the stem: support (holds leaves, flowers, and fruits in positions that receive light and allow pollination); transport (the xylem tissue in the stem transports water and dissolved minerals upward from roots to leaves; the phloem tissue transports photosynthates downward from leaves to roots, fruits, and other organs); and storage (some stems store water and carbohydrates; e.g. sugarcane, Irish potato tuber). Stem types relevant to vegetable production: erect stem (tomato, okra, amaranth); creeping/prostrate stem (waterleaf, sweet potato); climbing stem (cucumber, pumpkin, bitter gourd); underground stem modifications (Irish potato: tuber; onion: bulb; cocoyam: corm).

Fill in the blank: The two main types of root system are the ________ root system (one main primary root with laterals; e.g. carrot, tomato) and the fibrous root system (many fine equal-sized roots; e.g. onion, maize).

2.1.2 Leaves and their functions

The leaf is the primary organ of photosynthesis and gas exchange. A typical dicot leaf consists of the blade (lamina: the flat, expanded portion that captures light; contains the chloroplasts where photosynthesis occurs); the petiole (the stalk that connects the blade to the stem; allows the blade to be oriented towards the light); and stipules (small leaf-like outgrowths at the base of the petiole in some species). The leaf surface is covered by the epidermis, which secretes a waxy cuticle that reduces water loss. Stomata (singular: stoma) are tiny pores in the epidermis, mainly on the underside of the leaf, surrounded by guard cells that regulate their opening and closing; stomata allow CO_2 to enter for photosynthesis and water vapour and O_2 to exit.

Functions of the leaf: photosynthesis (the primary function; CO_2 and water are converted to glucose and oxygen using light energy trapped by chlorophyll); transpiration (water evaporates from the leaf surface through stomata, creating a water potential gradient that draws water upward from the roots); gas exchange (CO_2 enters and O_2 exits during the day; O_2 enters and CO_2 exits during the night for respiration); and food storage in some species (e.g. onion scale leaves store carbohydrates and water). Leaf modifications in vegetable crops: tendrils (modified leaves for climbing; cucumber, peas); succulent leaves (cactus; store water); spines (protection; modified leaves). Understanding leaf structure is important for recognising nutrient deficiency symptoms, disease lesions, and pest damage on vegetable crops.

Fill in the blank: ________ are tiny pores on the leaf surface, mainly on the underside, surrounded by guard cells; they allow CO_2 to enter for photosynthesis and water vapour to exit during transpiration.

2.1.3 Modified vegetative structures

Many vegetable crops have vegetative organs that are modified from their basic form to serve specialised functions, particularly food and water storage. Modified stems: tuber (an enlarged underground stem that stores starch; e.g. Irish potato; has buds ("eyes") that sprout new shoots; distinguished from a root by the presence of nodes and internodes); corm (a solid, upright underground stem base; e.g. cocoyam/taro, gladiolus); bulb (a modified bud consisting of a short stem disc covered by fleshy scale leaves; e.g. onion, garlic, shallot; the scale leaves store carbohydrates); rhizome (a horizontal underground stem; e.g. ginger, turmeric); stolon/runner (a horizontal stem that runs along the soil surface and roots at nodes to produce new plants; e.g. sweet potato, strawberry).

Modified roots: tuberous root (an enlarged root that stores food; e.g. sweet potato, cassava, yam bean; distinguished from a stem tuber by the absence of buds, nodes, and internodes). Modified leaves: tendrils (modified leaves in peas; aid climbing); succulent leaves (in plants adapted to dry conditions). These modified vegetative structures are of great economic importance in vegetable production because they are often the edible part of the plant (Irish potato tuber, onion bulb, cassava tuberous root, cocoyam corm, ginger rhizome); they are also the main vegetative propagation organs; and their presence in the soil is what makes root and tuber vegetables particularly sensitive to soil drainage, compaction, and disease.

Fill in the blank: An onion ________ is a modified bud consisting of a short stem disc covered by fleshy scale leaves that store carbohydrates; it is distinguished from a corm (solid stem) and a tuber (enlarged stem segment with buds) by its layered structure.

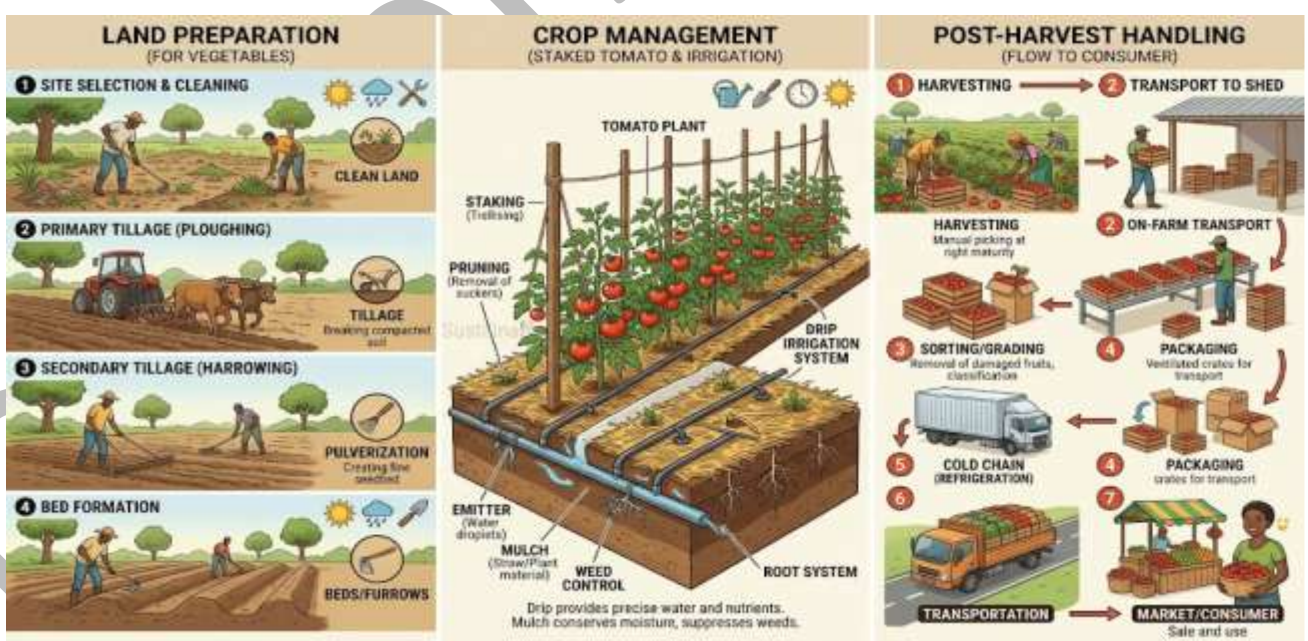

Figure 2.1: Vegetative plant structures

Pilot questions 2.1

6. State three functions of the root and name two types of root system with one example each.
7. State four functions of the stem and name three stem types found in Nigerian vegetable crops.
8. Describe the structure of a typical dicot leaf and state three functions of the leaf.
9. Explain what stomata are and state their role in plant physiology.
10. Distinguish between a stem tuber, a corm, and a bulb with one example each.

2.2 Reproductive Structures of Plants

2.2.1 Flowers: structure and function

The flower is the reproductive organ of angiosperms (flowering plants). A complete flower has four whorls of parts attached to the receptacle (the swollen tip of the flower stalk/pedicel): sepals (the outermost whorl; usually green; collectively called the calyx; protect the developing flower bud); petals (the second whorl; collectively called the corolla; usually coloured and scented to attract pollinators); stamens (the male reproductive organs; each consists of a filament topped by an anther that produces pollen grains containing the male gametophytes); and pistil (the female reproductive organ, also called carpel or gynoecium; consists of the stigma, which is the sticky surface that receives pollen; the style, which is the stalk connecting stigma to ovary; and the ovary, which contains one or more ovules that develop into seeds after fertilisation).

Flower types in vegetable crops: perfect (bisexual) flower (contains both stamens and pistil in the same flower; e.g. tomato, pepper, okra, garden egg; most vegetable crops); imperfect (unisexual) flower (contains either stamens or pistil but not both; e.g. cucumber, pumpkin, watermelon, maize; staminate = male flower; pistillate = female flower). Monoecious plants (both male and female flowers on the same plant; e.g. cucumber, pumpkin, maize); dioecious plants (male and female flowers on separate plants; e.g. fluted pumpkin, papaya, bitter gourd). Understanding flower types is important for planning artificial pollination, predicting pollination success, and understanding why some cucurbit flowers fall without setting fruit (male flowers drop naturally; female flowers set fruit only if pollinated).

Fill in the blank: A ________ (bisexual) flower contains both stamens (male) and pistil (female) in the same flower; examples include tomato, pepper, and okra; it is distinguished from an imperfect (unisexual) flower that contains only stamens or only pistil.

2.2.2 Pollination and fertilisation

Pollination is the transfer of pollen grains from the anther (where they are produced) to the stigma (the receptive surface of the pistil). Self-pollination: pollen is transferred from the anther to the stigma of the same flower or another flower on the same plant; e.g. tomato, pepper, cowpea; produces offspring genetically similar to the parent; the basis of pure-line variety development. Cross-pollination: pollen is transferred from the anther of one plant to the stigma of a different plant of the same species; e.g. cucumber, pumpkin, onion, maize, mango; produces genetically diverse offspring; the basis of hybrid variety development. Agents of pollination: wind (anemophily; e.g. maize; pollen light and abundant; flowers lack petals and nectar); insects, primarily bees (entomophily; e.g. cucumber, pumpkin, tomato, mango; flowers coloured and scented; produce nectar to attract bees).

Fertilisation is the fusion of the male gamete (contained in the pollen tube) with the female gamete (egg cell) inside the ovule. After successful pollination, the pollen grain germinates on the stigma and grows a pollen tube down through the style into the ovary, where it delivers the male gametes to the ovule. Double fertilisation occurs in angiosperms: one male gamete fuses with the egg cell to form the zygote (which develops into the embryo); a second male gamete fuses with the polar nuclei to form the endosperm nucleus (which develops into the food-storing endosperm of the seed). After fertilisation, the ovule develops into a seed and the ovary wall (pericarp) develops into the fruit. Understanding pollination and fertilisation helps the vegetable grower plan bee-attracting plantings near cucurbit fields, carry out hand pollination when pollinators are scarce, and understand why poor fruit set occurs in some seasons.

Fill in the blank: ________ -pollination transfers pollen from one plant to the stigma of another plant of the same species; agents include wind (maize) and insects (cucumber, pumpkin); it produces genetically diverse offspring and is the basis of hybrid variety development.

2.2.3 Fruit and seed development

After fertilisation, the flower parts undergo major changes. The ovary develops into the fruit (the mature ovary wall, or pericarp, encloses and protects the developing seeds): the pericarp of fleshy fruits (tomato, pepper, mango, banana) consists of three layers: exocarp (outer skin), mesocarp (fleshy middle layer), and endocarp (innermost layer, sometimes a hard stone as in mango and avocado). The ovule develops into the seed: the seed consists of the seed coat (testa), the embryo (the young plant with embryonic root/radicle, shoot/plumule, and one or two seed leaves/cotyledons), and the endosperm (food store for the germinating seedling). The petals, sepals, and stamens wither and fall; the style and stigma dry up; the ovary enlarges and ripens as the fruit.

Seed development and maturity: physiological maturity is the stage at which the seed reaches its maximum dry weight, germination capacity, and vigour; the seed is fully formed and viable at this point even if the fruit has not yet ripened externally. Seeds harvested before physiological maturity have lower germination and vigour. Seed dormancy: some seeds require a rest period (dormancy) before they will germinate; dormancy may be due to a hard seed coat (physical dormancy; e.g. cowpea, watermelon), inhibitory chemicals in the seed coat (chemical dormancy), or immaturity of the embryo. Dormancy can be broken by scarification (nicking or abrading the seed coat), soaking in water, or exposure to cold (stratification). Most vegetable seeds (tomato, pepper, okra, cabbage) have no or very short dormancy and will germinate readily when given adequate moisture, temperature, and oxygen.

Fill in the blank: After fertilisation, the ovule develops into a ________ (consisting of the testa, embryo, and endosperm) while the ovary wall develops into the pericarp (fruit wall); the petals, sepals, and stamens wither and fall.

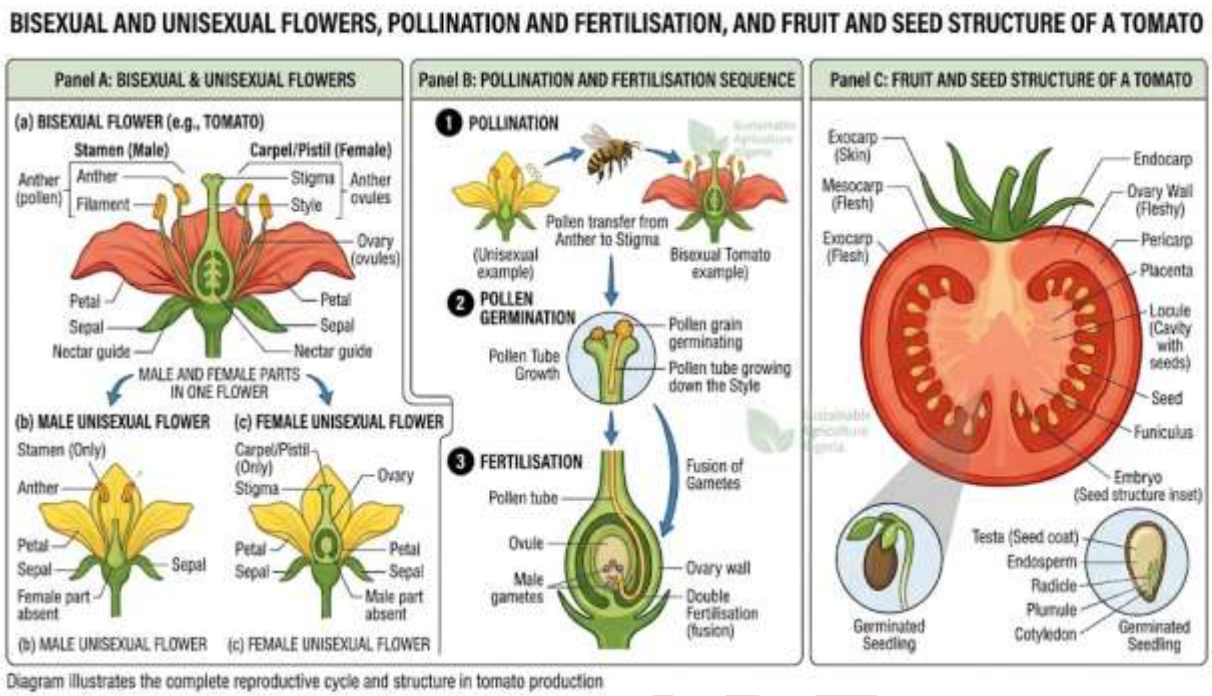

Figure 2.2: Reproductive structures and processes

Pilot questions 2.2

6. Describe the four whorls of a complete flower and state the function of each.
7. Distinguish between perfect (bisexual) and imperfect (unisexual) flowers with two examples each.
8. Distinguish between self-pollination and cross-pollination and state two agents of cross-pollination.
9. Explain what double fertilisation is and why it is important.
10. Describe how a fruit and a seed develop after fertilisation.

2.3 Basic Physiological Processes

2.3.1 Photosynthesis

Photosynthesis is the process by which green plants manufacture organic compounds (sugars) from inorganic raw materials (carbon dioxide and water) using light energy absorbed by chlorophyll. The overall equation is: $6CO_2 + 6H_2O$ + light energy → $C_6H_{12}O_6$ (glucose) + $6O_2$. Photosynthesis occurs in two stages in the chloroplasts: the light reactions (occur in the thylakoid membranes; light energy absorbed by chlorophyll splits water molecules, releasing oxygen and generating ATP and NADPH, which are used in the second stage); and the Calvin cycle/dark reactions (occur in the stroma of the chloroplast; ATP and NADPH from the light reactions are used to fix CO_2 into glucose through the Calvin cycle; does not directly require light). Factors affecting the rate of photosynthesis: light intensity (rate increases with light intensity up to a saturation point); CO_2 concentration (rate increases with rising CO_2 up to a point); temperature (rate increases with temperature up to about 30-35 degrees Celsius; then declines due to enzyme denaturation); and water availability (water deficit closes stomata, reducing CO_2 entry and thus photosynthesis).

Importance of photosynthesis in vegetable production: all the organic matter in vegetable crops (carbohydrates, proteins, lipids, vitamins) is ultimately produced by photosynthesis; increasing photosynthetic efficiency is therefore the key to higher yields. Management practices that maximise photosynthesis include: ensuring adequate leaf area (proper spacing; healthy plants; no excessive defoliation); maintaining sufficient light interception (correct planting density; staking and training to expose leaves to light; pruning to remove shading branches); providing adequate water and nutrients (water deficit and nitrogen deficiency both reduce photosynthesis); and selecting varieties with high photosynthetic capacity (C4 plants such as maize are more photosynthetically efficient than C3 plants such as tomato and pepper under high temperature and light conditions).

Fill in the blank: Photosynthesis produces ________ ($C_6H_{12}O_6$) and oxygen from CO_2, water, and light energy; all the organic matter in vegetable crops is ultimately derived from this process, making maximising photosynthesis the key to higher vegetable yields.

2.3.2 Respiration and transpiration

Respiration is the metabolic process by which plants (and all living organisms) break down organic compounds (primarily glucose) to release energy (ATP) for cellular work. The overall equation for aerobic respiration is: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy (ATP). Respiration occurs in all living cells of the plant (roots, stems, leaves, fruits) at all times (day and night). It is the reverse of photosynthesis in terms of gas exchange: photosynthesis consumes CO_2 and produces O_2; respiration consumes O_2 and produces CO_2. Net photosynthesis (apparent photosynthesis) is the difference between gross photosynthesis (total carbon fixed) and respiration (carbon consumed by the plant itself); only net photosynthate contributes to dry matter accumulation and yield. Temperature strongly affects the respiration rate: for every 10 degrees Celsius rise in temperature, the respiration rate approximately doubles; this is why vegetables deteriorate much faster in the tropical heat than in cool storage.

Transpiration is the loss of water vapour from plant surfaces, primarily through stomata. The transpiration stream (the flow of water from roots through stems to leaves, driven by evaporation from leaf surfaces) is the mechanism by which water and dissolved nutrients are transported upward through the plant. Transpiration performs several important functions: it drives the ascent of water and nutrients from roots to leaves; it cools leaf temperature by evaporative cooling (important in hot tropical environments); and it maintains leaf turgor, which is necessary for stomatal opening and thus for CO_2 entry and photosynthesis. Excessive transpiration when water supply is inadequate causes wilting (loss of leaf turgor); wilting closes stomata, reducing photosynthesis and plant growth. Factors affecting transpiration rate: temperature (higher temperature increases evaporation); humidity (low humidity increases the gradient for water vapour loss); wind speed (increases transpiration by removing humid air from around the leaf); and stomatal aperture (controlled by guard cells in response to light, CO_2, and water status).

Fill in the blank: ________ is the loss of water vapour from plant surfaces through stomata; it drives the ascent of water and nutrients from roots to leaves, cools the leaf by evaporative cooling, and maintains turgor for stomatal opening and photosynthesis.

2.3.3 Vegetative growth and reproductive growth

Vegetative growth is the phase of plant development during which the plant increases its biomass through cell division, elongation, and differentiation in the shoot apical meristem, root apical meristem, and lateral meristems; it produces roots, stems, and leaves but no flowers or fruits. Vegetative growth is promoted by: long days (for some species), adequate nitrogen (which promotes leafy growth), moderate temperatures, and abundant water and nutrients. In vegetable production, the vegetative growth phase is important because it builds the photosynthetic leaf area and root system that will support reproductive growth and fruit yield; a plant that is stressed during vegetative growth produces a smaller canopy and smaller yield.

Reproductive growth (flowering and fruiting) begins when the plant receives appropriate environmental signals to switch from vegetative to reproductive development. The transition from vegetative to reproductive growth is triggered by: photoperiod (day length; short-day plants flower when day length is below a critical threshold; long-day plants flower above a critical threshold; day-neutral plants are not affected by photoperiod; most tropical vegetable crops are day-neutral); vernalisation (exposure to cold temperatures; required for cabbage, carrot, celery, and other biennial crops to flower; normally not a concern in tropical Nigeria); and developmental maturity (after producing a minimum number of leaves, most vegetable crops will flower regardless of photoperiod). In vegetable production, the grower usually wants to maximise yield of the harvestable organ (fruit, seed, leaf, or root) and must manage the balance between vegetative and reproductive growth accordingly: too much nitrogen delays flowering of fruiting vegetables; water stress can trigger premature flowering and reduce yield.

Fill in the blank: The transition from vegetative to reproductive growth in plants is influenced by ________ (day length), vernalisation (cold exposure), and developmental maturity; most tropical vegetable crops are day-neutral and will flower after reaching a minimum number of leaves.

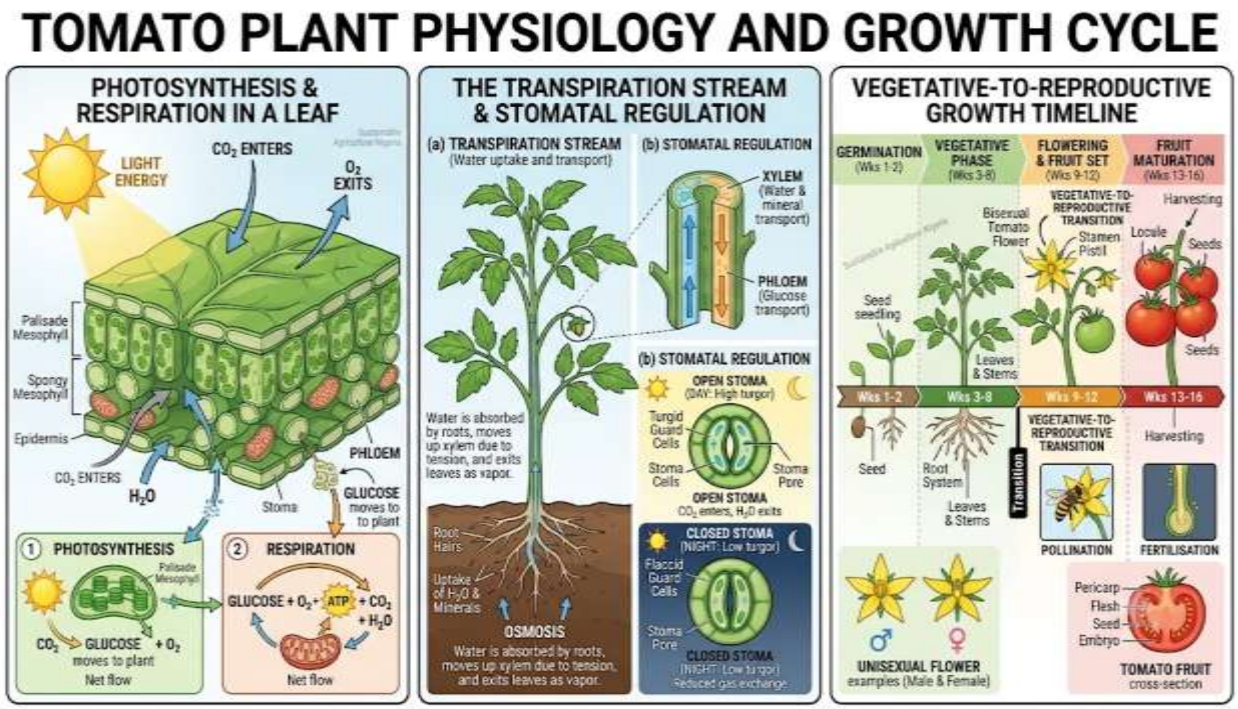

Figure 2.3: Key physiological processes in vegetable crops

Pilot questions 2.3

6. Write the overall chemical equation for photosynthesis and state four factors that affect its rate.
7. Explain the two stages of photosynthesis and where each occurs in the chloroplast.
8. Write the overall equation for aerobic respiration and explain why respiration rate is important for post-harvest vegetable quality.
9. Define transpiration and state three functions it performs in the plant.
10. Distinguish between vegetative growth and reproductive growth, and explain how photoperiod affects flowering.

2.4 Plant Propagation in Vegetable Production

2.4.1 Sexual propagation (seed propagation)

Sexual propagation is the reproduction of plants from seeds; it involves fusion of male and female gametes (sexual reproduction) and produces offspring that may differ genetically from each parent (genetic recombination). Advantages: seeds are small, light, and easy to store and transport; seed propagation can produce large numbers of plants quickly; seed-propagated plants often establish more vigorously (by growing their own root system from the beginning) than vegetatively propagated plants; seeds can be treated with fungicides and insecticides to prevent seed-borne disease and soil insect attack; many vegetable crops are naturally seed-propagated (tomato, pepper, okra, cowpea, cabbage, carrot, onion). Disadvantages: seeds of hybrid varieties cannot be saved and replanted (F1 hybrids produce genetically variable offspring); seed propagation introduces the genetic variability that can change crop characteristics; some vegetable crops propagated sexually take longer to reach production than vegetatively propagated plants.

Seed quality: for successful seed propagation, the seed must be: viable (alive; able to germinate; tested by germination percentage; most commercial vegetable seeds should have at least 75-85% germination); vigorous (the seedling emerges rapidly and uniformly; vigorous seeds establish better in difficult field conditions); free from seed-borne pathogens (bacterial, fungal, and viral diseases can be transmitted through infected seed); of the correct variety identity (labelled varieties must be true to type); and properly stored (seed viability declines with age; most vegetable seeds stored at low temperature (10-15 degrees Celsius) and low humidity (30-40% RH) remain viable for 2-5 years). Seed germination requires three conditions: adequate moisture (imbibition of water activates enzymes and initiates growth); suitable temperature (most vegetable seeds germinate best at 20-30 degrees Celsius; tomato at 25-28 degrees Celsius; onion at 18-25 degrees Celsius); and oxygen (aerobic respiration is needed to provide energy for germination; waterlogged soils inhibit germination).

Fill in the blank: For successful seed propagation, the seed must be ________ (able to germinate; tested by germination percentage), vigorous (rapid uniform emergence), free from seed-borne pathogens, true to type, and properly stored.

2.4.2 Asexual (vegetative) propagation

Asexual propagation is the reproduction of plants from vegetative organs (stem, root, leaf, or bud) rather than from seeds; it produces offspring genetically identical to the parent plant (clones). Advantages: all offspring are genetically identical to the selected parent, preserving desirable characteristics (disease resistance, fruit quality, yield); asexual propagation is faster than seed propagation for some crops; the offspring inherit the same disease status as the parent; some crops do not produce viable seeds or are improved varieties that do not breed true from seed. Disadvantages: vegetative propagules are heavier and bulkier than seeds; they can carry and spread pathogens (viruses, bacteria, fungi) from parent to offspring; large numbers of plants are difficult to produce quickly; propagules may deteriorate in storage.

Methods of asexual propagation used in vegetable and fruit production: stem cuttings (a portion of stem with leaf nodes is cut and rooted; e.g. bitter leaf, Telfairia occidentalis/ugu, cassava stem cuttings, sweet potato vine cuttings, sugarcane setts); division and separation of clumps (e.g. dividing a clump of lemongrass, leeks, or chives into individual plants); layering (a stem branch is bent to the soil, covered, and rooted while still attached to the parent plant; the rooted section is then cut free; e.g. tomato, passion fruit); grafting (the shoot of one plant, the scion, is joined to the rooted stem of another plant, the rootstock; used to combine disease-resistant roots with high-yielding shoots; e.g. tomato grafted onto disease-resistant Solanum torvum rootstock for Fusarium and bacterial wilt control); and tissue culture/micropropagation (producing large numbers of genetically uniform plants from small amounts of plant tissue in a sterile laboratory environment; important for virus-free planting material in banana, cassava, and improved vegetable varieties).

Fill in the blank: ________ cuttings are a form of asexual propagation in which a portion of stem with leaf nodes is rooted to produce a new plant; examples include bitter leaf, fluted pumpkin (ugu), cassava, and sweet potato vine cuttings.

2.4.3 Factors affecting successful propagation

Several factors determine the success of both sexual and asexual propagation. Temperature: most vegetable seeds germinate best at 20-30 degrees Celsius; very high temperatures (above 35 degrees Celsius) inhibit germination (thermoinhibition); very low temperatures slow or prevent germination; for vegetative cuttings, a warm rooting medium temperature (24-28 degrees Celsius) promotes rapid callus formation and root initiation. Moisture: seeds must imbibe sufficient water to activate germination enzymes; the rooting medium for vegetative cuttings must be moist but not waterlogged (excess water causes rotting). Light: seeds of most vegetables germinate in the dark or are light-neutral (sown below the soil surface); some small seeds (celery, lettuce) require light for germination (photoblastic seeds) and should not be covered with soil after sowing. Vegetative cuttings need shade (50% shade netting) until roots develop to reduce transpiration stress.

Rooting hormones and media: vegetative cuttings root more quickly when the cut end is dipped in a rooting hormone (indole-3-butyric acid, IBA, or auxin-based rooting powder); rooting media must be well-aerated, moist, free-draining, and low in nutrients (sharp sand, perlite, vermiculite, or a sand-compost mix are preferred; high-nutrient media promote shoot growth at the expense of root development). Hygiene and disease prevention: all propagation tools (knives, pruning shears) must be sterilised with alcohol or bleach solution between plants to prevent disease transmission; propagation media should be pasteurised or sterilised to eliminate soil-borne pathogens; seedling houses and mist propagation units should be regularly cleaned and disinfected. Genetic quality: use certified seed from reputable sources with known germination percentage, variety identity, and disease-free status; for vegetative propagation, select cuttings only from healthy, high-yielding, disease-free parent plants.

Fill in the blank: Vegetative cuttings root more quickly when the cut end is dipped in a ________ hormone (IBA or auxin-based rooting powder); the rooting medium should be well-aerated, moist, and low in nutrients to promote root rather than shoot development.

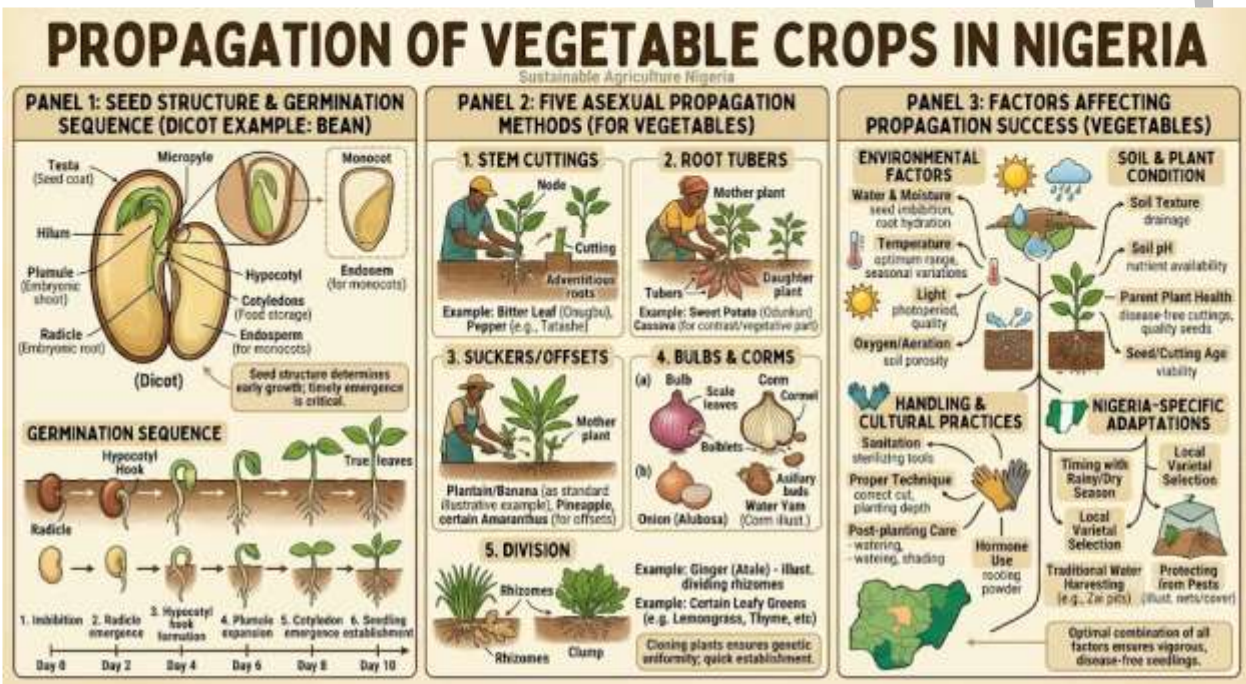

Figure 2.4: Plant propagation methods

Pilot questions 2.4

6. State four advantages and two disadvantages of sexual (seed) propagation.
7. State three conditions required for seed germination and explain each.
8. State four advantages and two disadvantages of asexual (vegetative) propagation.
9. Describe stem cutting as a method of asexual propagation and name two Nigerian vegetable crops propagated this way.
10. State five factors that affect successful plant propagation.

Series Summary

This Series examined the vegetative and reproductive structures of crop plants. **Vegetative structures are the non-reproductive parts of a plant, including roots, stems, and leaves.** Roots provide anchorage, absorption, and storage; stems support the plant and transport water and nutrients; leaves carry out photosynthesis, transpiration, and gas exchange. Important modified structures include tubers, corms, bulbs, rhizomes, and tuberous roots. **Reproductive structures are the flower, fruit, and seed involved in plant reproduction.** Flowers may be complete or incomplete, bisexual or unisexual, while pollination may be self or cross-pollination through wind or insects. Fertilisation produces the zygote and endosperm, after which the ovary develops into the fruit and the ovule becomes the seed.

The Series also covered major plant physiological processes and propagation methods. **Photosynthesis is the process by which green plants use light energy to produce glucose from carbon dioxide and water**, while respiration releases energy from glucose for plant growth and maintenance. **Transpiration is the loss of water vapour from plant surfaces, mainly through stomata**, and it supports cooling and nutrient transport. Vegetative growth involves root, stem, and leaf development, while reproductive growth includes flowering and fruiting. **Propagation is the multiplication of plants through sexual or asexual means.** Sexual propagation uses seeds, while asexual propagation produces genetically identical plants through cuttings, division, layering, grafting, or tissue culture. Successful growth depends on suitable moisture, temperature, light, nutrients, oxygen, hygiene, and healthy planting materials. By completing this Series, students should achieve SLOs 2.1–2.4.

Glossary of Terms

- **Anther:** the pollen-producing part of the stamen; sits on top of the filament; releases pollen grains when mature.

- **Asexual (vegetative) propagation:** reproduction from vegetative organs (stem, root, leaf, bud) producing genetically identical offspring (clones); methods include stem cutting, division, layering, grafting, and tissue culture.
- **Calvin cycle:** the second stage of photosynthesis; occurs in the stroma of the chloroplast; uses ATP and NADPH from the light reactions to fix CO2 into glucose.
- **Corm:** a solid, upright underground stem base that stores food; e.g. cocoyam/taro; distinguished from a bulb (fleshy scale leaves) and a tuber (enlarged stem segment with buds).
- **Cross-pollination:** transfer of pollen from one plant to the stigma of a different plant of the same species; produces genetically diverse offspring; the basis of hybrid seed production.
- **Double fertilisation:** the process in angiosperms where one male gamete fuses with the egg to form the zygote and a second fuses with the polar nuclei to form the endosperm.
- **Fibrous root system:** a root system with many fine, equal-sized roots and no dominant main root; e.g. onion, maize, grasses; associated with monocotyledonous plants.
- **Guard cells:** pairs of cells surrounding each stoma that regulate opening and closing by changing their turgor; they open the stoma when turgid (light, adequate water) and close it when flaccid (drought, dark).
- **Hardening off:** the process of gradually exposing nursery seedlings to outdoor conditions before transplanting; reduces transplanting shock.
- **IBA (Indole-3-butyric acid):** a synthetic auxin used as a rooting hormone powder or solution to promote root initiation on vegetative cuttings.
- **Monoecious:** a plant that bears both male (staminate) and female (pistillate) flowers on the same individual plant; e.g. cucumber, pumpkin, maize.
- **Net photosynthesis:** the difference between gross (total) photosynthesis and respiration; the carbon available for growth and yield accumulation.

- **Ovule:** the structure inside the ovary that develops into a seed after fertilisation.
- **Pericarp:** the fruit wall (mature ovary wall); consists of exocarp (skin), mesocarp (fleshy middle), and endocarp (innermost layer).
- **Photoperiod:** the relative length of day and night; triggers the transition from vegetative to reproductive growth in photoperiod-sensitive plants.
- **Pistil:** the female reproductive organ of a flower; consists of stigma (pollen-receiving surface), style (stalk), and ovary (containing ovules).
- **Respiration:** the metabolic breakdown of glucose to release energy (ATP) for cellular work; $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$; occurs in all living cells day and night.
- **Rhizome:** a horizontal underground stem that stores food; e.g. ginger, turmeric; distinguished from a root by the presence of nodes and scale leaves.
- **Self-pollination:** transfer of pollen from the anther to the stigma of the same flower or another flower on the same plant; produces offspring genetically similar to the parent.
- **Sexual propagation:** reproduction from seeds; involves fusion of gametes; produces genetically variable offspring.
- **Stamen:** the male reproductive organ of a flower; consists of the filament (stalk) and anther (pollen-producing head).
- **Stomata:** tiny pores on the leaf surface (mainly underside) surrounded by guard cells; allow CO_2 entry for photosynthesis and water vapour exit during transpiration.
- **Taproot system:** a root system with one large main primary root and smaller lateral branches; e.g. carrot, radish, tomato; associated with dicotyledonous plants.
- **Transpiration:** the loss of water vapour from plant surfaces through stomata; drives water and nutrient ascent, cools the leaf, and maintains turgor.
- **Vernalisation:** the requirement for exposure to cold temperatures to trigger flowering in biennial and some perennial crops (cabbage, carrot, celery); not usually a concern in tropical Nigeria.

Concept Check Questions [Series 2]

Objective Questions

6. The two main root systems are the ________ root (one main primary root; e.g. carrot, tomato) and the fibrous root (many equal-sized roots; e.g. onion, maize). (Linked to SLO 2.1)
7. ________ are tiny pores on the underside of leaves surrounded by guard cells; they allow CO_2 in for photosynthesis and water vapour out during transpiration. (Linked to SLO 2.1)
8. A ________ (bisexual) flower contains both stamens and pistil in the same flower; examples in vegetable crops include tomato, pepper, and okra. (Linked to SLO 2.2)
9. Photosynthesis produces ________ ($C_6H_{12}O_6$) and oxygen from CO_2, water, and light; all organic matter in vegetable crops is ultimately derived from this process. (Linked to SLO 2.3)
10. Vegetative cuttings root more quickly when the cut end is dipped in a ________ hormone (IBA or auxin-based rooting powder) before insertion in the rooting medium. (Linked to SLO 2.4)

Short-Answer Questions

11. State three functions of the root and distinguish between taproot and fibrous root systems. (Linked to SLO 2.1)
12. Describe the structure and functions of a leaf. (Linked to SLO 2.1)
13. Name the four whorls of a complete flower and state the function of each. (Linked to SLO 2.2)
14. Write the equation for photosynthesis and state four factors affecting its rate. (Linked to SLO 2.3)
15. State four advantages and two disadvantages of asexual propagation. (Linked to SLO 2.4)

Long-Answer Questions

14. Describe the vegetative structures of plants: roots, stems, leaves, and modified vegetative organs. (Linked to SLO 2.1)
15. Describe flower structure, pollination, fertilisation, and fruit and seed development. (Linked to SLO 2.2)
16. Explain photosynthesis, respiration, transpiration, vegetative and reproductive growth; describe sexual and asexual propagation and factors affecting propagation. (Linked to SLOs 2.3, 2.4)

Answers to Concept Check Questions [Series 2]

Objective Questions

1. Taproot.
2. Stomata.
3. Perfect.
4. Glucose.
5. Rooting.

Short-Answer Questions

1. Three functions: anchorage, absorption of water and nutrients, storage. Taproot: one main primary root with lateral branches; e.g. carrot, tomato. Fibrous: many fine equal-sized roots; no main root; e.g. onion, maize.
2. Leaf structure: blade (lamina), petiole, stipules; epidermis with waxy cuticle; stomata (mainly underside) with guard cells; mesophyll (palisade and spongy); vascular bundle (xylem and phloem). Functions: photosynthesis, transpiration, gas exchange, storage in some species.
3. Sepals (protect flower bud; calyx), petals (attract pollinators; corolla), stamens (produce pollen; male organ), pistil (receives pollen; contains ovules; female organ).
4. $6CO_2 + 6H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6O_2$. Four factors: light intensity, CO_2 concentration, temperature (optimum 25-30 degrees Celsius), water availability.

5. Advantages: offspring genetically identical to parent; preserves desirable traits; faster than seed for some crops; no hybrid breakdown. Disadvantages: propagules bulkier than seeds; can transmit pathogens (viruses, bacteria) from parent to offspring.

Long-Answer Questions

1. Root: anchorage, absorption, storage; taproot (carrot, tomato; dicots) and fibrous (onion, maize; monocots); root hairs increase absorptive surface. Stem: support, transport (xylem up; phloem down), storage; types: erect (tomato), creeping (waterleaf), climbing (cucumber), underground modifications (Irish potato tuber; onion bulb; cocoyam corm; ginger rhizome; sweet potato stolon). Leaf: blade, petiole, stipules; upper and lower epidermis with cuticle; stomata with guard cells (underside); palisade mesophyll (photosynthesis); spongy mesophyll (gas exchange); vascular bundle; functions: photosynthesis, transpiration, gas exchange, storage. Modified structures: tuber (Irish potato; stem; buds/eyes), corm (cocoyam; solid stem), bulb (onion; fleshy scale leaves), rhizome (ginger), tuberous root (sweet potato; no buds), stolon (sweet potato; horizontal; roots at nodes).
2. Complete flower whorls: sepals (protect bud), petals (attract pollinators), stamens (produce pollen; filament + anther), pistil (stigma + style + ovary with ovules). Perfect flower: stamens and pistil together (tomato, okra); imperfect: staminate or pistillate only (cucumber, pumpkin; monoecious; male and female flowers on same plant). Pollination: self (pollen to same flower/plant; tomato, pepper; genetically similar offspring); cross (pollen to different plant; cucumber, maize; genetically diverse; agents: wind/maize, insects/cucumber). Fertilisation: pollen germinates on stigma; pollen tube grows to ovule; double fertilisation (zygote from egg + male gamete; endosperm from polar nuclei + second male gamete). Fruit from ovary (exocarp, mesocarp, endocarp); seed from ovule (testa, embryo, endosperm); physiological maturity; dormancy may occur.
3. Photosynthesis: $6CO_2 + 6H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6O_2$; chloroplasts; light reactions (thylakoid; water split; O_2; ATP/NADPH); Calvin cycle (stroma; CO_2 fixed to glucose); factors: light, CO_2, temperature (25-30 degrees Celsius optimum), water. Respiration:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + ATP; all cells; day and night; rate doubles per 10 degrees Celsius; high temperature increases post-harvest losses. Transpiration: water vapour from stomata; drives nutrient ascent; cools leaf; maintains turgor; affected by temperature, humidity, wind, stomatal aperture. Vegetative growth: roots, stems, leaves; promoted by N, water, moderate temperature. Reproductive growth: flowering/fruiting; triggered by photoperiod (day-neutral most vegetables), vernalisation, maturity; N balance critical. Sexual propagation: seeds; genetically variable; easy to store; certified seed (viable, vigorous, disease-free, true-to-type); germination needs moisture, 20-30 degrees Celsius, O_2. Asexual propagation: genetically identical; methods: stem cutting (bitter leaf, ugu, cassava), division (lemongrass), layering, grafting (tomato on disease-resistant rootstock), tissue culture; factors: temperature, moisture, shade, rooting hormone (IBA), sterile medium, hygiene, healthy parent.

Answers to Pilot Questions [Series 2]

Part 2.1

1. Three functions of root: anchorage (holds plant in soil), absorption (water and minerals through root hairs), storage (carrot, cassava store food). Two root system types: taproot (one main primary root with lateral branches; e.g. carrot, tomato); fibrous (many fine equal-sized roots from stem base; no dominant root; e.g. onion, maize).
2. Four functions of stem: support (holds leaves and fruits in light), transport (xylem carries water up; phloem carries photosynthates down), storage (sugarcane, Irish potato), vegetative propagation (runners, stolons). Three stem types in Nigerian vegetables: erect (tomato, okra), creeping/prostrate (waterleaf, sweet potato vine), underground modification (Irish potato tuber, onion bulb, cocoyam corm).
3. Leaf structure: blade (lamina; flat; captures light), petiole (connects blade to stem), stipules (small outgrowths at petiole base); epidermis (upper and lower) with waxy cuticle; stomata with guard cells mainly on underside; palisade mesophyll (photosynthesis); spongy mesophyll (gas exchange); vascular bundle (xylem and

phloem). Three functions: photosynthesis ($CO_2 + H_2O$ + light → glucose + O_2), transpiration (water vapour lost through stomata), gas exchange (CO_2 in; O_2 out during day).

4. Stomata are tiny pores on the leaf surface (mainly underside) surrounded by pairs of guard cells that regulate opening and closing. Role: allow CO_2 to enter for photosynthesis; allow water vapour and O_2 to exit during transpiration; close during drought or darkness to reduce water loss.
5. Stem tuber (Irish potato): enlarged underground stem segment storing starch; has buds ("eyes") that sprout new shoots; nodes and internodes present. Corm (cocoyam): solid, upright underground stem base; stores starch; no distinct layering. Bulb (onion): modified bud with a short stem disc covered by fleshy scale leaves storing carbohydrates; has distinct concentric layers; no extended stem internodes.

Part 2.2

1. Four whorls: (1) Sepals (outermost; usually green; protect developing flower bud; collectively calyx). (2) Petals (second whorl; usually coloured and scented; attract pollinators; collectively corolla). (3) Stamens (male organs; filament + anther that produces pollen; third whorl). (4) Pistil (female organ; stigma + style + ovary containing ovules; innermost whorl; receives pollen and develops fruit and seeds).
2. Perfect (bisexual) flower: contains both stamens and pistil in the same flower; two examples: tomato, okra (and pepper, garden egg). Imperfect (unisexual) flower: contains either stamens or pistil but not both; two examples: cucumber (staminate and pistillate flowers on same plant; monoecious), fluted pumpkin (male and female flowers on separate plants; dioecious).
3. Self-pollination: pollen transferred from anther to stigma of the same flower or same plant; produces offspring similar to parent; e.g. tomato, pepper. Cross-pollination: pollen transferred from one plant to stigma of a different plant of the same species; produces genetically diverse offspring; two agents: wind (maize; light pollen; no petals/nectar) and insects/bees (cucumber, pumpkin; coloured petals; nectar present).
4. Double fertilisation is the process unique to angiosperms in which two male gametes are involved: one fuses with the egg cell to form the zygote (which develops into the embryo

and plant), and a second fuses with the polar nuclei to form the endosperm nucleus (which develops into the food-storing endosperm of the seed). It is important because it simultaneously produces both the embryo (new plant) and the nutritive endosperm tissue that feeds the germinating seedling.

5. After fertilisation: the ovary wall (pericarp) develops into the fruit with exocarp (skin), mesocarp (fleshy middle layer), and endocarp (innermost layer); the petals, sepals, and stamens wither and fall. The fertilised ovule develops into the seed: the testa (seed coat) from the integuments; the embryo (radicle, plumule, cotyledons) from the zygote; and the endosperm from the endosperm nucleus. The seed reaches physiological maturity when it achieves maximum dry weight and germination capacity.

Part 2.3

1. Overall equation: $6CO_2 + 6H_2O$ + light energy → $C_6H_{12}O_6$ (glucose) + $6O_2$. Four factors affecting rate: (1) Light intensity (rate increases with light up to saturation point). (2) CO_2 concentration (rate increases with rising CO_2). (3) Temperature (optimum 25-30 degrees Celsius; declines above 35 degrees Celsius due to enzyme denaturation). (4) Water availability (water deficit closes stomata, reducing CO_2 entry and thus photosynthesis rate).
2. Two stages: (1) Light reactions (occur in the thylakoid membranes of the chloroplast; light energy is absorbed by chlorophyll; water molecules are split releasing O_2; ATP and NADPH are produced for use in the second stage). (2) Calvin cycle/dark reactions (occur in the stroma of the chloroplast; ATP and NADPH from the light reactions are used to fix CO_2 molecules into glucose through a series of enzyme-catalysed reactions; does not directly require light but depends on the products of the light reactions).
3. Overall equation: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + ATP (energy). Post-harvest importance: harvested vegetables continue to respire, consuming their own sugars and nutrients and releasing heat; at high tropical temperatures, the respiration rate is very high (doubles for every 10 degrees Celsius rise), causing rapid quality deterioration; cooling vegetables slows respiration, extending shelf life; this is why post-harvest cooling is critical for vegetable quality in Nigeria.

4. Transpiration is the loss of water vapour from plant surfaces, primarily through stomata. Three functions: (1) Drives the ascent of water and dissolved minerals from roots to leaves through the xylem (the transpiration stream). (2) Cools the leaf by evaporative cooling, preventing heat damage in hot tropical environments. (3) Maintains leaf turgor, which is essential for stomatal opening and thus CO_2 entry for photosynthesis.
5. Vegetative growth: the phase of cell division and organ formation (roots, stems, leaves) in which the plant builds its photosynthetic capacity; promoted by adequate nitrogen, water, and moderate temperatures; no flowers or fruits produced. Reproductive growth: begins when the plant receives appropriate signals to flower and fruit; most tropical vegetables are day-neutral (photoperiod does not affect flowering); vernalisation (cold exposure) triggers flowering in biennial crops (cabbage, carrot); once a minimum number of leaves are produced, most vegetables flower regardless of day length.

Part 2.4

1. Four advantages of sexual propagation: seeds are small, light, and easy to store and transport; seed propagation can produce large numbers of plants quickly; most vegetable crops are naturally seed-propagated; seeds can be treated to prevent seed-borne disease. Two disadvantages: F1 hybrid seeds cannot be saved and replanted (genetically variable offspring); seed propagation introduces genetic variability that can change crop characteristics.
2. Three conditions for seed germination: (1) Adequate moisture (imbibition of water by the seed activates germination enzymes and initiates cell expansion; insufficient moisture prevents germination or causes seedling death). (2) Suitable temperature (most vegetables germinate best at 20-30 degrees Celsius; very high temperatures above 35 degrees Celsius cause thermoinhibition; low temperatures slow or prevent germination). (3) Oxygen (aerobic respiration provides the ATP energy needed for germination; waterlogged or compacted soils with low O_2 inhibit germination).
3. Four advantages of asexual propagation: all offspring are genetically identical to parent (preserves desirable traits); faster than seed for some crops; some crops do not produce

viable seed; important for virus-free planting material (tissue culture). Two disadvantages: vegetative propagules are bulkier and harder to transport than seeds; propagules can carry and spread pathogens (viruses, bacteria) from parent to offspring.

4. Stem cutting: a 10-15 cm portion of stem with 2-3 leaf nodes is cut from a healthy parent plant; leaves are trimmed to reduce transpiration; the cut end is dipped in IBA rooting hormone powder; the cutting is inserted in a moist, well-aerated rooting medium (sand-compost mix); placed under 50% shade netting; watered regularly; roots form within 2-4 weeks. Two Nigerian vegetables propagated by stem cutting: bitter leaf (Vernonia amygdalina) and fluted pumpkin/ugu (Telfairia occidentalis).
5. Five factors: (1) Temperature (20-30 degrees Celsius for seed germination; 24-28 degrees Celsius rooting medium for cuttings). (2) Moisture (seeds must imbibe water; rooting medium must be moist but not waterlogged to prevent rotting). (3) Light (most vegetable seeds are light-neutral or germinate in the dark; cuttings need 50% shade to reduce transpiration). (4) Rooting hormone (IBA or auxin promotes root initiation on vegetative cuttings). (5) Hygiene (sterilise tools between plants; pasteurise rooting medium to prevent disease transmission).

Textual References (Books and External Sources)

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- Taiz, L., & Zeiger, E. (2010). Plant physiology (5th ed.). Sinauer Associates, Sunderland, MA.
- Schippers, R. R. (2000). African indigenous vegetables: An overview of the cultivated species. NRI/ACP-EU Technical Centre, Chatham, UK.

Figures, Plates, Tables, and Boxes

- Figure 2.1: Vegetative plant structures Attribution: AI generated. Suggested OER search string: "plant vegetative structures taproot fibrous root leaf stomata modified stem tuber bulb corm rhizome vegetable crops Nigeria OER".
- Figure 2.2: Reproductive structures and processes Attribution: AI generated. Suggested OER search string: "flower structure stamen pistil pollination fertilisation fruit development seed structure tomato pepper cucumber vegetable Nigeria OER".
- Figure 2.3: Key physiological processes in vegetable crops Attribution: AI generated. Suggested OER search string: "photosynthesis respiration transpiration stomata vegetative growth reproductive growth flowering fruiting tomato vegetable crop Nigeria OER".
- Figure 2.4: Plant propagation methods Attribution: AI generated. Suggested OER search string: "seed propagation germination asexual vegetative stem cutting grafting layering tissue culture rooting hormone vegetable crops Nigeria OER".

Series 3: Orchard and Garden Layout Practices

- **Part 3.1: Site Selection for Orchards and Gardens**
  - Sub Part 3.1.1: Factors in site selection for fruit orchards
  - Sub Part 3.1.2: Factors in site selection for vegetable gardens
  - Sub Part 3.1.3: Soil and climate requirements
- **Part 3.2: Orchard Layout and Design**
  - Sub Part 3.2.1: Orchard planting systems
  - Sub Part 3.2.2: Spacing and density in orchard establishment
  - Sub Part 3.2.3: Windbreaks, roads, and support infrastructure
- **Part 3.3: Vegetable Garden Layout and Design**
  - Sub Part 3.3.1: Bed and plot systems
  - Sub Part 3.3.2: Crop arrangement and rotation planning
  - Sub Part 3.3.3: Irrigation and drainage layout
- **Part 3.4: Establishment and Early Management**
  - Sub Part 3.4.1: Orchard establishment practices
  - Sub Part 3.4.2: Garden establishment practices
  - Sub Part 3.4.3: Early management of newly established orchards and gardens

Introduction

A productive orchard or vegetable garden begins with a well-chosen site and a carefully designed layout. Decisions made at the planning and establishment stage, including site selection, spacing, planting system, and infrastructure layout, determine the productivity, ease of management, and profitability of the enterprise for many years to come, especially for perennial fruit trees that may remain in place for decades.

This Series covers the factors guiding site selection for orchards and vegetable gardens, the principal orchard planting systems and spacing decisions, the layout of vegetable beds and plots including irrigation and drainage, and the practical steps of establishing and managing new orchards and gardens in their early stages. This builds on the plant structure and physiology knowledge of Series 2 and prepares students for the production factors covered in Series 4.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 3.1** describe the factors guiding site selection for fruit orchards and vegetable gardens (Linked to Part 3.1),
- **SLO 3.2** describe orchard planting systems, spacing decisions, and support infrastructure (Linked to Part 3.2),
- **SLO 3.3** describe vegetable garden bed systems, crop arrangement, and irrigation/drainage layout (Linked to Part 3.3), and
- **SLO 3.4** describe the establishment and early management practices for orchards and vegetable gardens (Linked to Part 3.4).

3.1 Site Selection for Orchards and Gardens

3.1.1 Factors in site selection for fruit orchards

Because fruit trees are perennial and remain productive for 15-50 years or more, orchard site selection decisions have long-term consequences and must be made carefully. Climate suitability: temperature, rainfall, and humidity at the site must match the requirements of the chosen fruit species; citrus and mango require a marked dry season for good flowering; avocado and guava tolerate more humid conditions; highland fruits (apple, pear) require the cooler temperatures of the Jos or Mambilla Plateau. Topography: gentle slopes (2-8%) are preferred for natural drainage while avoiding excessive erosion; flat land is acceptable with good drainage; steep slopes (above 15%) require terracing and are generally avoided for new orchards because of erosion risk and management difficulty.

Soil depth and drainage: most fruit trees require a deep (at least 1-1.5 m), well-drained soil free of a hardpan or high water table, since their root systems extend deep into the soil profile; waterlogged or shallow soils cause root rot and stunted growth. Wind exposure: sites exposed to strong, persistent winds suffer fruit drop, branch breakage, and increased water loss; windbreaks are needed on exposed sites. Accessibility and market proximity: the orchard should have road access for input delivery and produce transport; proximity to markets or processing facilities reduces transport costs and post-harvest losses. Water availability: a reliable water source for irrigation, especially during establishment (the first 2-3 years) and the dry season, greatly improves orchard survival and productivity.

Fill in the blank: Because fruit trees are perennial and remain productive for ________ years or more, orchard site selection decisions have long-term consequences; key factors include climate suitability, topography, soil depth and drainage, wind exposure, and water availability.

3.1.2 Factors in site selection for vegetable gardens

Vegetable garden site selection shares some factors with orchard selection but with different emphasis because vegetable crops are short-cycle and shallow-rooted. Soil fertility and texture: vegetables prefer fertile, friable, well-drained loamy soils with good organic matter content; very sandy soils drain too fast and need frequent irrigation and fertilisation; heavy clay soils need amendment with organic matter and raised beds for drainage. Water supply: vegetable gardens require frequent, reliable irrigation, especially in the dry season; proximity to a borehole, stream, river, or irrigation pond is essential for year-round production; gardens without reliable water can only produce during the rainy season.

Sunlight exposure: most vegetable crops require full sun (at least 6-8 hours of direct sunlight daily) for good yield; sites shaded by trees or buildings for a large part of the day are unsuitable for most fruiting vegetables, though leafy vegetables tolerate partial shade better. Proximity to market and home: a garden close to the market reduces transport costs and post-harvest losses through faster delivery; a garden close to the home (for a home garden) facilitates frequent attention, watering, and pest monitoring. Protection from flooding and livestock: low-lying areas prone to flooding during the rainy season should be avoided or protected with drainage; the site should be fenced or otherwise protected from grazing animals and theft.

Fill in the blank: Most vegetable crops require ________ sun (at least 6-8 hours of direct sunlight daily) for good yield; sites heavily shaded by trees or buildings are unsuitable for fruiting vegetables, though leafy vegetables tolerate partial shade better.

3.1.3 Soil and climate requirements

Soil pH: most vegetables and fruits perform best in a slightly acidic to neutral pH range of 5.5-6.8; outside this range, nutrient availability is reduced (very acidic soils below pH 5.0 cause aluminium and manganese toxicity and reduce phosphorus and calcium availability; very alkaline soils above pH 7.5 reduce iron, zinc, and manganese availability); lime is applied to raise pH on acidic soils; sulphur or organic matter is applied to lower pH on alkaline soils. Soil texture: a loam or sandy loam texture is generally preferred for both orchards and vegetable gardens because it combines adequate water-holding capacity with good drainage and aeration; pure sand drains too quickly and holds too little water and nutrients; pure clay drains too slowly and becomes waterlogged and compacted.

Climatic zones in Nigeria relevant to fruit and vegetable production: the humid forest zone (south; high rainfall 1,500-3,000 mm; suitable for citrus, plantain, cocoyam, leafy vegetables, and pineapple); the derived and Guinea savanna zone (middle belt; moderate rainfall 1,000-1,500 mm; distinct dry season; suitable for mango, cashew, tomato, pepper, and most fruiting vegetables); the Sudan and Sahel savanna zone (north; low rainfall 500-1,000 mm; long dry season; suitable for irrigated vegetable production (onion, tomato, pepper) during the dry season using Fadama and irrigation schemes); and the Jos and Mambilla Plateau highlands (cooler temperatures due to elevation; suitable for temperate vegetables (cabbage, carrot, Irish potato) and temperate fruits (apple, pear, peach)).

Fill in the blank: Most vegetables and fruits perform best in a slightly acidic to neutral soil pH range of ________ ; outside this range, nutrient availability is reduced and lime or sulphur amendments may be needed to correct the pH.

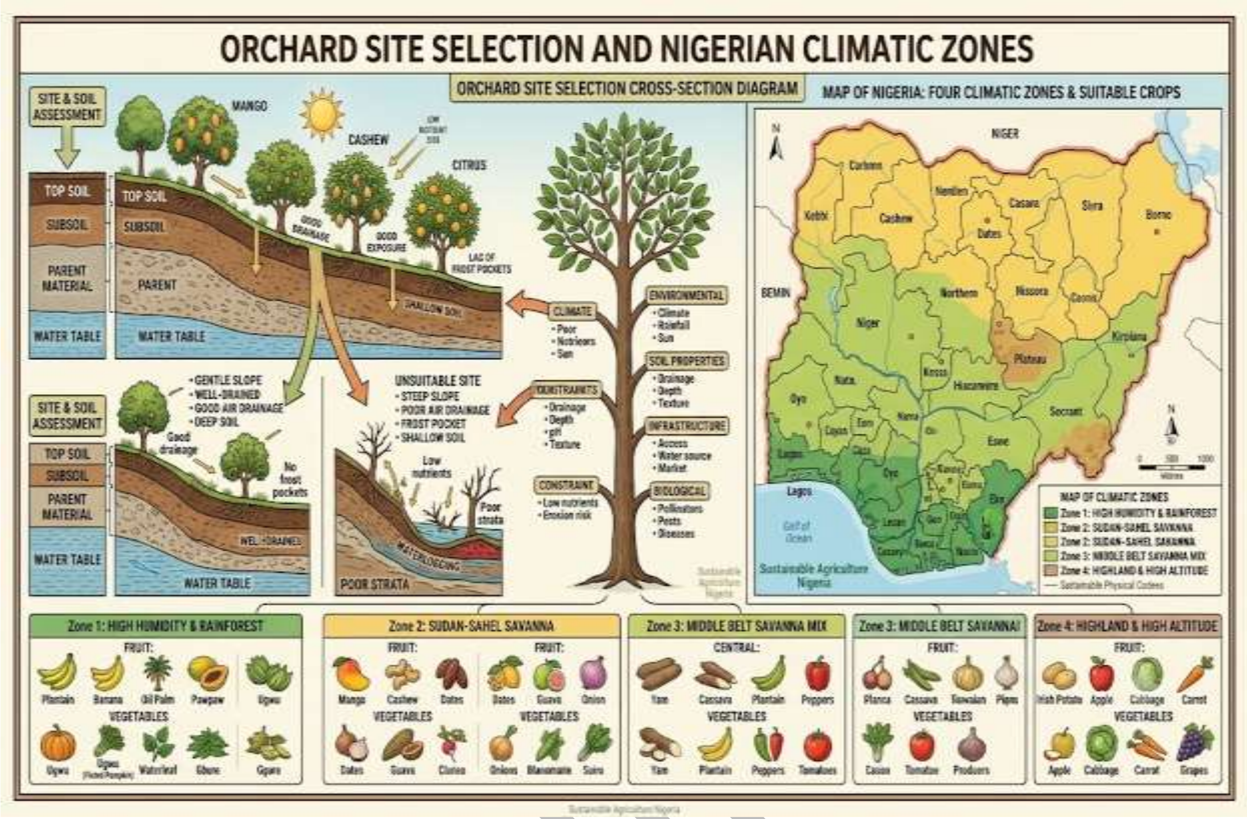

Figure 3.1: Site selection factors for orchards and gardens

Pilot questions 3.1

11. State five factors to consider when selecting a site for a fruit orchard.
12. State five factors to consider when selecting a site for a vegetable garden.
13. Explain why soil depth is more important for orchard sites than for vegetable garden sites.
14. State the optimum soil pH range for most vegetables and fruits and explain how to correct soils outside this range.
15. Name four climatic zones in Nigeria and state one suitable fruit or vegetable crop for each.

3.2 Orchard Layout and Design

3.2.1 Orchard planting systems

The planting system is the geometric arrangement of trees within the orchard. Square system: trees are planted at equal distances in rows and columns forming squares; the simplest and most widely used system; allows cultivation, spraying, and harvesting machinery to move in two directions; e.g. mango or citrus planted at 8 m x 8 m. Rectangular system: trees are planted at unequal distances between rows and within rows (wider between rows, closer within row); allows more trees per hectare while still permitting machinery access between rows; commonly used for high-density plantings.

Triangular (quincunx) system: trees are arranged so that each tree is equidistant from its six neighbours, forming a series of equilateral triangles; allows about 15% more trees per unit area than the square system at the same within-row spacing; more complex to lay out. Contour planting: on sloping land, trees are planted in rows that follow the natural contour lines rather than a rigid grid; reduces soil erosion and runoff; essential on slopes above 8-10%; commonly combined with terracing. Hedgerow (high-density) system: trees are planted very close together within rows (1-3 m) with wider spacing between rows (3-5 m), forming a continuous hedge; trees are kept small through pruning and training; allows very high planting density and early, high yields per hectare; increasingly used for modern citrus, mango, and cashew plantations in Nigeria.

Fill in the blank: The ________ system arranges trees so that each tree is equidistant from its six neighbours, forming equilateral triangles; it allows about 15% more trees per unit area than the square system at the same within-row spacing.

3.2.2 Spacing and density in orchard establishment

Spacing is the distance between trees within and between rows; it determines the planting density (number of trees per hectare) and has major effects on light interception, competition, yield per tree, yield per hectare, and ease of management. Factors determining appropriate spacing: the mature size and vigour of the species/variety (large-canopy trees such as mango and avocado need wider spacing, 8-12 m, than smaller trees such as citrus on dwarfing rootstock, 4-6 m); soil fertility (more fertile soils support larger canopies and may need slightly wider spacing); rainfall and irrigation availability (closer spacing increases competition for water; adequate irrigation can support closer spacing); and the management system (mechanised orchards need wider row spacing for equipment access; hand-managed orchards can use closer spacing).

Typical spacings for common Nigerian fruit trees: mango (10 m x 10 m for standard varieties; 6 m x 6 m for high-density/dwarf varieties); citrus, orange (6 m x 6 m to 7 m x 7 m); cashew (8 m x 8 m to 10 m x 10 m); guava (5 m x 5 m to 6 m x 6 m); avocado (8 m x 8 m to 10 m x 10 m); pawpaw/papaya (2.5 m x 2.5 m to 3 m x 3 m; a fast-growing, short-lived crop suitable for closer spacing); pineapple (30 cm x 30 cm within double rows; a non-tree crop planted at very high density). Planting density calculation: number of plants per hectare = 10,000 m2 divided by (row spacing x within-row spacing); for example, mango at 10 m x 10 m gives 10,000/(10x10) = 100 trees per hectare.

Fill in the blank: Planting density (number of plants per hectare) is calculated as 10,000 m2 divided by (row spacing x within-row spacing); mango planted at 10 m x ________ m gives a density of 100 trees per hectare.

3.2.3 Windbreaks, roads, and support infrastructure

Windbreaks: rows of tall, fast-growing trees (e.g. Casuarina, Gmelina, or Leucaena) planted around the perimeter of an orchard, especially on the windward side, to reduce wind speed and protect fruit trees from wind damage (branch breakage, fruit drop, leaf desiccation) and to reduce evapotranspiration losses; windbreaks are typically planted 1-2 years before the main orchard to allow them to establish first; they should be set back from the orchard edge by a distance equal to their expected mature height to avoid excessive shading and root competition with the crop trees.

Internal roads and access: a well-designed orchard includes a perimeter road around the boundary and internal access roads/lanes between blocks of trees, spaced according to the width of spraying and harvesting equipment to be used (typically every 4-8 rows); roads should be designed to follow the natural drainage and avoid creating channels for erosion. Irrigation infrastructure: water source (borehole, river, or reservoir), pump, mainline and submain pipes, and drip lines or microsprinklers are laid out according to the tree spacing and topography, typically before or during planting; gravity-fed systems are preferred where the topography allows to reduce pumping costs. Other support infrastructure: a packing shed or grading area near the orchard entrance; a tool and equipment store; a chemical/agrochemical store (separate, secure, away from water sources); and worker facilities (rest area, toilet, drinking water) for larger commercial orchards.

Fill in the blank: A ________ is a row of tall, fast-growing trees planted around the perimeter of an orchard, especially on the windward side, to reduce wind speed and protect fruit trees from wind damage and excessive water loss.

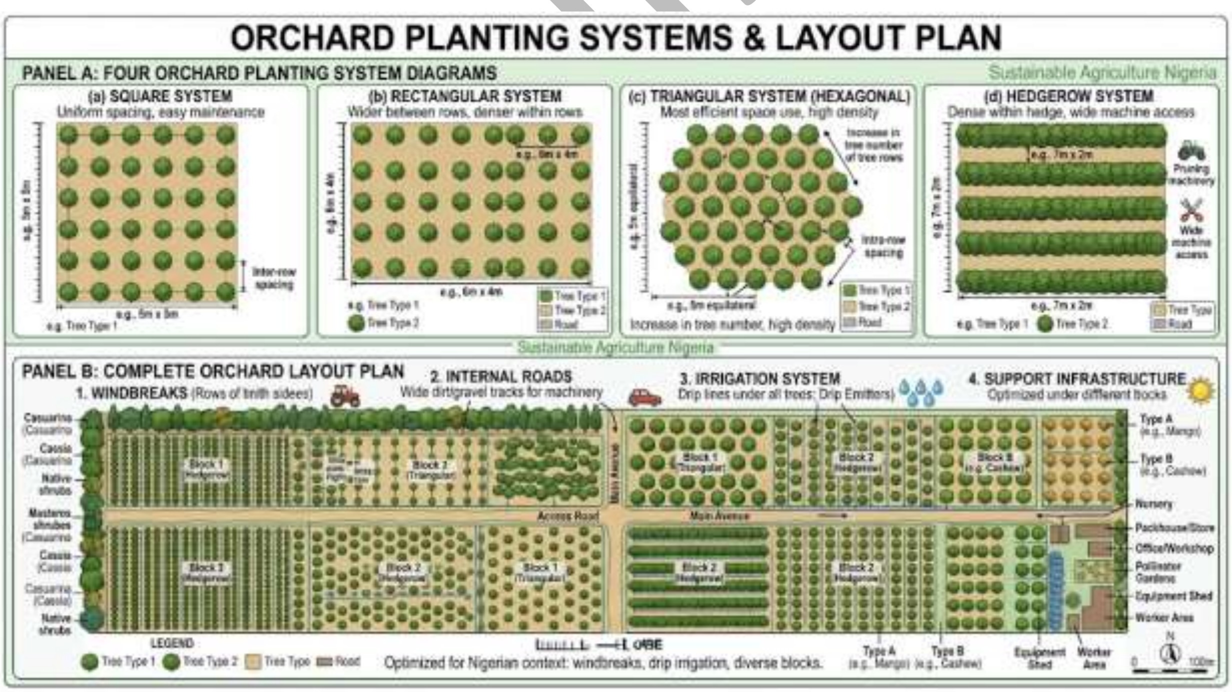

Figure 3.2: Orchard planting systems and infrastructure layout

Pilot questions 3.2

11. Describe the square and rectangular orchard planting systems.
12. Explain the triangular (quincunx) planting system and state its main advantage.
13. State four factors that determine appropriate tree spacing in orchard establishment.
14. Calculate the planting density for citrus planted at 6 m x 6 m spacing.
15. Explain the purpose of a windbreak and state where it should be planted relative to the orchard.

3.3 Vegetable Garden Layout and Design

3.3.1 Bed and plot systems

Raised bed system: the most common system for intensive vegetable production in Nigeria; beds are 1-1.2 m wide (narrow enough to reach the centre from either side without stepping on the bed), 15-30 cm high, and any convenient length, separated by 40-50 cm pathways; raised beds improve drainage, warm up faster in the rainy season, allow concentrated application of compost and fertiliser, and keep pathways and growing areas clearly separated to avoid soil compaction in the root zone. Flat bed system: beds are at the same level as the surrounding ground; simpler to construct than raised beds; suitable for well-drained soils and crops tolerant of less aeration; commonly used for direct-seeded field vegetables (okra, cowpea) grown at larger scale.

Sunken bed (basin) system: beds are slightly below the surrounding ground level, with raised borders; used in very dry areas to conserve irrigation water by directing it into the basin around each plant or row; common in Sahel zone dry-season vegetable production. Ridge system: soil is mounded into ridges 15-30 cm high; used for crops requiring loose, well-aerated soil for root or tuber development (e.g. some root vegetables) or to improve drainage on heavier soils; less common for leafy and fruiting vegetables than raised beds. Block/plot system: the garden is divided into rectangular plots of a convenient size (e.g. 5 m x 10 m), each assigned to a single crop or rotation group; plots are separated by access paths; commonly used in larger commercial market gardens and school gardens for ease of management, record keeping, and rotation planning.

Fill in the blank: The ________ bed system is the most common system for intensive vegetable production in Nigeria; beds are 1-1.2 m wide, 15-30 cm high, separated by 40-50 cm pathways, and improve drainage and aeration compared to flat beds.

3.3.2 Crop arrangement and rotation planning

Crop arrangement within the garden layout should consider: plant height and shading (tall crops such as okra and maize are placed on the north or east side, or in separate blocks, so they do not shade shorter crops; intercropped tall and short crops should be spatially arranged to allow adequate light to all); water requirements (crops with similar water needs are grouped together for efficient irrigation scheduling; drought-tolerant crops separated from high-water-demand crops); and harvest frequency (crops harvested frequently, such as leafy vegetables harvested every few days, are placed near the entrance and main path for easy access; crops harvested once, such as cabbage, can be placed further away).

Crop rotation planning is an essential part of vegetable garden layout: rotation is the planned sequence of different crop types on the same plot over successive seasons to prevent the buildup of soil-borne pests, diseases, and nutrient depletion associated with continuous monocropping. A simple rotation principle groups crops by plant family and rotates families through different plots each season: solanaceous crops (tomato, pepper, garden egg; susceptible to bacterial wilt and nematodes) should not follow each other in the same plot; cucurbits (cucumber, pumpkin, melon; susceptible to fusarium wilt) should be rotated with non-cucurbit crops; legumes (cowpea, beans; fix nitrogen) are excellent rotation crops to precede heavy nitrogen feeders like leafy vegetables and maize. A 3-4 year rotation cycle dividing the garden into 3-4 plots, each growing a different crop family in sequence, is a practical system for Nigerian market and school gardens.

Fill in the blank: Crop ________ is the planned sequence of different crop families on the same plot over successive seasons to prevent the buildup of soil-borne pests and diseases; legumes are valuable rotation crops because they fix nitrogen for the following crop.

3.3.3 Irrigation and drainage layout

Irrigation layout in a vegetable garden depends on the irrigation method selected. Drip irrigation: drip tape or pipe with emitters is laid along each row or down the centre of each bed; water is delivered directly to the root zone at low pressure; the most water-efficient method (50-70% savings compared to overhead methods); reduces weed growth between rows since pathways stay dry; requires a water source, pump (if not gravity-fed), filter, and a network of mainlines, submains, and drip lines; increasingly used in Nigerian commercial vegetable production. Sprinkler irrigation: overhead sprinklers (fixed or rotating) distribute water over the whole bed surface; simpler to install than drip but less water-efficient; wets foliage, which can increase disease risk in humid conditions; suitable for closely spaced leafy vegetables.

Furrow irrigation: water flows along furrows between raised beds or ridges, soaking into the bed from the sides; simple, low-cost, and does not require special equipment beyond a water source and channels; suitable for larger plots with available gravity flow; less precise water control than drip. Watering can irrigation: hand watering using watering cans; suitable for small home gardens and nursery beds; labour-intensive; not practical for larger commercial plots. Drainage layout: pathways between beds should be laid out to also function as drainage channels, sloping gently (0.5-1%) towards a main drainage channel at the lowest point of the garden; the main drainage channel should lead away from the garden to a natural watercourse or soakaway, never allowing water to pool within the cropped area; in heavy rainfall areas, raised beds combined with a well-planned pathway drainage network are essential to prevent waterlogging and root disease.

Fill in the blank: ________ irrigation delivers water directly to the root zone through emitters along each row, achieving 50-70% water savings compared to overhead sprinkler methods and reducing weed growth in the dry pathways between rows.

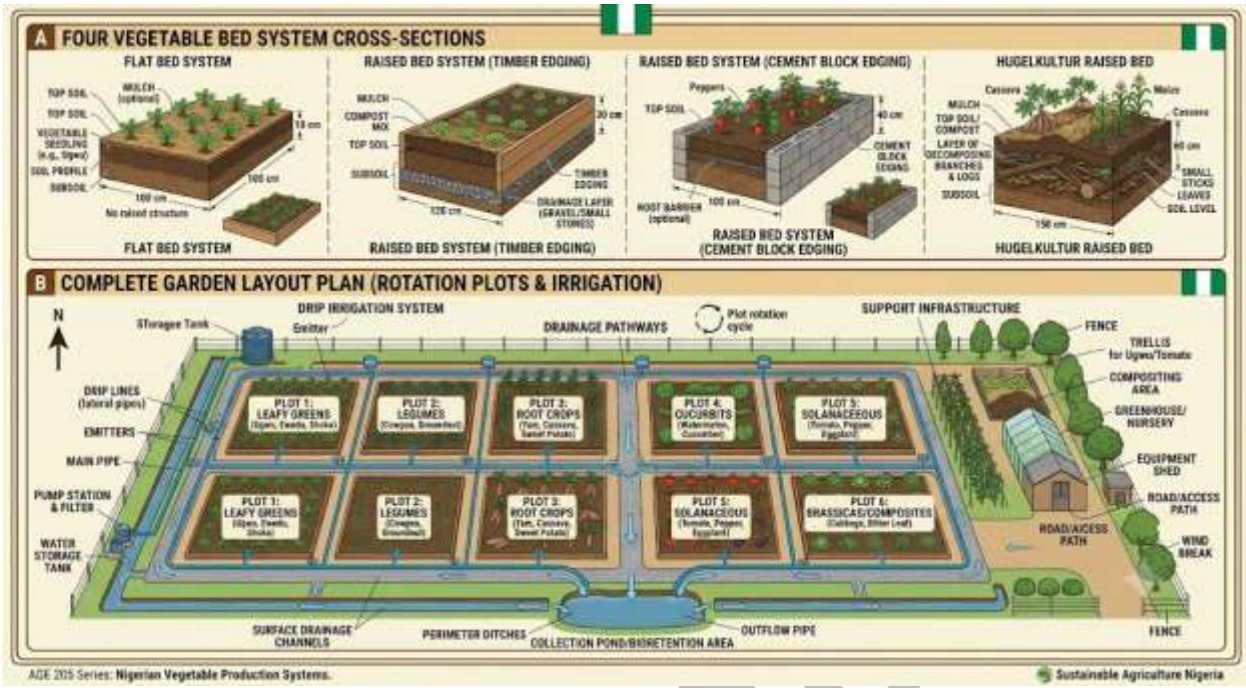

Figure 3.3: Vegetable garden bed systems and irrigation-drainage layout

Pilot questions 3.3

11. Describe the raised bed system and state two advantages over the flat bed system.
12. Explain the sunken bed (basin) system and state where it is commonly used in Nigeria.
13. Explain how plant height and water requirements influence crop arrangement in a garden layout.
14. Explain crop rotation and state one example of a good rotation sequence using legumes.
15. Compare drip irrigation and furrow irrigation in terms of water efficiency and cost.

3.4 Establishment and Early Management

3.4.1 Orchard establishment practices

Establishing a new orchard follows a defined sequence of operations. Land clearing and preparation: clear existing vegetation; remove tree stumps and roots that could harbour pests or interfere with new planting; plough or deep-dig the planting positions (or the whole area for smaller orchards) to break up compacted soil. Planting hole preparation: dig planting holes 60 cm x 60 cm x 60 cm (or larger for big-rooted species) at the planned spacing; mix the excavated topsoil with well-decomposed compost or farmyard manure (10-20 kg per hole) and a small quantity of rock phosphate or basal NPK fertiliser; refill the hole partially with this mixture before planting, leaving space for the root ball.

Planting: position grafted or budded seedlings so that the graft union remains 10-15 cm above the final soil level (to prevent rootstock suckering and scion rooting); firm the soil around the roots to eliminate air pockets; water thoroughly immediately after planting; apply a mulch of dry grass or straw around the base (keeping it away from direct stem contact to avoid collar rot) to conserve moisture and suppress weeds. Staking: newly planted trees, especially in windy locations, should be supported with a single stake tied loosely to the main stem to prevent wind rocking, which can damage the developing root system. Early irrigation: newly planted trees require regular watering (2-3 times per week) for the first 2-3 months until established, then gradually reduced; drought during this establishment period is the most common cause of orchard establishment failure.

Fill in the blank: When planting a grafted fruit tree seedling, the graft union should remain ________ cm above the final soil level to prevent rootstock suckering and scion rooting, which would defeat the purpose of using a disease-resistant or dwarfing rootstock.

3.4.2 Garden establishment practices

Establishing a new vegetable garden also follows a defined sequence. Site clearing and land preparation: clear vegetation, remove debris, and carry out primary and secondary tillage as described in Series 1 (ploughing to 25-30 cm; harrowing to a fine tilth). Layout marking: using pegs and string, mark out the boundaries of beds, pathways, and plots according to the garden plan; ensure pathways are wide enough (40-50 cm minimum) for comfortable movement with tools and harvested produce; mark the irrigation mainline route and drainage channel locations before bed formation begins. Bed formation: construct raised beds, flat beds, or ridges according to the chosen system; incorporate compost or manure during bed formation, not after, to ensure even distribution through the root zone.

Infrastructure installation: install the water source (borehole, tank) and irrigation system (drip lines, sprinklers, or furrow channels) before or immediately after bed formation; erect perimeter fencing to protect against livestock and theft; construct a small tool store and, for larger gardens, a farm office or shaded rest area. Initial planting: stagger the first planting across the available plots according to the crop rotation plan, so that the garden begins producing a range of vegetables rather than a single bulk harvest; nursery-raised seedlings (tomato, pepper, cabbage) are transplanted following the procedures described in Series 1; direct-seeded crops (okra, cowpea, leafy vegetables) are sown directly into the prepared beds.

Fill in the blank: Layout ________ using pegs and string is carried out before bed formation begins, marking the boundaries of beds, pathways, irrigation mainline routes, and drainage channels according to the garden design plan.

3.4.3 Early management of newly established orchards and gardens

Newly established orchards require specific early management to ensure good survival and future productivity. Weed control: weeds compete intensely with young trees for water and nutrients during establishment; a weed-free circle of 1-1.5 m radius should be maintained around each young tree by hand weeding, mulching, or careful herbicide use, avoiding contact with the young stem. Formative pruning: young fruit trees are pruned during the first 2-3 years to establish a strong, well-balanced framework of main branches (typically 3-4 main scaffold branches selected and spaced around the trunk); this formative pruning determines the tree's structure for its productive lifetime and influences future yield, light interception, and ease of harvesting. Gap filling: any trees that die or fail to establish within the first year should be replaced promptly to maintain a uniform stand and avoid productivity loss.

Newly established vegetable gardens require: regular monitoring of seedling establishment (replace any transplants that fail within the first week; gap fill direct-seeded rows with thinning or re-sowing as needed); early pest and disease scouting (newly transplanted and germinating seedlings are highly vulnerable to cutworms, damping-off disease, and other early-stage problems; daily inspection during the first 2-3 weeks allows early intervention); irrigation scheduling adjustment (newly transplanted seedlings need more frequent, lighter watering than established plants; this is gradually adjusted as root systems develop); and record keeping from the start (recording planting dates, varieties, inputs applied, and early observations establishes the foundation for the enterprise's production and financial records, as covered further in subsequent courses). Both orchards and gardens benefit from a written establishment plan and calendar that schedules all these early management tasks systematically rather than reactively.

Fill in the blank: ________ pruning of young fruit trees during the first 2-3 years establishes a strong, well-balanced framework of main scaffold branches; this determines the tree's structure for its entire productive lifetime and influences future yield and ease of harvesting.

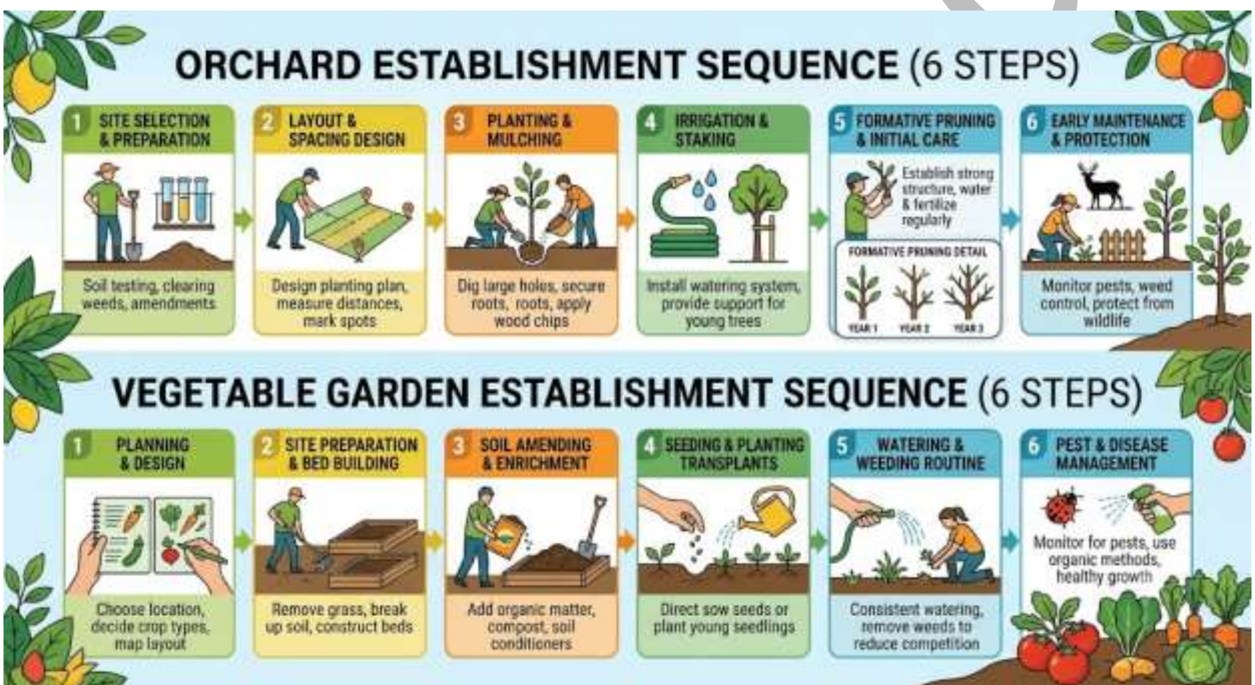

Figure 3.4: Orchard and garden establishment practices

Pilot questions 3.4

11. Describe the procedure for digging and preparing a planting hole for a fruit tree.
12. Explain why the graft union must remain above soil level when planting a grafted tree.
13. Describe the steps in establishing a new vegetable garden from land clearing to initial planting.
14. Explain the purpose of formative pruning in young fruit trees.
15. State four early management practices required for a newly established vegetable garden.

Series Summary

This Series examined the selection, layout, and establishment of orchards and vegetable gardens. **Orchard site selection is the process of choosing land with suitable climate, soil, slope, water supply, wind protection, and market access for long-term fruit production.** A good orchard site should have deep, well-drained soil, a gentle slope, reliable water, and protection from strong winds. **Garden site selection is the choice of land suitable for vegetable production**, with fertile friable soil, full sunlight, dependable water, easy access, and protection from flooding and livestock. Planting systems include square, rectangular, triangular, contour, and hedgerow arrangements, while tree spacing depends on crop type and canopy size. Important infrastructure includes roads, irrigation lines, windbreaks, packing sheds, fencing, and safe agrochemical storage.

The Series also covered garden-bed systems, crop arrangement, rotation, irrigation, drainage, and early management. **Garden beds are prepared planting areas designed to improve drainage, aeration, water conservation, and crop management.** They may be raised, flat, sunken, ridged, or divided into blocks. Crops should be arranged to reduce shading, grouped by water needs, and rotated by plant family to limit pests, diseases, and nutrient depletion. Orchard and garden establishment involve land clearing, tillage, marking, planting, compost application, irrigation installation, staking, mulching, pruning, gap filling, pest scouting, and record keeping. By completing this Series, students should achieve SLOs 3.1–3.4.

Glossary of Terms

- **Block/plot system:** a garden layout in which the area is divided into rectangular plots, each assigned to a crop or rotation group; used in commercial and school gardens for ease of management.
- **Contour planting:** planting trees in rows that follow the natural contour lines of sloping land to reduce erosion and runoff; essential on slopes above 8-10%.

- **Crop rotation:** the planned sequence of different crop families on the same plot over successive seasons to prevent buildup of soil-borne pests, diseases, and nutrient depletion.
- **Drip irrigation:** an irrigation method that delivers water directly to the root zone through emitters in a tube; the most water-efficient method; reduces weed growth in dry pathways.
- **Formative pruning:** pruning of young fruit trees during the first 2-3 years to establish a strong framework of 3-4 main scaffold branches; determines tree structure for its productive lifetime.
- **Furrow irrigation:** an irrigation method in which water flows along channels between raised beds or ridges and soaks into the bed from the sides; simple and low-cost.
- **Hedgerow (high-density) system:** an orchard planting system with very close within-row spacing (1-3 m) and wider between-row spacing, forming continuous hedges; allows very high planting density and early yields.
- **Planting density:** the number of plants per hectare; calculated as 10,000 m2 divided by the product of row spacing and within-row spacing.
- **Quincunx (triangular) system:** an orchard planting system in which each tree is equidistant from its six neighbours, forming equilateral triangles; allows about 15% more trees per unit area than the square system.
- **Raised bed:** a planting bed elevated 15-30 cm above the surrounding ground level, typically 1-1.2 m wide; the most common bed system for intensive vegetable production.
- **Rectangular system:** an orchard planting system with unequal row and within-row spacing (wider between rows, closer within row); allows more trees per hectare while permitting machinery access.
- **Square system:** an orchard planting system in which trees are planted at equal distances in rows and columns; the simplest and most widely used planting system.

- **Sunken bed (basin):** a vegetable bed slightly below the surrounding ground level with raised borders, used to conserve irrigation water in very dry areas such as the Sahel zone.
- **Windbreak:** a row of tall, fast-growing trees planted around the perimeter of an orchard, especially on the windward side, to reduce wind speed and protect crop trees from wind damage and excessive water loss.

Concept Check Questions [Series 3]

Objective Questions

1. Because fruit trees are perennial and remain productive for many years, orchard site selection must consider climate, topography, soil depth, wind exposure, and ________ availability. (Linked to SLO 3.1)
2. The ________ system arranges trees so each is equidistant from six neighbours, forming equilateral triangles, allowing about 15% more trees per unit area than the square system. (Linked to SLO 3.2)
3. The ________ bed system is the most common system for intensive vegetable production in Nigeria, with beds 1-1.2 m wide and 15-30 cm high. (Linked to SLO 3.3)
4. ________ irrigation delivers water directly to the root zone through emitters, achieving 50-70% water savings compared to overhead sprinklers. (Linked to SLO 3.3)
5. When planting a grafted fruit tree, the graft union should remain ________ cm above the final soil level to prevent rootstock suckering. (Linked to SLO 3.4)

Short-Answer Questions

1. State four factors in site selection for a fruit orchard. (Linked to SLO 3.1)
2. Name four orchard planting systems. (Linked to SLO 3.2)
3. Name four vegetable garden bed systems and state one use case for each. (Linked to SLO 3.3)
4. State three benefits of crop rotation in a vegetable garden. (Linked to SLO 3.3)
5. State four steps in establishing a new orchard. (Linked to SLO 3.4)

Long-Answer Questions

17. Describe the factors guiding site selection for orchards and vegetable gardens, including soil and climate requirements. (Linked to SLO 3.1)

18. Describe orchard planting systems, spacing decisions, and support infrastructure. (Linked to SLO 3.2)
19. Describe vegetable garden bed systems, crop rotation, irrigation/drainage layout, and establishment and early management practices for orchards and gardens. (Linked to SLOs 3.3, 3.4)

Answers to Concept Check Questions [Series 3]

Objective Questions

1. Water.
2. Triangular/quincunx.
3. Raised.
4. Drip.
5. 10-15.

Short-Answer Questions

1. Climate suitability, topography/slope, soil depth and drainage, wind exposure (and water availability).
2. Square, rectangular, triangular (quincunx), and hedgerow (high-density) systems.
3. Raised bed (intensive production; drainage); flat bed (simple; well-drained soils); sunken/basin (dry Sahel zone water conservation); block/plot (commercial and school garden management).
4. Prevents buildup of soil-borne pests and diseases; reduces nutrient depletion from continuous monocropping; legumes fix nitrogen for following crops.
5. Land clearing and stump removal; digging planting holes with compost and fertiliser; planting with correct graft union height; staking and mulching.

Long-Answer Questions

1. Orchard site factors: climate suitability (matching species needs); gentle slope (2-8%; avoid steep slopes above 15%); deep well-drained soil (1-1.5 m); wind exposure (windbreaks needed); water availability; market access. Garden site factors: fertile friable soil; reliable water supply; full sun (6-8 hours); proximity to market/home; protection from flooding and livestock. Soil/climate requirements: pH 5.5-6.8 optimum (lime for acidic; sulphur for alkaline); loam/sandy loam texture preferred; Nigerian zones: humid forest (citrus, plantain), Guinea savanna (mango, tomato), Sudan/Sahel (irrigated dry-season vegetables), Jos/Mambilla highlands (temperate crops).
2. Planting systems: square (equal spacing; simplest; two-way machinery access); rectangular (wider rows, closer within-row; higher density); triangular/quincunx (equidistant from six neighbours; 15% more trees); contour (sloping land; erosion control); hedgerow (very close within-row; high density; modern plantations). Spacing factors: mature tree size/vigour, soil fertility, rainfall/irrigation, management system. Typical spacings: mango 10x10 m; citrus 6x6-7x7 m; cashew 8x8-10x10 m; density = 10,000/(row x within-row spacing). Infrastructure: windbreak (perimeter; windward side; set back by mature height); internal roads (every 4-8 rows); irrigation mainlines and submains; packing shed; separate agrochemical store; worker facilities.
3. Bed systems: raised bed (most common; drainage/aeration), flat bed (simple), sunken/basin (Sahel water conservation), ridge (drainage/root crops), block/plot (rotation management). Crop rotation: rotate plant families (solanaceous, cucurbits, legumes, leafy vegetables) over 3-4 years; prevents pest/disease buildup; legumes fix nitrogen for following crops. Irrigation/drainage: drip (most efficient), sprinkler (simple but wets foliage), furrow (low-cost gravity), watering can (small scale); pathways double as drainage sloping to main channel and soakaway. Orchard establishment: clear land; dig holes (60x60x60 cm) with compost/rock phosphate; plant with graft union 10-15 cm above soil; stake; mulch; water regularly for 2-3 months. Garden establishment: clear and till; mark layout; form beds with compost; install infrastructure; stagger initial planting. Early management: weed-free circle

around trees; formative pruning (3-4 scaffold branches); gap filling; daily pest scouting; adjusted irrigation; record keeping.

Answers to Pilot Questions [Series 3]

Part 3.1

1. Five factors: climate suitability (matching species temperature/rainfall needs); topography (gentle 2-8% slope preferred); soil depth and drainage (deep, well-drained soil at least 1-1.5 m); wind exposure (windbreaks needed on exposed sites); water availability for irrigation, especially during establishment.
2. Five factors: soil fertility and texture (fertile, friable, well-drained loam); water supply (reliable irrigation source); sunlight exposure (6-8 hours full sun); proximity to market and home; protection from flooding and livestock.
3. Soil depth matters more for orchards because fruit trees develop deep, extensive root systems over their long lifespan (15-50 years) that must access water and nutrients from 1-1.5 m or more of soil depth; shallow soil restricts root development, causing instability and poor drought tolerance in mature trees. Vegetable crops are shallow-rooted and short-cycle, so they can perform well even where subsoil depth is more limited, provided the topsoil is fertile and well-drained.
4. Optimum pH range: 5.5-6.8. Correction: lime (calcium carbonate or dolomite) is applied to raise pH on acidic soils below this range; sulphur or organic matter amendments are used to lower pH on alkaline soils above this range.
5. Four zones: humid forest zone (south; citrus, plantain, pineapple); Guinea savanna zone (middle belt; mango, tomato); Sudan/Sahel savanna zone (north; irrigated dry-season onion/tomato); Jos/Mambilla highlands (temperate crops: cabbage, carrot, apple).

Part 3.2

1. Square system: trees planted at equal distances in rows and columns forming squares; allows machinery movement in two directions; simplest and most widely used. Rectangular system: trees planted at unequal distances (wider between rows, closer within row); allows more trees per hectare while still permitting machinery access between rows.
2. The triangular (quincunx) system arranges trees so each tree is equidistant from its six neighbours, forming equilateral triangles. Main advantage: it allows about 15% more trees per unit area than the square system at the same within-row spacing, increasing yield per hectare.
3. Four factors: mature size and vigour of the species/variety (larger canopy trees need wider spacing); soil fertility (more fertile soil may support wider spacing for larger canopies); rainfall and irrigation availability (irrigation supports closer spacing); management system (mechanised orchards need wider rows for equipment access).
4. Density = 10,000 m2 / (row spacing x within-row spacing) = 10,000 / (6 x 6) = 10,000/36 = approximately 278 trees per hectare.
5. A windbreak reduces wind speed and protects fruit trees from wind damage (branch breakage, fruit drop, leaf desiccation) and reduces evapotranspiration losses. It should be planted around the perimeter of the orchard, especially on the windward side, set back from the orchard edge by a distance approximately equal to its expected mature height to avoid excessive shading and root competition with the crop trees.

Part 3.3

1. The raised bed system uses beds 1-1.2 m wide and 15-30 cm high, separated by 40-50 cm pathways. Two advantages over flat beds: (1) improved drainage, reducing waterlogging risk; (2) better aeration and faster soil warming, supporting more vigorous root growth and earlier planting in the rainy season.
2. The sunken bed (basin) system places beds slightly below the surrounding ground level with raised borders, directing irrigation water into the basin around each plant or

row to conserve water. It is commonly used in the Sahel zone of northern Nigeria for dry-season irrigated vegetable production where water conservation is critical.

3. Plant height: tall crops (okra, maize) are placed on the north or east side or in separate blocks so they do not shade shorter crops; intercropped tall and short crops are spatially arranged to allow adequate light to all. Water requirements: crops with similar water needs are grouped together for efficient irrigation scheduling, with drought-tolerant crops separated from high-water-demand crops to avoid over- or under-watering any group.
4. Crop rotation is the planned sequence of different crop families on the same plot over successive seasons to prevent buildup of soil-borne pests, diseases, and nutrient depletion from continuous monocropping. Example: legumes (cowpea, beans), which fix atmospheric nitrogen, are grown before heavy nitrogen-feeding crops such as leafy vegetables or maize, improving soil fertility for the following crop.
5. Drip irrigation delivers water directly to the root zone through emitters, achieving 50-70% water savings compared to overhead methods, but requires higher initial investment in pipes, emitters, and filters. Furrow irrigation is simple and low-cost, requiring only channels and a gravity-fed or pumped water source, but is less water-efficient and offers less precise control over the amount of water each plant receives.

Part 3.4

1. Dig planting holes 60 cm x 60 cm x 60 cm (or larger for big-rooted species) at the planned spacing; mix the excavated topsoil with 10-20 kg of well-decomposed compost or farmyard manure and a small quantity of rock phosphate or basal NPK fertiliser; partially refill the hole with this mixture before planting, leaving enough space for the root ball.
2. The graft union must remain above soil level (10-15 cm) because burying it would allow the scion (the high-yielding upper variety) to develop its own roots and the rootstock to produce suckers, both of which defeat the purpose of using a disease-

resistant or dwarfing rootstock and can lead to the desirable scion characteristics being lost over time.

3. Clear the site and carry out primary and secondary tillage; mark the layout of beds, pathways, irrigation routes, and drainage channels with pegs and string; form the beds (raised, flat, or ridge) incorporating compost during formation; install infrastructure (water source, irrigation system, fencing, tool store); carry out staggered initial planting of transplants and direct-seeded crops according to the rotation plan.
4. Formative pruning establishes a strong, well-balanced framework of 3-4 main scaffold branches in young fruit trees during their first 2-3 years. This determines the tree's structure for its entire productive lifetime, influencing future yield potential, light interception within the canopy, and ease of spraying and harvesting operations.
5. Four practices: regular monitoring of seedling establishment with prompt gap filling; early and frequent pest and disease scouting during the first 2-3 weeks (cutworms, damping-off); adjusted irrigation scheduling (more frequent, lighter watering for new transplants); record keeping from the start (planting dates, varieties, inputs, observations).

References and Attributions

Textual References (Books and External Sources)

- FAO (Food and Agriculture Organization of the United Nations). (2025). Guidelines for sustainable agriculture. FAO.
- Tindall, H. D. (1983). Vegetables in the tropics. Macmillan Press, London.
- Westwood, M. N. (1993). Temperate-zone pomology: Physiology and culture (3rd ed.). Timber Press, Portland.
- Janick, J., & Paull, R. E. (2008). The encyclopedia of fruit and nuts. CABI Publishing, Wallingford.

Figures, Plates, Tables, and Boxes

- Figure 3.1: Site selection factors for orchards and gardens Attribution: AI generated. Suggested OER search string: "orchard site selection slope drainage windbreak Nigeria climatic zones fruit vegetable production map OER".
- Figure 3.2: Orchard planting systems and infrastructure layout Attribution: AI generated. Suggested OER search string: "orchard planting system square rectangular triangular hedgerow windbreak irrigation layout Nigeria fruit OER".
- Figure 3.3: Vegetable garden bed systems and irrigation-drainage layout Attribution: AI generated. Suggested OER search string: "vegetable garden bed system raised flat sunken ridge crop rotation drip irrigation drainage layout Nigeria OER".
- Figure 3.4: Orchard and garden establishment practices Attribution: AI generated. Suggested OER search string: "orchard establishment planting hole formative pruning vegetable garden establishment layout marking bed formation Nigeria OER".

Series 4: Factors Influencing Vegetable and Fruit Production

- **Part 4.1: Climatic Factors**
    - Sub Part 4.1.1: Temperature and its effects on vegetable and fruit crops
    - Sub Part 4.1.2: Rainfall, humidity, and water relations
    - Sub Part 4.1.3: Light and solar radiation
- **Part 4.2: Soil and Edaphic Factors**
    - Sub Part 4.2.1: Soil physical properties
    - Sub Part 4.2.2: Soil chemical properties and nutrients
    - Sub Part 4.2.3: Soil biological factors
- **Part 4.3: Biological and Genetic Factors**
    - Sub Part 4.3.1: Variety and genetic potential
    - Sub Part 4.3.2: Pollinators and beneficial organisms
    - Sub Part 4.3.3: Competing organisms: weeds, pests, and diseases
- **Part 4.4: Management and Socio-Economic Factors**
    - Sub Part 4.4.1: Agronomic management practices
    - Sub Part 4.4.2: Input availability and cost
    - Sub Part 4.4.3: Market access and socio-economic considerations

Introduction

Vegetable and fruit yield and quality are the product of a complex interaction between the genetic potential of the crop, the environment in which it is grown, and the management practices applied by the farmer. Understanding the full range of factors that influence production, climatic, soil, biological, and management/socio-economic, equips the vegetable and fruit grower to diagnose production problems and make informed decisions to improve yield and quality.

This Series examines climatic factors (temperature, rainfall, light); soil and edaphic factors (physical, chemical, and biological properties); biological and genetic factors (variety potential, pollinators, weeds, pests, and diseases); and management and socio-economic factors (agronomic practices, input availability, and market access) that together determine the success of vegetable and fruit production. This understanding sets the stage for the detailed study of pests, diseases, and sustainable management in Series 5.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 4.1** explain the effects of temperature, rainfall, humidity, and light on vegetable and fruit production (Linked to Part 4.1),
- **SLO 4.2** describe the soil physical, chemical, and biological factors that influence vegetable and fruit production (Linked to Part 4.2),
- **SLO 4.3** describe the biological and genetic factors, including variety potential, pollinators, weeds, pests, and diseases, that influence production (Linked to Part 4.3), and
- **SLO 4.4** explain the management and socio-economic factors that influence vegetable and fruit production (Linked to Part 4.4).

4.1 Climatic Factors

4.1.1 Temperature and its effects on vegetable and fruit crops

Temperature affects nearly every physiological process in plants, including germination, vegetative growth, flowering, fruit set, fruit development, and ripening. Each crop has a minimum, optimum, and maximum temperature for growth: below the minimum, growth stops or the plant is damaged by chilling; above the maximum, growth stops or the plant is damaged by heat stress; growth and yield are maximised near the optimum. Most tropical vegetables (tomato, pepper, okra) have an optimum growth temperature of 20-30 degrees Celsius; temperatures consistently above 35 degrees Celsius cause flower abortion, poor fruit set, and reduced fruit quality (blossom end rot, sunscald) in tomato and pepper.

Temperate vegetables (cabbage, carrot, Irish potato, lettuce) have lower optimum temperatures (15-20 degrees Celsius) and perform poorly in the Nigerian lowland heat; they are successfully grown in the cooler highland zones (Jos and Mambilla Plateau) or during the coolest months of the year (December-January harmattan period) in the lowlands. Temperature also affects fruit tree flowering: many temperate fruits (apple, pear, peach) require a period of winter chilling (accumulated hours below 7 degrees Celsius) to break dormancy and flower normally; this chilling requirement is the main reason temperate fruits can only be grown successfully on the cooler Nigerian highlands. Diurnal temperature range (the difference between day and night temperature) also affects fruit quality: a wide diurnal range improves fruit colour, sugar accumulation, and flavour in many fruits.

Fill in the blank: Most tropical vegetables (tomato, pepper, okra) have an optimum growth temperature of ________ degrees Celsius; temperatures consistently above 35 degrees Celsius cause flower abortion and poor fruit set.

4.1.2 Rainfall, humidity, and water relations

Rainfall amount and distribution strongly influence vegetable and fruit production. Most vegetables require 25-50 mm of water per week (through rainfall, irrigation, or both) for optimum growth; insufficient water causes wilting, reduced growth, flower and fruit drop, and smaller, lower-quality produce; excessive rainfall or poor drainage causes waterlogging, root rot, and increased disease incidence (especially fungal diseases). Rainfall distribution (not just total amount) matters greatly: a long, uninterrupted dry season (as in northern Nigeria) limits rain-fed vegetable production to the rainy season unless irrigation is available; erratic rainfall with dry spells during critical growth stages (flowering, fruit set) can cause significant yield loss even in a season with adequate total rainfall.

Relative humidity affects both plant growth and disease pressure. Moderate humidity (50-70%) is generally favourable for vegetable growth; very low humidity increases transpiration stress and water demand; very high humidity (above 85%), common in the humid forest zone and during the rainy season, favours the development and spread of fungal and bacterial diseases (late blight, bacterial wilt, anthracnose, powdery mildew) and can interfere with pollination in some crops by causing pollen to clump. Drought stress (water deficit) at different growth stages has different effects: drought during germination prevents seedling establishment; drought during vegetative growth reduces leaf area and photosynthetic capacity; drought during flowering and fruit set causes the most severe yield loss, as it directly reduces the number of fruits or seeds that develop.

Fill in the blank: Drought stress during ________ and fruit set causes the most severe yield loss in vegetable and fruit crops because it directly reduces the number of fruits or seeds that develop, even if vegetative growth was previously adequate.

4.1.3 Light and solar radiation

Light is the energy source for photosynthesis and also regulates many developmental processes through its intensity, duration (photoperiod), and quality (wavelength composition). Light intensity: most vegetables and fruit trees require full sun (at least 6-8 hours of direct sunlight) for maximum photosynthesis and yield; shading reduces yield, causes etiolation (excessive stem elongation and weak growth as plants stretch towards light), and delays flowering and fruiting; some leafy vegetables (lettuce, some Amaranthus types) tolerate partial shade better than fruiting vegetables. Photoperiod (day length): as discussed in Series 2, most tropical vegetables are day-neutral; however, some crops (onion bulbing, certain cultivars) are sensitive to day length, requiring a specific photoperiod range for bulb formation or flowering; onion varieties bred for tropical (short-day) conditions must be matched to the latitude of cultivation.

Light quality and canopy management: within a dense plant canopy, lower leaves receive less light and a different spectral composition (more far-red, less blue/red light) than upper leaves, which can trigger shade-avoidance responses (stem elongation, reduced branching); proper plant spacing and pruning/training (as discussed in Series 3) optimise light distribution within the canopy, improving overall photosynthetic efficiency and fruit quality. Solar radiation and fruit quality: adequate light exposure during fruit development improves sugar content, colour development (lycopene in tomato, anthocyanins in some fruits), and overall fruit quality; fruits that develop in heavy shade are often pale, low in sugar, and of poor market quality. This is one reason why proper orchard and garden spacing (Series 3) is critical not just for yield quantity but also for produce quality.

Fill in the blank: Most vegetables and fruit trees require full sun (at least ________ hours of direct sunlight) for maximum photosynthesis and yield; shading reduces yield and causes etiolation (excessive stem elongation as plants stretch towards light).

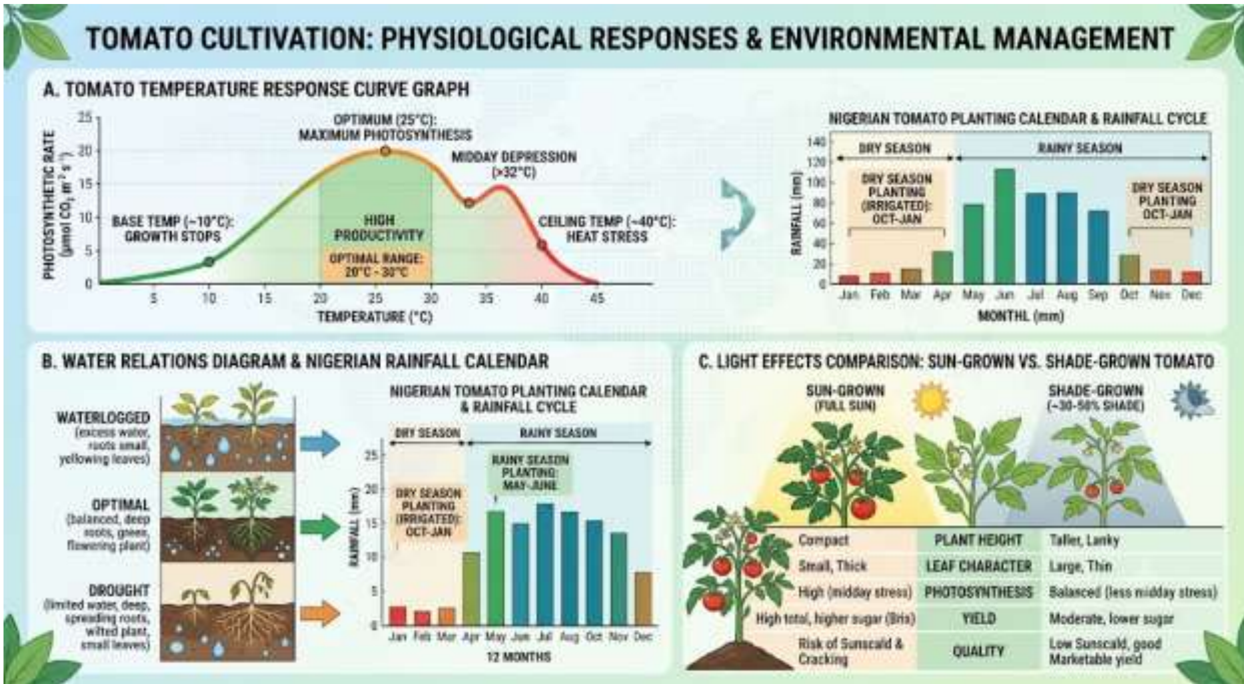

Figure 4.1: Climatic factors affecting vegetable and fruit production

Pilot questions 4.1

1. Explain how temperature affects vegetable crop growth, including the effects of temperatures above the maximum.
2. Explain why temperate fruits such as apple and pear are restricted to the Nigerian highlands.
3. State the typical weekly water requirement for vegetables and explain the effects of both drought and waterlogging.
4. Explain why drought during flowering and fruit set causes more severe yield loss than drought during vegetative growth.
5. Explain the effect of shading on vegetable crop growth and fruit quality.

4.2 Soil and Edaphic Factors

4.2.1 Soil physical properties

Soil texture (the relative proportion of sand, silt, and clay particles) determines the soil's water-holding capacity, drainage rate, and aeration: sandy soils drain rapidly and hold little water and nutrients, requiring frequent irrigation and fertilisation; clay soils hold water and nutrients well but drain slowly and can become waterlogged and compacted; loam soils (a balanced mixture) are generally optimal for most vegetables and fruit trees, combining adequate water retention with good drainage and aeration. Soil structure (the arrangement of soil particles into aggregates) affects root penetration, water infiltration, and aeration: a well-structured, crumbly (friable) soil allows roots to penetrate easily and water and air to move through the soil profile; a compacted or massive structure restricts root growth and reduces infiltration, increasing waterlogging and runoff risk.

Soil depth determines the volume of soil available for root exploration and therefore the water and nutrient reserves accessible to the plant; shallow soils (less than 50 cm to a hardpan, rock, or high water table) severely limit fruit tree development and reduce vegetable yields, especially for deep-rooted or root/tuber crops. Drainage class (how quickly excess water moves through and out of the soil profile) determines waterlogging risk: poorly drained soils require artificial drainage (channels, raised beds) or are unsuitable for most vegetables and fruit trees except those tolerant of wet conditions (some leafy vegetables, rice). Bulk density and compaction (often caused by heavy machinery traffic, livestock trampling, or repeated cultivation without organic matter addition) restrict root growth, reduce water infiltration, and increase runoff and erosion risk; compaction is corrected by deep tillage, organic matter addition, and controlled traffic.

Fill in the blank: Soil ________ (the proportion of sand, silt, and clay) determines water-holding capacity, drainage rate, and aeration; loam soils, combining all three particle sizes in balanced proportion, are generally optimal for most vegetables and fruit trees.

4.2.2 Soil chemical properties and nutrients

Soil pH (as introduced in Series 3) strongly influences nutrient availability: most vegetables and fruits prefer pH 5.5-6.8; outside this range, specific nutrient deficiencies or toxicities occur (e.g. very acidic soils cause aluminium toxicity and reduced phosphorus availability; very alkaline soils reduce iron and zinc availability). Macronutrients required in relatively large amounts: nitrogen (N; promotes vegetative growth, leaf colour, and protein synthesis; deficiency causes yellowing of older leaves and stunted growth; excess delays flowering and increases susceptibility to pests and diseases); phosphorus (P; essential for root development, flowering, and fruit/seed formation; deficiency causes purplish leaf discolouration and poor root growth); potassium (K; regulates water relations, improves fruit quality, size, and disease resistance; deficiency causes marginal leaf scorch and poor fruit quality).

Secondary macronutrients: calcium (Ca; essential for cell wall strength; deficiency causes blossom end rot in tomato and pepper, and tip burn in cabbage and lettuce); magnesium (Mg; central atom of the chlorophyll molecule; deficiency causes interveinal chlorosis of older leaves); sulphur (S; component of amino acids and enzymes; deficiency causes general yellowing similar to nitrogen deficiency). Micronutrients (required in small amounts but essential): iron, zinc, manganese, boron, copper, molybdenum; deficiencies cause specific symptoms (e.g. boron deficiency causes hollow stem and cracked fruit in many vegetables; zinc deficiency causes small, distorted leaves). Cation exchange capacity (CEC) measures the soil's capacity to hold and supply exchangeable nutrient cations; sandy soils have low CEC (poor nutrient retention; need frequent, smaller fertiliser applications) while clay and organic-matter-rich soils have higher CEC (better nutrient retention; can receive larger, less frequent applications).

Fill in the blank: ________ (Ca) deficiency in the soil causes blossom end rot in tomato and pepper and tip burn in cabbage and lettuce; it is a secondary macronutrient essential for cell wall strength.

4.2.3 Soil biological factors

Soil organic matter (decomposed plant and animal residues) is one of the most important soil properties influencing vegetable and fruit production: it improves soil structure and aggregate stability; increases water-holding capacity; provides a slow-release source of nutrients as it decomposes; increases cation exchange capacity; and supports a diverse and beneficial soil microbial community. Nigerian tropical soils are generally low in organic matter (often below 1-2%) due to rapid decomposition under high temperature and humidity; regular addition of compost, farmyard manure, and crop residues is essential to maintain soil organic matter and fertility for sustained vegetable and fruit production.

Soil microorganisms perform essential functions: decomposer organisms (bacteria, fungi, actinomycetes) break down organic matter and recycle nutrients; nitrogen-fixing bacteria (Rhizobium in legume root nodules; free-living Azotobacter) convert atmospheric nitrogen into plant-available forms; mycorrhizal fungi form symbiotic associations with plant roots, greatly increasing the effective root surface area for water and phosphorus uptake, particularly important in low-fertility tropical soils; beneficial fungi and bacteria can also suppress soil-borne pathogens through competition and antagonism (biological control). Soil-borne pests and pathogens (nematodes, fungal wilts, bacterial wilts, soil insects) are also biological factors that reduce yield; their populations are influenced by crop rotation, organic matter management, and soil health; healthy, biologically active soils generally have greater natural resistance to pest and disease buildup than degraded, low-organic-matter soils.

Fill in the blank: ________ fungi form symbiotic associations with plant roots, greatly increasing the effective root surface area for water and phosphorus uptake; this is particularly important for plant nutrition in low-fertility tropical soils.

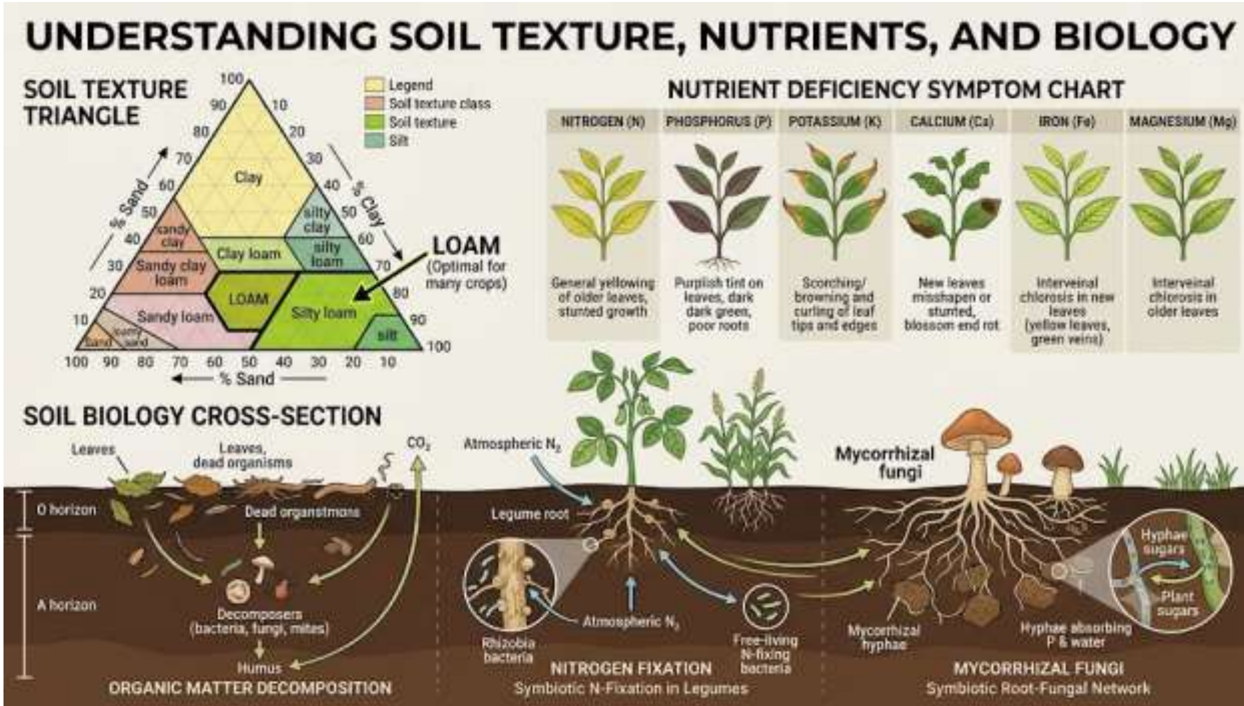

Figure 4.2: Soil factors affecting vegetable and fruit production

Pilot questions 4.2

1. Explain how soil texture affects water-holding capacity and drainage, and state which texture is generally optimal for vegetables.
2. State the functions of nitrogen, phosphorus, and potassium in plant growth and the deficiency symptom of each.
3. Explain the role of calcium in plant growth and name the disorder caused by its deficiency in tomato.
4. Explain why Nigerian tropical soils are generally low in organic matter and state why this is important for vegetable production.
5. Explain the role of mycorrhizal fungi and nitrogen-fixing bacteria in soil fertility.

4.3 Biological and Genetic Factors

4.3.1 Variety and genetic potential

The genetic potential of the variety planted sets the upper limit on the yield, quality, and adaptability that can be achieved, regardless of how well other factors are managed; no amount of fertiliser or irrigation can make a low-yielding, poorly adapted variety outperform its genetic potential. Improved varieties (developed by research institutions such as IITA, NIHORT, and IAR) generally offer higher yield potential, better disease and pest resistance, improved fruit quality and shelf life, and adaptation to local conditions (heat tolerance, drought tolerance) compared to unimproved local landraces. Hybrid (F1) varieties combine the favourable traits of two parent lines through controlled crossing; they typically show hybrid vigour (heterosis), giving higher yield, uniformity, and vigour than either parent or open-pollinated varieties, but seed must be purchased each season since saved F1 seed produces variable, generally inferior offspring.

Open-pollinated (OP) varieties breed true from saved seed, allowing farmers to save and replant their own seed each season at no additional cost; they are generally less uniform and may have somewhat lower yield potential than hybrids but offer valuable cost savings and genetic diversity. Disease and pest resistance bred into varieties (e.g. Fusarium wilt resistance in tomato, bacterial wilt resistance via grafting onto resistant rootstock, root-knot nematode resistance) substantially reduces crop losses and the need for chemical control. Variety selection should match the specific production environment (climatic zone, season, market requirement) and the farmer's management capacity and resources (hybrid seed cost versus expected yield benefit); selecting the wrong variety for the local environment is one of the most common and costly mistakes in Nigerian vegetable and fruit production.

Fill in the blank: ________ (F1) varieties combine favourable traits of two parent lines through controlled crossing and typically show hybrid vigour (heterosis), but seed must be purchased each season since saved seed produces variable, generally inferior offspring.

4.3.2 Pollinators and beneficial organisms

As discussed in Series 2, many vegetable and fruit crops depend partly or wholly on insect pollination (entomophily) for fruit set, especially cucurbits (cucumber, pumpkin, melon, watermelon), which have separate male and female flowers requiring insect transfer of pollen. Honeybees (Apis mellifera) are the most important commercial pollinators; their decline due to pesticide misuse, habitat loss, and disease is a growing concern globally and increasingly in Nigeria, threatening pollination services for cucurbit and fruit tree crops. Other beneficial pollinators include solitary bees, certain wasps, and some fly species; maintaining flowering hedgerows and avoiding broad-spectrum insecticide application during flowering helps conserve these populations.

Beneficial predatory and parasitic organisms (natural enemies of pests) play a crucial biological control role: ladybird beetles (Coccinellidae) and their larvae prey on aphids; lacewings prey on aphids, mites, and small caterpillars; parasitic wasps lay eggs inside pest insects (caterpillars, whiteflies, aphids), killing the host as the wasp larva develops; predatory mites consume pest mites; spiders consume a wide range of insect pests. Conserving these beneficial organisms (by minimising broad-spectrum insecticide use, maintaining habitat diversity such as flowering border plants, and using selective, targeted pest control methods) is a cornerstone of integrated pest management, which will be covered in detail in Series 5. The presence of a healthy population of pollinators and natural enemies is itself an indicator of a well-managed, ecologically balanced production system.

Fill in the blank: ________ wasps lay eggs inside pest insects such as caterpillars, whiteflies, and aphids; the developing wasp larva kills the host insect, making these wasps an important biological control agent in vegetable and fruit production.

4.3.3 Competing organisms: weeds, pests, and diseases

Weeds compete directly with vegetable and fruit crops for light, water, nutrients, and space; uncontrolled weeds can reduce vegetable yields by 30-90% depending on the crop, weed species, and timing; weeds also serve as alternate hosts for many crop pests and diseases, harbouring them between cropping seasons. The critical period for weed control (the period during which weed competition causes the most yield loss) is usually the first 3-6 weeks after planting or transplanting, when the crop canopy has not yet closed and weeds can establish quickly; effective weed management during this period (hand weeding, mulching, or selective herbicide) is the highest priority for weed control.

Insect pests directly damage vegetable and fruit crops by feeding on leaves, stems, flowers, fruits, and roots, reducing yield and quality and sometimes transmitting plant viruses (aphids and whiteflies are major virus vectors); common pests of Nigerian vegetables include aphids, whiteflies, thrips, fruit flies, stem borers, and leaf miners (covered in detail in Series 5). Plant diseases (caused by fungi, bacteria, viruses, and nematodes) damage crops through tissue destruction, wilting, rotting, and stunting; the severity of disease depends on the interaction of three factors known as the disease triangle: a susceptible host plant, a virulent pathogen, and favourable environmental conditions (usually high humidity and moderate to warm temperature for most tropical vegetable diseases); managing any one of these three factors (resistant varieties, pathogen-free seed/seedlings, or environmental modification through spacing and drainage) reduces disease risk. The detailed identification and management of specific pests and diseases is the subject of Series 5.

Fill in the blank: The disease ________ describes the interaction of three factors required for plant disease to occur: a susceptible host plant, a virulent pathogen, and favourable environmental conditions; managing any one factor reduces disease risk.

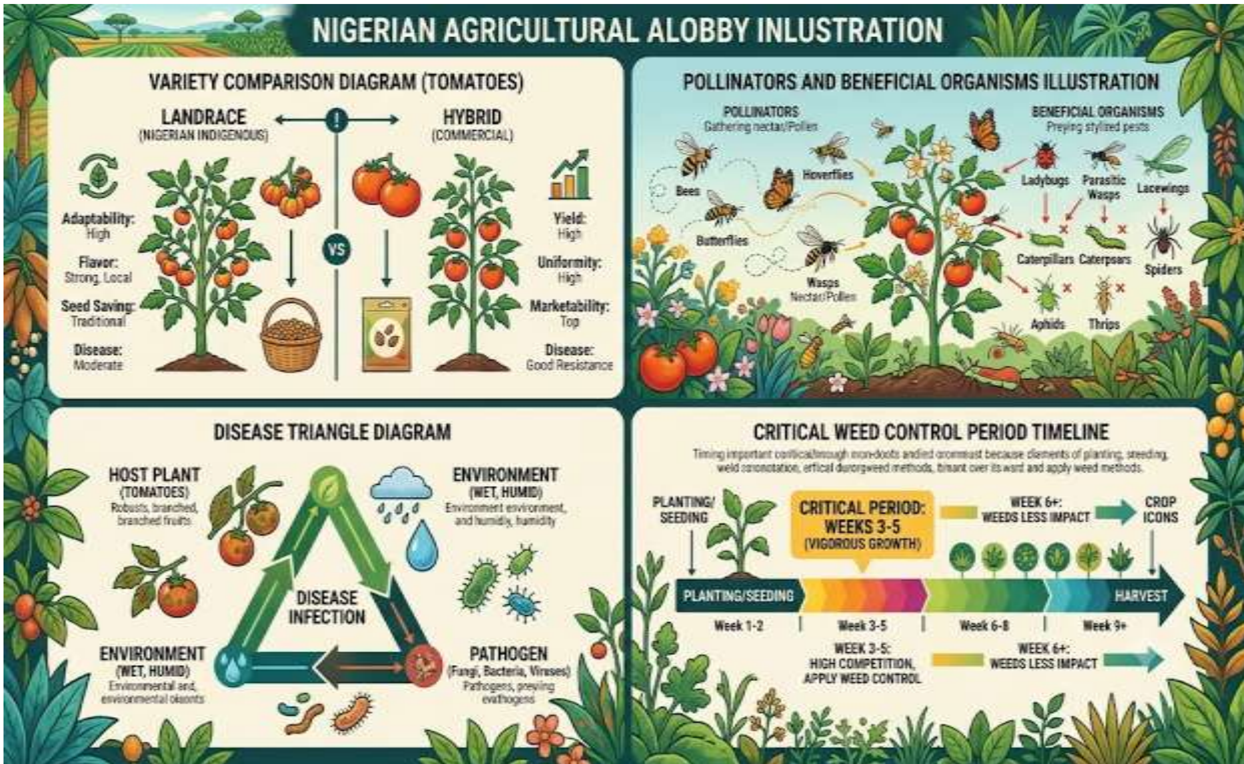

Figure 4.3: Biological and genetic factors in vegetable and fruit production

Pilot questions 4.3

1. Explain why genetic potential sets the upper limit on crop yield regardless of management.
2. Distinguish between hybrid (F1) and open-pollinated varieties, with one advantage of each.
3. Explain the role of honeybees in vegetable and fruit production and state one threat to their populations.
4. Name three beneficial predatory or parasitic organisms and state the pest each controls.
5. Explain the disease triangle and state how each factor can be managed to reduce disease risk.

4.4 Management and Socio-Economic Factors

4.4.1 Agronomic management practices

The quality and timeliness of agronomic management practices, applied by the farmer, strongly influences how closely actual yield approaches the genetic and environmental potential of the crop. Timing of operations (land preparation, planting, fertiliser application, weeding, pest control, and harvesting carried out at the correct time relative to crop growth stage and seasonal conditions) is critical; delayed planting at the start of the rains, delayed weeding past the critical period, or delayed harvest past crop maturity all reduce yield and quality, even when all other factors are favourable. Correct application rates (of seed, fertiliser, and pesticides) avoid both the yield losses from under-application and the waste, cost, and potential crop damage or environmental harm from over-application.

Irrigation management (timing, amount, and method of water application, as covered in Series 3) must match the crop's water requirement at each growth stage; both under- and over-irrigation reduce yield and can increase disease incidence. Integrated nutrient management (combining organic and inorganic fertiliser sources based on soil test results and crop requirement, as introduced in Series 1 and 3) optimises both yield and long-term soil fertility, compared to either neglecting fertilisation or applying it without regard to actual crop and soil needs. Record keeping and monitoring (tracking input use, weather, pest and disease observations, and yield from season to season) allows the farmer to identify which management practices are working well and which need adjustment, supporting continuous improvement in production efficiency.

Fill in the blank: The ________ of agronomic operations (land preparation, planting, fertilisation, weeding, pest control, harvesting) relative to crop growth stage and season is critical; delays at any stage reduce yield and quality even when all other production factors are favourable.

4.4.2 Input availability and cost

Access to quality inputs at the right time and at an affordable price is a major determinant of actual farm-level vegetable and fruit production, often more limiting than biological or environmental factors in Nigeria. Seed and seedling availability: many Nigerian vegetable farmers rely on informal seed sources of uncertain quality and variety identity; access to certified seed of improved varieties from reputable agro-dealers or research institutions (IITA, NIHORT) is often limited by distance, cost, and lack of awareness, leading many farmers to plant lower-yielding, disease-susceptible material. Fertiliser and agrochemical availability: the cost of fertiliser, fungicides, and insecticides in Nigeria fluctuates with currency exchange rates and global supply chains; smallholder farmers often cannot afford recommended application rates, leading to under-fertilisation and reduced yields, or resort to counterfeit or substandard products sold by unscrupulous dealers.

Irrigation equipment and energy costs: drip irrigation systems, pumps, and generators represent a significant capital investment that many smallholder vegetable farmers cannot afford without credit access; the cost of diesel or petrol to run irrigation pumps is a major recurrent cost, especially during the dry season when irrigation demand is highest. Credit access: formal agricultural credit (from banks, the Bank of Agriculture, or government schemes such as the CBN Anchor Borrowers Programme) remains limited for many smallholder vegetable and fruit farmers, particularly those without land titles (Certificate of Occupancy) to use as collateral; this constrains investment in quality inputs, irrigation, and improved varieties, perpetuating a cycle of low productivity. Labour availability and cost: vegetable production is labour-intensive (especially for transplanting, weeding, staking, and harvesting); rural-urban migration of youth has increased labour scarcity and cost in many farming communities, motivating interest in labour-saving technologies and practices.

Fill in the blank: Access to quality ________ (seed, fertiliser, agrochemicals, irrigation equipment) at the right time and affordable price is often more limiting to actual Nigerian vegetable and fruit yields than biological or environmental factors alone.

4.4.3 Market access and socio-economic considerations

Market access influences not just the income farmers receive but also the production decisions they make, including which crops and varieties to grow, how much to invest in inputs, and the level of post-harvest care applied. Distance to market and transport infrastructure: poor rural road conditions increase transport time and cost and accelerate post-harvest deterioration of perishable vegetables and fruits, particularly in the rainy season when roads become impassable; farmers far from good roads often grow only what can be consumed locally or processed (cassava into garri) rather than highly perishable, high-value vegetables. Price volatility: Nigerian vegetable and fruit prices fluctuate significantly with seasonal supply gluts (during peak harvest, prices can collapse) and scarcity periods (prices rise sharply); this volatility discourages investment in production expansion and makes farm income planning difficult.

Market information and bargaining power: smallholder farmers often lack access to current market price information and sell through multiple layers of middlemen, receiving a smaller share of the final consumer price than farmers in markets with better information flow and farmer organisation; mobile phone-based market information services and farmer cooperatives can improve bargaining power and farmgate prices. Land tenure and farm size: as covered in AGE 201, secure land tenure encourages investment in perennial fruit trees and irrigation infrastructure, while insecure tenure discourages such long-term investment; very small or fragmented landholdings limit the scale of commercial vegetable and fruit production and the ability to achieve economies of scale in input purchase and produce marketing. Government policy and extension support: agricultural policies (subsidies, import/export regulations, extension service funding) and the availability of trained extension workers significantly influence farmers' access to knowledge, inputs, and markets, and therefore their production decisions and outcomes.

Fill in the blank: Poor rural road conditions increase transport time and cost and accelerate post-harvest ________ of perishable vegetables and fruits, particularly in the rainy season, influencing farmers to grow less perishable crops if market access is limited.

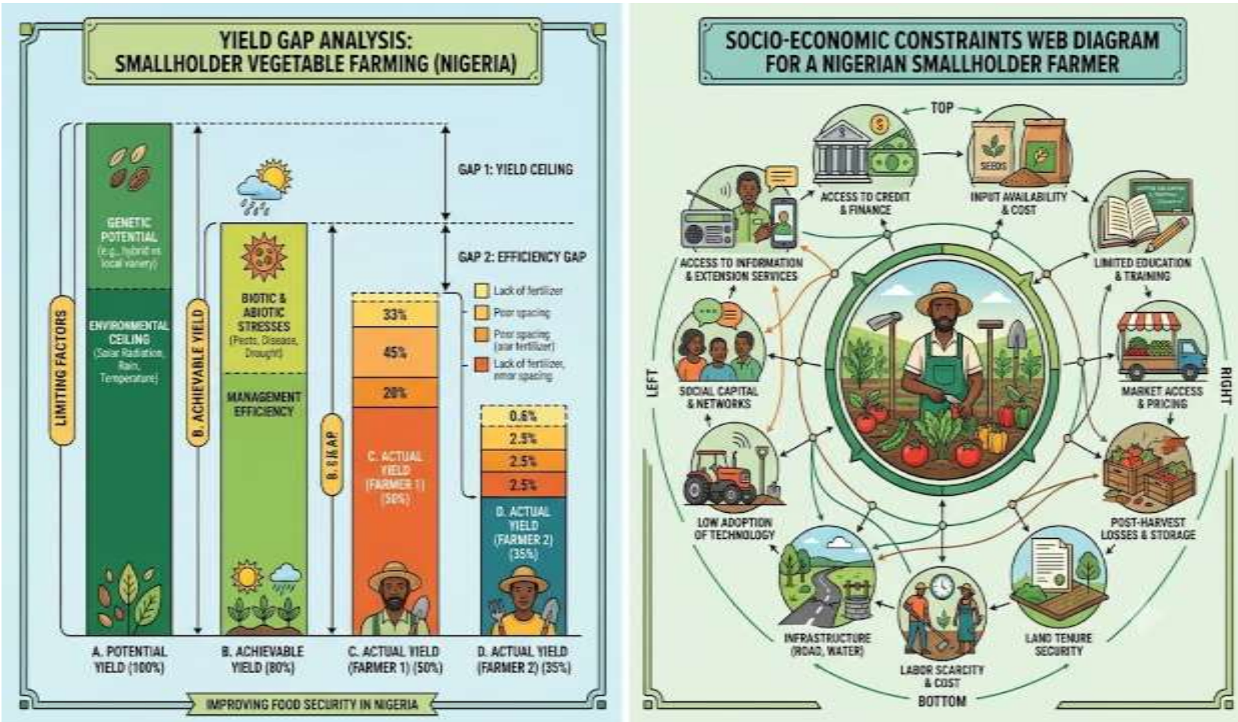

Figure 4.4: Management and socio-economic factors in vegetable and fruit production

Pilot questions 4.4

1. Explain why timing of agronomic operations is critical to achieving good vegetable and fruit yields.
2. State three input access constraints facing Nigerian vegetable and fruit farmers.
3. Explain how poor rural road infrastructure affects vegetable and fruit marketing decisions.
4. Explain how price volatility affects farmer investment decisions in vegetable and fruit production.
5. Explain the concept of the yield gap and name three categories of factors that contribute to it.

Series Summary

This Series examined the major factors that influence vegetable and fruit production. **Climatic factors are environmental conditions such as temperature, rainfall, humidity, and light that affect crop growth and yield.** Most tropical vegetables perform well at about **20–30°C**, while temperatures above **35°C** may cause flower abortion. Adequate water is essential, especially during flowering and fruit formation, but waterlogging can cause root diseases. High humidity encourages fungal and bacterial infections, while insufficient light reduces growth and fruit quality. **Soil factors are the physical, chemical, and biological properties of soil that determine its suitability for crop production.** Important factors include texture, structure, depth, drainage, pH, nutrient supply, organic matter, and soil organisms. Loamy, well-drained soils with a pH of about **5.5–6.8** are generally most suitable.

Biological and genetic factors are crop and living-organism characteristics that influence productivity. Variety potential, disease resistance, pollination, beneficial organisms, weeds, pests, and diseases all affect yield. Good management includes timely planting, correct input application, irrigation scheduling, integrated nutrient and pest management, and proper record keeping. Production is also affected by seed quality, fertiliser and chemical costs, labour, credit, market access, roads, land tenure, government policy, and extension services. The yield gap is the difference between the crop's potential yield, the yield possible under local climate and soil conditions, and the actual yield obtained by farmers. By completing this Series, students should achieve SLOs 4.1–4.4.

Glossary of Terms

- **Bulk density:** the mass of soil per unit volume; high bulk density indicates compaction, which restricts root growth and reduces water infiltration.
- **Cation exchange capacity (CEC):** the capacity of soil to hold and supply exchangeable nutrient cations; sandy soils have low CEC and clay/organic soils have higher CEC.

- **Critical period (weed control):** the period after planting, usually the first 3-6 weeks, during which weed competition causes the greatest yield loss; the highest priority period for weed management.
- **Diurnal temperature range:** the difference between daytime maximum and nighttime minimum temperature; a wide range improves fruit colour, sugar content, and flavour in many crops.
- **Disease triangle:** the interaction of a susceptible host, a virulent pathogen, and a favourable environment required for plant disease to develop; managing any one factor reduces disease risk.
- **Entomophily:** pollination by insects, primarily bees; required for fruit set in cucurbits (cucumber, pumpkin, melon) and many fruit trees.
- **Heterosis (hybrid vigour):** the superior performance (yield, uniformity, vigour) of F1 hybrid offspring compared to either parent line; the basis of hybrid seed production.
- **Hybrid (F1) variety:** a variety produced by controlled crossing of two parent lines; shows hybrid vigour but does not breed true from saved seed.
- **Mycorrhizal fungi:** fungi that form symbiotic associations with plant roots, increasing the effective root surface area for water and phosphorus uptake.
- **Open-pollinated (OP) variety:** a variety that breeds true from saved seed, allowing farmers to save and replant seed each season at no additional cost.
- **Photoperiod:** the relative length of day and night; affects flowering and bulbing in photoperiod-sensitive crops such as some onion varieties.
- **Soil organic matter:** decomposed plant and animal residues in soil; improves structure, water-holding capacity, nutrient supply, and CEC; generally low in Nigerian tropical soils.
- **Soil structure:** the arrangement of soil particles into aggregates; affects root penetration, water infiltration, and aeration.

- **Soil texture:** the relative proportion of sand, silt, and clay particles in soil; determines water-holding capacity, drainage, and aeration.
- **Yield gap:** the difference between potential yield (genetic ceiling), achievable yield (after climatic/soil constraints), and actual farmer yield (after management/socio-economic constraints).

Concept Check Questions [Series 4]

Objective Questions

1. Most tropical vegetables (tomato, pepper, okra) have an optimum growth temperature of ________ degrees Celsius; temperatures above 35 degrees Celsius cause flower abortion. (Linked to SLO 4.1)
2. Soil ________ (the proportion of sand, silt, and clay) determines water-holding capacity, drainage, and aeration; loam is generally optimal for vegetables and fruit trees. (Linked to SLO 4.2)
3. ________ (F1) varieties show hybrid vigour but do not breed true from saved seed; open-pollinated varieties breed true and allow farmers to save seed. (Linked to SLO 4.3)
4. The disease ________ describes the interaction of a susceptible host, a virulent pathogen, and a favourable environment required for plant disease to occur. (Linked to SLO 4.3)
5. The ________ gap is the difference between potential yield (genetic), achievable yield (climate/soil constraints), and actual farmer yield (management/socio-economic constraints). (Linked to SLO 4.4)

Short-Answer Questions

1. State the effects of temperatures above and below the optimum range on vegetable crops. (Linked to SLO 4.1)
2. Name the three primary macronutrients and state one function and deficiency symptom of each. (Linked to SLO 4.2)
3. Distinguish between hybrid and open-pollinated varieties. (Linked to SLO 4.3)
4. Name three beneficial organisms and the pest each controls. (Linked to SLO 4.3)
5. State four management and socio-economic factors that limit Nigerian vegetable and fruit production. (Linked to SLO 4.4)

6. Long-Answer Questions
7. Explain the effects of temperature, rainfall/humidity, and light on vegetable and fruit production. (Linked to SLO 4.1)
8. Describe the soil physical, chemical, and biological factors that influence vegetable and fruit production. (Linked to SLO 4.2)
9. Describe biological/genetic factors (variety, pollinators, weeds, pests, diseases) and management/socio-economic factors that influence production. (Linked to SLOs 4.3, 4.4)

Answers to Concept Check Questions [Series 4]

Objective Questions

1. 20-30.
2. Texture.
3. Hybrid.
4. Triangle.
5. Yield.

Short-Answer Questions

1. Above optimum: flower abortion, poor fruit set, heat stress symptoms (blossom end rot, sunscald). Below optimum: growth stops or slows; chilling damage in sensitive species.
2. Nitrogen: vegetative growth; deficiency causes yellowing of older leaves. Phosphorus: root/flower/fruit development; deficiency causes purplish leaf discolouration. Potassium: water relations and fruit quality; deficiency causes marginal leaf scorch.

3. Hybrid (F1): higher yield potential and uniformity through hybrid vigour; seed cannot be saved. Open-pollinated: breeds true from saved seed; generally lower yield potential than hybrids.
4. Ladybird beetles (aphids); parasitic wasps (caterpillars and whiteflies); predatory mites (pest mites).
5. Input availability/cost (seed, fertiliser, agrochemicals); credit access; labour availability/cost; market access (roads, price volatility).

Long-Answer Questions

1. Temperature: optimum 20-30 degrees Celsius for tropical vegetables; above 35 degrees Celsius causes flower abortion and heat stress; temperate fruits need winter chilling, restricting them to highlands. Rainfall/humidity: 25-50 mm/week needed; drought during flowering/fruit set most damaging; waterlogging causes root rot; high humidity (above 85%) favours fungal/bacterial disease. Light: 6-8 hours full sun needed for maximum yield; shading causes etiolation and poor fruit quality; photoperiod affects onion bulbing and some flowering responses.
2. Physical: texture (loam optimal; sand drains fast; clay drains slowly), structure (affects root penetration and aeration), depth (limits root volume), drainage class, compaction (restricts growth). Chemical: pH (5.5-6.8 optimal); macronutrients (N for growth, P for roots/fruit, K for water relations/quality); secondary nutrients (Ca: blossom end rot if deficient; Mg: chlorophyll); micronutrients (B, Zn, Fe). Biological: organic matter (low in Nigerian soils; needs compost/manure); decomposer microorganisms; Rhizobium nitrogen fixation; mycorrhizal fungi (improve P uptake); soil-borne pathogens influenced by rotation and organic matter management.
3. Variety/genetic: sets yield ceiling; hybrid (vigour, no seed saving) vs open-pollinated (breeds true); disease resistance breeding reduces losses. Pollinators: honeybees essential for cucurbits; declining populations a concern; conserve via reduced insecticide use. Beneficial organisms: ladybird beetles, lacewings, parasitic wasps control pests biologically. Weeds: 30-90% yield loss if uncontrolled; critical period

weeks 1-6. Pests/diseases: disease triangle (host, pathogen, environment); managing any factor reduces risk. Management factors: timing of operations critical; correct input rates; irrigation scheduling; record keeping. Socio-economic: input cost/availability (seed, fertiliser); credit access; labour cost/availability; market access (roads, price volatility, market information); land tenure; government policy/extension support.

Answers to Pilot Questions [Series 4]

Part 4.1

1. Temperature affects germination, vegetative growth, flowering, fruit set, and ripening. Within the optimum range (20-30 degrees Celsius for tropical vegetables), growth is maximised. Above the maximum (above 35 degrees Celsius), flower abortion occurs, fruit set is poor, and heat stress symptoms such as blossom end rot and sunscald develop, reducing both yield and quality.
2. Temperate fruits (apple, pear, peach) require a period of winter chilling (accumulated hours below 7 degrees Celsius) to break dormancy and flower normally. This chilling requirement cannot be met in the warm Nigerian lowlands, so these fruits are restricted to the cooler highland zones (Jos and Mambilla Plateau) where temperatures are low enough to satisfy the chilling requirement.
3. Typical weekly requirement: 25-50 mm of water. Drought effects: wilting, reduced growth, flower and fruit drop, smaller and lower-quality produce. Waterlogging effects: root rot, oxygen deficiency in the root zone, increased incidence of fungal disease, and stunted or dying plants.
4. Drought during flowering and fruit set causes the most severe yield loss because it directly reduces the number of flowers that set fruit and the number of fruits or seeds that develop, permanently limiting the harvestable yield. Drought during vegetative growth reduces leaf area and photosynthetic capacity, but the plant can sometimes

recover this capacity later if water becomes available before reproductive growth begins.

5. Shading reduces photosynthesis and yield; it causes etiolation (excessive stem elongation and weak growth as plants stretch towards available light), and delays flowering and fruiting. Fruits that develop in shade are often pale, lower in sugar content, and of poorer overall market quality compared to fruits that develop in full sun.

Part 4.2

1. Soil texture determines water-holding capacity and drainage: sandy soils drain rapidly and hold little water (requiring frequent irrigation); clay soils hold water well but drain slowly (waterlogging risk); loam soils, a balanced mixture of sand, silt, and clay, are generally optimal for most vegetables because they combine adequate water retention with good drainage and aeration.
2. Nitrogen: promotes vegetative growth and leaf colour; deficiency causes yellowing of older leaves and stunted growth. Phosphorus: essential for root development, flowering, and fruit/seed formation; deficiency causes purplish leaf discolouration and poor root growth. Potassium: regulates water relations and improves fruit quality and disease resistance; deficiency causes marginal leaf scorch and poor fruit quality.
3. Calcium is essential for cell wall strength and structural integrity of plant tissues. Its deficiency causes blossom end rot in tomato (a dark, sunken patch at the bottom of the fruit) and a similar disorder in pepper, as well as tip burn in cabbage and lettuce.
4. Nigerian tropical soils are generally low in organic matter because high temperature and humidity cause rapid decomposition of plant residues, releasing carbon back to the atmosphere faster than it can accumulate in the soil. This is important for vegetable production because organic matter improves soil structure, water-holding capacity, and nutrient supply; without regular addition of compost and manure, tropical soils quickly become depleted and less productive.

5. Mycorrhizal fungi form symbiotic associations with plant roots, greatly increasing the effective root surface area for water and especially phosphorus uptake, which is critical in low-fertility tropical soils where phosphorus is often limiting. Nitrogen-fixing bacteria (Rhizobium in legume nodules; free-living Azotobacter) convert atmospheric nitrogen gas into plant-available forms, reducing the need for nitrogen fertiliser and improving soil fertility for subsequent crops.

Part 4.3

1. Genetic potential sets the upper limit on yield because it determines the maximum biological capacity of the plant for growth, flowering, fruit production, and stress tolerance; no amount of fertiliser, irrigation, or pest control can make a plant produce beyond what its genes allow it to produce. Good management can help a crop reach its genetic potential but cannot exceed it.
2. Hybrid (F1) varieties: produced by controlled crossing of two parent lines; show hybrid vigour (higher yield, uniformity); seed cannot be saved for replanting since offspring are variable. Advantage: higher yield potential and uniformity. Open-pollinated varieties: breed true from saved seed; generally somewhat lower yield potential than hybrids. Advantage: farmers can save and replant their own seed at no additional cost each season.
3. Honeybees are the most important commercial pollinators for cucurbit crops (cucumber, pumpkin, melon, watermelon) which have separate male and female flowers requiring insect-mediated pollen transfer for fruit set; without adequate bee visitation, fruit set and yield are severely reduced. One threat: pesticide misuse (broad-spectrum insecticide application during flowering kills bees and reduces pollination services).
4. Three organisms: (1) Ladybird beetles (Coccinellidae) and their larvae prey on aphids. (2) Lacewings prey on aphids, mites, and small caterpillars. (3) Parasitic wasps lay eggs inside pest insects such as caterpillars and whiteflies, killing the host as the wasp larva develops.

5. The disease triangle describes the three factors that must all be present for plant disease to occur: a susceptible host plant, a virulent pathogen, and a favourable environment (usually high humidity and warm temperature). Management: host factor managed by planting resistant varieties; pathogen factor managed by using pathogen-free seed/seedlings and sanitation; environment factor managed by improving drainage, spacing for airflow, and avoiding overhead irrigation that increases leaf wetness.

Part 4.4

1. Timing is critical because each crop growth stage has a specific window during which a given operation is most effective: late planting misses the optimal rainfall window; delayed weeding past the critical period (weeks 1-6) allows weeds to cause irreversible yield loss; delayed harvest past maturity reduces quality and increases losses. Even with ideal genetics, soil, and climate, poor timing of management operations prevents the crop from reaching its potential yield.
2. Three constraints: (1) Limited access to certified seed of improved varieties due to distance, cost, and lack of awareness, leading farmers to plant lower-quality informal seed. (2) High and fluctuating cost of fertiliser and agrochemicals, leading to under-fertilisation or use of counterfeit products. (3) Limited access to formal credit (especially without land title as collateral), restricting investment in quality inputs and irrigation equipment.
3. Poor rural road conditions increase transport time and cost to market and accelerate post-harvest deterioration of perishable produce, especially during the rainy season when roads become difficult to pass. As a result, farmers far from good roads often choose to grow less perishable crops (cassava processed into garri) that can withstand transport delays, rather than highly perishable, high-value vegetables and fruits that require rapid delivery to market.
4. Price volatility (large seasonal swings between supply gluts at peak harvest, when prices collapse, and scarcity periods, when prices rise sharply) makes farm income

difficult to predict from season to season. This unpredictability discourages farmers from investing in expanding production, purchasing quality inputs, or adopting new technologies, since they cannot be confident of recovering their investment through stable, reliable prices.

5. The yield gap is the difference between the potential yield (the genetic ceiling of the variety under ideal conditions), the achievable yield (potential yield reduced by climatic and soil constraints at the actual site), and the actual yield obtained by the farmer (achievable yield further reduced by management and socio-economic constraints). Three categories of contributing factors: genetic/biological factors (variety potential, pests, diseases), environmental factors (climate, soil), and management/socio-economic factors (input access, credit, labour, market access, farmer skill and timing).

Refereneces and Attributions

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Figures, Plates, Tables, and Boxes

- Figure 4.1: Climatic factors affecting vegetable and fruit production Attribution: AI generated. Suggested OER search string: "temperature rainfall light effects vegetable fruit production drought waterlogging shade etiolation Nigeria OER".
- Figure 4.2: Soil factors affecting vegetable and fruit production Attribution: AI generated. Suggested OER search string: "soil texture loam nutrient deficiency symptoms nitrogen phosphorus potassium calcium boron soil biology mycorrhiza Nigeria vegetable OER".
- Figure 4.3: Biological and genetic factors in vegetable and fruit production Attribution: AI generated. Suggested OER search string: "vegetable variety hybrid pollinator beneficial insect disease triangle weed competition Nigeria production factors OER".
- Figure 4.4: Management and socio-economic factors in vegetable and fruit production Attribution: AI generated. Suggested OER search string: "vegetable fruit production yield gap socio-economic factors input access credit market access Nigeria smallholder farmer OER".

Series 5: Diseases, Pests and Sustainable Management

- **Part 5.1: Major Diseases of Vegetable and Fruit Crops**
  - Sub Part 5.1.1: Fungal diseases
  - Sub Part 5.1.2: Bacterial and viral diseases
  - Sub Part 5.1.3: Nematode diseases
- **Part 5.2: Major Pests of Vegetable and Fruit Crops**
  - Sub Part 5.2.1: Sucking and piercing insect pests
  - Sub Part 5.2.2: Chewing and boring insect pests
  - Sub Part 5.2.3: Other pests: mites, rodents, and birds
- **Part 5.3: Integrated Pest and Disease Management**
  - Sub Part 5.3.1: Cultural and physical control methods
  - Sub Part 5.3.2: Biological control methods
  - Sub Part 5.3.3: Chemical control and safe pesticide use
- **Part 5.4: Sustainable Vegetable and Fruit Production**
  - Sub Part 5.4.1: Principles of sustainable production
  - Sub Part 5.4.2: Organic and low-input production systems
  - Sub Part 5.4.3: Climate-smart and resilient vegetable and fruit production

Introduction

Diseases and pests are among the most significant constraints to vegetable and fruit production in Nigeria, often causing yield losses of 30-100% when uncontrolled. Effective management requires accurate identification of the problem, understanding of the causal organism's biology, and a strategic combination of control methods that minimise crop loss while protecting human health, beneficial organisms, and the environment.

This final Series surveys the major fungal, bacterial, viral, and nematode diseases and the major insect, mite, and vertebrate pests affecting Nigerian vegetable and fruit crops; introduces the principles and methods of integrated pest and disease management; and discusses sustainable, organic, and climate-smart approaches to vegetable and fruit production. This Series draws together all the knowledge built across the previous four Series of AGE 207.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 5.1** identify and describe the major fungal, bacterial, viral, and nematode diseases of vegetable and fruit crops (Linked to Part 5.1),
- **SLO 5.2** identify and describe the major insect, mite, and vertebrate pests of vegetable and fruit crops (Linked to Part 5.2),
- **SLO 5.3** describe cultural, biological, and chemical methods of integrated pest and disease management (Linked to Part 5.3), and
- **SLO 5.4** explain the principles of sustainable, organic, and climate-smart vegetable and fruit production (Linked to Part 5.4).

5.1 Major Diseases of Vegetable and Fruit Crops

5.1.1 Fungal diseases

Fungal diseases are the most common and economically damaging disease group in Nigerian vegetable and fruit production, favoured by the warm, humid tropical climate. Early blight (Alternaria solani) and late blight (Phytophthora infestans) affect tomato and pepper: dark concentric spots on leaves (early blight) or water-soaked lesions that rapidly enlarge in cool, wet conditions (late blight); both cause defoliation and reduced yield; managed by resistant varieties, fungicide spray, and field sanitation. Anthracnose (Colletotrichum species) affects pepper, tomato, mango, and many fruits: sunken, dark, circular lesions on fruit; causes major post-harvest losses; managed by field sanitation, fungicide application, and proper post-harvest handling.

Powdery mildew (Oidium and related fungi) affects cucurbits (cucumber, pumpkin, melon) and other vegetables: white powdery growth on leaf surfaces; reduces photosynthesis and yield; favoured by moderate temperature and high humidity but not free water on leaves; managed by resistant varieties, adequate spacing for airflow, and sulphur-based or systemic fungicides. Damping-off (Pythium, Rhizoctonia species) affects seedlings in the nursery: pre-emergence (seed rots before emerging) or post-emergence (seedling collapses at the soil line) damping-off; favoured by overcrowded, overwatered, poorly drained nursery beds; managed by well-drained sterile seedbed media, avoiding overwatering, and seed treatment with fungicide. Fusarium wilt (Fusarium oxysporum) affects tomato and many other crops: a soil-borne fungus that blocks the plant's vascular system, causing wilting and death; persists in soil for years; managed primarily through resistant varieties and crop rotation since chemical control is largely ineffective once established.

Fill in the blank: ________ (Pythium, Rhizoctonia species) causes pre-emergence seed rot or post-emergence seedling collapse in the nursery; it is favoured by overcrowded, overwatered, poorly drained seedbeds and is managed by well-drained sterile media and avoiding overwatering.

5.1.2 Bacterial and viral diseases

Bacterial wilt (Ralstonia solanacearum) affects tomato, pepper, and garden egg: a soil-borne bacterium that blocks the vascular system, causing sudden wilting without yellowing (distinguishing it from Fusarium wilt, which causes yellowing before wilting); confirmed by cutting the stem and observing milky bacterial ooze; persists in soil for years and spreads through infected soil, water, and tools; managed by resistant varieties, grafting susceptible varieties onto resistant rootstock (e.g. tomato onto Solanum torvum), crop rotation, and field sanitation, since chemical control is ineffective. Bacterial spot and bacterial speck (Xanthomonas and Pseudomonas species) affect tomato and pepper: small, dark, water-soaked spots on leaves and fruit that may have a yellow halo; spread by rain splash and contaminated seed; managed by pathogen-free seed, copper-based bactericides, and avoiding overhead irrigation.

Viral diseases are transmitted primarily by insect vectors (aphids, whiteflies, thrips) and cannot be cured once a plant is infected; management focuses entirely on prevention. Tomato yellow leaf curl virus (TYLCV), transmitted by whiteflies, causes severe leaf curling, yellowing, and stunting, with major yield losses in tomato across Nigeria and West Africa; managed by whitefly control (insecticides, reflective mulch, insect-proof nursery netting), resistant varieties, and removal of infected plants. Cucumber mosaic virus (CMV), transmitted by aphids, affects a wide range of vegetables including cucumber, pepper, and tomato, causing mottled yellow-green leaf patterns, distortion, and stunting; managed by aphid control and resistant varieties. Okra mosaic virus and pepper veinal mottle virus are also significant aphid-transmitted viral diseases of Nigerian vegetables; since no curative treatment exists for viral diseases, vector (aphid/whitefly) control and the use of certified virus-free planting material are the primary management strategies.

Fill in the blank: Bacterial ________ (Ralstonia solanacearum) causes sudden wilting in tomato and pepper without prior yellowing, distinguishing it from Fusarium wilt; it is confirmed by cutting the stem and observing milky bacterial ooze.

5.1.3 Nematode diseases

Nematodes are microscopic, worm-like soil organisms; plant-parasitic nematodes feed on or within plant roots, causing direct damage and creating entry points for secondary fungal and bacterial infections. Root-knot nematode (Meloidogyne species) is the most economically important nematode pest of Nigerian vegetables, affecting tomato, pepper, okra, and cucurbits: characteristic galls (knots) form on infected roots, visible when roots are dug up and washed; infected plants show stunting, yellowing, and wilting, especially under moisture stress, because the damaged root system cannot supply adequate water and nutrients; severe infestation can cause complete crop failure.

Management of root-knot nematode and other plant-parasitic nematodes relies on an integrated approach since no curative chemical treatment is practical for most smallholder farmers: crop rotation with non-host crops (cereals such as maize and sorghum are generally resistant; marigold, a companion crop, suppresses nematode populations through root exudates); resistant varieties and rootstocks (some tomato varieties and rootstocks used for grafting carry nematode resistance genes); soil solarisation (covering moist soil with clear plastic sheeting for 4-6 weeks during the hot dry season; soil temperatures rise high enough to kill nematodes and many soil pathogens in the upper soil layers; a low-cost, chemical-free method increasingly promoted in Nigeria); organic matter addition (compost and certain organic amendments such as neem cake suppress nematode populations and improve general soil health); and field sanitation (removing and destroying infected plant roots; avoiding the transfer of infested soil on tools and footwear between fields).

Fill in the blank: ________ -knot nematode (Meloidogyne species) is the most economically important nematode pest of Nigerian vegetables; it causes characteristic galls on infected roots and is managed through crop rotation, resistant varieties, and soil solarisation.

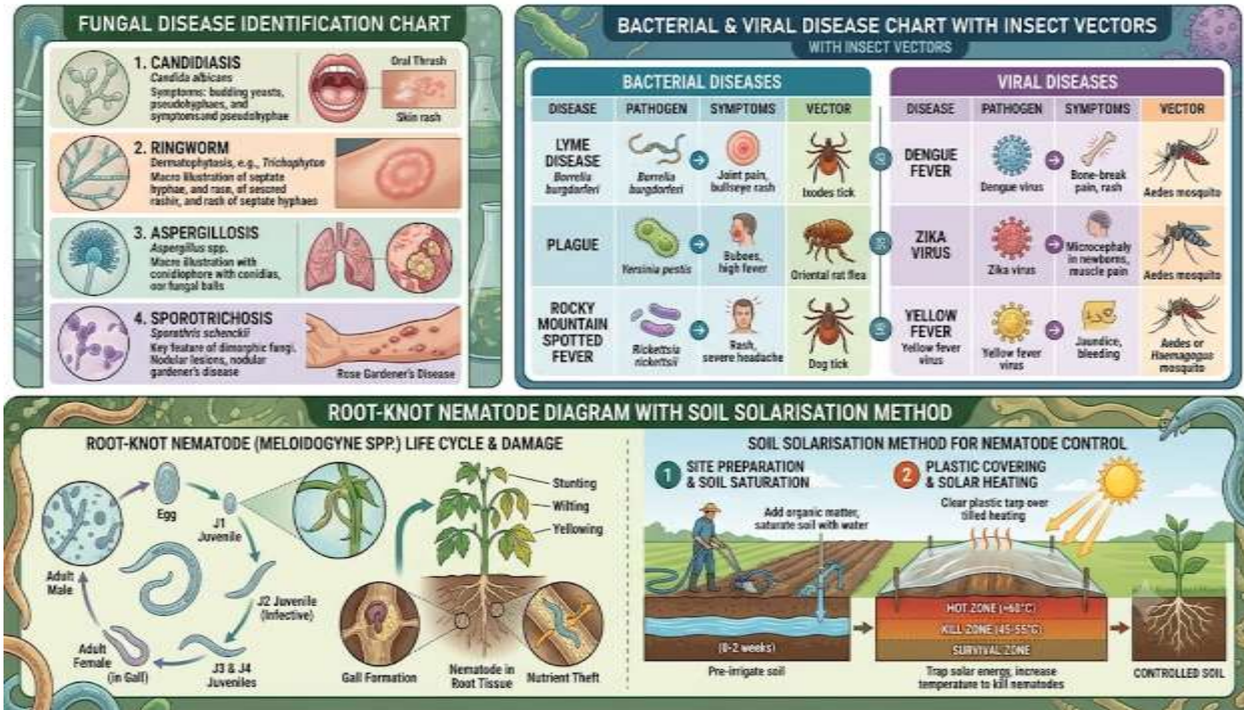

Figure 5.1: Major diseases of vegetable and fruit crops

Pilot questions 5.1

1. Name four fungal diseases of vegetable crops and state one symptom and one management practice for each.
2. Distinguish between bacterial wilt and Fusarium wilt in tomato.
3. Name two viral diseases of Nigerian vegetables, their insect vectors, and one management strategy.
4. Describe the symptoms of root-knot nematode infestation and state three management practices.
5. Explain soil solarisation as a method of nematode and soil pathogen control.

5.2 Major Pests of Vegetable and Fruit Crops

5.2.1 Sucking and piercing insect pests

Sucking and piercing insects feed by inserting mouthparts into plant tissue and withdrawing sap, causing direct feeding damage and often transmitting plant viruses. Aphids (various species) are small (1-3 mm), soft-bodied insects that cluster on young leaves, shoots, and flower buds; they cause direct damage (curled, distorted leaves; stunted growth; honeydew secretion that promotes sooty mould growth) and indirect damage by transmitting numerous plant viruses (cucumber mosaic virus, okra mosaic virus); they reproduce extremely rapidly (parthenogenetically, without mating, in favourable conditions), allowing populations to explode within days. Whiteflies (Bemisia tabaci) are small (1-2 mm), white, moth-like insects found on the underside of leaves; major direct damage from sap removal and honeydew/sooty mould; the primary vector of tomato yellow leaf curl virus (TYLCV), one of the most damaging tomato viruses in Nigeria; populations increase rapidly in hot, dry conditions.

Thrips (various species) are very small (1-2 mm), slender insects that feed by rasping plant tissue and sucking the exuded sap; cause characteristic silvery streaking and stippling on leaves and flowers, distorted growth, and reduced fruit set; also transmit some plant viruses (tospoviruses); particularly damaging to pepper, onion, and many flowering vegetables. Mealybugs and scale insects affect fruit trees (citrus, mango, guava): sap-sucking insects often covered in a white waxy or hard shell-like covering; cause direct damage and honeydew/sooty mould; often protected by ants that feed on their honeydew and defend them from natural enemies, complicating biological control. Management of sucking/piercing pests integrates monitoring (yellow sticky traps for aphids and whiteflies; blue sticky traps for thrips), cultural methods (reflective mulch repels whiteflies and aphids; removing weed hosts), biological control (ladybird beetles, lacewings, parasitic wasps), and targeted insecticide use (systemic insecticides for severe infestations, applied judiciously to conserve natural enemies and avoid resistance development).

Fill in the blank: ________ (Bemisia tabaci) are small, white, moth-like insects found on the underside of leaves; they are the primary insect vector of tomato yellow leaf curl virus (TYLCV) and their populations increase rapidly in hot, dry conditions.

5.2.2 Chewing and boring insect pests

Chewing and boring insects consume plant tissue directly, causing visible defoliation, tunnelling, or fruit damage. Caterpillars (larvae of various moth and butterfly species) chew leaves, buds, and fruit; the tomato fruit borer/African cotton leafworm (Spodoptera species) bores into tomato and pepper fruit, causing direct fruit damage and entry points for secondary rot; cabbage looper and diamondback moth larvae cause severe defoliation of cabbage and other brassicas; managed by handpicking on small plots, biological insecticides (Bacillus thuringiensis, Bt), pheromone traps for monitoring, and targeted insecticide application timed to the vulnerable young larval stage. Stem borers and fruit flies: the okra/cotton stem borer tunnels inside stems, weakening and sometimes killing the plant; fruit flies (Bactrocera and Ceratitis species) lay eggs in ripening fruit (mango, citrus, guava, pepper); larvae develop inside the fruit, causing internal rot and rendering fruit unmarketable; one of the most economically damaging pests of Nigerian fruit, causing rejection of export consignments.

Management of fruit flies relies heavily on an integrated approach: field sanitation (collecting and destroying fallen and infested fruit, which harbour developing larvae and pupae, breaks the life cycle); bait traps (food-based or pheromone-based traps that attract and kill adult flies before they lay eggs); bagging individual fruits (wrapping developing fruit in paper or cloth bags to physically exclude egg-laying females; labour-intensive but effective and chemical-free for high-value fruit); and biological control (parasitic wasps that attack fruit fly larvae). Leaf miners (small fly or moth larvae that tunnel within leaf tissue, creating visible winding tunnels) reduce photosynthetic leaf area in many vegetables; managed by removing and destroying mined leaves, yellow sticky traps for adults, and biological control by parasitic wasps. Weevils (e.g. cowpea weevil, sweet potato weevil) damage stored grain/seed or tunnel into tubers; managed by proper storage in sealed containers, timely harvest, and resistant varieties.

Fill in the blank: ________ flies (Bactrocera and Ceratitis species) lay eggs in ripening fruit such as mango, citrus, and guava; the developing larvae cause internal rot, making this one of the most economically damaging pests of Nigerian fruit production.

5.2.3 Other pests: mites, rodents, and birds

Spider mites (Tetranychus species), though not insects (they are arachnids, related to spiders), are major pests of many vegetables and fruit trees: extremely small (barely visible to the naked eye), they feed on the underside of leaves, causing fine stippling, yellowing, and a characteristic fine silk webbing on heavily infested plants; thrive in hot, dry conditions and often become a problem when broad-spectrum insecticides have killed off their natural predators (predatory mites); managed by maintaining adequate humidity (overhead irrigation can reduce mite populations, though this conflicts with disease management for some crops), conserving predatory mites by avoiding unnecessary broad-spectrum insecticide use, and selective acaricides (mite-specific pesticides) for severe infestations.

Rodents (rats, mice, grasscutters/cane rats) damage vegetable and fruit crops by gnawing on stems, roots, tubers, and fruit, and by consuming stored grain and seed; particularly damaging to root and tuber crops (sweet potato, cassava) and to maturing maize and stored produce; managed by field sanitation (removing weeds and debris that provide rodent harbourage), trapping, rodenticide baits (used cautiously to avoid harming non-target wildlife and domestic animals), and physical barriers around high-value plots. Birds, particularly weaver birds and other grain-eating species, cause significant damage to ripening grain crops (maize, sorghum, rice) and can also damage soft fruits (grapes, some berries, ripening tomato); managed by netting over high-value fruit plantings, scarecrows and visual/auditory deterrents, and timely harvesting to minimise the period during which the crop is vulnerable.

Fill in the blank: ________ mites are tiny arachnids (not insects) that cause fine stippling and silk webbing on leaves; they thrive in hot, dry conditions and often increase in number when broad-spectrum insecticide use has killed off their natural predatory mite enemies.

Figure 5.2: Major pests of vegetable and fruit crops

Pilot questions 5.2

1. Describe the damage caused by aphids and whiteflies and name one virus each transmits.
2. Describe the damage caused by thrips and state two crops particularly affected.
3. Describe four methods for managing fruit fly infestation in Nigerian fruit production.
4. Distinguish between spider mites and insect pests in terms of classification and the conditions that favour their increase.
5. State two management methods each for rodent pests and bird pests in vegetable and fruit production.

5.3 Integrated Pest and Disease Management

5.3.1 Cultural and physical control methods

Cultural control methods modify normal farming practices to make the environment less favourable for pests and diseases, without relying on chemical inputs. Crop rotation (introduced in Series 3) breaks the life cycle of soil-borne pests and pathogens that depend on a specific host crop being present continuously; resistant variety selection (Series 4) provides a strong first line of defence against many diseases and some pests; field sanitation (removing and destroying crop residues, fallen fruit, and weeds that harbour pests and pathogens between seasons) reduces the carry-over of problems from one season to the next; proper spacing (avoiding overcrowding, as introduced in Series 1) improves airflow, reducing humidity around leaves and lowering fungal and bacterial disease pressure.

Physical control methods use barriers, traps, or manual removal rather than chemicals. Handpicking and removal of pests (caterpillars, beetles) and infected plant parts is effective and chemical-free for small plots, though labour-intensive for larger areas. Insect-proof netting over nursery beds and high-value crops physically excludes flying pests (whiteflies, aphids, thrips, fruit flies). Sticky traps (yellow for aphids and whiteflies; blue for thrips) and pheromone traps (which attract male moths using synthetic female sex pheromones) are used for both monitoring (to detect when pest populations exceed an action threshold) and direct control (mass trapping reduces breeding populations). Soil solarisation (Series 5.1.3) and crop residue burial or removal further reduce soil-borne pest and pathogen populations between cropping cycles. Mulching (Series 1 and 3) suppresses weed hosts and can create a physical barrier disrupting some soil-dwelling pest life cycles.

Fill in the blank: ________ traps (yellow for aphids and whiteflies; blue for thrips) are used for both monitoring pest populations to detect when an action threshold is exceeded, and for direct control through mass trapping that reduces breeding populations.

5.3.2 Biological control methods

Biological control uses living organisms (predators, parasites, and pathogens of pests) to suppress pest populations, reducing reliance on chemical pesticides. Conservation biological control preserves and enhances naturally occurring beneficial organisms already present in the field (ladybird beetles, lacewings, parasitic wasps, predatory mites, as introduced in Series 4) by minimising broad-spectrum insecticide use, maintaining flowering border plants that provide nectar and shelter for beneficial insects, and avoiding unnecessary disturbance of the field ecosystem. Augmentative biological control involves deliberately releasing additional natural enemies (purchased or reared on-farm) to boost populations beyond what occurs naturally, used for high-value crops where pest pressure exceeds what natural populations of beneficial organisms can control.

Microbial biopesticides use living microorganisms or their derived toxins as a targeted, often less environmentally disruptive alternative to synthetic chemical pesticides: Bacillus thuringiensis (Bt) produces a protein toxin specific to caterpillars (Lepidoptera larvae) when ingested, with minimal impact on beneficial insects, pollinators, and humans; entomopathogenic fungi (Beauveria bassiana, Metarhizium species) infect and kill a range of insect pests including aphids, whiteflies, and thrips; Trichoderma species (beneficial soil fungi) suppress soil-borne fungal pathogens (Fusarium, Pythium, Rhizoctonia) through competition and direct antagonism, and can be applied to seed, seedbeds, or soil. Botanical pesticides derived from plants (neem (Azadirachta indica) seed extract, pyrethrum, and other locally available plant materials) provide an accessible, low-cost, and relatively safe option for many Nigerian smallholder vegetable and fruit farmers, though they generally act more slowly and require more frequent application than synthetic chemicals.

Fill in the blank: ________ thuringiensis (Bt) is a microbial biopesticide that produces a protein toxin specific to caterpillars (Lepidoptera larvae) when ingested, with minimal impact on beneficial insects, pollinators, and humans.

5.3.3 Chemical control and safe pesticide use

Chemical (synthetic) pesticides remain an important tool in integrated pest and disease management, particularly for severe infestations or diseases where cultural and biological methods alone are insufficient, but they must be used judiciously as part of a broader strategy rather than as the sole or first response. Pesticide selection should consider: efficacy against the specific target pest or disease (broad-spectrum products kill beneficial organisms along with the target pest and should be reserved for situations where this trade-off is justified; selective products that spare natural enemies are preferred where available); pre-harvest interval (the minimum time that must elapse between the last pesticide application and harvest, to allow chemical residues to decline to safe levels; violating the pre-harvest interval is a serious food safety and regulatory violation); and resistance management (repeated use of the same pesticide mode of action allows resistant pest or pathogen populations to develop and spread; rotating between different chemical classes delays resistance development).

Safe pesticide use practices essential for protecting the applicator, consumers, and the environment: always read and follow the product label instructions for the correct target pest, application rate, timing, and pre-harvest interval; wear appropriate personal protective equipment (gloves, mask, protective clothing) during mixing and application; apply pesticides during calm weather (avoiding wind drift onto non-target areas and water bodies) and avoid spraying during flowering when bees are actively foraging; calibrate spray equipment correctly to avoid over- or under-application; store pesticides in their original labelled containers, locked away from children, food, and water sources; and dispose of empty containers and unused pesticide safely according to local regulations, never into water bodies or open burning. The use of counterfeit, banned, or unregistered pesticides (a significant problem in some Nigerian markets) poses serious risks to human health, the environment, and produce safety, and should always be avoided in favour of products registered with NAFDAC and purchased from reputable agro-dealers.

Fill in the blank: The pre-harvest ________ is the minimum time that must elapse between the last pesticide application and crop harvest, allowing chemical residues to decline to safe levels; violating this period is a serious food safety and regulatory violation.

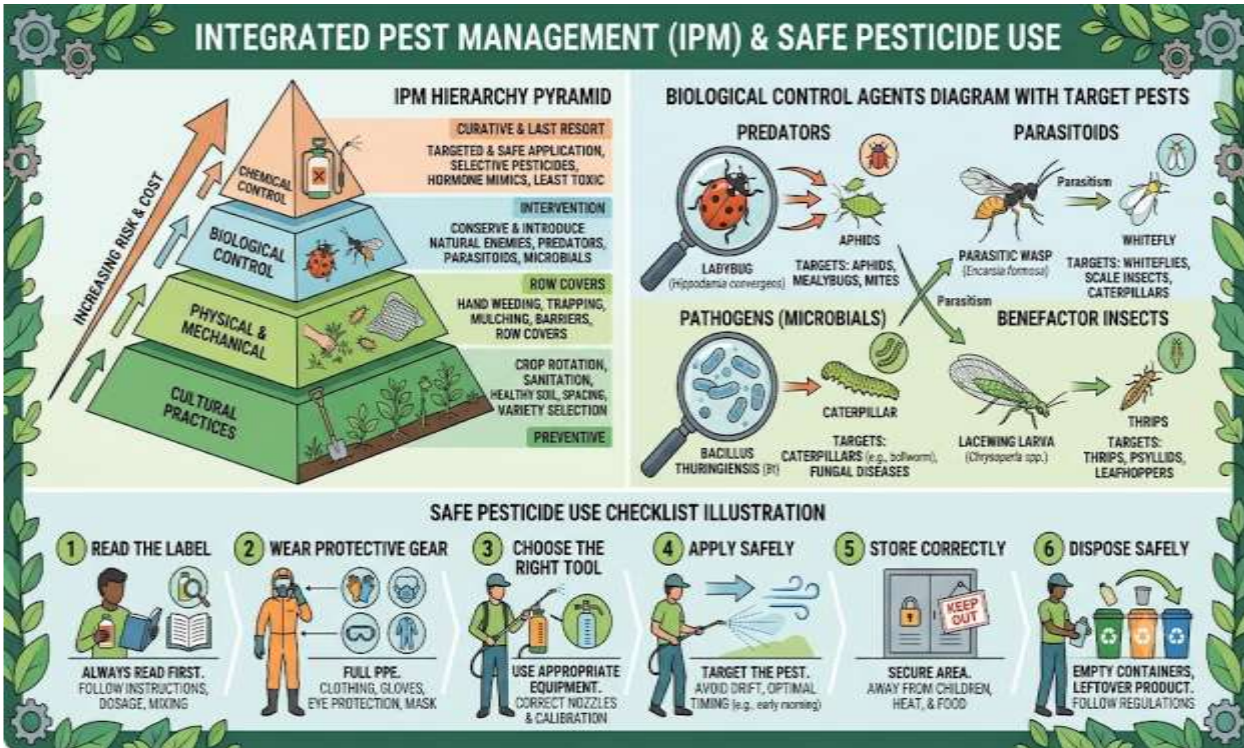

Figure 5.3: Integrated pest and disease management strategies

Pilot questions 5.3

1. State four cultural control methods used in integrated pest and disease management.
2. Distinguish between conservation and augmentative biological control.
3. Name three microbial biopesticides and state the pest or disease each controls.
4. Explain what the pre-harvest interval is and why it is important.
5. State five safe pesticide use practices that protect the applicator and consumer.

5.4 Sustainable Vegetable and Fruit Production

5.4.1 Principles of sustainable production

Sustainable vegetable and fruit production aims to meet current production and income needs without compromising the ability of the land and ecosystem to support production in the future, balancing productivity, environmental health, and economic viability. Soil health management:

maintaining and building soil organic matter through compost, manure, and cover crops; minimising tillage where practical to preserve soil structure and biological activity; preventing erosion through contour farming, mulching, and appropriate ground cover; these practices (introduced throughout Series 1-4) form the foundation of long-term productive capacity. Water resource management: efficient irrigation methods (drip irrigation, as covered in Series 3) that minimise water waste; rainwater harvesting and storage to reduce dependence on groundwater and surface water during the dry season; avoiding over-extraction of groundwater that can lower water tables and affect other users.

Biodiversity conservation: maintaining diverse cropping systems (intercropping, crop rotation, agroforestry with fruit trees) rather than large monocultures, which are more resilient to pest and disease outbreaks and provide habitat for beneficial organisms; conserving pollinator and natural enemy populations through reduced and judicious pesticide use, as covered in Part 5.3. Reduced external input dependence: integrating organic and inorganic nutrient sources, biological and cultural pest control, and locally available resources reduces dependence on expensive, imported synthetic inputs and improves the resilience and profitability of smallholder production systems. Economic and social sustainability: ensuring that production practices generate adequate and stable income for farm families, provide fair labour conditions, and contribute positively to community food security and livelihoods, not just maximise short-term yield or profit.

Fill in the blank: Sustainable vegetable and fruit production aims to meet current production and income needs without compromising the ability of the land and ecosystem to support production in the ________ , balancing productivity, environmental health, and economic viability.

5.4.2 Organic and low-input production systems

Organic production systems exclude synthetic fertilisers, pesticides, and genetically modified organisms, relying instead on natural processes and inputs to maintain soil fertility and manage pests and diseases. Organic soil fertility management relies on compost, farmyard manure, green manures (leguminous cover crops incorporated into the soil), and biological nitrogen fixation (Rhizobium-legume associations, as introduced in Series 2 and 4) rather than synthetic fertilisers; organic matter management is even more central to organic systems than to conventional systems because it is the primary nutrient source. Organic pest and disease management relies entirely on the cultural, physical, and biological control methods covered in Part 5.3 (resistant varieties, crop rotation, biological control agents, botanical pesticides such as neem) since synthetic chemical pesticides are excluded.

Certified organic production (meeting formal organic certification standards, which in Nigeria are still developing relative to more established markets) opens access to premium export and niche domestic markets but requires detailed record keeping and, often, a multi-year transition period during which residual synthetic chemicals must be absent from the soil. Low-input (though not necessarily fully organic) production systems reduce but do not entirely eliminate synthetic inputs, using them strategically and minimally while emphasising organic matter management, biological control, and cultural practices as the primary strategy; this approach is often more practical and accessible for Nigerian smallholder farmers than full organic certification, since it captures many of the environmental and cost benefits of organic production while retaining flexibility to use targeted chemical control for severe outbreaks that would otherwise cause crop failure.

Fill in the blank: ________ production systems exclude synthetic fertilisers, pesticides, and genetically modified organisms, relying instead on compost, manure, biological nitrogen fixation, and cultural/biological pest control to maintain soil fertility and manage pests.

5.4.3 Climate-smart and resilient vegetable and fruit production

Climate change is increasingly affecting Nigerian vegetable and fruit production through rising temperatures, more erratic and intense rainfall, longer and more severe dry seasons in some regions, and increased pest and disease pressure as warmer temperatures favour faster reproduction of many pest and pathogen species. Climate-smart agriculture aims to simultaneously increase productivity and farmer income, build resilience to climate variability and extreme events, and reduce greenhouse gas emissions where possible. Heat and drought-tolerant varieties: selecting varieties bred or selected for tolerance to high temperature and water stress reduces the risk of crop failure during increasingly frequent heat waves and dry spells; this is an increasingly important variety selection criterion alongside yield and disease resistance (Series 4).

Water-efficient practices: drip irrigation, mulching, and rainwater harvesting (covered in Series 1, 3, and 5.4.1) become even more critical under climate change as water availability becomes less predictable; shifting some production to the dry season using stored or groundwater irrigation can reduce exposure to increasingly erratic rainy-season conditions. Diversification as a resilience strategy: growing a diverse range of crops and varieties with different climate sensitivities spreads risk, so that a climate shock affecting one crop does not eliminate the farmer's entire income; income diversification beyond a single crop, including value-added processing (as covered for other crops in AGE 201 Series 5), further builds household resilience. Climate information services: access to seasonal forecasts and weather advisories (increasingly available through mobile phone services in Nigeria) allows farmers to time planting, irrigation, and pest management decisions more precisely in response to actual and predicted conditions, rather than relying solely on traditional planting calendars that may no longer match the shifting climate. Adopting these climate-smart practices, alongside the sustainable production principles and organic/low-input approaches covered earlier in this Part, positions Nigerian vegetable and fruit producers to maintain productivity and profitability under an increasingly variable and challenging climate.

Fill in the blank: ________ -smart agriculture aims to simultaneously increase productivity and farmer income, build resilience to climate variability and extreme events, and reduce greenhouse gas emissions where possible, in response to rising temperatures and more erratic rainfall affecting Nigerian agriculture.

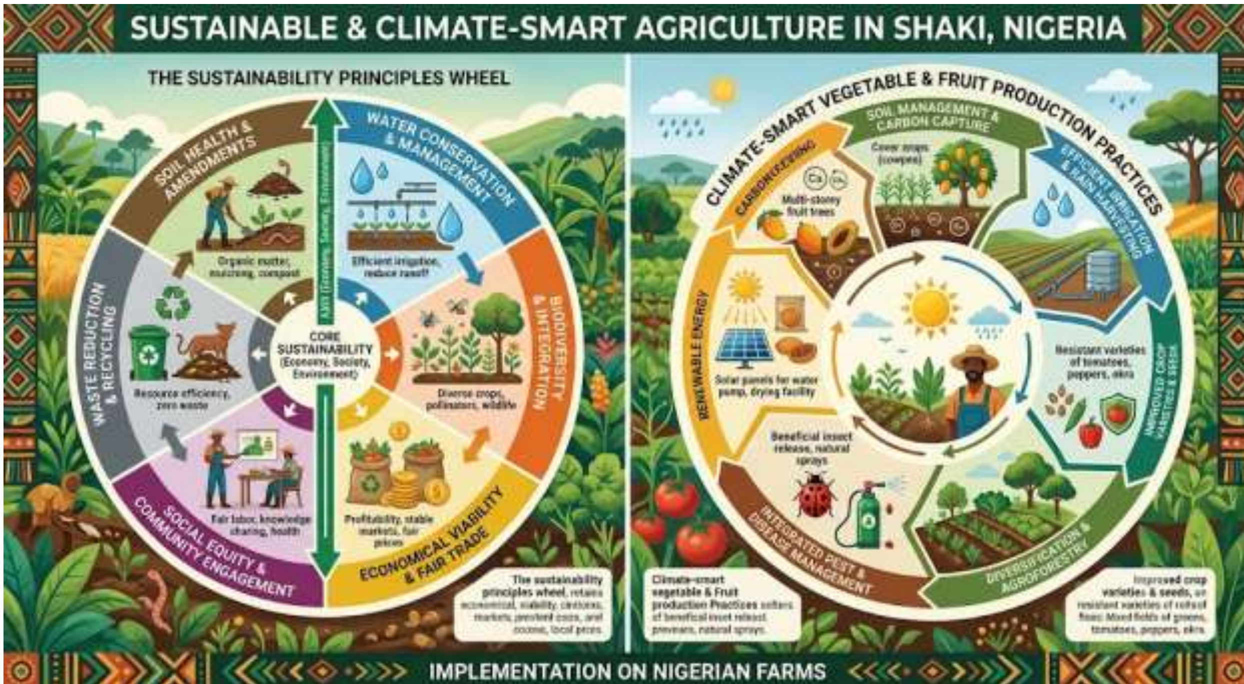

Figure 5.4: Sustainable and climate-smart vegetable and fruit production

Pilot questions 5.4

16. State four principles of sustainable vegetable and fruit production.
17. Distinguish between organic and low-input production systems.
18. Explain why organic matter management is even more central to organic production than to conventional production.
19. State four climate-smart practices that build resilience in Nigerian vegetable and fruit production.
20. Explain how diversification serves as a climate resilience strategy for smallholder farmers.

Series Summary

This Series examined the major diseases and pests affecting vegetable and fruit crops. **Plant diseases are harmful conditions caused by pathogens such as fungi, bacteria, viruses, and nematodes.** Important fungal diseases include blight, anthracnose, powdery mildew, damping-off, and Fusarium wilt. Bacterial diseases include bacterial wilt and bacterial spot, while viral diseases such as TYLCV and CMV are mainly spread by insect vectors and have no direct cure. Root-knot nematodes damage roots and reduce plant growth. Major pests include aphids, whiteflies, thrips, mealybugs, caterpillars, fruit flies, leaf miners, weevils, spider mites, rodents, and birds.

The Series also covered **integrated pest management (IPM), which combines cultural, physical, biological, and chemical methods to control pests safely and sustainably.** Resistant varieties, crop rotation, sanitation, traps, netting, beneficial organisms, and selective pesticides should be used in that order where possible. Sustainable production also requires good soil health, efficient water use, biodiversity conservation, safe labour practices, and stable farm income. Organic systems depend mainly on natural inputs and biological control, while climate-smart agriculture uses tolerant varieties, water-saving methods, diversification, and climate information to reduce production risks. By completing this Series, students should achieve SLOs 5.1–5.4 and all AGE 207 course outcomes.

Glossary of Terms

- **Anthracnose:** a fungal disease (Colletotrichum species) causing sunken, dark, circular lesions on fruit; affects pepper, tomato, mango, and many fruits; major cause of post-harvest loss.
- **Bacterial wilt:** a soil-borne bacterial disease (Ralstonia solanacearum) causing sudden wilting of tomato and pepper without prior yellowing; confirmed by milky ooze from a cut stem.

- **Biological control:** the use of living organisms (predators, parasites, pathogens) to suppress pest populations; includes conservation and augmentative approaches.
- **Climate-smart agriculture:** an approach that simultaneously increases productivity and income, builds resilience to climate variability, and reduces greenhouse gas emissions where possible.
- **Damping-off:** a fungal disease (Pythium, Rhizoctonia) causing pre- or post-emergence seedling death in the nursery, favoured by overwatered, poorly drained seedbeds.
- **Fusarium wilt:** a soil-borne fungal disease (Fusarium oxysporum) that blocks the plant vascular system, causing wilting; persists in soil for years; managed by resistant varieties and rotation.
- **Integrated pest management (IPM):** a strategy combining cultural, biological, and chemical control methods in a hierarchy, using the least disruptive effective methods first and reserving broad-spectrum chemicals for severe outbreaks.
- **Pre-harvest interval:** the minimum time that must elapse between the last pesticide application and crop harvest, allowing chemical residues to decline to safe levels.
- **Root-knot nematode:** a microscopic soil-dwelling worm (Meloidogyne species) that causes characteristic galls on plant roots; the most economically important nematode pest of Nigerian vegetables.
- **Soil solarisation:** covering moist soil with clear plastic sheeting during the hot dry season to raise soil temperature and kill nematodes and soil pathogens; a low-cost, chemical-free method.
- **Sustainable production:** an approach that meets current production and income needs without compromising the ability of the land and ecosystem to support production in the future.
- **TYLCV (Tomato yellow leaf curl virus):** a whitefly-transmitted viral disease causing severe leaf curling, yellowing, and stunting in tomato; a major cause of yield loss in Nigeria and West Africa.

Concept Check Questions [Series 5]

Objective Questions

11. ________ -off (Pythium, Rhizoctonia species) causes pre-emergence seed rot or post-emergence seedling collapse in the nursery, favoured by overwatered, poorly drained seedbeds. (Linked to SLO 5.1)
12. ________ (Bemisia tabaci) are small white moth-like insects that are the primary vector of tomato yellow leaf curl virus (TYLCV). (Linked to SLO 5.2)
13. ________ traps (yellow for aphids/whiteflies; blue for thrips) are used for both monitoring pest populations and direct control through mass trapping. (Linked to SLO 5.3)
14. The pre-harvest ________ is the minimum time between the last pesticide application and harvest, allowing residues to decline to safe levels. (Linked to SLO 5.3)
15. ________ -smart agriculture aims to increase productivity and income, build resilience to climate variability, and reduce greenhouse gas emissions where possible. (Linked to SLO 5.4)

Short-Answer Questions

16. Name four fungal diseases of vegetable crops and one symptom of each. (Linked to SLO 5.1)
17. Distinguish between aphids and whiteflies in terms of the viruses they transmit. (Linked to SLO 5.2)
18. State four cultural control methods in integrated pest and disease management. (Linked to SLO 5.3)
19. Name three microbial biopesticides and the pest/disease each controls. (Linked to SLO 5.3)
20. State four principles of sustainable vegetable and fruit production. (Linked to SLO 5.4)

Long-Answer Questions

20. Describe the major fungal, bacterial, viral, and nematode diseases of vegetable and fruit crops. (Linked to SLO 5.1)
21. Describe the major insect, mite, and vertebrate pests of vegetable and fruit crops. (Linked to SLO 5.2)
22. Describe integrated pest and disease management and the principles of sustainable, organic, and climate-smart production. (Linked to SLOs 5.3, 5.4)

Answers to Concept Check Questions [Series 5]

Objective Questions

1. Damping.
2. Whiteflies.
3. Sticky.
4. Interval.
5. Climate.

Short-Answer Questions

1. Early blight (concentric leaf spots); late blight (water-soaked rapidly enlarging lesions); powdery mildew (white powdery leaf coating); Fusarium wilt (yellowing and vascular wilt).
2. Aphids transmit cucumber mosaic virus and okra mosaic virus; whiteflies transmit tomato yellow leaf curl virus (TYLCV).
3. Crop rotation; resistant variety selection; field sanitation; proper plant spacing for airflow.

4. Bacillus thuringiensis (caterpillars); Trichoderma (soil-borne fungal pathogens); entomopathogenic fungi/Beauveria bassiana (aphids, whiteflies, thrips).
5. Soil health management; water resource management; biodiversity conservation; reduced external input dependence (and economic/social sustainability).

Long-Answer Questions

1. Fungal: early/late blight (leaf spots/lesions on tomato/pepper), anthracnose (fruit lesions; post-harvest losses), powdery mildew (white coating on cucurbits), damping-off (nursery seedling collapse), Fusarium wilt (soil-borne vascular wilt). Bacterial: bacterial wilt (sudden wilt; milky ooze; rootstock grafting management), bacterial spot/speck (leaf/fruit spots; copper bactericides). Viral: TYLCV (whitefly-vectored; tomato curling/stunting), CMV (aphid-vectored; mottled leaves); no cure; vector control essential. Nematode: root-knot nematode (galls on roots; stunting/wilting; managed by rotation, resistant varieties, soil solarisation, organic matter).
2. Sucking/piercing: aphids (curling leaves; virus vectors), whiteflies (TYLCV vector), thrips (silvery streaking; pepper/onion), mealybugs/scale (citrus, mango; ant-protected). Chewing/boring: caterpillars (fruit borers; Bt control), stem borers, fruit flies (mango/citrus; sanitation, bait traps, bagging), leaf miners, weevils (stored grain/tubers). Other: spider mites (arachnids; hot/dry conditions; stippling/webbing), rodents (tubers/stored grain; trapping/sanitation), birds (ripening grain/fruit; netting/scarecrows).
3. IPM hierarchy: cultural/physical (rotation, resistant varieties, sanitation, traps, netting; base/routine methods), biological (conservation/augmentative; Bt, Trichoderma, beneficial insects, botanicals like neem), chemical (selective first; broad-spectrum as last resort); safe use (label instructions, PPE, pre-harvest interval, calibration, safe storage, avoid counterfeits). Sustainable production: soil health (organic matter, minimal tillage), water management (drip irrigation, rainwater harvesting), biodiversity (diverse cropping, pollinator conservation), economic/social sustainability. Organic: excludes synthetic inputs; relies on

compost/manure/biological N fixation and cultural/biological pest control; certification opens premium markets. Climate-smart: heat/drought-tolerant varieties, water-efficient practices, diversification, climate information services (mobile weather advisories).

Answers to Pilot Questions [Series 5]

Part 5.1

1. Four diseases: (1) Early blight (Alternaria solani): dark concentric leaf spots; managed by resistant varieties and fungicide. (2) Late blight (Phytophthora infestans): water-soaked rapidly enlarging lesions; managed by fungicide and field sanitation. (3) Powdery mildew: white powdery coating on cucurbit leaves; managed by resistant varieties and adequate spacing. (4) Fusarium wilt: yellowing and vascular wilt; managed primarily by resistant varieties and crop rotation since chemical control is largely ineffective.
2. Bacterial wilt causes sudden wilting without prior yellowing, confirmed by milky bacterial ooze when the stem is cut; it is caused by Ralstonia solanacearum and persists in soil for years. Fusarium wilt causes yellowing of leaves before wilting occurs and is caused by a soil-borne fungus rather than a bacterium; the absence of bacterial ooze distinguishes it from bacterial wilt.
3. Two viral diseases: (1) Tomato yellow leaf curl virus (TYLCV), transmitted by whiteflies, causing severe leaf curling and stunting; managed by whitefly control (insecticides, reflective mulch) and resistant varieties. (2) Cucumber mosaic virus (CMV), transmitted by aphids, causing mottled yellow-green leaves and distortion in cucumber, pepper, and tomato; managed by aphid control and resistant varieties.
4. Symptoms: characteristic galls (knots) on infected roots visible when roots are washed; stunting, yellowing, and wilting above ground, especially under moisture stress. Three management practices: crop rotation with non-host crops (maize,

sorghum); resistant varieties or rootstocks; soil solarisation (covering moist soil with clear plastic during the dry season).

5. Soil solarisation involves covering moist soil with clear plastic sheeting for 4-6 weeks during the hot dry season; the plastic traps solar heat, raising soil temperature in the upper layers high enough to kill nematodes and many soil-borne fungal and bacterial pathogens. It is a low-cost, chemical-free method increasingly promoted for Nigerian smallholder vegetable production.

Part 5.2

1. Aphids cause curled, distorted leaves, stunted growth, and honeydew/sooty mould, and transmit cucumber mosaic virus. Whiteflies cause similar direct sap-removal damage and honeydew, and are the primary vector of tomato yellow leaf curl virus (TYLCV).
2. Thrips cause characteristic silvery streaking and stippling on leaves and flowers, distorted growth, and reduced fruit set. Two crops particularly affected: pepper and onion (and many flowering vegetables generally).
3. Four methods: (1) Field sanitation (collecting and destroying fallen and infested fruit to break the larval/pupal life cycle). (2) Bait traps (food- or pheromone-based traps that attract and kill adult flies before egg-laying). (3) Bagging individual fruits (wrapping developing fruit to physically exclude egg-laying females). (4) Biological control (parasitic wasps that attack fruit fly larvae).
4. Spider mites are arachnids (related to spiders), not insects, distinguishing them taxonomically from true insect pests such as aphids and whiteflies. They thrive and increase in hot, dry conditions, and their populations often explode when broad-spectrum insecticide use has killed off their natural predatory mite enemies, a phenomenon not typically seen with most true insect pests under the same conditions.
5. Rodent pests: (1) Field sanitation (removing weeds and debris that provide harbourage); (2) trapping or cautious use of rodenticide baits. Bird pests: (1) Netting

over high-value fruit plantings; (2) scarecrows and visual/auditory deterrents (and timely harvest to reduce vulnerable period).

Part 5.3

1. Four cultural methods: crop rotation (breaks soil-borne pest/pathogen life cycles); resistant variety selection (first line of defence); field sanitation (removes carry-over of pests/pathogens between seasons); proper plant spacing (improves airflow, reducing disease pressure).
2. Conservation biological control preserves and enhances naturally occurring beneficial organisms already present in the field by minimising broad-spectrum insecticide use and maintaining habitat. Augmentative biological control involves deliberately releasing additional natural enemies (purchased or reared on-farm) to boost populations beyond natural levels, used for high-value crops where pest pressure exceeds natural biological control capacity.
3. Three biopesticides: (1) Bacillus thuringiensis (Bt): controls caterpillars (Lepidoptera larvae). (2) Entomopathogenic fungi (Beauveria bassiana, Metarhizium): control aphids, whiteflies, and thrips. (3) Trichoderma species: suppress soil-borne fungal pathogens such as Fusarium, Pythium, and Rhizoctonia.
4. The pre-harvest interval is the minimum time that must elapse between the last pesticide application and crop harvest. It is important because it allows chemical residues on the crop to decline to levels considered safe for human consumption; violating this interval risks harmful pesticide residues reaching consumers and constitutes a serious food safety and regulatory violation.
5. Five practices: read and follow product label instructions (target pest, rate, timing, pre-harvest interval); wear appropriate personal protective equipment during mixing and application; apply during calm weather, avoiding spraying during bee foraging at flowering; calibrate spray equipment correctly; store pesticides in original labelled containers away from children, food, and water, and dispose of containers safely.

Part 5.4

1. Four principles: soil health management (building organic matter, minimising tillage, preventing erosion); water resource management (efficient irrigation, rainwater harvesting); biodiversity conservation (diverse cropping systems, pollinator/natural enemy conservation); economic and social sustainability (stable farm income, fair labour conditions, community food security).
2. Organic production systems entirely exclude synthetic fertilisers, pesticides, and genetically modified organisms, relying solely on compost, manure, green manures, biological nitrogen fixation, and cultural/biological pest control. Low-input systems reduce but do not entirely eliminate synthetic inputs, using them strategically and minimally while still emphasising organic matter management and biological/cultural practices as the primary strategy, offering a more practical middle ground for many Nigerian smallholder farmers.
3. Organic matter management is even more central to organic production because, with synthetic fertilisers excluded by definition, compost, manure, and green manures become the primary (rather than supplementary) source of plant nutrients; without diligent organic matter management, an organic system cannot supply adequate fertility for good yields, whereas a conventional system can compensate for poor organic matter management with synthetic fertiliser application.
4. Four climate-smart practices: heat and drought-tolerant variety selection; water-efficient practices (drip irrigation, mulching, rainwater harvesting); diversification of crops and varieties to spread climate risk; access to climate information services (seasonal forecasts and weather advisories via mobile phone) for better-timed planting and management decisions.
5. Diversification serves as a climate resilience strategy because growing a range of crops and varieties with different climate sensitivities (heat tolerance, water requirement, growing season) spreads risk across the farm; if a climate shock (drought, heat wave, unusual rainfall pattern) severely affects one crop, other crops in the diversified system may be less affected or even benefit, so the farmer's total

income and food supply are not entirely lost to a single climate event, unlike in a monoculture system.

References and Attributions

Textual References (Books and External Sources)

- FAO (Food and Agriculture Organization of the United Nations). (2025). Guidelines for sustainable agriculture. FAO.
- Tindall, H. D. (1983). Vegetables in the tropics. Macmillan Press, London.
- IITA (International Institute of Tropical Agriculture). (2020). Annual report. IITA, Ibadan.
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Figures, Plates, Tables, and Boxes

- Figure 5.1: Major diseases of vegetable and fruit crops Attribution: AI generated. Suggested OER search string: "tomato pepper disease early blight late blight powdery mildew bacterial wilt TYLCV root-knot nematode Nigeria vegetable OER".
- Figure 5.2: Major pests of vegetable and fruit crops Attribution: AI generated. Suggested OER search string: "aphid whitefly thrips fruit fly caterpillar spider mite rodent bird pest vegetable fruit crop Nigeria identification OER".
- Figure 5.3: Integrated pest and disease management strategies Attribution: AI generated. Suggested OER search string: "integrated pest management IPM biological control Bacillus thuringiensis safe pesticide use PPE pre-harvest interval Nigeria OER".
- Figure 5.4: Sustainable and climate-smart vegetable and fruit production Attribution: AI generated. Suggested OER search string: "sustainable vegetable fruit production organic climate-smart agriculture drought-tolerant variety drip irrigation Nigeria OER".