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AGE 301

HORTICULTURE EDUCATION

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Series 1: Classification and Importance of Crops

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Introduction

Horticulture is one of the most diverse and economically significant branches of agriculture. It encompasses the cultivation of vegetables, fruits, ornamental plants, and other high-value crops that contribute directly to human nutrition, health, aesthetics, and economic wellbeing. In Nigeria, horticultural crops form a critical part of the diet of over 220 million people and provide livelihoods for millions of smallholder farmers, market traders, and agro-processors.

This Series introduces the definition, scope, and branches of horticulture; explains how horticultural crops are classified by botanical family, edible part, life cycle, growth habit, and climatic requirement; and examines the nutritive value of fruits and vegetables in the human diet. A sound understanding of crop classification is essential for organising knowledge about production requirements, identifying plants in the field, and designing appropriate management systems.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 1.1** define horticulture, describe its main branches, and distinguish it from agronomy (Linked to Part 1.1),
- **SLO 1.2** explain the importance of horticulture to Nigeria's food security, nutrition, economy, and environment (Linked to Part 1.1),
- **SLO 1.3** classify vegetable crops by botanical family, edible part, life cycle, and temperature requirement, giving Nigerian examples (Linked to Part 1.2),
- **SLO 1.4** classify fruit crops by botanical family, growth habit, and climatic requirement, and identify important minor and underutilised fruits in Nigeria (Linked to Part 1.3), and
- **SLO 1.5** describe the macronutrient and micronutrient composition of important Nigerian fruits and vegetables and explain their roles in human health (Linked to Part 1.4).

1.1 Definition and Scope of Horticulture

1.1.1 Definition and branches of horticulture

Horticulture is derived from the Latin words hortus (garden) and cultura (cultivation); it is broadly defined as the science and art of growing, processing, and marketing fruits, vegetables, flowers, ornamental plants, and other garden crops. Unlike broad-acre field crops (maize, sorghum, cassava), horticultural crops are typically grown in smaller areas with more intensive management, higher inputs, and higher value per unit area. Horticulture differs from other branches of agriculture in the diversity of crops, the intensity of cultivation, the perishability of the products, and the importance of aesthetic and nutritional quality.

The four main branches of horticulture are: (1) Pomology (fruit science): the science of fruit cultivation, including tropical fruits (mango, citrus, pineapple, banana, plantain, pawpaw), temperate fruits (apple, grape, pear), and nuts (cashew, kola, groundnut as a botanical legume-nut). (2) Olericulture (vegetable science): the science of vegetable production, including leaf vegetables (fluted pumpkin, waterleaf, African nightshade), fruit vegetables (tomato, pepper, okra, garden egg), root vegetables (carrot, radish, sweet potato), and bulb vegetables (onion, garlic). (3) Floriculture (flower and ornamental science): the science of growing flowers, ornamental foliage plants, and decorative plant products for cut flowers, potted plants, and landscape use. (4) Landscape horticulture: the design, installation, and maintenance of outdoor and indoor plant environments, including lawn management, garden design, and urban green infrastructure.

Fill in the blank: Horticulture is derived from the Latin words hortus (garden) and cultura (cultivation); its four main branches are pomology (fruit science), _____ (vegetable science), floriculture (flower and ornamental science), and landscape horticulture.

1.1.2 Distinction between horticulture and agronomy

Agronomy is the science and practice of producing field (arable) crops and managing soils for crop production; it primarily deals with large-scale, extensive production of staple food and fibre crops such as maize, sorghum, rice, cassava, cowpea, and cotton. Horticulture, by contrast,

focuses on high-value crops typically grown in smaller areas with greater intensity of management. Key distinctions: (1) Scale of production: agronomy involves large-scale, extensive systems (1 to hundreds of hectares per enterprise); horticulture typically involves small plots (0.1 to 5 ha for smallholders; larger for commercial operations), intensive management, and high input use per unit area. (2) Crop diversity: agronomy focuses on a relatively small number of staple crops; horticulture encompasses hundreds of vegetable, fruit, flower, and ornamental species. (3) Product nature: agronomic crops are generally storable, durable commodities (grains, tubers); horticultural products are mostly perishable, fresh, or semi-processed, requiring cold chain logistics and rapid marketing.

(4) Economic value: horticultural crops typically have a much higher value per hectare than staple crops; tomatoes at N3 to 5 million per ha compared to N500,000 to 800,000 per ha for maize in the same region. (5) Management intensity: horticulture requires more frequent irrigation, fertilisation, pest and disease management, staking, pruning, and harvesting operations than agronomy. (6) Labour requirement: horticultural crops are generally more labour-intensive than field crops; they contribute significantly to rural employment in vegetable-producing areas of Nigeria (Kaduna, Plateau, Kano, and Ogun states). Both disciplines share soil science, plant physiology, genetics, and pest management, and many Nigerian farmers practise both on the same farm.

Fill in the blank: Horticultural crops are typically grown in _____ areas with more intensive management and command a higher value per hectare than agronomic staple crops; tomatoes, for example, may yield N3 to 5 million per ha compared with N500,000 to 800,000 per ha for maize.

1.1.3 Importance of horticulture to Nigeria

Horticulture contributes to Nigeria in multiple dimensions: (1) Food security and nutrition: fruits and vegetables supply essential vitamins (A, C, B-complex), minerals (iron, calcium, potassium), dietary fibre, and antioxidants that are absent or inadequate in staple-grain-dominated diets; they are critical to addressing hidden hunger (micronutrient deficiency) which affects approximately 30 to 40 percent of Nigerian children under five. (2) Income and livelihoods: horticultural crops provide higher returns per unit area than most staple crops; they are a major income source for

urban and peri-urban smallholder farmers, particularly women vegetable growers in the fadama systems of northern Nigeria and the garden city systems of the south. (3) Employment: vegetable and fruit production, marketing, processing, and distribution employ millions of people along the value chain; Lagos, Kano, and Port Harcourt vegetable markets are among the largest employers in their cities.

(4) Export earnings: Nigeria exports cashew nuts (approximately 180,000 to 200,000 tonnes annually; major export crop to Vietnam, India, and Europe), sesame seeds, ginger, chilli pepper, and fresh vegetables to regional markets; horticultural export diversification is a key national agricultural policy objective. (5) Agro-industrial raw materials: tomatoes, peppers, onions, and citrus supply the food processing industry (tomato paste, hot sauce, fruit juice, essential oils); mangoes, pineapples, and plantains supply export-oriented processing companies. (6) Environmental and aesthetic values: urban gardens, parks, and ornamental plantings improve air quality, reduce urban heat island effects, and contribute to mental health and wellbeing of city residents. (7) Health and pharmacology: many Nigerian horticultural plants have documented medicinal properties (bitter leaf, moringa, African basil, lemon grass), supporting the traditional medicine sector and pharmaceutical raw material supply.

Fill in the blank: Nigeria exports approximately 180,000 to 200,000 tonnes of _____ nuts annually, making it one of Africa's major exporters; other important Nigerian horticultural exports include ginger, sesame seeds, chilli pepper, and fresh vegetables.

Pilot questions 1.1

1. Define horticulture and name and briefly describe its four main branches.
2. Distinguish between horticulture and agronomy under four headings.
3. State four ways in which horticulture is important to Nigeria's food security and economy.
4. Name two horticultural crops that are important Nigerian export commodities and state their main export markets.
5. Explain why horticultural crops are considered to address hidden hunger in Nigeria.

1.2 Classification of Vegetable Crops

1.2.1 Botanical classification of vegetables

A vegetable is any herbaceous plant or plant part that is eaten raw or cooked as part of the main meal (as opposed to a sweet dessert). Vegetables belong to diverse botanical families, and knowing the family of a vegetable helps predict its growing requirements, pest and disease susceptibility, and nutritional profile. Major botanical families of Nigerian vegetables: Solanaceae (nightshade family): tomato (Solanum lycopersicum), pepper (Capsicum annuum and C. frutescens), garden egg/African eggplant (Solanum melongena and S. aethiopicum), potato (Solanum tuberosum); characterised by alternate leaves, 5-petalled flowers, and berry or capsule fruits; many contain alkaloids. Cucurbitaceae (gourd family): pumpkin/ugu (Telfairia occidentalis), fluted pumpkin leaves, cucumber (Cucumis sativus), watermelon (Citrullus lanatus), bitter gourd (Momordica charantia); characterised by tendril-bearing vines, unisexual flowers, and fleshy pepo fruits.

Fabaceae/Leguminosae (legume family): cowpea (Vigna unguiculata), garden bean (Phaseolus vulgaris), groundbean (Vigna subterranea), yard-long bean (Vigna unguiculata subsp. sesquipedalis); characterised by compound leaves, papilionaceous (butterfly-shaped) flowers, and pod (legume) fruits; fix atmospheric nitrogen. Amaranthaceae: vegetable amaranth/tete (Amaranthus hybridus, A. cruentus); high-protein leaf vegetable. Apiaceae (carrot family): carrot (Daucus carota), celery (Apium graveolens), coriander (Coriandrum sativum); characterised by compound umbel inflorescences. Asteraceae (composite family): lettuce (Lactuca sativa), bitter leaf (Vernonia amygdalina), African daisy. Convolvulaceae: sweet potato (Ipomoea batatas; leaves and tubers both edible). Basellaceae: Indian spinach/Malabar spinach (Basella alba; widely grown in southern Nigeria). Knowing the family helps identify related pests and diseases (Solanaceae share bacterial wilt and TSWV; Cucurbitaceae share powdery mildew and aphids).

Fill in the blank: Tomato (Solanum lycopersicum), pepper (Capsicum annuum), and garden egg (Solanum melongena) all belong to the family _____, which is characterised by 5-petalled flowers, berry or capsule fruits, and a susceptibility to bacterial wilt disease.

1.2.2 Classification by edible part

Classifying vegetables by edible part is the most practically useful system for farm planning, market categorisation, and nutritional analysis. (1) Leaf vegetables: the leaves (and sometimes stems) are the edible part. Examples in Nigeria: fluted pumpkin leaves (Telfairia occidentalis; ugu); waterleaf (Talinum triangulare; gbure); African nightshade (Solanum nigrum; ododun); bitter leaf (Vernonia amygdalina; onugbu); African basil (Ocimum gratissimum; efirin); moringa leaves (Moringa oleifera); Malabar spinach (Basella alba). Leaf vegetables are rich in iron, calcium, vitamins A and C, and dietary fibre; they are the primary sources of micronutrients in low-income diets. (2) Fruit vegetables: the fruit (botanical fruit; ripened ovary containing seeds) is the edible part. Examples: tomato (Solanum lycopersicum), pepper (Capsicum species), okra (Abelmoschus esculentus; ila), garden egg/eggplant (Solanum species), cucumber (Cucumis sativus), watermelon (Citrullus lanatus).

(3) Root and tuber vegetables: the underground root, corm, or tuber is the edible part. Examples: carrot (Daucus carota), radish (Raphanus sativus), sweet potato (Ipomoea batatas; tuber and leaves both edible), cassava (Manihot esculenta; grown primarily as a starch crop but classified horticulturally when grown for leaves and young tubers). (4) Bulb vegetables: the swollen leaf bases (bulb) are the edible part. Examples: onion (Allium cepa; yabasi), garlic (Allium sativum; ayu), shallot (Allium ascalonicum). (5) Stem vegetables: the stem or stem-like structures are edible. Examples: asparagus (Asparagus officinalis; the young shoot), kohlrabi (Brassica oleracea var. gongylodes; swollen stem). (6) Flower vegetables: the inflorescence or flower parts are edible. Examples: cauliflower and broccoli (Brassica oleracea var. botrytis and var. italica; only beginning to be grown in cool Nigerian highlands). Each category has distinct production requirements, harvest timing, and post-harvest handling needs.

Fill in the blank: Onion (Allium cepa), garlic (Allium sativum), and shallot (Allium ascalonicum) are classified as _____ vegetables because the swollen leaf bases (bulbs) are the edible part; they are important flavouring and condiment crops in Nigerian cuisine.

1.2.3 Classification by life cycle and temperature requirement

Life cycle classification: (1) Annual vegetables complete their entire life cycle (germination to seed production) within one growing season (less than 12 months). They are further divided into warm-season annuals (thrive at 20 to 30 degrees C; damaged by frost; planted after last frost or in rainy season in Nigeria: tomato, pepper, okra, cucumber, watermelon, cowpea) and cool-season annuals (thrive at 10 to 20 degrees C; tolerate light frost; best grown in the harmattan period in northern Nigeria or in highland areas: carrot, onion, lettuce, radish, cabbage). (2) Biennial vegetables require two growing seasons to complete their life cycle (vegetative growth in the first season; flowering and seeding in the second season, often after exposure to cold). Examples: carrot, onion, and celery are commercially grown as annuals but are botanically biennial. (3) Perennial vegetables persist for many years and produce repeatedly. Examples in Nigeria: fluted pumpkin (Telfairia occidentalis; the vine is perennial, regrowing from the stem base after harvest), African nightshade, moringa, bitter leaf.

Temperature requirement classification: (1) Cool-season crops: optimum temperature 10 to 20 degrees C; includes cabbage (Brassica oleracea), carrot (Daucus carota), onion (Allium cepa), lettuce (Lactuca sativa), radish (Raphanus sativus), peas (Pisum sativum). These crops perform best during the harmattan period (November to February) in northern Nigeria or year-round in the Jos Plateau and other highland areas (above 900 m). Heat and long days cause premature bolting (flowering and seed production before harvestable vegetative growth). (2) Warm-season crops: optimum temperature 20 to 30 degrees C; includes tomato, pepper, okra, cowpea, cucumber, watermelon, garden egg. These are the dominant vegetable crops of southern Nigeria and the bulk of vegetable production in Nigeria. High temperatures above 35 degrees C reduce fruit set in tomato and pepper (pollen viability falls); cool nights are important for flavour development in many warm-season crops.

Fill in the blank: Cool-season vegetables thrive at temperatures of 10 to 20 degrees C and are best grown during the harmattan period in northern Nigeria or year-round in highland areas such as the _____ Plateau; they include carrot, onion, lettuce, cabbage, and radish.

Pilot questions 1.2

1. Name the botanical families of the following vegetables and state one characteristic of each family: (a) tomato; (b) pumpkin; (c) cowpea; (d) carrot.
2. Classify the following vegetables by edible part: onion, fluted pumpkin leaves, tomato, carrot, okra, asparagus.
3. Distinguish between warm-season and cool-season vegetables with two Nigerian examples of each and state the optimum temperature range for each group.
4. Give three examples of perennial vegetables grown in Nigeria and state an advantage of perennial over annual vegetable production.
5. Explain why a farmer in Jos Plateau can grow cool-season vegetables year-round while a farmer in Kano must restrict cool-season production to a specific period.

1.3 Classification of Fruit Crops

1.3.1 Botanical classification of fruit crops

In botanical terms, a fruit is the ripened ovary of a flowering plant, containing seeds. In horticultural usage, fruits are plant products that are sweet or flavourful and typically eaten as snacks or dessert. Nigeria grows a wide range of tropical and subtropical fruit crops across its diverse ecological zones. Major botanical families of Nigerian fruit crops: Anacardiaceae (cashew family): mango (Mangifera indica), cashew (Anacardium occidentale), ube (Dacryodes edulis; African pear); the family is characterised by resinous, sometimes irritant sap and drupe (stone fruit) fruits. Musaceae: banana (Musa acuminata) and plantain (Musa paradisiaca); technically herbs (not woody trees); the fruit is a berry. Rutaceae (citrus family): sweet orange (Citrus sinensis), tangerine/mandarin (Citrus reticulata), grapefruit (Citrus paradisi), lemon (Citrus limon), lime (Citrus aurantifolia); characterised by aromatic oil glands in leaves; hesperidium fruit type.

Caricaceae: pawpaw/papaya (Carica papaya); fast-growing soft-wooded tree; berry fruit; contains the enzyme papain used in tenderising meat and in pharmaceutical applications. Bromeliaceae: pineapple (Ananas comosus); terrestrial bromeliad; multiple fruit formed from coalescence of many individual berries from the inflorescence. Sapindaceae (soapberry family):

ackee (Blighia sapida), lychee (Litchi chinensis), longan; also includes the horticulturally important avocado (Persea americana; family Lauraceae). Moraceae (mulberry family): breadfruit (Artocarpus altilis), jackfruit (Artocarpus heterophyllus); multiple fruits; Ficus species (fig). Punicaceae/Lythraceae: pomegranate (Punica granatum). Arecaceae (palm family): oil palm (Elaeis guineensis; the mesocarp and kernel are processed for edible oil rather than eaten fresh), coconut (Cocos nucifera), raphia palm. Knowing the botanical family of a fruit crop assists in identifying diseases, selecting rootstocks for grafting, and understanding harvest indices.

Fill in the blank: Mango (Mangifera indica) and cashew (Anacardium occidentale) both belong to the family _____, which is characterised by resinous sap and drupe (stone fruit) fruits; the cashew nut is actually the kidney-shaped seed attached to the outside of the cashew apple (a swollen receptacle).

1.3.2 Classification by growth habit and climate

Growth habit classification: (1) Tree fruits: woody perennial trees that grow for many years and produce fruit annually after reaching maturity. Examples: mango (15 to 40 m; matures in 3 to 5 years from seedling or 2 to 3 years from budded plant), citrus (3 to 10 m; matures in 3 to 5 years), avocado, breadfruit, jackfruit. (2) Shrub fruits: woody perennials of smaller stature. Examples: guava (Psidium guajava; 3 to 10 m; matures in 2 to 3 years); cashew (3 to 12 m; early-bearing). (3) Vine fruits: climbing or trailing plants. Examples: passion fruit (Passiflora edulis; climbs by tendrils; fruits in 9 to 12 months from planting), grapes (Vitis vinifera; limited growing areas in Nigeria at higher elevations). (4) Herbaceous perennial fruits: plants with no persistent woody stem above ground; the above-ground parts die and regrow from roots or corms. Examples: banana and plantain (Musa species; technically herbaceous; the pseudostem is leaf bases), pineapple (terrestrial bromeliad). (5) Annual fruits: complete their cycle in one season. Examples: watermelon (Citrullus lanatus; treated as a vegetable-fruit; annual), strawberry (Fragaria x ananassa; perennial but commercially grown as annual in some systems).

Climatic classification: (1) Tropical fruits: require frost-free conditions and high temperatures (25 to 35 degrees C year-round); include mango, banana, plantain, pawpaw, pineapple, citrus

(most species), avocado, breadfruit, jackfruit, cashew, African pear. These are the dominant fruit crops of southern Nigeria and the middle belt. (2) Subtropical fruits: tolerate mild frost and grow best in areas with distinct dry and cool periods; include citrus (particularly mandarin and grapefruit), avocado (some varieties), guava (tolerates mild cooling). (3) Temperate fruits: require a cold dormancy period (winter chilling hours below 7 degrees C); include apple (Malus domestica), pear (Pyrus species), grape (Vitis vinifera); these cannot be grown economically in most of Nigeria except at the highest elevations of the Mambilla and Jos plateaus where temperatures are sufficiently cool. Knowledge of climatic requirements is essential for site selection and variety choice in Nigerian fruit production.

Fill in the blank: Banana and plantain (Musa species) are classified as _____ perennial fruits because they have no persistent woody stem above ground; the pseudostem (which looks like a trunk) is actually formed by tightly packed leaf bases and dies after fruiting.

1.3.3 Minor and underutilised fruit crops in Nigeria

Nigeria has a rich diversity of indigenous and exotic fruit species that are locally consumed but receive little research attention or commercial development. Important underutilised fruits: (1) African pear (Dacryodes edulis; ube): a drupe with oily, buttery flesh; widely consumed in southern and eastern Nigeria; roasted or cooked; rich in fatty acids and vitamins; a traditional food of Igbo, Yoruba, and Efik communities; very limited commercial cultivation despite high demand. (2) African star apple (Chrysophyllum albidum; agbalumo/udara): a berry with sweet, milky-juiced flesh; highly seasonal (January to March); rich in vitamin C and antioxidants; sold widely in Nigerian urban markets; poorly domesticated. (3) Velvet tamarind (Dialium guineense; awin): a pod fruit with sweet-sour pulp; eaten as a snack; high in vitamin C; grown wild but rarely cultivated. (4) Bush mango/African mango (Irvingia gabonensis; ogbono): fruit consumed fresh; seed (ogbono) is the primary commercial part used as a soup thickener; highly valued but poorly managed in the wild. (5) African breadfruit (Treculia africana; ukwa/afon): a large multiple fruit; seeds are cooked and eaten; nutritious (high protein, carbohydrate); virtually uncultivated.

(6) Soursop (Annona muricata; sawa-sawa): an introduced species now widely naturalised; large spiny green fruit with white, fragrant, slightly acidic flesh; rich in vitamin C and B vitamins; consumed fresh, as juice, and in ice cream; potential for commercial cultivation and export. (7) Sugar apple/sweetsop (Annona squamosa): sweet, custard-like flesh; eaten fresh. (8) Monkey kola (Cola pachycarpa, C. lateritia, and C. verticillata): small tree; aril surrounding seeds is edible; consumed in southern Nigeria. Promoting the commercial cultivation, processing, and marketing of these underutilised fruits would improve nutritional diversity, generate income for rural communities, and conserve Nigeria's plant biodiversity.

Fill in the blank: African star apple (Chrysophyllum albidum), known as _____ in Yoruba and udara in Igbo, is a highly seasonal Nigerian fruit rich in vitamin C and antioxidants; it is widely sold in urban markets from January to March but remains largely uncultivated in formal orchards.

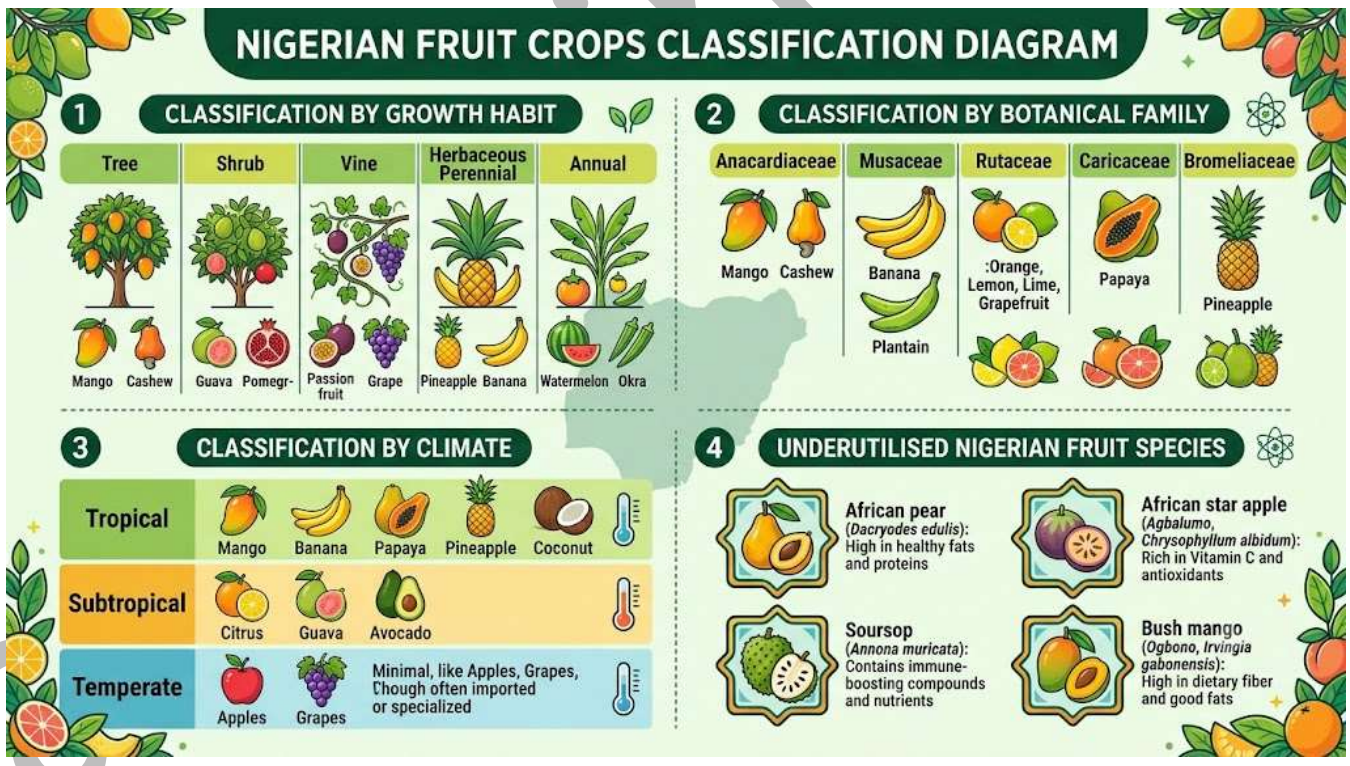

Figure 1.1: Classification of Nigerian fruit crops by growth habit, botanical family, climate, and utilisation status

Pilot questions 1.3

1. Name the botanical families of the following fruits and state one characteristic of each family: (a) mango; (b) banana; (c) citrus; (d) pawpaw.
2. Classify the following fruits by growth habit: mango, pineapple, passion fruit, guava, watermelon, banana.
3. Distinguish between tropical and temperate fruits in terms of temperature requirement and state why temperate fruits cannot be grown economically in most of Nigeria.
4. Name four underutilised fruit crops in Nigeria, state the common local name for each, and give one nutritional benefit.
5. Explain the difference between a botanical fruit and a horticultural fruit and give two examples of crops that are botanically fruits but culinarily classed as vegetables.

1.4 Nutritive Value of Fruits and Vegetables

1.4.1 Macronutrients and micronutrients in fruits and vegetables

Fruits and vegetables supply all three macronutrient categories (carbohydrates, proteins, and lipids) but are particularly valued for their micronutrient content (vitamins and minerals) and non-nutritive health-promoting compounds (dietary fibre, phytochemicals, antioxidants). Carbohydrates: most fruits are rich in simple sugars (glucose, fructose, sucrose; 5 to 20 percent of fresh weight in ripe tropical fruits); root vegetables (sweet potato, carrot) are rich in starch; leafy vegetables are low in total carbohydrate but provide dietary fibre (cellulose, hemicellulose, pectin) which promotes gut health, reduces constipation, and may lower cholesterol. Proteins: most fruits and vegetables are low in protein (0.5 to 3 percent fresh weight); exceptions include leafy green vegetables (moringa leaves: 27 percent protein on dry weight basis; fluted pumpkin leaves: 23 to 28 percent protein on dry weight basis; cowpea leaves: 20 to 25 percent protein on dry weight basis), which are important protein sources in vegetable-based diets.

Vitamins in fruits and vegetables: Vitamin C (ascorbic acid): abundant in citrus fruits, guava, fresh pepper, and African star apple; essential for collagen synthesis, immune function, and iron absorption; guava (Psidium guajava) contains 180 to 228 mg/100 g, far exceeding orange (50 to

60 mg/100 g). Vitamin A (as beta-carotene in orange-flesh fruits and vegetables; converted to retinol in the body): abundant in mango, pawpaw (orange-flesh varieties), carrot, pumpkin, sweet potato (orange-flesh), and red palm oil; essential for vision, immune function, and skin health; vitamin A deficiency affects approximately 30 percent of Nigerian children under five. Vitamin K: abundant in leafy green vegetables (bitter leaf, moringa, fluted pumpkin). B vitamins (thiamin, riboflavin, niacin, folate): widely distributed in vegetables; folate is particularly important for pregnant women (prevention of neural tube defects in the foetus). Minerals: iron (bitter leaf, African nightshade, moringa; combating anaemia); calcium (moringa leaves: 440 mg/100 g dry weight; among the richest plant sources); potassium (banana, plantain, avocado; essential for blood pressure regulation); zinc (leguminous vegetables: cowpea, groundbean).

Fill in the blank: Guava (Psidium guajava) contains 180 to 228 mg of vitamin _____ per 100 g of fresh fruit, making it one of the richest plant sources of this vitamin; this far exceeds the vitamin C content of sweet orange (50 to 60 mg/100 g).

1.4.2 Nutritional composition of selected Nigerian fruits and vegetables

Moringa (Moringa oleifera; zogale/ewe ile): referred to as the miracle tree; leaves contain per 100 g dry weight: protein 27 g; calcium 440 mg; iron 28 mg; vitamin A (beta-carotene) 18.9 mg; vitamin C 220 mg; potassium 1,324 mg. These values are far higher than those of many conventional foods (calcium 17 times that of milk per gram; iron 25 times that of spinach per gram in dry form). Moringa leaves are used to prepare soups and sauces in northern Nigeria and to fortify weaning foods for infants. Fluted pumpkin (Telfairia occidentalis; ugu): leaves are among the most nutritious vegetables in West Africa; protein 23 to 28 percent DW; iron 20 to 25 mg/100 g DW; calcium 170 mg/100 g FW; folate; rich in phytochemicals (saponins, flavonoids, tannins). Bitter leaf (Vernonia amygdalina; onugbu/ewuro): protein approximately 18 percent DW; vitamins A, C, E; minerals; known pharmacological properties including antimalarial, anti-diabetic, and hepatoprotective effects; widely used in traditional medicine.

Mango (Mangifera indica): ripe flesh provides vitamin C (28 mg/100 g), beta-carotene (1.8 mg/100 g), vitamin E, and folate; also contains mangiferin (a xanthone with antioxidant and anti-

inflammatory properties). Pawpaw (Carica papaya): rich in beta-carotene (especially orange-flesh varieties: 1.0 to 3.4 mg/100 g), vitamin C (62 mg/100 g), folate, and the enzyme papain which aids digestion; the latex from unripe papaya is used in traditional medicine for wound healing and as a vermifuge. Banana (Musa species): energy-dense (89 kcal/100 g); rich in potassium (358 mg/100 g), vitamin B6, vitamin C, and resistant starch; an important weaning food for infants in southern Nigeria. Plantain (Musa paradisiaca): higher starch content than banana (approximately 32 g/100 g in green plantain); major dietary energy source in southern Nigeria; provides potassium and vitamin B6; plantain flour is used in infant food formulations.

Fill in the blank: Moringa (Moringa oleifera) leaves contain approximately _____ mg of calcium per 100 g dry weight, making them among the richest plant sources of calcium; this is approximately 17 times the calcium content of milk on a gram-for-gram basis.

1.4.3 Role of fruits and vegetables in human health and diet

Fruits and vegetables play six key roles in human health and nutrition: (1) Micronutrient supply: they are the primary dietary sources of vitamins A, C, K, and folate, and minerals iron, calcium, potassium, and magnesium; their absence from the diet causes deficiency diseases (scurvy: vitamin C deficiency; xerophthalmia and night blindness: vitamin A deficiency; iron-deficiency anaemia; osteoporosis: calcium deficiency). (2) Antioxidant protection: polyphenols, flavonoids, carotenoids, and vitamin C and E in fruits and vegetables neutralise free radicals, reducing the risk of oxidative stress-related non-communicable diseases (cardiovascular disease, type 2 diabetes, certain cancers). (3) Dietary fibre: the insoluble and soluble fibre in vegetables and fruits promotes regular bowel movements, feeds beneficial gut bacteria (prebiotic effect), slows glucose absorption, and reduces cholesterol absorption; inadequate fibre intake is associated with constipation, colorectal cancer, and metabolic syndrome.

(4) Phytochemical and medicinal effects: many Nigerian horticultural plants contain bioactive compounds with documented health effects: lycopene in tomato (associated with reduced prostate cancer risk); quercetin in onion (anti-inflammatory; antiviral); cucurbitacins in bitter gourd (anti-diabetic); andrographolide in bitter leaf (antimalarial); sulphur compounds in garlic (allicin; antimicrobial, cardioprotective). (5) Weight management: most fruits and vegetables are

low in energy density (high water and fibre content; low fat and sugar in vegetables) and high in satiety; regular consumption is associated with lower body weight and reduced obesity risk. (6) Disease prevention: the WHO/FAO recommends a minimum of 400 g of fruits and vegetables per day (approximately 5 servings) for prevention of non-communicable diseases; surveys suggest most Nigerians consume well below this threshold, increasing the risk of diet-related diseases. Increasing fruit and vegetable consumption is therefore both a nutritional and a public health imperative in Nigeria.

Fill in the blank: The WHO/FAO recommends a minimum of _____ grams of fruits and vegetables per day for prevention of non-communicable diseases; most Nigerian consumers fall below this threshold, increasing the risk of micronutrient deficiency and diet-related chronic diseases.

Fruit/Vegetable	Key Vitamins	Key Minerals	Protein Content	Notable Phytochemical	Primary Health Benefit
Moringa leaves	High Vit A, C, K	Calcium, Iron, Potassium	~19–25 g/100g	Flavonoids, Alkaloids, Phenols	Boosts immunity, antioxidant, supports bone health
Fluted pumpkin	Vit A, B1, B2	Potassium, Phosphorus, Magnesium	~21–30 g/100g	Tannins, Saponins, Phytates	Blood enrichment, fertility support, antioxidant
Bitter leaf	Vit B1, B2, E, C	Potassium, Magnesium, Iron, Zinc	~4–9 g/100g	Saponins, Alkaloids, Flavonoids	Anti-diabetic, anti-malarial, liver protection

Tomato	Vit C, A, Lycopene	Potassium, Calcium, Magnesium	~0.8–10 g/100g	Lycopene, Beta-carotene	Antioxidant, heart health, cancer prevention
Carrot	Very high Vit A (β-carotene), Vit C	Potassium, Calcium, Magnesium	~0.9–4 g/100g	Carotenoids, Flavonoids	Eye health, skin protection, anticancer
Mango	Vit A, C, Folate	Potassium, Magnesium, Calcium	~1.3–1.6 g/100g	Carotenoids, Polyphenols	Digestive aid, immunity boost, antioxidant
Pawpaw	Vit C, A, E, Niacin	Calcium, Iron, Potassium	~6–11 g/100g	Alkaloids, Flavonoids, Saponins	Improves digestion, antioxidant, supports heart health
Banana	Vit B6, C, A	Potassium, Magnesium, Phosphorus	~1–12 g/100g	Phenolics, Carotenoids	Energy source, regulates blood pressure, gut health

Box 1.1: Nutritional composition and primary health benefits of selected Nigerian fruits and vegetables

Pilot questions 1.4

1. State the main vitamins found in the following Nigerian fruits and vegetables and name one deficiency disease prevented by each: (a) carrot; (b) guava; (c) moringa leaves; (d) banana.

2. Explain why moringa (Moringa oleifera) is referred to as a ‘miracle tree’ in terms of its nutritional composition.
3. Describe three roles that dietary fibre from fruits and vegetables plays in maintaining human health.
4. State the WHO/FAO daily recommendation for fruit and vegetable consumption and explain the consequences of not meeting this recommendation for Nigerian consumers.
5. Explain the importance of beta-carotene in fruits and vegetables such as carrot and pawpaw to human health in Nigeria.

Series Summary

This Series examined **horticulture, the science and practice of cultivating fruits, vegetables, flowers, ornamental plants, and landscapes**. Its major branches are pomology, olericulture, floriculture, and landscape horticulture. Horticulture differs from agronomy because it is usually more intensive, labour-demanding, high-value, and focused on perishable crops. It contributes to Nigerian food security, nutrition, employment, income, exports, agro-industry, environmental improvement, and traditional medicine. Vegetables may be classified by botanical family, edible part, life cycle, or temperature requirement, while fruits may be grouped by family, growth habit, or climatic adaptation.

The Series also covered important fruit and vegetable crops, including several underutilised indigenous fruits such as African pear, African star apple, African breadfruit, bush mango, soursop, and velvet tamarind. **Fruits and vegetables are important sources of carbohydrates, fibre, vitamins, minerals, antioxidants, and other protective phytochemicals.** Carrot, mango, and pawpaw supply provitamin A; guava, citrus, and pepper are rich in vitamin C; leafy vegetables provide folate, vitamin K, iron, and calcium; while banana, plantain, and avocado supply potassium. Regular consumption supports healthy body weight, improves digestion, reduces micronutrient deficiencies, and lowers the risk of non-communicable diseases.

Glossary of Terms

- **African pear (Dacryodes edulis):** a drupe fruit known as ube in southern Nigeria; the oily buttery flesh is eaten roasted or cooked; rich in fatty acids and vitamins; an underutilised but highly demanded indigenous fruit.
- **African star apple (Chrysophyllum albidum):** known as agbalumo (Yoruba) and udara (Igbo); a seasonal berry-type fruit rich in vitamin C and antioxidants; highly popular in urban Nigerian markets from January to March but rarely cultivated in orchards.
- **Beta-carotene:** an orange-yellow pigment and provitamin A found in carrot, mango, orange-flesh pawpaw, sweet potato, and pumpkin; converted to retinol (vitamin A) in the body; essential for vision and immune function.

- **Biennial vegetable:** a vegetable that requires two growing seasons to complete its life cycle; vegetative growth in the first season and flowering and seed production in the second after cold exposure; carrot and onion are commercially grown as annuals but are botanically biennial.
- **Cool-season vegetable:** a vegetable crop with an optimum growing temperature of 10 to 20 degrees C; includes carrot, onion, lettuce, cabbage, and radish; best grown during the harmattan period in northern Nigeria or year-round in highland areas such as the Jos Plateau.
- **Floriculture:** the branch of horticulture dealing with the cultivation and marketing of flowers, ornamental foliage plants, and decorative plant products for cut flowers, potted plants, and landscape use.
- **Horticulture:** the science and art of growing, processing, and marketing fruits, vegetables, flowers, and ornamental plants; derived from the Latin hortus (garden) and cultura (cultivation); involves more intensive management than agronomic field crop production.
- **Landscape horticulture:** the branch of horticulture dealing with the design, installation, and maintenance of outdoor and indoor plant environments, including lawn management, garden design, and urban green infrastructure.
- **Moringa (Moringa oleifera):** a multipurpose tree known as zogale (Hausa) and ewe ile (Yoruba); the leaves are among the most nutritious foods known, containing 27 percent protein, 440 mg calcium, and 28 mg iron per 100 g dry weight; used to fortify weaning foods.
- **Olericulture:** the branch of horticulture dealing with the science and practice of vegetable production; covers all vegetable types from leaf to root, bulb, stem, flower, and fruit vegetables.
- **Perennial vegetable:** a vegetable that persists for many years and produces repeatedly; examples in Nigeria include fluted pumpkin (Telfairia occidentalis), bitter leaf (Vernonia amygdalina), and moringa (Moringa oleifera).

- **Phytochemicals:** non-nutritive bioactive compounds produced by plants (polyphenols, flavonoids, carotenoids, sulphur compounds, alkaloids) that have health-promoting effects; examples include lycopene in tomato, quercetin in onion, and allicin in garlic.
- **Pomology:** the branch of horticulture dealing with the science of fruit cultivation, including tropical fruits (mango, citrus, banana, pineapple), subtropical fruits (avocado, guava), and nuts (cashew, kola).
- **Soursop (Annona muricata):** known as sawa-sawa; a large spiny green fruit with white fragrant acidic flesh; rich in vitamin C and B vitamins; consumed fresh or as juice; growing interest in commercial cultivation for export.
- **Warm-season vegetable:** a vegetable crop with an optimum growing temperature of 20 to 30 degrees C; includes tomato, pepper, okra, cowpea, cucumber, and garden egg; the dominant vegetable group in Nigerian production.

Concept Check Questions [Series 1]

Objective Questions

1. Horticulture is derived from the Latin words hortus (garden) and _____ (cultivation); it is the science and art of growing, processing, and marketing fruits, vegetables, flowers, and ornamental plants. (Linked to SLO 1.1)
2. The branch of horticulture dealing specifically with vegetable production is called _____; it covers leaf, fruit, root, bulb, stem, and flower vegetables. (Linked to SLO 1.1)
3. Tomato (Solanum lycopersicum), pepper, and garden egg all belong to the botanical family _____, which is characterised by 5-petalled flowers and berry or capsule fruits. (Linked to SLO 1.3)
4. Mango and cashew both belong to the family _____, characterised by resinous sap and drupe (stone fruit) fruits. (Linked to SLO 1.4)
5. Guava (Psidium guajava) contains 180 to 228 mg of vitamin _____ per 100 g of fresh fruit, making it one of the richest plant sources of this vitamin. (Linked to SLO 1.5)

Short-Answer Questions

6. Define horticulture and distinguish it from agronomy under three headings. (Linked to SLO 1.1)
7. Classify the following vegetables by edible part: bitter leaf, tomato, onion, carrot, okra. (Linked to SLO 1.3)
8. Distinguish between cool-season and warm-season vegetables with two Nigerian examples of each. (Linked to SLO 1.3)
9. Name four underutilised fruit crops in Nigeria and state one nutritional benefit of each. (Linked to SLO 1.4)
10. Describe three roles that fruits and vegetables play in maintaining human health. (Linked to SLO 1.5)

Long-Answer Questions

11. Define horticulture, describe its branches and importance to Nigeria, and classify vegetable crops by botanical family, edible part, life cycle, and temperature requirement. (Linked to SLOs 1.1, 1.2, 1.3)
12. Classify fruit crops by botanical family, growth habit, and climatic requirement. Describe the underutilised fruit crops of Nigeria. Explain the nutritive value of fruits and vegetables and their role in human health. (Linked to SLOs 1.4, 1.5)

Answers to Concept Check Questions [Series 1]

Objective Questions

1. Cultura.
2. Olericulture.
3. Solanaceae.
4. Anacardiaceae.
5. C.

Short-Answer Questions

6. Horticulture is the science and art of growing, processing, and marketing fruits, vegetables, flowers, and ornamental plants. Distinction from agronomy: (1) scale (horticulture: small, intensive plots; agronomy: large-scale extensive fields); (2) product nature (horticulture: perishable fresh products; agronomy: storable durable commodities); (3) value per hectare (horticulture: higher; e.g. tomatoes N3 to 5 million/ha vs maize N500,000 to 800,000/ha).
7. Bitter leaf: leaf vegetable. Tomato: fruit vegetable. Onion: bulb vegetable. Carrot: root vegetable. Okra: fruit vegetable.
8. Cool-season: optimum 10 to 20 degrees C; examples: carrot, onion; best in harmattan or highlands. Warm-season: optimum 20 to 30 degrees C; examples: tomato, pepper; dominant in most of Nigeria; damaged by cold below 10 degrees C.
9. African pear (ube; Dacryodes edulis): rich in fatty acids and vitamins. African star apple (agbalumo; Chrysophyllum albidum): rich in vitamin C and antioxidants. Soursop (sawa-sawa; Annona muricata): rich in vitamin C and B vitamins. African breadfruit (ukwa; Treculia africana): high protein and carbohydrate content.
10. Micronutrient supply (vitamins A, C, K, folate; minerals iron, calcium, potassium). Antioxidant protection (polyphenols, carotenoids, vitamins C and E reduce oxidative stress and non-communicable disease risk). Dietary fibre (promotes gut health, reduces cholesterol and constipation, slows glucose absorption).

Long-Answer Questions

11. Horticulture: science and art of growing, processing, and marketing fruits, vegetables, flowers, and ornamentals; from Latin hortus + cultura. Branches: pomology (fruit science: mango, citrus, banana, cashew); olericulture (vegetable science: tomato, okra, carrot, onion); floriculture (flowers and ornamentals); landscape horticulture (garden design, lawn management). Distinction from agronomy: scale (small intensive vs large extensive); product nature (perishable vs storable); value per ha (higher in horticulture); labour intensity (higher). Importance to Nigeria: food security and micronutrient supply (vitamins A, C, K; minerals); income and livelihoods (higher returns per ha); employment (value chain jobs); export earnings (cashew 180,000 to 200,000 t/year; ginger, sesame); agro-industry raw materials (tomato paste, fruit juice, palm oil); environmental values; traditional medicine (bitter leaf, moringa). Vegetable classification: by family (Solanaceae: tomato, pepper, garden egg; Cucurbitaceae: pumpkin, cucumber; Fabaceae: cowpea, garden bean; Apiaceae: carrot); by edible part (leaf: ugu, waterleaf, bitter leaf; fruit: tomato, okra; root: carrot, sweet potato; bulb: onion, garlic; stem: asparagus; flower: cauliflower); by life cycle (annual: tomato, cowpea; biennial: carrot commercially grown as annual; perennial: fluted pumpkin, bitter leaf, moringa); by temperature (cool-season 10 to 20 degrees C: carrot, onion, cabbage, lettuce; warm-season 20 to 30 degrees C: tomato, pepper, okra).
12. Fruit classification by family: Anacardiaceae (mango, cashew: drupe, resinous sap); Musaceae (banana, plantain: berry, herbaceous); Rutaceae (citrus: hesperidium, aromatic leaves); Caricaceae (pawpaw: berry, papain enzyme); Bromeliaceae (pineapple: multiple fruit). By growth habit: tree (mango, citrus, avocado); shrub (guava, cashew); vine (passion fruit); herbaceous perennial (banana, plantain, pineapple); annual (watermelon). By climate: tropical (mango, banana, pawpaw, pineapple, cashew; frost-free); subtropical (citrus, guava; mild cool tolerance); temperate (apple, grape; need cold dormancy; only at high Nigerian elevations). Underutilised: African pear (Dacryodes edulis; ube; oily flesh; fatty acids); African star apple (Chrysophyllum albidum; agbalumo; rich in vitamin C); African breadfruit (Treculia africana; ukwa; high protein); bush mango (Irvingia gabonensis; ogbono; seed used as soup thickener); soursop (Annona muricata; sawa-sawa; vitamin C, B vitamins); velvet tamarind (Dialium guineense; awin; vitamin C). Nutritive value: macronutrients (carbohydrates: sugars in fruits, starch in root vegetables,

fibre in all; proteins: low except leafy greens: moringa 27% DW, fluted pumpkin 25% DW; lipids: low except avocado, African pear); vitamins (A: carrot, pawpaw, mango; C: guava 180 to 228 mg/100 g, citrus, pepper; K: leafy greens; folate: leafy vegetables; B vitamins widely distributed); minerals (iron: moringa 28 mg/100 g DW, bitter leaf; calcium: moringa 440 mg/100 g DW; potassium: banana, plantain). Health roles: micronutrient supply (preventing scurvy, xerophthalmia, anaemia); antioxidant protection (polyphenols, carotenoids, vitamin C; reducing NCD risk); dietary fibre (gut health, cholesterol, glucose control); phytochemicals (lycopene in tomato; quercetin in onion; allicin in garlic; andrographolide in bitter leaf); weight management; WHO/FAO recommendation 400 g/day (most Nigerians fall below).

Answers to Pilot Questions [Series 1]

Part 1.1

1. Horticulture: science and art of growing, processing, and marketing fruits, vegetables, flowers, and ornamentals. Branches: pomology (fruit science; mango, citrus, cashew); olericulture (vegetable science; tomato, carrot, okra); floriculture (flower and ornamental science; roses, chrysanthemums); landscape horticulture (garden design and maintenance; lawn management, urban greening).
2. Scale: horticulture uses small, intensive plots with high input per ha; agronomy uses large extensive fields. Product nature: horticultural products are perishable fresh items; agronomic products are storable durable commodities. Value per ha: horticultural crops command higher returns (tomatoes N3 to 5 million/ha vs maize N500,000 to 800,000/ha). Labour intensity: horticulture requires more frequent irrigation, pest management, pruning, and harvesting operations.
3. Food security and nutrition (supply vitamins and minerals absent in staple-grain diets; address hidden hunger). Income and livelihoods (higher returns per ha for smallholder farmers, especially women fadama vegetable growers). Employment (millions employed in vegetable and fruit production, marketing, and processing). Export earnings (cashew 180,000 to 200,000 t/year; ginger, sesame, chilli pepper).

4. Cashew nuts: exported to Vietnam, India, and Europe; approximately 180,000 to 200,000 tonnes annually. Ginger: exported to Europe, Asia, and USA; Kaduna State is a major producer of export ginger.
5. Hidden hunger refers to micronutrient deficiency without obvious symptoms of energy undernutrition; approximately 30 to 40 percent of Nigerian children under five are deficient in vitamin A, iron, and zinc. Fruits and vegetables are the primary dietary sources of these micronutrients (vitamin A from carrot and pawpaw; iron from moringa and bitter leaf); increasing their consumption directly addresses micronutrient deficiency.

Part 1.2

1. (a) Tomato (Solanum lycopersicum): Solanaceae; characterised by 5-petalled flowers, alternate leaves, and berry or capsule fruits. (b) Pumpkin (Telfairia occidentalis; Cucurbitaceae: characterised by tendril-bearing vines, unisexual flowers, and fleshy pepo fruits. (c) Cowpea (Vigna unguiculata): Fabaceae; characterised by compound leaves, papilionaceous (butterfly-shaped) flowers, and pod fruits; nitrogen-fixing. (d) Carrot (Daucus carota): Apiaceae; characterised by compound umbel inflorescences and aromatic, often feathery leaves.
2. Onion: bulb (swollen leaf bases). Fluted pumpkin leaves: leaf. Tomato: fruit. Carrot: root. Okra: fruit. Asparagus: stem (young shoot).
3. Warm-season: optimum 20 to 30 degrees C; examples: tomato and pepper; damaged by cold below 10 degrees C; grown in the rainy season or dry season with irrigation in most of Nigeria. Cool-season: optimum 10 to 20 degrees C; examples: carrot and onion; grown during the harmattan period (November to February) in northern Nigeria or year-round on the Jos Plateau; premature bolting occurs in high temperatures.
4. Perennial vegetable examples: fluted pumpkin (Telfairia occidentalis; vine regrows from stem base after harvest; provides leaves year-round); bitter leaf (Vernonia amygdalina; woody shrub; leaves harvested repeatedly for many years); moringa (Moringa oleifera; tree; leaves harvested repeatedly). Advantage: once established, perennials produce without the need for annual replanting, reducing labour and seed costs and providing a continuous supply of leaves.

5. The Jos Plateau (above 900 m altitude) has cool temperatures year-round (mean temperature 18 to 22 degrees C) due to its elevation; this allows cool-season crops such as carrot, cabbage, lettuce, and onion to be grown throughout the year without heat stress or premature bolting. Kano State (low elevation; mean temperature 25 to 35 degrees C) is too hot for cool-season crops during most of the year; only the harmattan period (November to February) provides temperatures low enough for satisfactory production.

Part 1.3

1. (a) Mango: Anacardiaceae; characterised by resinous sap and drupe (stone fruit) with a fibrous fleshy mesocarp. (b) Banana: Musaceae; characterised by large herbaceous plants (not trees) with a pseudostem of leaf bases and berry-type fruit. (c) Citrus: Rutaceae; characterised by aromatic oil glands in leaves and hesperidium fruit type with a leathery rind containing essential oils. (d) Pawpaw: Caricaceae; fast-growing soft-wooded tree with latex-containing sap and large berry fruit containing the enzyme papain.
2. Mango: tree fruit. Pineapple: herbaceous perennial fruit. Passion fruit: vine fruit (climbs by tendrils). Guava: shrub fruit. Watermelon: annual (vegetable-fruit). Banana: herbaceous perennial fruit.
3. Tropical fruits (optimum 25 to 35 degrees C year-round; frost-sensitive): mango, banana, pawpaw, pineapple, cashew. Temperate fruits (require cold dormancy with chilling hours below 7 degrees C): apple, pear, grape. Most of Nigeria is too warm (average temperatures 25 to 35 degrees C) to provide the chilling requirement of temperate fruits; only the Mambilla and Jos plateaus at elevations above 1,200 m occasionally have temperatures low enough; even there chilling hours are usually insufficient for commercial production.
4. African pear (Dacryodes edulis; ube): rich in fatty acids and vitamins for energy and skin health. African star apple (Chrysophyllum albidum; agbalumo): rich in vitamin C and antioxidants; immune function support. African breadfruit (Treculia africana; ukwa): high protein and carbohydrate; important food security crop. Velvet tamarind (Dialium guineense; awin): high in vitamin C; antioxidant properties.
5. A botanical fruit is the ripened ovary of a flowering plant, containing seeds; it may be sweet, sour, starchy, or savoury. A horticultural fruit is a plant product that is sweet or

flavourful and typically eaten as a snack or dessert. Crops that are botanically fruits but culinarily classed as vegetables: tomato (Solanum lycopersicum; ripened ovary with seeds; eaten as part of main meal, not as dessert); cucumber (Cucumis sativus; similarly a botanical fruit eaten as a vegetable).

Part 1.4

1. (a) Carrot: beta-carotene (provitamin A); prevents night blindness and xerophthalmia (vitamin A deficiency). (b) Guava: vitamin C; prevents scurvy (vitamin C deficiency; also essential for immune function and iron absorption). (c) Moringa leaves: vitamins A, C, K, and B vitamins; prevents multiple micronutrient deficiencies simultaneously; particularly important for infants and pregnant women. (d) Banana: vitamin B6 and potassium; prevents B6 deficiency (peripheral neuropathy) and supports blood pressure regulation.
2. Moringa is called the miracle tree because its leaves contain exceptionally high concentrations of multiple nutrients simultaneously: 27 percent protein on dry weight basis (comparable to meat); 440 mg calcium per 100 g DW (17 times that of milk per gram); 28 mg iron per 100 g DW (25 times that of spinach per gram); 220 mg vitamin C per 100 g DW (7 times that of orange); and high beta-carotene; all in a drought-tolerant tree easily grown in most Nigerian ecological zones.
3. Promotes regular bowel movements: insoluble fibre adds bulk to stool and speeds transit through the colon, preventing constipation and reducing colorectal cancer risk. Feeds beneficial gut bacteria: soluble fibre (pectin, inulin) serves as a prebiotic, nourishing beneficial bacteria (Lactobacillus, Bifidobacterium) that maintain gut microbial balance and immune function. Slows glucose absorption: soluble fibre forms a gel that slows the digestion and absorption of carbohydrates, reducing post-meal blood glucose spikes and lowering the risk of type 2 diabetes.
4. WHO/FAO recommendation: minimum 400 g of fruits and vegetables per day (approximately 5 servings). Consequences of not meeting recommendation: increased risk of micronutrient deficiency (vitamins A, C, K; iron, calcium); increased risk of non-communicable diseases (cardiovascular disease, type 2 diabetes, certain cancers, hypertension) due to insufficient antioxidant and anti-inflammatory phytochemical intake; increased risk of constipation and bowel disorders due to low dietary fibre.

5. Beta-carotene is a provitamin A carotenoid converted to retinol (vitamin A) in the intestine. In Nigeria, vitamin A deficiency affects approximately 30 percent of children under five, causing night blindness (inability to see in dim light), xerophthalmia (dry eyes leading to corneal ulceration and blindness), and increased susceptibility to infectious diseases. Consuming orange-coloured fruits and vegetables (carrot, orange-flesh pawpaw, mango, orange-flesh sweet potato, pumpkin) regularly is the most practical and sustainable way to prevent vitamin A deficiency, particularly for low-income households who cannot afford liver, eggs, or dairy products.

References and Attributions [Series 1]

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Figures, Plates, Tables, and Boxes

- Figure 1.1: Classification of Nigerian fruit crops by growth habit, botanical family, climate, and utilisation status. Attribution: AI generated. Suggested OER search string: "Nigerian fruit crops classification growth habit botanical family climate underutilised diagram OER".
- Box 1.1: Nutritional composition and primary health benefits of selected Nigerian fruits and vegetables. Attribution: AI generated. Suggested OER search string: "Nigerian fruits vegetables nutritional composition vitamins minerals protein phytochemicals health benefits table OER".

Series 2: Ecological Distribution and Adaptation

- **Part 2.1: Nigeria's Vegetation Zones and Horticultural Potential**
  - Sub Part 2.1.1: Overview of Nigeria's ecological zones
  - Sub Part 2.1.2: Horticultural crops of the humid forest zone
  - Sub Part 2.1.3: Horticultural crops of the savanna and semi-arid zones
- **Part 2.2: Climatic Factors and Crop Distribution**
  - Sub Part 2.2.1: Rainfall: amount, distribution, and seasonality
  - Sub Part 2.2.2: Temperature and photoperiod effects on horticultural crops
  - Sub Part 2.2.3: Humidity, wind, and radiation effects
- **Part 2.3: Soil Factors and Adaptation**
  - Sub Part 2.3.1: Soil types and their suitability for horticultural crops
  - Sub Part 2.3.2: Soil pH and nutrient availability
  - Sub Part 2.3.3: Soil water management in horticulture
- **Part 2.4: Exotic Vegetable and Fruit Variety Adaptation**
  - Sub Part 2.4.1: Introduction of exotic horticultural varieties to Nigeria
  - Sub Part 2.4.2: Adaptation trials and variety evaluation
  - Sub Part 2.4.3: Locally adapted versus exotic varieties: trade-offs

Introduction

The ecological diversity of Nigeria, spanning from the humid coastal mangroves and rainforests of the south to the semi-arid Sahel of the far north, creates a wide range of environments for horticultural crop production. Understanding how vegetation zones, climate, and soils determine which crops can be grown where, and how to modify the environment to overcome limiting factors, is fundamental to planning successful horticultural enterprises across the country.

This Series examines the ecological distribution of vegetables and fruit crops across Nigeria's major vegetation zones, analyses how rainfall, temperature, photoperiod, humidity, and soil characteristics affect crop performance and distribution, and explores the adaptation of exotic varieties to Nigerian conditions. The knowledge gained here underpins variety selection, seasonal planning, and site-specific management decisions for horticultural production.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 2.1** describe Nigeria's major ecological zones and identify the principal horticultural crops associated with each zone (Linked to Part 2.1),
- **SLO 2.2** explain how rainfall, temperature, photoperiod, humidity, and radiation influence the distribution and performance of horticultural crops in Nigeria (Linked to Part 2.2),
- **SLO 2.3** describe the major soil types in Nigeria, explain the influence of soil pH on nutrient availability, and describe soil water management approaches in horticulture (Linked to Part 2.3), and
- **SLO 2.4** describe the introduction and evaluation of exotic horticultural varieties in Nigeria and explain the trade-offs between exotic and locally adapted varieties (Linked to Part 2.4).

2.1 Nigeria's Vegetation Zones and Horticultural Potential

2.1.1 Overview of Nigeria's ecological zones

Nigeria spans approximately 10 degrees of latitude (4 to 14 degrees N) and exhibits a strong north-south gradient of rainfall, temperature, and vegetation corresponding to six major ecological zones. From south to north: (1) Mangrove and freshwater swamp forest: coastal zone (Lagos, Delta, Bayelsa, Rivers, Cross River states); rainfall 2,000 to 4,000 mm/year; dominated by Rhizophora and Avicennia mangroves; limited horticultural potential due to waterlogged, saline soils; some tidal vegetable gardens (waterleaf, fluted pumpkin) on elevated creek banks. (2) Lowland tropical rainforest: humid forest belt (Edo, Ondo, Ogun, Osun, Cross River, Ekiti, Oyo states); rainfall 1,500 to 2,500 mm/year; bimodal rainfall with two planting seasons (March to July; September to November); high biodiversity; supports year-round production of most tropical horticultural crops.

(3) Derived savanna (forest-savanna transition): transitional zone (southern Kwara, Kogi, Benue, Oyo, Ogun states); rainfall 1,200 to 1,500 mm/year; one main rainy season with a short dry season; important for vegetable production under irrigation during the dry season; dominantly cultivated. (4) Guinea savanna woodland: largest vegetation zone (Kwara, Kogi, Benue, Niger, FCT, Kaduna, Plateau, Nasarawa, Oyo, Ekiti states); rainfall 800 to 1,200 mm/year; 5 to 7 month growing season; major zone for cowpea, tomato, pepper, onion, and fadama vegetable production; the Jos Plateau (above 900 m altitude within this zone) has a cool highland microclimate supporting year-round production of cool-season vegetables. (5) Sudan savanna: drier north (Sokoto, Kebbi, Zamfara, Katsina, Kano, Jigawa, Bauchi, Gombe, Adamawa states); rainfall 500 to 1,000 mm/year; 3 to 5 month growing season; dry-season fadama irrigation is critical; onion, tomato, pepper, carrot, and garlic are major dry-season crops. (6) Sahel savanna and semi-arid zone: far north (Borno, Yobe, northern Katsina, northern Sokoto states); rainfall below 500 mm/year; extreme temperature and water stress; limited horticulture primarily in irrigated oasis-type systems along the shores of Lake Chad.

Fill in the blank: Nigeria's largest vegetation zone is the Guinea _____ woodland, covering states such as Kwara, Kogi, Benue, Plateau, and Kaduna; it receives 800 to 1,200 mm of rainfall per year and is a major zone for tomato, onion, pepper, and fadama vegetable production.

2.1.2 Horticultural crops of the humid forest zone

The humid forest zone (lowland rainforest and derived savanna) of southern Nigeria supports the greatest diversity of horticultural crops due to its high rainfall, warm temperatures, and two distinct rainy seasons. Major horticultural crops of this zone: (1) Fruit crops: plantain (Musa paradisiaca; grown throughout the forest zone; major staple food); banana (Musa acuminata); pawpaw (Carica papaya; grown in home gardens and orchards); pineapple (Ananas comosus; especially Ondo, Ogun, Cross River, and Delta states); citrus (sweet orange, mandarin, lime, grapefruit; Ogun, Osun, Ekiti, and Cross River states); avocado (Persea americana; Cross River, Ondo, and Ogun states); African pear (Dacryodes edulis; Edo, Delta, Cross River, and Imo states). (2) Vegetable crops: fluted pumpkin (Telfairia occidentalis; dominant leafy vegetable of southern Nigeria; grown year-round); waterleaf (Talinum triangulare; fast-growing; planted throughout the year); okra (Abelmoschus esculentus; grown in both rainy seasons); African nightshade (Solanum nigrum complex); garden egg (Solanum aethiopicum and S. macrocarpon); bitter leaf (Vernonia amygdalina; perennial shrub).

The bimodal rainfall pattern of the humid forest zone allows two distinct planting seasons: first rainy season (March to July) and second rainy season (September to November). The dry season (December to February) is a challenge for vegetable production due to low humidity and the desiccating effect of the harmattan wind; however, irrigation from streams and wells extends production. Pest and disease pressure is highest in the humid forest zone: fungal diseases (Phytophthora, Pythium, Cercospora), bacterial diseases (bacterial wilt), and a diverse range of insect pests (aphids, whiteflies, fruit flies, melon beetle) are major production constraints. High air humidity promotes fungal and bacterial leaf diseases that are less problematic in the drier north.

Fill in the blank: The bimodal rainfall of the humid forest zone creates two main planting seasons for vegetables: the first rainy season from _____ to July and the second from September to November; the dry harmattan period from December to February is a challenge for production without irrigation.

2.1.3 Horticultural crops of the savanna and semi-arid zones

The savanna zones (Guinea savanna, Sudan savanna) are the primary production areas for commercial vegetable crops in Nigeria, particularly during the dry season (October to March) when the absence of rain allows intensive production under irrigation from rivers, streams, wells, and fadama wetlands. Key horticultural production areas: Kano State (Dawanau vegetable production zone; onion, tomato, pepper, carrot, cabbage, lettuce, radish; major supplier to northern and urban markets); Kaduna State (Maigana, Kujama; tomato, pepper, onion); Plateau State (Jos Plateau; cool highland; cabbage, carrot, Irish potato, lettuce, tomato, strawberry; year-round production); Sokoto and Kebbi states (onion production; Sokoto red onion is a distinct cultivar exported to neighbouring countries; also pepper and tomato).

The unimodal rainfall of the savanna zone (one main rainy season: May to October in the Guinea savanna; June to September in the Sudan savanna) means that during the rainy season, the fadama flood plains and valley bottom soils support a different set of crops from the upland (tomatoes and peppers on uplands during rain; leafy vegetables and root crops in fadama during dry season). The harsh dry season conditions (temperatures exceeding 40 degrees C in March to April; relative humidity below 20 percent; strong harmattan winds) are challenging for irrigated vegetable production, particularly for frost-tender crops. However, the absence of fungal and bacterial diseases during the dry season, the availability of irrigation water from the many rivers in the Sudan-Sahel zone (Sokoto, Rima, Hadejia, Yobe), and the high solar radiation provide ideal conditions for high-quality onion, tomato, and carrot production with excellent shelf life.

Fill in the blank: The Sokoto _____ onion is a distinct cultivar grown in Sokoto and Kebbi states and exported to neighbouring West African countries; it is one of Nigeria's most important dry-season vegetable crops.

Pilot questions 2.1

6. Name Nigeria's six main ecological zones from south to north and state the approximate annual rainfall range of each.
7. Name six horticultural crops grown in the humid forest zone and state one production advantage of this zone.

8. Explain why the dry season (October to March) is the most important period for commercial vegetable production in the Nigerian savanna zones.
9. Name three states in Nigeria's savanna zone that are major vegetable-producing centres and state the key crop(s) of each.
10. Explain how the bimodal rainfall pattern of the humid forest zone differs from the unimodal pattern of the savanna zone and how each affects planting schedules.

2.2 Climatic Factors and Crop Distribution

2.2.1 Rainfall: amount, distribution, and seasonality

Rainfall is the most important climatic factor determining the distribution of horticultural crops in Nigeria because of its role in supplying soil moisture for plant growth. Three rainfall characteristics matter most for horticulture: (1) Annual amount: minimum rainfall requirements vary by crop (onion can be produced on 300 mm/year if well timed; mango requires 600 to 1,000 mm; banana and pineapple require above 1,200 mm). Many horticultural crops can be grown outside their natural rainfall range if irrigation supplements deficiencies. (2) Seasonal distribution: whether rainfall is bimodal (two wet seasons separated by a short dry period; typical of the humid south) or unimodal (one long rainy season followed by a long dry season; typical of the savanna) determines planting schedules, irrigation needs, and pest and disease pressure. (3) Rainfall intensity and distribution within seasons: heavy, intense rainfall (common at the start of the rainy season in southern Nigeria; 50 to 100 mm in a few hours) causes soil erosion, waterlogging, and physical damage to soft-tissued vegetables (tomatoes, lettuces); reliable, well-distributed rainfall is more valuable to horticulture than the same amount concentrated in a few events.

The Inter-Tropical Convergence Zone (ITCZ) drives Nigeria's rainfall pattern; its annual northward and southward migration between January and August and back determines the onset and end of the rainy season at each latitude. The ITCZ reaches its northernmost position (approximately 20 degrees N) in August; as it retreats southward, the harmattan (a dry, dusty north-easterly wind from the Sahara) advances from the north, bringing the dry season. The harmattan arrives in Lagos by December and retreats by February; in Sokoto it may persist from

October to April. Understanding the ITCZ migration schedule is essential for planning planting dates, irrigation scheduling, and post-harvest crop management in Nigerian horticulture.

Fill in the blank: The _____ Convergence Zone (ITCZ) drives Nigeria's rainfall pattern through its annual north-south migration; its northward advance brings the rainy season and its southward retreat allows the harmattan (dry north-easterly wind) to advance from the Sahara.

2.2.2 Temperature and photoperiod effects on horticultural crops

Temperature affects all aspects of plant growth: germination, vegetative development, flowering, fruit set, and fruit quality. Each crop has a cardinal temperature range defined by: (1) minimum temperature (below which growth stops); (2) optimum temperature (at which growth is fastest); (3) maximum temperature (above which growth stops or damage occurs). For warm-season vegetables (tomato, pepper, okra): minimum approximately 10 degrees C; optimum 20 to 30 degrees C; maximum approximately 38 to 40 degrees C; fruit set in tomato and pepper fails when day temperatures exceed 35 to 38 degrees C (pollen becomes non-viable) or night temperatures exceed 25 degrees C (disrupts pollination and fruit development). For cool-season vegetables (carrot, onion, cabbage, lettuce): optimum 10 to 20 degrees C; bolting (premature flowering) occurs when temperatures exceed 25 to 30 degrees C; flavour and colour development in carrot requires cool nights. High temperatures in the Nigerian lowlands (mean annual 27 to 35 degrees C) are a major constraint on cool-season vegetable production outside the Jos and Mambilla plateaus.

Photoperiod (day length) is the relative duration of light and darkness in a 24-hour period. It is a critical environmental cue for flowering in many horticultural crops. Photoperiodic responses: (1) Short-day plants (SDP): flower when the dark period exceeds a critical length (day length is shorter than the critical day length); they flower in the short-day conditions of the harmattan (October to February in Nigeria when day length falls to approximately 11.5 hours in the south and 11 hours in the north). Examples of SDP important in Nigeria: cowpea (Vigna unguiculata; many varieties), sweet potato (Ipomoea batatas; tuberisation promoted by short days), kenaf, sesame. (2) Long-day plants (LDP): flower when the dark period is shorter than critical; they

flower in longer days. Examples: wheat, barley, most temperate vegetables (less relevant to Nigeria). (3) Day-neutral plants (DNP): flower independently of day length; triggered by temperature or other cues. Examples: tomato, pepper, okra, pineapple (which can be induced to flower by ethylene). Understanding photoperiodism is important for variety selection (some cowpea varieties are day-length sensitive; planting date determines flowering time) and for timing of production seasons.

Fill in the blank: _____ plants flower when the dark period exceeds a critical length; many cowpea varieties grown in Nigeria are in this category and flower in the short-day conditions of the harmattan season (October to February) regardless of when they were planted.

2.2.3 Humidity, wind, and radiation effects

Relative humidity (RH): high RH (above 80 percent; typical of the humid south during the rainy season) promotes fungal and bacterial diseases (downy mildew, Botrytis grey mould, bacterial soft rot, Phytophthora blight) and reduces the effectiveness of some pesticides. Low RH (below 30 percent; typical of harmattan) accelerates water loss from leaves (desiccation of vegetable crops grown without irrigation), causes tip-burn in lettuce, and increases fire risk on dry farm residues. Post-harvest moisture loss from fresh horticultural produce is also strongly influenced by ambient RH: in high-RH environments (south during rains), tomatoes and mangoes ripen rapidly and succumb to fungal rots; in the dry north, tomatoes and onions dry naturally and store well. The optimal RH for most post-harvest storage of fresh vegetables is 85 to 95 percent.

Wind: the harmattan wind (from November to March) desiccates vegetation, increases evapotranspiration, and deposits fine Saharan dust on leaf surfaces, reducing photosynthetic efficiency. Windbreaks (Casuarina equisetifolia, Eucalyptus camaldulensis, neem trees, or grass hedges) are used in northern Nigerian horticultural gardens to reduce wind speed, lower evapotranspiration, and protect soft-tissued crops. Strong rainy-season winds can lodge tall crops (plantain, banana, tall pepper varieties), break branches, and distribute fungal spores (facilitating disease spread). Solar radiation: Nigeria receives high solar radiation throughout the year (16 to 22 MJ/m2/day); photosynthesis is rarely radiation-limited except during periods of heavy cloud

cover at the height of the rainy season. Shade is required for certain shade-tolerant leafy vegetables (Malabar spinach, waterleaf) grown under plantation crops or as under-storey plants; excess radiation and heat load can cause sunscald on exposed fruit (tomatoes, garden egg) during the dry season.

Fill in the blank: _____ winds (dry north-easterly winds from the Sahara) blow from November to March in Nigeria; they desiccate vegetation, increase evapotranspiration, and make irrigation essential for dry-season vegetable production in the savanna zones.

Pilot questions 2.2

6. Explain three characteristics of rainfall (annual amount, seasonal distribution, and intensity) and how each affects horticultural crop production in Nigeria.
7. Explain what cardinal temperatures are and how high temperatures limit the production of (a) tomato and (b) carrot in the Nigerian lowlands.
8. Define photoperiodism and distinguish between short-day, long-day, and day-neutral plants with one Nigerian horticultural example of each.
9. Explain two ways in which high relative humidity and two ways in which the harmattan affect horticultural crop production in Nigeria.
10. Explain why windbreaks are important in dry-season vegetable production in northern Nigeria and name two species commonly used.

2.3 Soil Factors and Adaptation

2.3.1 Soil types and their suitability for horticultural crops

Nigeria's soils are diverse and reflect the interaction of parent material, climate, vegetation, and management history over millennia. The main soil types relevant to horticulture: (1) Ferralsols (Oxisols): deeply weathered, iron-rich, red or yellow soils; dominant in the humid forest zone; highly leached with low inherent fertility; low CEC; high phosphorus fixation; require heavy organic matter and phosphate fertilisation for vegetable and fruit production; support oil palm, cocoa, and perennial fruit crops naturally but need significant inputs for annual vegetables. (2) Lixisols/Luvisols (Alfisols): moderately leached, with a clay-enriched subsurface horizon

(argillic horizon); widespread in the derived and Guinea savanna; moderately fertile; better than Ferralsols for vegetable production but prone to surface crusting and erosion when poorly managed; support maize, cowpea, sorghum, tomato, and pepper. (3) Vertisols: heavy black cotton soils with high clay content (smectite); crack deeply when dry; waterlog when wet; common in the upper Benue Valley and parts of Borno; difficult to manage; suitable for fadama rice and flood-season vegetables but challenging for most horticultural crops due to poor drainage and physical management difficulties.

(4) Arenosols (Entisols; sandy soils): wind-deposited or weathered sandy soils; very common in the Sudan-Sahel zone; low water-holding capacity; low nutrient retention; require frequent irrigation and fertilisation; well-drained but drought-prone; suitable for carrot, onion, and garlic in the dry season under irrigation; the deep, well-structured sandy loam fadama soils along rivers in Kano and Sokoto are among Nigeria's most productive vegetable soils. (5) Fluvisols (alluvial soils): deposited by rivers and streams in floodplains; variable texture (sandy to clayey); generally fertile with good moisture retention; excellent for vegetable and fruit crop production when properly managed for drainage; include the important fadama soils of northern Nigeria and the riparian gardens of the south. (6) Histosols (peats): rare; organic matter-rich waterlogged soils in coastal swamps. For most horticultural crops, a deep (above 60 cm), well-drained, loamy soil with moderate organic matter content (above 2 percent), good water-holding capacity, and a pH of 6.0 to 6.8 is ideal.

Fill in the blank: The _____ soils (Fluvisols) deposited by rivers and streams in flood plains, including the fadama soils of northern Nigeria, are among the most productive vegetable-growing soils in Nigeria due to their good fertility, moisture retention, and relatively fine texture.

2.3.2 Soil pH and nutrient availability

Soil pH (the negative logarithm of the hydrogen ion concentration) is one of the most important soil chemical properties for horticultural crop production because it determines the solubility and availability of all plant nutrients. At a pH of 6.0 to 7.0 (slightly acid to neutral), most macro and micronutrients are at their maximum availability: nitrogen is mineralised actively by bacteria

(optimum pH 6.0 to 7.0); phosphorus is soluble and not fixed by aluminium or iron; potassium, calcium, and magnesium are available; micronutrients (iron, manganese, zinc, copper, boron) are adequately available. Below pH 5.5 (acidic): aluminium and manganese become soluble to toxic concentrations; phosphorus is fixed by iron and aluminium hydroxides and becomes unavailable; calcium and magnesium deficiency occurs; nitrogen-fixing bacteria (Rhizobium) are inhibited; most vegetable crops show symptoms of nutrient deficiency or toxicity even when fertilisers are applied. Above pH 7.5 (alkaline): iron, manganese, zinc, and boron become insoluble; plants show interveinal chlorosis due to iron deficiency; phosphorus precipitates as calcium phosphate.

pH requirements of horticultural crops: most vegetables prefer pH 6.0 to 7.0; blueberry (Vaccinium; pH 4.5 to 5.5; not widely grown in Nigeria); Irish potato (pH 5.0 to 6.0; lower pH reduces scab); onion (pH 6.0 to 7.5); cruciferous vegetables (cabbage, broccoli; pH 6.0 to 7.5). Liming: application of calcium carbonate (agricultural lime; $CaCO_3$) or calcium-magnesium carbonate (dolomitic lime) to acid soils raises pH; recommended at 1 to 3 tonnes/ha depending on soil buffer capacity; applied and incorporated 2 to 4 weeks before planting. Most humid-zone Nigerian soils (Ferralsols, Lixisols) are naturally acid (pH 4.5 to 5.5) and benefit from liming for vegetable production. Soils in the Sudan-Sahel zone may be alkaline (pH 7.0 to 8.5) and may require acidification through sulphur application or use of acidic fertilisers.

Fill in the blank: At soil pH below 5.5, _____ and manganese become soluble to toxic concentrations while phosphorus is fixed and unavailable; liming with agricultural lime raises pH and restores nutrient availability for horticultural crop production on acid Nigerian soils.

2.3.3 Soil water management in horticulture

Soil water management is central to horticultural crop production because most vegetables have shallow root systems and high water demand; they are far more sensitive to water stress than field crops like maize or sorghum. Key soil water management concepts: Field capacity (FC): the moisture content retained in soil after excess water has drained (typically 24 to 48 hours after saturation); represents the upper limit of plant-available water. Permanent wilting point (PWP): the moisture content at which plants wilt permanently and cannot recover even if water is added;

represents the lower limit of plant-available water. Available water capacity (AWC) = FC - PWP; the water that plants can actually extract from the soil; loamy soils have higher AWC than sandy or heavy clay soils. Management aim: keep soil moisture between FC and approximately 50 to 60 percent of AWC for most vegetables (trigger irrigation before the soil dries below 50 percent of AWC; this is the management allowed deficit, MAD).

Drainage: waterlogging (soil saturated for more than 24 to 48 hours) causes anaerobic conditions in the root zone; roots are damaged by oxygen deficiency and ethylene accumulation; most vegetable crops show wilting, chlorosis, and death within 2 to 5 days of waterlogging. Raised beds (15 to 30 cm height; 1.0 to 1.5 m width) improve drainage and aeration in poorly drained soils common in the humid forest zone and fadama gardens. Mulching: applying organic mulch (rice straw, dry grass, sugarcane trash) to the soil surface reduces evaporation, lowers soil temperature, suppresses weeds, and maintains soil structure; mulched vegetable beds use 30 to 50 percent less water than bare soil. Irrigation methods: flood/furrow irrigation (common in fadama gardens; low cost but high water use and disease risk); drip irrigation (delivers water directly to the root zone; very efficient; 30 to 50 percent water saving; reduces foliar disease; increasingly adopted in commercial Nigerian vegetable farms); overhead sprinkler irrigation (suitable for nurseries and leafy vegetables; promotes even germination).

Fill in the blank: Raised beds of 15 to 30 cm height improve _____ and aeration in poorly drained horticultural soils; they are widely used in humid southern Nigerian vegetable gardens and in fadama production areas where the water table is close to the soil surface.

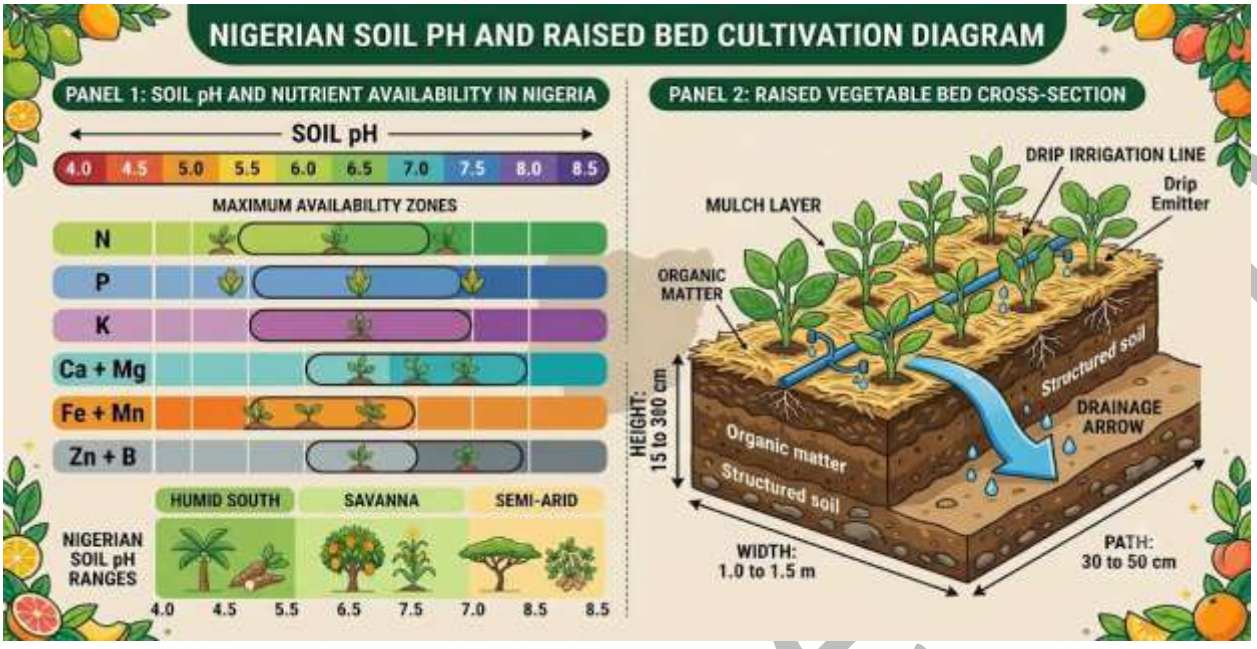

Figure 2.1: Soil pH and nutrient availability (left) and raised-bed design for Nigerian horticultural gardens (right)

Pilot questions 2.3

6. Name four soil types found in Nigeria and state the suitability of each for horticultural crop production.
7. Explain how soil pH affects the availability of phosphorus, aluminium, and iron in Nigerian soils.
8. Define field capacity, permanent wilting point, and available water capacity and explain how these concepts guide irrigation scheduling.
9. Explain two benefits of raised beds and two benefits of mulching in Nigerian vegetable production.
10. Compare flood/furrow irrigation with drip irrigation in terms of water use efficiency, disease risk, and suitability for Nigerian smallholders.

2.4 Exotic Vegetable and Fruit Variety Adaptation

2.4.1 Introduction of exotic horticultural varieties to Nigeria

An exotic variety (also called an introduced variety) is a cultivar developed and selected in a different country or region and introduced to Nigeria for trial or commercial production. The

introduction of exotic horticultural varieties to Nigeria has been driven by: (1) demand for higher yields than traditional local varieties can provide (many modern hybrid tomato, pepper, and cabbage varieties from Asia and Europe can produce 2 to 5 times the yield of local cultivars under optimal conditions); (2) disease resistance not available in local germplasm (e.g. bacterial wilt resistance in improved tomato varieties from AVRDC/World Vegetable Center; Fusarium wilt resistance in melon; TYLCV (tomato yellow leaf curl virus) resistance); (3) processing quality (determinate tomato varieties with concentrated ripening, high paste quality, and thick pericarp developed for tomato paste production); (4) consumer preference for fruit size, colour, and taste that may not be met by local varieties (large, uniform tomato for urban markets; seedless watermelon; sweet, low-acid orange varieties).

Major sources of exotic horticultural varieties introduced to Nigeria: World Vegetable Center (AVRDC; now WorldVeg; Taiwan; heat-tolerant tomato, leafy vegetable, hot pepper hybrids); International Institute of Tropical Agriculture (IITA; Ibadan; cowpea, banana, plantain, cassava, yam; breeds and introduces varieties adapted to West African conditions); national seed companies (SEEDAN member companies; introduce Asian F1 hybrid tomato, pepper, cucumber, watermelon, cabbage, and carrot varieties from China, Taiwan, Israel, and the Netherlands); international seed companies (Syngenta, Bayer CropScience, East-West Seed; market research-driven variety introductions). Phytosanitary controls: all seed and planting material introductions must be cleared through the National Agricultural Quarantine Service (NAQS) and comply with ISTA (International Seed Testing Association) standards to prevent the introduction of exotic pests and diseases.

Fill in the blank: The _____ Agricultural Quarantine Service (NAQS) is responsible for clearing all imported seeds and planting material to prevent the introduction of exotic pests and diseases into Nigeria; all exotic variety introductions must comply with its phytosanitary requirements.

2.4.2 Adaptation trials and variety evaluation

Before an exotic variety is recommended for commercial production in Nigeria, it must be evaluated in adaptation trials to determine whether it performs adequately under Nigerian ecological conditions. The adaptation trial process: (1) Introduction and quarantine: new varieties

are first grown in quarantine facilities to ensure they are free of pests and diseases. (2) Preliminary evaluation (screening): multiple varieties are grown at one or two locations under standard management; basic agronomic data are collected (days to first flower, days to maturity, yield, disease incidence); clearly unsuitable varieties are discarded. (3) Multi-location trials: promising varieties are tested across several locations representing the range of ecological conditions in the target production zone (e.g. Kano, Kaduna, and Jos for northern tomato; Ibadan, Abeokuta, and Benin for southern tomato). (4) Farmer participatory evaluation: selected varieties are grown by representative farmers under their own management systems; farmer preferences on ease of cultivation, market acceptability, taste, storage, and seed saving are assessed.

Key adaptation parameters evaluated: (1) Heat tolerance: performance at high temperatures (tomato fruit set at 35 to 40 degrees C); (2) Photoperiod response: whether flowering is day-length sensitive (important for cowpea, sweet potato); (3) Disease resistance: tolerance or resistance to locally important diseases (bacterial wilt, early blight, TYLCV in tomato; downy mildew in cucurbits); (4) Water use efficiency: performance under water-limited conditions; (5) Yield potential: marketable yield under local management; (6) Fruit quality: size, colour, shelf life, taste, and processing suitability. Successful varieties from adaptation trials are registered with the National Agricultural Seeds Council (NASC) and recommended for production in specific ecological zones through the Variety Recommendation List (VRL) published by FMARD/NASC.

Fill in the blank: Promising exotic varieties that pass preliminary evaluation are tested across several locations in _____ trials to determine their performance across the range of ecological conditions in the target production zone in Nigeria.

2.4.3 Locally adapted versus exotic varieties: trade-offs

The choice between locally adapted (traditional/indigenous) varieties and exotic (modern/hybrid) varieties involves significant trade-offs that affect profitability, risk, and sustainability. Advantages of locally adapted varieties: (1) Adaptation to local conditions: traditional varieties have been selected over many generations for performance under local temperatures, rainfall patterns, soil types, and pest pressures; they often perform more reliably under stress conditions

than exotic hybrids. (2) Seed availability and cost: local variety seeds can be saved by farmers from each harvest, eliminating annual seed purchase costs; F1 hybrid seeds must be purchased new each season because saved seed from F1 hybrids does not breed true (genetic segregation reduces yield and uniformity). (3) Consumer acceptability: traditional varieties often have superior taste, texture, and cooking quality preferences by local consumers (local tomato varieties for jollof rice and stew; local pepper varieties for specific regional sauces and soups). (4) Biodiversity conservation: maintaining locally adapted varieties preserves genetic diversity in the crop population, providing a reservoir of genes for future breeding.

Advantages of exotic (modern hybrid) varieties: (1) Higher yield potential: F1 hybrid tomato varieties commonly yield 30 to 60 t/ha under optimal management in Nigeria compared with 8 to 15 t/ha for open-pollinated local varieties. (2) Disease resistance: many modern varieties carry resistance to bacterial wilt, Fusarium wilt, TYLCV, and other major pathogens. (3) Uniformity and market quality: F1 hybrids produce more uniform fruit size, colour, and maturity, reducing sorting costs and improving market acceptance. (4) Shelf life: many exotic varieties have been bred for longer shelf life and firmer fruit, reducing post-harvest losses. Integrated approach: in practice, the most successful Nigerian horticultural enterprises use a combination of improved open-pollinated varieties (OPVs; bred for local adaptation with improved agronomic traits; seeds can be saved) and selected F1 hybrids for high-value market-oriented production where high yield and uniformity justify the seed cost.

Fill in the blank: F1 hybrid vegetable varieties must be purchased as new _____ each season because seeds saved from hybrid plants do not breed true; this is in contrast to open-pollinated varieties (OPVs) from which farmers can save seed for the following season.

Trait	Traditional Varieties	Exotic F1 Hybrids
Yield Potential	Moderate yields, stable across seasons	Very high yields under optimal management
Seed Cost	Low cost, often freely exchanged	High cost, commercially purchased
Disease Resistance	Strong resilience to local pests/diseases	Engineered resistance to specific diseases, but may fail under local strains

Adaptation to Local Stress	Well adapted to drought, poor soils, and local climate	Performs best under controlled conditions, less tolerant of stress
Consumer Taste	Preferred traditional flavor and texture	Sometimes less flavorful, bred for appearance and uniformity
Uniformity	Variable size and shape	Highly uniform, consistent produce
Shelf Life	Shorter shelf life, prone to quick spoilage	Longer shelf life, better for transport and markets
Seed Saving Ability	Seeds can be saved and replanted reliably	Seeds cannot be saved; new purchase required each season

Box 2.1: Comparison of locally adapted and exotic F1 hybrid horticultural varieties for Nigerian production

Pilot questions 2.4

6. Define an exotic horticultural variety and state three reasons why exotic varieties have been introduced to Nigeria.
7. Describe the steps of an adaptation trial for an exotic tomato variety introduced to Nigeria.
8. State three advantages of locally adapted varieties and three advantages of exotic F1 hybrid varieties for Nigerian vegetable producers.
9. Explain why seeds saved from F1 hybrid tomato plants should not be used for the next season's planting.
10. Name two institutions that breed or introduce improved horticultural varieties for Nigeria and state one contribution of each.

Series Summary

This Series examined **Nigeria's ecological zones as regions with distinct rainfall, temperature, soils, and vegetation that determine the crops and production systems suitable for each area**. The major zones are mangrove and swamp forest, lowland rainforest, derived savanna, Guinea savanna, Sudan savanna, and Sahel or semi-arid zones. The humid south supports diverse fruits and year-round leafy vegetables but faces high pest and disease pressure. The savanna and northern zones depend more on seasonal rainfall and dry-season irrigation, with important crops such as tomato, onion, carrot, and pepper. Jos Plateau also supports cool-season crops because of its lower temperature.

The Series also covered the climatic, soil, and varietal factors affecting horticultural production. Rainfall pattern, temperature, photoperiod, humidity, wind, and soil type influence planting time, crop growth, and yield. Productive horticultural soils generally have good drainage and a pH of about **6.0–7.0**, while practices such as liming, raised beds, mulching, windbreaks, and drip irrigation improve crop performance. **Exotic varieties are introduced cultivars selected for traits such as high yield, uniformity, disease resistance, and processing quality**, while local varieties are often better adapted to stress and consumer preferences. F_1 hybrids may produce higher and more uniform yields, but their seeds are costly and usually must be purchased each season.

Glossary of Terms

- **Adaptation trial:** a systematic evaluation of exotic or newly introduced horticultural varieties across multiple locations to determine their performance under local ecological conditions before recommending them for commercial production.
- **Available water capacity (AWC):** the amount of water in the soil that plants can actually extract; calculated as field capacity minus permanent wilting point; highest in loamy soils and lowest in sandy or heavy clay soils.

- **Cardinal temperatures:** the minimum, optimum, and maximum temperatures that define the temperature range within which a crop can grow; beyond the minimum or maximum, growth stops and damage may occur.
- **Day-neutral plant (DNP):** a plant that flowers independently of day length; flowering is triggered by other cues such as temperature or plant age; examples include tomato, pepper, and okra.
- **Fadama:** the Hausa word for low-lying floodplain land adjacent to rivers and streams; fadama soils (Fluvisols) are the most productive vegetable-growing soils in northern Nigeria, used for dry-season irrigated production.
- **F1 hybrid variety:** a variety produced by crossing two distinct inbred parent lines; offspring (F1) show hybrid vigour (heterosis) and uniform performance; seeds saved from F1 plants segregate in the next generation and should not be replanted.
- **Field capacity (FC):** the soil moisture content retained after excess water has drained; the upper limit of plant-available soil water; typically measured 24 to 48 hours after soil saturation.
- **Inter-Tropical Convergence Zone (ITCZ):** a belt of low pressure and rainfall near the equator formed by the convergence of the north-east and south-east trade winds; its annual north-south migration drives Nigeria's seasonal rainfall pattern.
- **Liming:** the application of calcium carbonate (agricultural lime) or dolomitic lime to acid soils to raise soil pH; raises pH to 6.0 to 7.0 for vegetable production on the naturally acid Ferralsols of southern Nigeria.
- **Mulching:** the application of organic material (rice straw, dry grass, sugarcane trash) or plastic film to the soil surface to reduce evaporation, suppress weeds, moderate soil temperature, and maintain soil structure.
- **Permanent wilting point (PWP):** the soil moisture content at which plants wilt permanently and cannot recover even if water is added; the lower limit of plant-available water; typically approximately -1,500 kPa soil water potential.
- **Photoperiodism:** the response of plants to the relative length of the light and dark periods in a 24-hour day; critical for flowering in short-day plants (cowpea), long-day plants, and day-neutral plants.
- **Raised bed:** a vegetable bed elevated 15 to 30 cm above the surrounding soil surface to improve drainage and aeration; typically 1.0 to 1.5 m wide with 30 to 50 cm pathways between beds.

- **Short-day plant (SDP):** a plant that flowers when the duration of the dark period exceeds a critical length (i.e. when day length is shorter than a critical threshold); examples include cowpea (many varieties) and sweet potato; flowers in the harmattan short-day conditions in Nigeria.
- **Sokoto red onion:** a distinct cultivar of Allium cepa grown in Sokoto and Kebbi states; has a characteristic red outer skin and pungent flavour; well adapted to the semi-arid climate; a major export to neighbouring West African countries.
- **Variety Recommendation List (VRL):** a list of horticultural and other crop varieties that have been evaluated through official multi-location trials and approved for commercial production in specific ecological zones in Nigeria; published by FMARD and NASC.

Concept Check Questions [Series 2]

Objective Questions

1. Nigeria's largest vegetation zone, covering states such as Kwara, Plateau, and Kano, is the Guinea _____ woodland, which receives 800 to 1,200 mm of rainfall per year. (Linked to SLO 2.1)
2. The annual north-south migration of the Inter-Tropical _____ Zone (ITCZ) drives Nigeria's seasonal rainfall pattern, bringing the rainy season as it advances northward and the harmattan as it retreats. (Linked to SLO 2.2)
3. Tomato fruit set fails when day temperatures exceed 35 to 38 degrees C because pollen becomes non-_____ at high temperatures; this limits the production of tomato in the Nigerian lowlands during the hot dry season. (Linked to SLO 2.2)
4. Cowpea (Vigna unguiculata) is a _____ plant that flowers when the dark period exceeds a critical length; many varieties flower in the short-day conditions of the harmattan season. (Linked to SLO 2.2)
5. F1 hybrid vegetable varieties produce higher yields than open-pollinated varieties but require new _____ to be purchased each season because saved seed from F1 plants does not breed true. (Linked to SLO 2.4)

Short-Answer Questions

6. Name four of Nigeria's ecological zones and state one important horticultural crop associated with each. (Linked to SLO 2.1)
7. Explain how the harmattan wind affects dry-season vegetable production in northern Nigeria and state two measures used to reduce its impact. (Linked to SLO 2.2)
8. Explain the effect of soil pH below 5.5 on nutrient availability and state how this problem is corrected for vegetable production. (Linked to SLO 2.3)
9. Define available water capacity (AWC) and explain how raised beds and mulching improve soil water management in Nigerian horticultural gardens. (Linked to SLO 2.3)
10. State three advantages and two disadvantages of exotic F1 hybrid varieties compared with locally adapted open-pollinated varieties. (Linked to SLO 2.4)

11. Long-Answer Questions

12. Describe Nigeria's major ecological zones and the horticultural crops associated with each. Explain how rainfall, temperature, and photoperiod influence the distribution and production of horticultural crops in Nigeria. (Linked to SLOs 2.1, 2.2)

13. Describe the major soil types in Nigeria and their suitability for horticulture. Explain soil pH effects, soil water management principles, and the process of introducing and evaluating exotic horticultural varieties. (Linked to SLOs 2.3, 2.4)

Answers to Concept Check Questions [Series 2]

Objective Questions

1. Savanna.
2. Convergence.
3. Viable.
4. Short-day.
5. Seed.

Short-Answer Questions

6. Mangrove/swamp forest (waterleaf; waterlogged saline soils; limited production). Lowland rainforest (plantain, pawpaw, fluted pumpkin; year-round production; bimodal rainfall). Guinea savanna (tomato, onion, pepper; Jos Plateau cool-season crops: carrot, cabbage). Sudan savanna (onion, carrot, garlic; dry-season fadama irrigation).
7. The harmattan wind desiccates vegetation, increases evapotranspiration, and deposits dust on leaf surfaces, making irrigation essential and reducing photosynthetic efficiency. Two measures: (1) windbreaks of Casuarina, neem, or eucalyptus trees planted on the windward side of gardens to reduce wind speed; (2) mulching to reduce soil evaporation and maintain soil moisture.
8. Below pH 5.5: aluminium and manganese become soluble to toxic concentrations; phosphorus is fixed by iron and aluminium and becomes unavailable; nitrogen mineralisation is reduced; most vegetable crops show nutrient deficiency symptoms even when fertilised. Correction: apply agricultural lime (CaCO3) at 1 to 3 t/ha, incorporated 2 to 4 weeks before planting, to raise pH to 6.0 to 7.0.
9. AWC = field capacity minus permanent wilting point; it is the water plants can actually extract from the soil. Raised beds improve drainage (excess water drains away; reduces waterlogging and root oxygen deficiency); roots have better aeration. Mulching reduces evaporation from the soil surface (30 to 50 percent water saving); maintains soil temperature; reduces weed competition; conserves soil moisture between irrigations.

10. Three advantages of F1 hybrids: higher yield potential (30 to 60 t/ha vs 8 to 15 t/ha for tomato); improved disease resistance (bacterial wilt, TYLCV); better uniformity and shelf life. Two disadvantages: seeds must be repurchased every season (expensive; cannot be saved); may have inferior local taste acceptability compared with traditional varieties.

Long-Answer Questions

11. Nigeria's six ecological zones: (1) Mangrove/swamp (above 2,000 mm; coastal; limited horticulture; waterleaf on elevated creek banks). (2) Lowland rainforest (1,500 to 2,500 mm; bimodal rainfall; two planting seasons; plantain, banana, pawpaw, pineapple, citrus, avocado; fluted pumpkin, okra, waterleaf; high pest and disease pressure). (3) Derived savanna (1,200 to 1,500 mm; transitional; year-round production with irrigation). (4) Guinea savanna (800 to 1,200 mm; unimodal; major commercial zone; tomato, onion, pepper, cowpea; Jos Plateau: cool highland; cool-season crops year-round; carrot, cabbage, Irish potato, lettuce). (5) Sudan savanna (500 to 1,000 mm; dry-season fadama irrigation; onion, carrot, garlic, pepper; Sokoto red onion exported regionally). (6) Sahel (below 500 mm; oasis irrigation). Climatic factors: Rainfall: annual amount (crop minimum requirements vary); distribution (bimodal south vs unimodal north); intensity (heavy rains cause erosion and waterlogging). ITCZ migration drives seasonality. Temperature: cardinal temperatures (minimum, optimum, maximum); tomato fruit set fails above 35 to 38 degrees C; cool-season crops fail above 25 to 30 degrees C (bolting); Jos and Mambilla plateaus support cool-season crops. Photoperiodism: short-day plants (cowpea, sweet potato; flower in harmattan short days); day-neutral (tomato, pepper, okra; unaffected by day length); long-day (temperate crops rarely grown in Nigeria). Humidity: high RH promotes disease; harmattan desiccates crops. Windbreaks reduce harmattan impact. High solar radiation rarely limits photosynthesis but sunscald occurs on exposed fruit.
12. Soil types: Ferralsols (humid south; acid pH 4.5 to 5.5; low fertility; high P fixation; need lime and organic matter; support perennial crops better than annual vegetables). Lixisols/Alfisols (savanna; moderate fertility; argillic horizon; prone to crusting). Vertisols (crack clays; Benue Valley; difficult management; waterlogging). Arenosols (sandy soils; semi-arid north; low water retention; good for onion/carrot under irrigation). Fluvisols/fadama soils (alluvial; most productive; good fertility and moisture retention). Soil pH: optimum 6.0 to 7.0; below 5.5: Al and Mn toxicity; P fixation; Ca/Mg deficiency; nitrogen mineralisation inhibited; correct with lime at 1 to 3 t/ha. Above 7.5: Fe/Mn/Zn/B deficiency; correct with sulphur or acidic fertilisers. Soil water: FC (upper limit of plant-available water); PWP (lower limit); AWC = FC minus PWP; trigger irrigation at 50 to 60 percent AWC depletion. Raised beds improve drainage and aeration.

Mulching reduces evaporation (30 to 50 percent saving); suppresses weeds; lowers soil temperature. Irrigation: flood/furrow (common; low cost; high water use; disease risk); drip (30 to 50 percent water saving; reduces foliar disease; commercial adoption increasing); sprinkler (nurseries and leafy vegetables). Exotic variety introduction: reasons (higher yield, disease resistance, uniformity, processing quality). Process: quarantine and preliminary evaluation; multi-location trials; farmer participatory evaluation; NASC registration on VRL. Local varieties: better stress adaptation; seed-saving; consumer taste. F1 hybrids: 30 to 60 t/ha vs 8 to 15 t/ha for tomato; uniformity; disease resistance; annual seed purchase needed. Integrated approach: OPVs plus selected hybrids.

Answers to Pilot Questions [Series 2]

Part 2.1

1. Mangrove/swamp forest (above 2,000 mm). Lowland tropical rainforest (1,500 to 2,500 mm). Derived savanna (1,200 to 1,500 mm). Guinea savanna (800 to 1,200 mm). Sudan savanna (500 to 1,000 mm). Sahel/semi-arid (below 500 mm).
2. Six horticultural crops of the humid forest zone: plantain, banana, pawpaw, pineapple, fluted pumpkin (ugu), and okra. Production advantage: bimodal rainfall provides two distinct planting seasons (March to July and September to November), allowing year-round production of most vegetable crops and continuous harvest of perennial fruit crops without expensive irrigation.
3. The dry season (October to March) is the most important period for commercial vegetable production in the savanna because: rainfall is absent (no waterlogging or fungal disease); high solar radiation and low humidity produce high-quality, long-shelf-life vegetables (especially onion, carrot, tomato); irrigation from rivers, streams, and wells is reliable and controllable; cool harmattan temperatures (20 to 28 degrees C) are ideal for onion, carrot, and leafy vegetables; pest and disease pressure is lower without the wet conditions that favour fungal pathogens.
4. Kano State (Dawanau zone; onion, tomato, carrot, cabbage). Plateau State (Jos Plateau; cabbage, carrot, Irish potato, lettuce, tomato; year-round cool climate). Sokoto State (onion; Sokoto red onion; pepper and tomato under dry-season irrigation).
5. Bimodal rainfall (humid south): two wet seasons (March to July and September to November) separated by two short dry periods; allows two planting cycles per year; vegetable farmers plan first and second season plantings. Unimodal rainfall (savanna): one rainy season (May to October Guinea savanna; June to September Sudan savanna) followed by a long dry season (October to

April or May); farmers plant one rainy-season crop and one dry-season irrigated crop; the dry season is the more important commercial season.

Part 2.2

1. Annual amount: minimum requirements vary by crop (banana needs above 1,200 mm; onion can be produced on 300 mm if well-timed); crops outside their rainfall range must rely on irrigation. Seasonal distribution: bimodal (two planting seasons; south) vs unimodal (one rainy season; savanna) determines planting schedules and irrigation timing. Intensity: heavy intense rainfall at season onset causes soil erosion, waterlogging of vegetable beds, and physical damage to soft-tissued vegetables; well-distributed moderate rainfall is more suitable for horticultural production.
2. Cardinal temperatures define the minimum (below which growth stops), optimum (fastest growth), and maximum (above which growth stops or damage occurs) for each crop. (a) Tomato: maximum temperature approximately 38 degrees C; pollen becomes non-viable above 35 to 38 degrees C and fruit set fails; night temperatures above 25 degrees C disrupt pollination; both limits are frequently exceeded in the Nigerian lowlands during the hot dry season, making tomato production difficult without evaporative cooling or shade. (b) Carrot: optimum 10 to 20 degrees C; temperatures above 25 to 30 degrees C cause premature bolting (flowering) before harvestable roots develop and reduce the orange colour due to carotenoid degradation; only achievable in Nigerian lowlands during the coolest harmattan months or year-round on the Jos Plateau.
3. Photoperiodism: the response of plants to the relative duration of light and darkness in a 24-hour cycle; critical for flowering in many species. Short-day plant (SDP): flowers when dark period exceeds critical length; Nigerian example: cowpea (Vigna unguiculata; most varieties are SDP and flower in the harmattan short-day conditions). Long-day plant (LDP): flowers when the dark period is shorter than critical; Nigerian relevance: most temperate vegetables are LDP (not well adapted to Nigerian conditions). Day-neutral plant (DNP): flowers independently of day length; Nigerian example: tomato (Solanum lycopersicum; flowers at any day length once sufficiently mature).
4. High RH effects: (1) promotes fungal diseases (Phytophthora blight, downy mildew, grey mould, early blight) on vegetable crops; (2) reduces the effectiveness of contact fungicide sprays. Harmattan effects: (1) desiccates vegetable crops through high evapotranspiration, causing wilting and tip-burn without irrigation; (2) deposits Saharan dust on leaf surfaces, blocking stomata and reducing photosynthetic efficiency.
5. Windbreaks reduce wind speed in the crop growing area, lowering evapotranspiration and reducing desiccation stress on vegetable crops during the harmattan; they also protect soft crops (pepper, lettuce) from physical wind damage and lodging. Two species: Casuarina equisetifolia

(she-oak; fast-growing; drought-tolerant; commonly planted as windbreaks in northern Nigeria); Azadirachta indica (neem; drought-tolerant; multipurpose; leaves, oil, and bark have additional agronomic and pesticidal uses).

Part 2.3

1. Ferralsols (humid south; acid, low fertility, high P fixation; suitable for perennial fruit crops with heavy inputs but challenging for annual vegetables without lime and organic matter). Lixisols/Alfisols (savanna; moderate fertility; suitable for cowpea, tomato, pepper, sorghum; prone to surface crusting if not mulched). Arenosols (sandy soils; semi-arid north; low water retention; good for onion and carrot under irrigation; require frequent irrigation and fertilisation). Fluvisols/fadama soils (alluvial flood plain soils; most productive; excellent moisture retention and fertility; suitable for all vegetable crops with good drainage management).
2. Below pH 5.5: aluminium dissolves to toxic concentrations that damage roots. Iron and aluminium fix phosphorus into insoluble compounds (iron phosphate, aluminium phosphate), making it unavailable to plants even when P fertiliser is applied. Above pH 7.5: iron precipitates as iron hydroxide and becomes insoluble; plants develop interveinal chlorosis (iron deficiency); similarly zinc and manganese become unavailable.
3. Field capacity (FC): moisture remaining in soil after free drainage has ceased (24 to 48 hours after saturation); upper limit of plant-available water. Permanent wilting point (PWP): moisture content at which plants wilt permanently; lower limit of plant-available water. Available water capacity (AWC) = FC minus PWP. Irrigation scheduling: irrigate when the soil moisture falls to 50 to 60 percent of AWC depleted (management allowed deficit); this triggers irrigation before plant stress occurs while avoiding water wastage.
4. Raised beds: (1) improve drainage in waterlogged or heavy-textured soils, preventing root oxygen deficiency; (2) warm up faster in cool highland conditions, extending the growing season for warm-season crops. Mulching: (1) reduces soil evaporation by 30 to 50 percent, conserving soil moisture between irrigations; (2) suppresses weed growth, reducing competition for water and nutrients.
5. Flood/furrow: low installation cost; uses existing furrows between beds; high water application per session; water contacts foliage promoting fungal diseases; significant water wastage through evaporation and runoff; practical for smallholders without capital for drip equipment. Drip: delivers water directly to root zone; 30 to 50 percent water saving; reduces foliar disease by keeping leaves dry; suitable for soluble fertigation; high initial cost (pipes, emitters, header tank); more appropriate for commercial farmers or supported smallholder schemes.

Part 2.4

1. An exotic horticultural variety is a cultivar developed in another country or region and introduced to Nigeria for trial or commercial production. Three reasons for introduction: (1) higher yield potential than available local varieties (F1 hybrid tomato: 30 to 60 t/ha vs local 8 to 15 t/ha); (2) disease resistance not present in local germplasm (bacterial wilt resistance, TYLCV resistance, Fusarium wilt resistance); (3) improved processing or market quality (determinate ripening for tomato paste; large uniform fruit size for urban fresh markets).
2. Quarantine (imported seed grown in isolation; checked for exotic pests and diseases). Preliminary evaluation/screening (variety grown at one or two sites; basic agronomic data collected; unsuitable varieties discarded). Multi-location trials (promising varieties grown at multiple representative sites across the target ecological zone; yield, disease resistance, and adaptation evaluated). Farmer participatory evaluation (selected varieties grown by farmers under their own conditions; farmer preferences on cultivation ease, taste, storage, and market acceptability assessed). NASC registration (varieties that pass all stages are registered on the Variety Recommendation List for the relevant ecological zone).
3. Local varieties: (1) better adapted to local stresses (temperature extremes, erratic rainfall, local soil conditions); (2) seeds can be saved by farmers each season, eliminating annual purchase cost; (3) often preferred by consumers for traditional cooking quality and flavour. F1 hybrid varieties: (1) significantly higher yield potential (2 to 4 times that of local varieties under optimal management); (2) built-in resistance to major diseases (bacterial wilt, TYLCV, Fusarium); (3) uniform fruit size, colour, and maturity, reducing sorting costs and improving market presentation.
4. F1 hybrid varieties are produced by crossing two distinct inbred parent lines; the first-generation offspring (F1) are all uniform due to hybrid vigour. When F1 plants are allowed to self-pollinate and produce seed, genetic segregation occurs in the next generation (F2); the resulting plants show a wide range of types, most yielding far below the F1 parent; uniformity is lost. Commercial seed companies therefore maintain the parental inbred lines and produce F1 seed afresh each season.
5. IITA (International Institute of Tropical Agriculture; Ibadan; breeds and releases improved cowpea, banana, plantain, and cassava varieties adapted to West African agroecological conditions; conducts germplasm evaluation and distribution). WorldVeg/AVRDC (World Vegetable Center; Taiwan; develops and provides heat-tolerant tomato, leafy vegetable, and hot pepper varieties adapted to tropical conditions; provides vegetable germplasm to Nigerian research institutes).

References and Attributions [Series 2]

Textual References (Books and External Sources)

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- Tindall, H. D. (1983). Vegetables in the tropics. Macmillan Education, London.

Figures, Plates, Tables, and Boxes

- Figure 2.1: Soil pH and nutrient availability chart and raised-bed design for Nigerian horticultural gardens. Attribution: AI generated. Suggested OER search string: “soil pH nutrient availability chart raised bed vegetable garden design Nigeria horticulture OER⇓.
- Box 2.1: Comparison of locally adapted and exotic F1 hybrid horticultural varieties for Nigerian production. Attribution: AI generated. Suggested OER search string: “traditional local variety versus F1 hybrid vegetable variety comparison Nigeria horticulture table OER⇓.

Series 3: Systems and Processes of Production

- **Part 3.1: Systems of Vegetable Production**
  - Sub Part 3.1.1: Open-field vegetable production
  - Sub Part 3.1.2: Protected cultivation and greenhouse horticulture
  - Sub Part 3.1.3: Urban and peri-urban horticulture
- **Part 3.2: Systems of Fruit Production**
  - Sub Part 3.2.1: Smallholder and homestead fruit production
  - Sub Part 3.2.2: Commercial orchard production
  - Sub Part 3.2.3: Agroforestry and multi-strata fruit systems
- **Part 3.3: Production Processes of Tropical Fruit Crops**
  - Sub Part 3.3.1: Site selection and land preparation for orchards
  - Sub Part 3.3.2: Orchard establishment: planting, spacing, and training
  - Sub Part 3.3.3: Orchard management: nutrition, irrigation, and pest control
- **Part 3.4: Cultivation of Leaf, Fruit, and Root Vegetables**
  - Sub Part 3.4.1: Cultivation of leaf vegetables in Nigeria
  - Sub Part 3.4.2: Cultivation of fruit vegetables: tomato, pepper, and okra
  - Sub Part 3.4.3: Cultivation of root and bulb vegetables: carrot and onion

Introduction

The production of horticultural crops in Nigeria takes place across a wide range of systems, from the smallholder home garden in which a few square metres of vegetables are grown alongside tree crops, to large-scale commercial orchards and greenhouse vegetable enterprises. Each system has distinct management requirements, investment levels, risks, and market linkages. Understanding the systems and processes of production equips the horticulturist to select the most appropriate production approach for a given crop, site, and market target.

This Series examines the major systems of vegetable and fruit production used in Nigeria, describes the specific production processes for tropical fruit crops in orchards, and provides detailed cultivation guidelines for the most important leaf, fruit, and root vegetables grown in the country. The emphasis throughout is on practical, evidence-based production knowledge applicable to Nigerian conditions.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 3.1** describe the main systems of vegetable production in Nigeria, including open-field, protected cultivation, and urban horticulture (Linked to Part 3.1),
- **SLO 3.2** describe the main systems of fruit production in Nigeria including smallholder, commercial orchard, and agroforestry systems (Linked to Part 3.2),
- **SLO 3.3** outline the production processes for tropical fruit crops including site selection, orchard establishment, and orchard management (Linked to Part 3.3), and
- **SLO 3.4** describe the cultivation practices for important Nigerian leaf vegetables, fruit vegetables (tomato, pepper, okra), and root and bulb vegetables (carrot, onion) (Linked to Part 3.4).

3.1 Systems of Vegetable Production

3.1.1 Open-field vegetable production

Open-field vegetable production is the most prevalent system in Nigeria, in which crops are grown outdoors in naturally lit, naturally ventilated conditions on prepared soil, raised beds, or mounds. It encompasses: (1) Rainfed upland production: vegetables grown on upland plots during the rainy season, relying on rainfall for water supply; dominant in the humid south (tomato, pepper, okra, fluted pumpkin, cowpea during rains); low input cost but highly seasonal and subject to pest, disease, and flood risk. (2) Irrigated dry-season production (fadama): dry-season vegetable cultivation using supplementary irrigation from rivers, streams, and wells on flood plains and valley bottom soils; dominant in northern Nigeria (Kano, Kaduna, Sokoto, Katsina, Borno, Plateau states); major source of year-round vegetables for Nigerian cities; crops include onion, tomato, pepper, carrot, cabbage, lettuce, and radish. (3) Peri-urban irrigated gardens: small irrigated gardens on the outskirts of major cities (Lagos, Ibadan, Port Harcourt, Enugu, Abuja); often using recycled wastewater from streams or boreholes; contribute substantially to urban vegetable supply.

Management of open-field vegetable production: land preparation (clearing, ploughing or digging, ridging or bed-making); seeding or transplanting; irrigation scheduling; fertiliser application (basal and top-dressing); weed management (hand weeding, hoe weeding, or selective herbicide application); pest and disease scouting and management; staking and training (tomato, climbing beans, cucumbers); and harvest and post-harvest handling. Open-field production is vulnerable to environmental extremes (drought, flooding, excessive heat, hailstorms) and pest outbreaks; these risks increase with climate variability and make crop insurance and market linkages important risk management tools for smallholder vegetable farmers.

Fill in the blank: _____ vegetable production is the most common system in Nigeria; it includes rainfed upland production during the rains and irrigated dry-season fadama production, the latter being dominant in northern Nigeria for crops such as onion, tomato, carrot, and cabbage.

3.1.2 Protected cultivation and greenhouse horticulture

Protected cultivation refers to the growing of horticultural crops under some form of structure that modifies the growing environment, providing protection from adverse weather (excessive rain, hail, wind, extreme heat), reducing pest and disease incidence, and extending or improving the growing season. Structures used in Nigeria: (1) Low tunnels: simple wire or bamboo hoops covered with polyethylene film or shade netting; used for nursery seedling production, for protecting transplants during establishment, and for extending the growing season at the beginning and end of the rains; low cost; accessible to smallholders. (2) Shade nets (shade houses): structures of galvanised pipe or timber frames covered with woven shade cloth (30 to 75 percent shade); used for nursery production, seedling raising, and production of shade-tolerant leafy vegetables (lettuce, waterleaf, spinach) during the hot dry season; reduces temperature and solar radiation; controls aphids and whiteflies with fine mesh nets. (3) Greenhouses (plastic houses): enclosed structures with polyethylene film roofing and walls; provide temperature, humidity, and solar radiation control; allow year-round production of high-value crops (tomato, pepper, cucumber, flowers); more common in commercial and institutional farms (University Teaching Farms; commercial cut flower producers in Abuja and Lagos); require significant capital investment (N500,000 to N5 million per unit depending on size and technology).

Benefits of protected cultivation: reduced pest and disease incidence (exclusion netting keeps out whitefly vectors of TYLCV; shade reduces aphid activity); improved product quality (uniform fruit size, colour, and cleanliness; no soil splash marks); extended growing season; higher yields per unit area (well-managed greenhouse tomato can yield 60 to 120 t/ha compared with 15 to 30 t/ha in open field); possibility of off-season production when prices are highest. Constraints in Nigeria: high initial capital cost; lack of technical knowledge for greenhouse management; inadequate supply of greenhouse inputs (shade cloth, drip tapes, irrigation controllers); high energy cost for cooling and ventilation in the hot season; limited market infrastructure for premium-priced protected produce.

Fill in the blank: Shade nets covering structures with 30 to 75 percent shade cloth are used in Nigeria for nursery seedling production and for growing shade-tolerant leafy vegetables such as

_____ and waterleaf during the hot dry season when unshaded outdoor temperatures exceed crop tolerance limits.

3.1.3 Urban and peri-urban horticulture

Urban and peri-urban horticulture (UPH) refers to the production of horticultural crops within and on the outskirts of cities and towns, contributing to urban food supply, income generation, and environmental management. In Nigeria, UPH is widespread: surveys estimate that 30 to 40 percent of urban households in major cities (Lagos, Ibadan, Kano, Port Harcourt) grow some food within their compounds, on roadsides, or on vacant land; peri-urban professional farmers supply a significant proportion of the fresh vegetables consumed in Nigerian cities. Common UPH systems: compound gardens (small plots within residential compounds; primarily for household consumption; fluted pumpkin, amaranth, okra, bitter leaf); roadside and median strip gardens (vegetables grown in public spaces; common in Ibadan and Kano; contested access to land); container and rooftop gardens (buckets, sacks, drums filled with soil or growing media; used in densely built urban areas); and commercial peri-urban farms (0.5 to 5 ha farms on city fringes; intensive irrigation; daily supply to nearby markets).

Challenges and opportunities of UPH: use of wastewater (polluted urban streams and wastewater from households is often used for irrigation, introducing heavy metals and pathogens into vegetable produce; a major food safety concern); insecure land tenure (urban farmers grow on borrowed or rented land with no long-term security; discourages investment); limited access to quality inputs (seeds, fertilisers) within urban areas; proximity to markets (a major advantage; reduces transport costs and post-harvest losses for fresh vegetables; enables daily harvesting for peak freshness). The Federal Government of Nigeria and state governments have increasingly recognised UPH as a food security strategy and have promoted it through urban agriculture programmes, though implementation and enforcement of food safety standards in UPH remain weak.

Fill in the blank: _____ and peri-urban horticulture (UPH) contributes significantly to Nigerian city vegetable supply; common systems include compound gardens, roadside gardens, container gardens, and commercial peri-urban farms, though wastewater use and insecure land tenure are major challenges.

Pilot questions 3.1

11. Distinguish between rainfed upland vegetable production and irrigated dry-season fadama production in terms of location, season, water source, and key crops.
12. Define protected cultivation and name three types of protective structures used in Nigerian horticulture.
13. State three benefits of protected cultivation over open-field vegetable production.
14. Define urban and peri-urban horticulture (UPH) and name four systems practised in Nigerian cities.
15. State two advantages and two challenges of urban horticulture in Nigeria.

3.2 Systems of Fruit Production

3.2.1 Smallholder and homestead fruit production

Smallholder and homestead fruit production is the dominant system of fruit cultivation in Nigeria and across sub-Saharan Africa. In this system, fruit trees are grown in or around homesteads (compound gardens), on farm boundaries, or interplanted with food crops on small plots (0.1 to 2 ha per household), with minimal purchased inputs and primarily family labour. Characteristics: fruit trees are typically planted from seeds or wildlings (natural seedlings from the forest); tree density and spacing are irregular; management is minimal (no systematic pruning, irrigation, or pest control); trees are multi-purpose, providing shade, fruit for household consumption, and occasional cash income from surplus sales; the system relies on the natural resilience and long production life of tropical fruit trees (mango, cashew, citrus, avocado, pawpaw, banana, plantain, African pear, African star apple).

Homestead fruit production makes important contributions to household food security and nutrition even when yields per tree are low; a single mango tree in a compound can supply 100 to 300 fruits per season for direct consumption; a single pawpaw plant produces 20 to 60 fruits per year. The system is sustainable (low external input use; trees contribute organic matter from leaf fall; no soil erosion under tree canopy) and resilient to market price fluctuations (production is primarily for household use, not market sale). Limitations: low and variable yields (seedling

mango trees typically yield 20 to 50 kg/tree vs 100 to 300 kg/tree for grafted improved varieties); poor fruit quality and consistency (seeded trees produce variable fruit); limited market surplus; few management interventions means high post-harvest losses (fruit fall, pest damage, fungal rots).

Fill in the blank: Smallholder and homestead fruit trees in Nigeria are most commonly planted from _____ or wildlings, producing highly variable fruit quality and lower yields than grafted improved varieties; a grafted mango tree may yield 100 to 300 kg/tree compared with 20 to 50 kg/tree for seedling trees.

3.2.2 Commercial orchard production

Commercial orchard production is a business-oriented system in which fruit crops are planted at recommended spacings in blocks, managed with purchased inputs (fertilisers, pesticides, irrigation), and harvested for market sale. Commercial orchards exist for cashew (Anacardium occidentale; Nigeria's most important commercial fruit crop; predominantly in Oyo, Enugu, Kogi, Kwara, Ondo, Cross River, and Osun states; bulk of production exported as raw cashew nuts); citrus (sweet orange, mandarin; Ogun, Osun, Ekiti, and Benue states; supplied to urban fresh markets and juice processing plants); mango (Mangifera indica; commercial orchards increasingly established in Benue, Kogi, and Kaduna states for export fresh mango); pineapple (Ananas comosus; large plantations in Osun, Ondo, Ogun, and Cross River states); and plantain (Musa paradisiaca; commercial plantain farms in Edo, Delta, Cross River, and Ogun states).

Commercial orchard management involves: site selection (well-drained, fertile loamy soils; adequate rainfall or irrigation; good road access for harvest logistics); land clearing and preparation; planting of vegetatively propagated (grafted, budded, or suckered) planting material at recommended spacing; systematic fertilisation (NPK 15:15:15 at establishment; subsequent maintenance fertilisation based on soil and leaf analysis); irrigation (supplementary irrigation during the dry season for citrus, mango, and pineapple); pruning and canopy management (to maintain tree shape, improve light penetration, and facilitate harvesting and pest control); pest and disease management (regular scouting; spray programmes); harvesting at correct maturity indices; and post-harvest sorting, grading, and packing for market. Commercial orchards require

significant capital investment (planting, infrastructure, inputs) but generate higher returns per hectare and better market access than homestead production.

Fill in the blank: Nigeria's most important commercial fruit crop is _____ (Anacardium occidentale), predominantly cultivated in Oyo, Enugu, Kogi, and Ondo states; the bulk of production is exported as raw cashew nuts to Vietnam, India, and Europe.

3.2.3 Agroforestry and multi-strata fruit systems

Agroforestry systems integrate trees (including fruit trees) with crops and/or livestock in the same land unit, creating a multi-strata system that mimics the structure of natural forest while producing food, income, and environmental services. In Nigerian horticulture, important agroforestry fruit systems include: (1) Homegardens (multi-strata home gardens): a complex, species-rich assemblage of trees (mango, avocado, breadfruit, African pear, citrus), shrubs (guava, cashew), herbaceous crops (banana, plantain, pineapple, yam, cassava, vegetables), and sometimes livestock in the same compound space; most common in the humid south (Edo, Ondo, Cross River, Imo, Anambra states); provide year-round food supply, micronutrient diversity, and income from diverse sources. (2) Cocoa-fruit tree systems: cocoa (Theobroma cacao) grown with plantain (as shade during establishment), banana, citrus, cola, avocado, and other fruit trees; dominant in Ondo, Ogun, Oyo, Ekiti, Cross River, and Edo states; the associated fruit trees provide additional income and food and support pollinator diversity for cocoa. (3) Oil palm mixed systems: oil palm (Elaeis guineensis) interplanted with plantain, banana, cassava, maize, vegetables, and other crops during the early years before the palm canopy closes; common in Rivers, Delta, Bayelsa, Imo, Abia, and Cross River states.

Advantages of multi-strata fruit systems: biodiversity conservation (species diversity provides habitat for beneficial insects; reduces pest outbreaks); reduced external input requirement (nutrient cycling from leaf litter; biological pest control); multiple income streams and food sources (reduces risk from price collapse of any single crop); better land use efficiency compared with monoculture (total production per ha of diverse system often exceeds monoculture systems); improved soil health (continuous organic matter input from leaf fall; root diversity

improves soil structure). Limitation: management complexity (different crops have different input, pruning, and harvesting requirements); difficulty in mechanisation; light competition between strata can reduce yields of light-demanding species.

Fill in the blank: The _____ (multi-strata home garden) is the most complex and species-rich agroforestry fruit system in southern Nigeria; it integrates mango, avocado, citrus, plantain, banana, yam, cassava, and vegetables in the same compound space, providing year-round food and income diversity.

Pilot questions 3.2

11. Distinguish between smallholder homestead fruit production and commercial orchard production under three headings.
12. Name Nigeria's most important commercial fruit crop, state its primary export markets, and name three states where it is predominantly grown.
13. Describe three management practices applied in commercial citrus or mango orchards in Nigeria.
14. Define agroforestry and describe two agroforestry fruit systems common in Nigeria.
15. State three advantages of multi-strata agroforestry fruit systems over monoculture fruit orchards.

3.3 Production Processes of Tropical Fruit Crops

3.3.1 Site selection and land preparation for orchards

Proper site selection is the most critical decision in orchard establishment because fruit trees remain in place for 20 to 50 years and mistakes cannot be easily corrected. Site selection criteria: (1) Soil: deep (minimum 1 m), well-drained loamy soil; no impermeable hardpan within 60 cm; soil pH 5.5 to 7.0 (most fruit crops); avoid waterlogged depressions. (2) Topography: gentle slopes (1 to 5 percent) allow natural drainage and facilitate mechanised operations; avoid flood-prone valley bottoms; terracing is needed on steeper slopes above 10 percent to prevent erosion. (3) Water availability: access to reliable water source for irrigation during the dry season (river, dam, borehole); particularly critical for citrus, mango, and pineapple which need dry-season irrigation to maintain productivity and induce flowering. (4) Accessibility: proximity to all-weather roads for input delivery and product evacuation; poor road access increases post-harvest

losses and lowers farmgate prices. (5) Security: particularly important for cashew and citrus, which are subject to theft and vandalism at harvest; remote sites without community support are risky.

Land preparation: clearing existing vegetation (manual, mechanical, or chemical; avoid burning if possible to preserve soil organic matter); stump removal or chemical stump treatment; ploughing or ripping to break compacted subsoil layers; marking out planting holes or rows at recommended spacing (mango: 8 x 8 m to 10 x 10 m; citrus: 6 x 6 m to 7 x 7 m; pineapple: 30 x 30 cm or 30 x 60 cm on double rows; cashew: 8 x 8 m to 10 x 10 m); digging planting holes (60 x 60 x 60 cm for tree crops) and filling with topsoil mixed with organic matter (compost or decomposed manure at 5 to 10 kg per hole) and basal phosphate fertiliser (SSP at 100 to 200 g per hole) at least 2 to 4 weeks before planting to allow soil to settle.

Fill in the blank: Planting holes for tree fruits such as mango and citrus should be _____ x 60 x 60 cm; the hole is filled with topsoil mixed with organic matter and basal phosphate fertiliser at least 2 to 4 weeks before planting to allow the soil to settle and organic matter to begin decomposing.

3.3.2 Orchard establishment: planting, spacing, and training

Planting material: vegetatively propagated planting material is strongly preferred over seedlings for commercial orchards because it reproduces the exact genetic characteristics of the mother plant, produces fruit earlier, and ensures more uniform fruit quality. Methods: (1) Budding (T-budding or patch budding): a bud from the scion variety is inserted under the bark of a rootstock seedling; used for mango, citrus, avocado; mature in 2 to 3 years. (2) Grafting (tongue-and-wedge, cleft, approach): the scion shoot is united with the rootstock; used for mango, avocado, guava. (3) Marcotting (air layering): a branch is girdled, wrapped with moist media, and allowed to root; used for citrus, guava, avocado; the rooted branch is detached and transplanted. (4) Suckers and ratoons: for banana and plantain, suckers (offshoots from the rhizome) are detached from the mother plant and planted directly; this is the standard banana/plantain propagation method. (5) Slips and crowns: for pineapple, slips (offshoots from the peduncle), ratoons

(suckers from the base of the plant), or the crown (leafy top of the fruit) are used as planting material; slips and ratoons are preferred over crowns as they produce fruit faster.

Spacing and planting: recommended spacings vary by species and management system (mango: 8 x 8 m = 156 trees/ha; hedgerow high-density mango 4 x 2 m = 1,250 trees/ha; citrus: 6 x 6 m = 278 trees/ha; pawpaw: 3 x 3 m = 1,111 plants/ha; pineapple: 30 x 60 cm double row = 55,000 plants/ha). Planting is ideally done at the onset of the rainy season to take advantage of rainfall for establishment; holes should be pre-wetted before planting; soil firmed around roots to eliminate air pockets. Training systems: (1) Open-centre (vase) system: the central leader is removed early; 3 to 4 primary scaffold branches develop from near the trunk; good light penetration; common for mango and guava. (2) Modified central leader: a central trunk is maintained with scaffold branches at intervals; better structural strength; used for avocado and some citrus. (3) Hedgerow: trees planted close together in rows, pruned to a narrow wall shape; allows high tree density and mechanised harvesting; increasing in commercial mango orchards.

Fill in the blank: Banana and plantain are propagated commercially using _____ (offshoots from the rhizome of the mother plant) which are detached and planted directly; this method reproduces the parent plant exactly and produces a crop faster than growing from seed.

3.3.3 Orchard management: nutrition, irrigation, and pest control

Nutrition management: fruit trees have high long-term nutrient demands. A fertilisation programme for mango (example): Year 1 (establishment): 50 g N per tree split into 3 applications; 50 g P_2O_5; 50 g K_2O; applied in holes around the drip line, covered with soil, and watered in. Maintenance fertilisation (from year 3 onwards): NPK 15:15:15 at 0.5 to 2 kg per tree per year increasing with age; additional nitrogen (urea) top-dressing after harvest to promote vegetative flush; micronutrients (zinc sulphate, borax, manganese sulphate) as foliar sprays if deficiency symptoms appear. Organic matter (compost, green manure) applied around the drip line annually improves soil structure and reduces fertiliser requirement. For pineapple: NPK 15:15:15 at 400 to 600 kg/ha; nitrogen sources critical for crown development (urea spray or granular application); potassium critical for fruit quality and sugar content.

Irrigation: most tropical fruit crops require supplementary irrigation during the dry season, particularly for flowering induction (mango requires a dry period of 2 to 3 months followed by brief irrigation or rainfall to trigger uniform flowering; citrus requires mild water stress before flowering). Drip irrigation is the most efficient method for orchards; surface basin irrigation (flooding the area around the tree) is the traditional method used by most Nigerian fruit farmers. Pest and disease management in orchards: mango (mango seed weevil Sternochetus mangiferae; anthracnose Colletotrichum gloeosporioides; powdery mildew Oidium mangiferae; mango fruit fly Bactrocera species; managed by sanitation, fungicide spray programmes, and fruit fly baiting); citrus (citrus psyllid and citrus greening disease; citrus canker Xanthomonas axonopodis; use of certified disease-free planting material and copper-based bactericides); pawpaw (Papaya ringspot virus PRSV; whitefly vectors; controlled by roguing infected plants and insecticide-treated sticky traps); pineapple (mealybugs and associated wilt; mealy bug wilt is the most important disease complex; controlled by hot water treatment of planting material and ant management).

Fill in the blank: Mango _____ (Colletotrichum gloeosporioides) is a major post-harvest and orchard disease that blackens developing flowers, young fruits, and leaves; it is managed by fungicide spray programmes during flowering and fruit development.

Pilot questions 3.3

11. List five criteria for selecting a site for a commercial mango or citrus orchard in Nigeria.
12. Name four methods of vegetative propagation used for tropical fruit crops in Nigeria and state one crop to which each method is applied.
13. State the recommended spacing and plant population per hectare for (a) mango at 8 x 8 m and (b) pineapple at 30 x 60 cm double rows.
14. Describe the fertilisation programme for mango trees in the first year of orchard establishment.
15. Name two important pests or diseases of mango orchards in Nigeria and state one control measure for each.

3.4 Cultivation of Leaf, Fruit, and Root Vegetables

3.4.1 Cultivation of leaf vegetables in Nigeria

Fluted pumpkin (Telfairia occidentalis; ugu): a perennial vine widely grown in southern Nigeria for its leaves (primary use) and seeds (secondary use). Ecological adaptation: humid forest zone; grows best at 25 to 35 degrees C; requires 1,500 to 2,500 mm rainfall or irrigation. Land preparation: ridges or mounds 30 to 50 cm high; spacing 1 to 2 m between mounds; 2 to 3 seeds per mound; germination in 5 to 7 days. Management: staking or trellising with poles, strings, or existing trees to support vines; weeding 2 to 3 times in first month; NPK 20:10:10 or 15:15:15 at 250 to 400 kg/ha applied at 4 weeks and 8 weeks after planting; irrigation in dry season. First leaf harvest: 6 to 8 weeks after planting; subsequent harvests every 3 to 4 weeks by cutting terminal shoots; perennial vine regrows for several years from the crown. Pests and diseases: thrips; aphids; downy mildew; root rot (Pythium, Phytophthora) in waterlogged conditions; fruit fly attacks immature fruits and seeds.

Waterleaf (Talinum triangulare; gbure): a fast-growing succulent herb with high water content. Adaptation: humid south; tolerates shade; grows near water and in home gardens. Spacing: 20 x 20 cm; broadcast sown or planted from stem cuttings (15 to 20 cm sections) which root rapidly. Harvesting begins 3 to 4 weeks after planting; harvested by cutting the whole plant at 5 cm above ground, allowing rapid regrowth; 6 to 8 harvests per growing season. Bitter leaf (Vernonia amygdalina; onugbu): perennial shrub; propagated by stem cuttings (15 to 20 cm); planted in rows or at field boundaries; minimum management required; leaves harvested by stripping or pruning branches; bitter taste due to sesquiterpene lactones (reduced by squeezing and washing before cooking). Moringa (Moringa oleifera; zogale): fast-growing multipurpose tree; propagated by seed or stem cuttings; planted at 1 x 1 m to 3 x 3 m for leaf production (high-density systems for young leaf production); leaves harvested at 60 to 70 days for commercial production; cut back to 1 m height for ratoon production; highly drought-tolerant; excellent on poor soils.

Fill in the blank: Fluted pumpkin (Telfairia occidentalis) is a _____ vine that is first harvested for its leaves 6 to 8 weeks after planting; subsequent leaf harvests are taken every 3 to 4 weeks by cutting terminal shoots, and the vine regrows from the crown for several years.

3.4.2 Cultivation of fruit vegetables: tomato, pepper, and okra

Tomato (Solanum lycopersicum): the most economically important vegetable crop in Nigeria. Varieties: open-pollinated (Roma VF, Tropicana, Beske; local preference for jollof rice quality); F1 hybrids (Platinum, Cobra, Lindo, Padma; higher yield). Nursery: seeds sown in raised nursery beds or trays at 300 to 500 seeds per m2; germination in 5 to 8 days; seedlings transplanted at 3 to 4 true-leaf stage (21 to 28 days old). Field transplanting: spacing 50 to 75 cm between rows x 30 to 45 cm within rows; raised beds with drip irrigation recommended. Fertilisation: basal application of NPK 15:15:15 at 250 to 400 kg/ha at transplanting; urea top-dressing at 50 to 100 kg N/ha at 3 to 4 weeks after transplanting; calcium nitrate foliar sprays to prevent blossom end rot. Staking: bamboo stakes or strings to support indeterminate varieties; prevents fruit contact with soil and disease. Pest and disease management: bacterial wilt (Ralstonia solanacearum; use resistant varieties; avoid waterlogging; crop rotation); early blight (Alternaria solani; fungicide spray; resistant varieties); tomato yellow leaf curl virus (TYLCV; whitefly control; resistance varieties); fruit fly (Bactrocera dorsalis; protein bait trapping). Harvest: 60 to 90 days from transplanting; harvest at turning (breaker) stage for distant markets or fully red for local consumption.

Pepper (Capsicum annuum and C. frutescens): includes sweet (bell) pepper, tatashe, and hot pepper (rodo, shombo, atarodo). Similar production requirements to tomato; slightly more tolerant of heat and drought. Key differences: slower to establish (75 to 100 days to first harvest from transplanting); perennial in humid conditions (can be managed as a ratoon crop through pruning and fertilisation for a second season); major dry-season crop in northern Nigeria under fadama irrigation; processing (grinding, drying) for pepper paste and dried chilli is a major value-adding activity. Okra (Abelmoschus esculentus; ila): warm-season annual; rapid growth (50 to 60 days from seed to first harvest in warm conditions). Direct seeded at 60 x 30 cm or 60 x 60 cm; 2 to 3 seeds per hole, thinned to 1 plant. NPK 15:15:15 at 200 to 300 kg/ha at planting and urea top-dressing at 4 weeks. Fruit harvested every 2 to 3 days when pods are 7 to 10 cm long (before fibres harden); daily harvesting maintains productivity; neglected pods become fibrous and unmarketable, reducing plant productivity.

Fill in the blank: Tomato seeds are first sown in _____ beds or trays and seedlings are transplanted to the field at 3 to 4 true-leaf stage (21 to 28 days old); transplanting is preferred over direct seeding because it gives more uniform plant establishment and better seedling management.

3.4.3 Cultivation of root and bulb vegetables: carrot and onion

Carrot (Daucus carota): cool-season biennial grown as annual; optimum temperature 15 to 20 degrees C; grown on Jos Plateau year-round and in Sudan-Sahel zone during harmattan (October to January). Varieties: Chantenay (short, broad shoulders; suited to heavy soils), Nantes (cylindrical; high quality; preferred by processors), Imperator (long, tapering; for light sandy soils). Land preparation: deep, stone-free, well-drained sandy loam to loam soil is essential; stones, clods, and hardpans cause forking and misshapen roots (unmarketable); soil worked to 30 to 40 cm depth; raised beds 15 cm high reduce waterlogging. Seeding: direct-seeded (very small seed; 1 g contains 700 to 1,000 seeds); mixed with dry sand for even distribution; shallow furrows 1 to 2 cm deep; row spacing 20 to 30 cm; thin to 5 to 8 cm within row at 3 weeks after germination. Fertilisation: basal NPK 15:15:15 at 200 to 300 kg/ha; high potassium promotes root enlargement and colour; avoid excess nitrogen (promotes leafy growth at expense of root). Irrigation: critical; uneven watering causes root cracking; drip or furrow irrigation at 3 to 5 day intervals in dry season. Harvest: 90 to 110 days from sowing; roots harvested when shoulders are 1.5 to 2 cm diameter; delayed harvest causes roots to become fibrous and bitter (lignification of xylem).

Onion (Allium cepa): the most important bulb vegetable in Nigeria; major production in Sokoto, Kebbi, Niger, Kaduna, Plateau, and Kano states. Two production systems: (1) Transplant method (most common): seeds sown in nursery beds at high density; seedlings transplanted at 6 to 8 weeks when pencil-thick (6 to 8 mm diameter); field spacing 20 x 10 cm (500,000 plants/ha); allows better weeding and management. (2) Direct seeding: seeds sown in rows 20 to 25 cm apart; thinned to 10 cm within row; less labour for seeding but weeding more difficult. Fertilisation: high nitrogen (urea at 100 to 150 kg N/ha split into 3 applications) for leaf growth; phosphorus for root development; potassium for bulb quality and shelf life; stop nitrogen application 4 to 6 weeks before harvest to promote bulb maturation and skin tightening. Harvest:

100 to 130 days from transplanting for Sokoto red onion; harvest when 50 to 75 percent of tops have fallen over naturally (neck softening); cure in field or under shade for 2 to 3 weeks to dry outer skins and extend shelf life. Post-harvest: the natural long shelf life of Sokoto red onion (4 to 6 months under traditional rope storage in cool, ventilated conditions) makes it one of Nigeria's few vegetables with significant export potential.

Fill in the blank: Onion bulbs are ready for harvest when 50 to 75 percent of the tops have _____ naturally (neck softening); after harvest, bulbs are cured for 2 to 3 weeks under shade or in the field to dry the outer skins and extend shelf life to 4 to 6 months.

Crop	Ecological Zone	Planting Season	Planting Method	Field Spacing	Days to Harvest	Expected Yield Range
Fluted Pumpkin	Humid rainforest, derived savanna	March–May (rainy season)	Direct seeding or transplanting	1 m × 1 m	60–90 days	10–15 t/ha leaves
Tomato	Northern Guinea savanna, Sudan savanna	Dry season (Nov–Feb) with irrigation; rainy season (June–Aug)	Nursery transplanting	50 cm × 60 cm	70–90 days	15–25 t/ha fruits
Pepper	Rainforest, savanna zones	Rainy season (April–July)	Nursery transplanting	60 cm × 60 cm	90–120 days	8–15 t/ha fruits
Okra	All zones, especially rainforest and savanna	Rainy season (April–July)	Direct seeding	60 cm × 30 cm	60–75 days	5–10 t/ha pods
Carrot	Northern savanna, Jos Plateau	Cool dry season (Nov–Feb)	Direct seeding	30 cm × 10 cm	90–120 days	20–30 t/ha roots

Onion	Northern savanna, Sudan savanna	Dry season (Nov–Feb)	Nursery transplanting	20 cm × 20 cm	90–120 days	15–25 t/ha bulbs

Box 3.1: Production calendar and key parameters for important Nigerian vegetable crops

Pilot questions 3.4

11. Describe the propagation and first harvest of fluted pumpkin (Telfairia occidentalis) for leaf production in southern Nigeria.
12. Describe the nursery stage and transplanting requirements for tomato production in Nigeria.
13. Name two important diseases of tomato in Nigeria and state one management measure for each.
14. Describe the land preparation requirements for carrot production and explain why deep, stone-free soil is essential.
15. Describe the maturity and post-harvest curing procedure for Sokoto red onion.

Series Summary

This Series examined **vegetable and fruit production systems as the organised methods used to grow horticultural crops under different environmental, technological, and market conditions**. Vegetable production may be open-field, protected, urban, or peri-urban. Open-field production includes rainfed farming during the wet season and irrigated fadama farming during the dry season, while protected cultivation uses shade nets, tunnels, or greenhouses to improve crop control and yield. Fruit production may occur in smallholder homesteads, commercial orchards, or agroforestry systems. Homestead systems mainly support household nutrition, commercial orchards use improved planting materials and systematic management, while agroforestry combines fruit trees with crops or other tree species to provide biodiversity and multiple income sources.

The Series also covered orchard establishment and the cultivation of major vegetables. Orchard establishment requires suitable land, good drainage, water and road access, proper land preparation, healthy planting materials, correct spacing, training, fertilisation, irrigation, and disease control. Common propagation methods include budding, grafting, marcotting, suckers, slips, and crowns. Important vegetable crops include fluted pumpkin, tomato, pepper, okra, carrot, and onion, each with specific planting, spacing, fertiliser, irrigation, pest-management, and harvesting requirements. Good production depends on timely operations, suitable varieties, proper crop care, and effective post-harvest handling.

Glossary of Terms

- **Agroforestry:** a land-use system that deliberately integrates trees (including fruit trees) with crops and/or livestock in the same land unit; provides food, income, and environmental services simultaneously.
- **Anthracnose:** a fungal disease of mango (Colletotrichum gloeosporioides) that causes black lesions on flowers, young fruits, and leaves; one of the most economically important orchard diseases in Nigeria.

- **Budding:** a vegetative propagation method in which a bud from a scion variety is inserted under the bark of a rootstock seedling; used for mango, citrus, and avocado; ensures genetic uniformity and earlier fruiting than seedling trees.
- **Curing (onion):** the process of drying onion bulbs after harvest under shade or in the field for 2 to 3 weeks to dry outer skins and close the neck; extends shelf life to 4 to 6 months for Sokoto red onion.
- **Fadama:** low-lying floodplain land adjacent to rivers used for dry-season irrigated vegetable production in northern Nigeria; among the most productive vegetable-growing environments in the country.
- **Greenhouse:** an enclosed structure with polyethylene film roofing used for protected cultivation; allows year-round production of high-value crops with controlled temperature, humidity, and radiation; tomato yields 60 to 120 t/ha under good management.
- **Homegarden:** a multi-strata, species-rich agroforestry system combining fruit trees, shrubs, herbaceous crops, and sometimes livestock within or around a household compound; most common in southern Nigeria.
- **Marcotting (air layering):** a vegetative propagation method in which a branch is girdled, wrapped with moist media, and allowed to root before detachment; used for citrus, guava, and avocado.
- **Mound / ridge:** a raised earthen planting site (30 to 60 cm high) used for vegetables such as fluted pumpkin, yam, and okra; improves drainage, warms the root zone, and facilitates root development.
- **Nursery:** a protected area where seeds are germinated and young seedlings are raised until they are large enough for transplanting to the field; essential for tomato, pepper, onion, and citrus production in Nigeria.
- **Open-field production:** vegetable or fruit crop production in outdoor, naturally lit, naturally ventilated conditions; the most common production system in Nigeria; includes rainfed upland and irrigated fadama systems.
- **Protected cultivation:** the growing of horticultural crops under structures (low tunnels, shade nets, greenhouses) that modify the growing environment; reduces pest and disease incidence and extends or improves the growing season.

- **Sokoto red onion:** a distinct cultivar of Allium cepa grown in Sokoto and Kebbi states; characterised by red outer skin, pungent flavour, and very long shelf life (4 to 6 months); a major export to neighbouring West African countries.
- **Staking:** supporting tomato, pepper, or other vining vegetable plants with bamboo poles or strings to keep stems and fruits off the soil surface; prevents disease, reduces fruit damage, and improves air circulation.
- **Urban and peri-urban horticulture (UPH):** the production of horticultural crops within and on the outskirts of cities; systems include compound gardens, roadside gardens, container gardens, and commercial peri-urban farms; contributes to urban food supply and income.

Concept Check Questions [Series 3]

Objective Questions

6. _____ vegetable production in Nigeria includes rainfed upland cropping during the rains and irrigated dry-season fadama cultivation; the latter is dominant in the northern savanna for onion, tomato, carrot, and cabbage. (Linked to SLO 3.1)
7. Shade _____ with 30 to 75 percent shade are used in Nigerian horticulture for nursery production and growing shade-tolerant leafy vegetables such as lettuce and waterleaf during the hot dry season. (Linked to SLO 3.1)
8. Nigeria's most important commercial fruit crop is _____ (Anacardium occidentale); the bulk of production is exported as raw nuts to Vietnam, India, and Europe. (Linked to SLO 3.2)
9. Banana and plantain are propagated commercially using _____ (offshoots from the rhizome), which reproduce the parent plant exactly and produce a crop faster than seedlings. (Linked to SLO 3.3)
10. Onion bulbs are ready for harvest when 50 to 75 percent of the tops have _____ naturally; after harvest they are cured for 2 to 3 weeks to dry the outer skins and extend shelf life. (Linked to SLO 3.4)

Short-Answer Questions

11. Distinguish between rainfed upland vegetable production and dry-season fadama production under three headings. (Linked to SLO 3.1)
12. Define protected cultivation and state three types of protective structures used in Nigerian horticulture. (Linked to SLO 3.1)
13. State five criteria for selecting a site for a commercial orchard in Nigeria. (Linked to SLO 3.3)
14. Describe the nursery and transplanting requirements for tomato production in Nigeria. (Linked to SLO 3.4)
15. Describe the maturity index and post-harvest curing procedure for Sokoto red onion. (Linked to SLO 3.4)

Long-Answer Questions

13. Describe the systems of vegetable and fruit production in Nigeria, including open-field, protected, urban, smallholder homestead, commercial orchard, and agroforestry systems. (Linked to SLOs 3.1, 3.2)

14. Describe the production processes for tropical fruit crops (site selection, planting material, spacing, training, nutrition, and pest management) and the cultivation practices for tomato, carrot, and onion. (Linked to SLOs 3.3, 3.4)

Answers to Concept Check Questions [Series 3]

Objective Questions

1. Open-field.
2. Nets.
3. Cashew.
4. Suckers.
5. Fallen.

Short-Answer Questions

1. Rainfed upland: grown on upland plots during rainy season; depends on rainfall; crops include tomato, okra, and cowpea. Dry-season fadama: grown on floodplain soils during dry season (October to March); irrigated from rivers or wells; crops include onion, carrot, and cabbage; dominant commercial system in northern Nigeria.
2. Protected cultivation grows crops under structures that modify the environment. Three types: low tunnels (wire hoops and polyethylene film; for nursery and transplant protection); shade nets (30 to 75 percent shade cloth; nursery and leafy vegetable production); greenhouses (polyethylene enclosed structures; year-round high-value crop production).
3. Deep, well-drained loamy soil (minimum 1 m depth). Gentle slope (1 to 5 percent) for drainage and mechanisation. Reliable water source for dry-season irrigation. Good road access for input delivery and produce evacuation. Security from theft and vandalism.
4. Seeds sown in raised nursery beds or trays at 300 to 500 seeds/m2; germinate in 5 to 8 days; seedlings transplanted at 3 to 4 true-leaf stage (21 to 28 days old) to the field at 50 to 75 cm x 30 to 45 cm spacing on raised beds.
5. Harvest when 50 to 75 percent of tops have fallen (neck softening). After harvest, bulbs are cured under shade or in the field for 2 to 3 weeks to dry outer skins; properly cured Sokoto red onion stores for 4 to 6 months under cool, ventilated rope storage.

Long-Answer Questions

1. Vegetable production systems: open-field (rainfed upland: humid south during rains; tomato, okra, cowpea); dry-season fadama (northern Nigeria; irrigated; onion, carrot, cabbage); protected cultivation (low tunnels: transplant protection; shade nets: nursery and leafy vegetable in hot season; greenhouses: year-round high-value production; 60 to 120 t/ha tomato; high capital cost); urban/peri-urban (compound gardens, roadside, container, commercial peri-urban farms; wastewater risk; good market proximity). Fruit production systems: smallholder homestead (seedling trees; minimal management; household nutrition; 20 to 50 kg/tree mango); commercial orchards (vegetatively propagated material; cashew dominant export crop; citrus, mango, pineapple, plantain; systematic management); agroforestry (homegardens: diverse multi-strata species assemblage; cocoa-fruit systems: plantain shade + citrus + avocado; oil palm mixed systems; biodiversity, multiple income; management complexity).
2. Orchard establishment: site selection (deep loamy soil; gentle slope; water access; road access; security); land prep (clearing; deep ripping; planting holes 60 x 60 x 60 cm with organic matter and SSP); planting material (budding for mango/citrus; suckers for banana/plantain; slips for pineapple); spacing (mango 8 x 8 m = 156 trees/ha; citrus 6 x 6 m = 278 trees/ha; pineapple 30 x 60 cm = 55,000 plants/ha); training (open-centre for mango; hedgerow for high-density); nutrition (NPK 15:15:15 increasing with age); irrigation (dry-season supplementary; drip preferred); pest control (anthracnose fungicide in mango; certified disease-free planting material for citrus). Tomato: nursery sow at 300 to 500 seeds/m2; transplant at 21 to 28 days at 50 to 75 x 30 to 45 cm; NPK 15:15:15 + urea top-dressing; stake indeterminate varieties; harvest at 60 to 90 days; major diseases: bacterial wilt (use resistant varieties, crop rotation) and TYLCV (whitefly control, resistant varieties). Carrot: deep stone-free sandy loam; raised beds 15 cm; direct seed in furrows 20 to 30 cm apart; thin to 5 to 8 cm; NPK 15:15:15 at 200 to 300 kg/ha; drip irrigation; harvest at 90 to 110 days before lignification. Onion: nursery transplant at 6 to 8 weeks; 20 x 10 cm field spacing; 100 to 150 kg N/ha in splits; stop N at 4 to 6 weeks before harvest; harvest at 50 to 75 percent top fall; cure 2 to 3 weeks; Sokoto red onion stores 4 to 6 months.

Answers to Pilot Questions [Series 3]

Part 3.1

1. Rainfed upland: upland plots; rainy season; rainfall as water source; tomato, okra, cowpea. Fadama irrigated: floodplain soils; dry season (October to March); rivers or wells as water source; onion, carrot, cabbage; dominant commercial system in northern Nigeria.
2. Protected cultivation grows crops under structures that modify the environment. Three types: low tunnels (polyethylene film over hoops; nursery and transplant protection); shade nets (30 to 75 percent shade cloth; nursery and leafy vegetables in hot season); greenhouses (enclosed polyethylene structures; year-round high-value crop production).
3. Reduced pest and disease incidence (exclusion netting blocks whitefly and aphid vectors). Improved product quality (uniform fruit; no soil splash; better colour). Extended growing season allowing off-season production when prices are highest.
4. UPH is the production of horticultural crops within and on the outskirts of cities. Four systems: compound gardens (residential plots; household consumption); roadside gardens (public spaces; Ibadan, Kano); container gardens (sacks, drums; densely built areas); commercial peri-urban farms (0.5 to 5 ha; daily supply to nearby markets).
5. Advantages: proximity to markets (reduces transport costs and post-harvest losses); daily harvesting for peak freshness possible. Challenges: wastewater use for irrigation (heavy metals and pathogens in produce); insecure land tenure (farmers on rented or borrowed land; discourages investment).

Part 3.2

1. Smallholder homestead: seedling trees; irregular spacing; family labour; minimal inputs; household consumption; 20 to 50 kg/tree mango. Commercial orchard: vegetatively propagated material; regular spacing; purchased inputs; systematic management; market-oriented production; 100 to 300 kg/tree for grafted mango. Third distinction: homestead produces diverse fruit species for family use; commercial orchard focuses on one or two crops for market sale.
2. Cashew (Anacardium occidentale). Primary export markets: Vietnam, India, and Europe. Three states: Oyo, Enugu, Kogi (also Kwara, Ondo, Cross River).
3. Fertilisation (NPK 15:15:15 at 0.5 to 2 kg/tree/year plus urea top-dressing after harvest). Irrigation (dry-season supplementary irrigation; drip method preferred). Pest/disease management (fungicide spray programmes for anthracnose; fruit fly baiting for Bactrocera; regular pruning for canopy aeration).

4. Agroforestry is a land-use system deliberately integrating trees with crops and/or livestock in the same land unit. Two systems: (1) Homegardens: diverse multi-strata assemblage of fruit trees, shrubs, and crops in the compound; common in southern Nigeria. (2) Cocoa-fruit tree systems: cocoa grown with plantain (as shade), citrus, avocado, and other fruit trees; dominant in Ondo, Ogun, and Cross River states.
5. Biodiversity conservation (diverse species support beneficial insects and reduce pest outbreaks). Multiple income streams and food sources (reduces risk from price collapse of any single crop). Improved soil health (continuous leaf litter input maintains organic matter and soil structure).

Part 3.3

1. Deep, well-drained loamy soil (minimum 1 m depth; no hardpan within 60 cm). Gentle slope 1 to 5 percent (natural drainage; mechanisation possible). Reliable water source for dry-season irrigation. Good road access for inputs and produce. Security from theft at harvest.
2. Budding (mango, citrus). Grafting (mango, avocado). Marcotting/air layering (citrus, guava). Suckers (banana, plantain).
    (a) Mango at 8 x 8 m: 10,000 / (8 x 8) = 156 trees/ha. (b) Pineapple at 30 x 60 cm double rows: 10,000 / (0.30 x 0.60) = 55,556 plants/ha.
3. Year 1: 50 g N, 50 g P2O5, and 50 g K2O per tree applied in three splits; placed in holes around the drip line, covered with soil, and watered in. Supplemented with 5 to 10 kg organic compost per hole mixed with the soil at planting.
4. Anthracnose (Colletotrichum gloeosporioides): managed with fungicide spray programmes during flowering and fruit development. Mango fruit fly (Bactrocera species): managed by protein bait trapping and field sanitation (removal of fallen fruits).

Part 3.4

1. Seeds sown 2 to 3 per mound at 1 to 2 m spacing on raised ridges or mounds; germinate in 5 to 7 days; staked with poles or strings at 3 to 4 weeks; fertilised with NPK 15:15:15 at 250 to 400 kg/ha. First leaf harvest at 6 to 8 weeks by cutting terminal shoots; subsequent harvests every 3 to 4 weeks; the perennial vine regrows from the crown for several years.
2. Seeds sown in raised nursery beds or trays at 300 to 500 seeds/m2; germinate in 5 to 8 days; seedlings transplanted at 3 to 4 true-leaf stage (21 to 28 days) to the field at 50 to 75 cm x 30 to 45 cm spacing on raised beds with drip irrigation.
3. Bacterial wilt (Ralstonia solanacearum): use disease-resistant varieties; practice crop rotation; avoid waterlogging. Tomato yellow leaf curl virus (TYLCV): control whitefly vectors with insecticides or exclusion nets; plant TYLCV-resistant varieties.

4. Deep, stone-free, well-drained sandy loam soil worked to 30 to 40 cm depth on raised beds 15 cm high. Stones and clods cause forking and misshapen roots that are unmarketable; impermeable layers prevent normal taproot elongation.
5. Harvest when 50 to 75 percent of tops have fallen (neck softening). After harvest, cure bulbs under shade or in the field for 2 to 3 weeks to dry outer skins; properly cured Sokoto red onion stores for 4 to 6 months under cool, ventilated rope storage.

References and Attributions [Series 3]

Textual References (Books and External Sources)

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Figures, Plates, Tables, and Boxes

- Box 3.1: Production calendar and key parameters for important Nigerian vegetable crops. Attribution: AI generated. Suggested OER search string: “Nigerian vegetable crops production calendar planting spacing harvest season yield table OER⇓.

Series 4: Propagation and Ornamental Plant Establishment

- **Part 4.1: Principles and Methods of Plant Propagation**
  - Sub Part 4.1.1: Sexual propagation: seed germination and seedling establishment
  - Sub Part 4.1.2: Asexual propagation: cuttings, layering, and division
  - Sub Part 4.1.3: Grafting and budding in horticultural crops
- **Part 4.2: Nursery Management in Horticulture**
  - Sub Part 4.2.1: Types and layout of horticultural nurseries
  - Sub Part 4.2.2: Nursery media, containers, and seedling care
  - Sub Part 4.2.3: Hardening-off and transplanting procedures
- **Part 4.3: Introduction to Ornamental Horticulture**
  - Sub Part 4.3.1: Definition, scope, and importance of ornamental horticulture
  - Sub Part 4.3.2: Classification of ornamental plants
  - Sub Part 4.3.3: Important ornamental plants in Nigeria
- **Part 4.4: Establishment of Ornamental Plants**
  - Sub Part 4.4.1: Propagation of ornamental plants
  - Sub Part 4.4.2: Planting and establishment of ornamental gardens
  - Sub Part 4.4.3: Care and maintenance of established ornamentals

Introduction

Plant propagation is the foundation of all horticultural enterprise: every production cycle begins with the establishment of new plants, whether from seed, cuttings, grafts, or other vegetative means. Understanding the biological basis of propagation, the practical skills of nursery management, and the specific requirements of different horticultural crops for propagation and establishment is essential knowledge for any horticulturist.

This Series covers the principles and methods of both sexual and asexual plant propagation, the design and management of horticultural nurseries, and the principles and practices of ornamental horticulture. It examines the classification and importance of ornamental plants in Nigeria, the propagation and establishment of ornamental gardens, and the care and maintenance of established ornamental plantings. Together, these topics prepare students for practical horticultural management across production and aesthetic applications.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 4.1** explain the principles of sexual and asexual propagation and describe the practical methods of cutting, layering, division, grafting, and budding as applied to Nigerian horticultural crops (Linked to Part 4.1),
- **SLO 4.2** describe the types, layout, and management of horticultural nurseries, including nursery media selection, container use, seedling care, hardening-off, and transplanting (Linked to Part 4.2),
- **SLO 4.3** define ornamental horticulture, classify ornamental plants by growth habit, function, and life cycle, and identify important ornamental plants used in Nigeria (Linked to Part 4.3), and
- **SLO 4.4** describe the propagation methods, planting and establishment procedures, and care and maintenance practices for ornamental plants in Nigerian gardens (Linked to Part 4.4).

4.1 Principles and Methods of Plant Propagation

4.1.1 Sexual propagation: seed germination and seedling establishment

Sexual propagation uses seeds produced by the union of male and female gametes (fertilisation). Each seed contains the embryo of the next plant generation along with stored food (endosperm or cotyledons) and a protective seed coat (testa). Sexual propagation is the primary method for annual vegetables (tomato, pepper, okra, carrot, onion, cowpea), most flowering annuals, and many tree fruits where seedlings serve as rootstocks. Advantages: low cost per plant; rapid production of large numbers; easy storage and transport of seed; introduction of genetic variation (important for breeding but a disadvantage for uniformity in production). Disadvantages: genetic variability means plants may not be identical to the parent; long juvenile period before flowering and fruiting in fruit trees (5 to 15 years for seedling mango vs 2 to 3 years for grafted trees); seed dormancy may require special pre-treatments.

Seed germination conditions: (1) Water (imbibition): dry seeds absorb water rapidly, rehydrating the embryo and activating enzymes; the seed must be kept moist but not waterlogged (anaerobic conditions inhibit germination). (2) Temperature: each species has a cardinal temperature range for germination; warm-season vegetables (tomato, pepper, okra) germinate best at 25 to 30 degrees C; cool-season crops (carrot, lettuce, onion) at 15 to 20 degrees C; germination fails below minimum or above maximum temperature. (3) Oxygen: aerobic respiration by the germinating embryo requires oxygen; waterlogged or compacted media limit germination. (4) Light: most horticultural seeds are light-indifferent for germination (planted below soil surface); exceptions include lettuce (positively photoblastic; germinates better in light) and some ornamental seeds. Seed dormancy: dormancy mechanisms (hard testa preventing water uptake; chemical inhibitors in the seed; immature embryo) may require scarification (mechanical or acid scarification to break the seed coat), stratification (cold, moist treatment to satisfy chilling requirement), or soaking in water or hormones (gibberellin; cytokinin) to break dormancy before planting.

Fill in the blank: Seed _____ is the pre-treatment used to break seed coat dormancy in hard-seeded species; it includes mechanical scarification (nicking or filing the seed coat) or chemical scarification (soaking in sulphuric acid) to allow water uptake by the embryo.

4.1.2 Asexual propagation: cuttings, layering, and division

Asexual (vegetative) propagation reproduces plants from non-reproductive organs (stems, leaves, roots, or specialised vegetative structures) without involving seed. Advantages: plants are genetically identical to the parent (true-to-type); shorter juvenile period before production; desirable characteristics are exactly preserved; plants often produce earlier than seedlings. Disadvantages: slower than seed for producing very large numbers; risk of transmitting systemic diseases (viruses, bacteria) from infected mother plants; requires skilled management and special facilities.

(1) Stem cuttings: sections of stem (usually 10 to 20 cm long with 2 to 4 nodes) are cut from the mother plant and rooted in a suitable medium. Types: hardwood cuttings (woody, dormant stems; used for roses, cassava, bitter leaf, moringa); semi-hardwood cuttings (partially matured stems; used for crotons, hibiscus, many ornamental shrubs); softwood cuttings (young, actively growing stem tips; root rapidly but wilt easily; used for impatiens, chrysanthemum, coleus). Rooting is promoted by: wounding the base of the cutting; application of indole-butyric acid (IBA) rooting powder or gel at 1,000 to 3,000 ppm; placing in a well-drained, aerated medium (sand:peat 1:1; perlite; coco coir); maintaining high humidity (mist propagation bench; plastic tent) to reduce transpiration stress while roots develop. (2) Leaf cuttings: leaves or leaf sections are used to generate new plants; used for succulent ornamentals (Sansevieria, Begonia, African violet/Saintpaulia, Echeveria). (3) Root cuttings: sections of fleshy roots produce new shoots; used for roses, breadfruit. (4) Layering: a branch is induced to root while still attached to the parent plant; types include simple layering (bending a stem to the ground and covering a portion with soil), mound layering, and air layering (marcotting; already described for citrus and guava). (5) Division: clump-forming plants are divided into segments, each with roots and shoots; used for ornamental grasses, bird of paradise (Strelitzia), heliconias, ginger lilies, and many herbaceous perennials.

Fill in the blank: Indole-butyric acid (IBA) at 1,000 to 3,000 ppm is applied to the base of stem _____ to stimulate adventitious root formation; it is the most widely used rooting hormone in horticultural nurseries for both ornamental and fruit crop propagation.

4.1.3 Grafting and budding in horticultural crops

Grafting and budding are specialised asexual propagation techniques that unite tissues from two different plants: the rootstock (which provides the root system) and the scion (which becomes the above-ground plant and determines fruit or flower characteristics). The union is achieved through the fusion of cambium layers from both plants; the cambium is the thin meristematic layer between the bark and wood that produces new vascular tissue. Success depends on: (1) Cambial contact between scion and rootstock; (2) Compatible species (grafting between closely related species succeeds; between distant relatives it fails: intraspecific or same-species grafts most reliable); (3) Tight binding to hold the union together while callus forms; (4) Exclusion of air and moisture loss from the graft union (wax or polythene tape).

Common grafting methods used in Nigerian horticulture: (1) Cleft (wedge) graft: the rootstock is cut horizontally; a vertical split is made; a wedge-shaped scion is inserted into the cleft; used for mango (Mangifera indica) whip-and-tongue variant; and avocado. (2) Veneer graft: a shallow cut on the rootstock receives a scion of matching size; used for mango; gives a high success rate (85 to 95 percent) with experienced operators. (3) Approach graft: two potted plants are placed side by side and their stems are partially cut and tied together to unite; used for mango when other methods fail; labour-intensive. (4) T-budding: a T-shaped cut is made in rootstock bark; a bud shield with a bud from the scion variety is inserted under the bark flap; used for citrus (Citrus species), roses (Rosa species); very high success rate in actively growing plants. (5) Patch budding: a rectangular patch of bark containing a bud is cut from the scion and inserted into a matching patch cut from the rootstock; used for difficult species. Advantages of grafting: combines the best root characteristics of the rootstock (vigour, disease resistance, soil adaptation) with the best aerial characteristics of the scion (fruit quality, precocity, disease resistance); earlier bearing (grafted mango bears in 2 to 3 years vs 5 to 8 years for seedling); dwarfing rootstocks allow high-density planting.

Fill in the blank: In _____ budding, a T-shaped cut is made in the rootstock bark and a bud shield from the scion variety is inserted under the bark flap; it is the standard budding method for citrus and roses and achieves a very high success rate in actively growing plants.

Pilot questions 4.1

16. Define sexual propagation and state two advantages and two disadvantages compared with asexual propagation.
17. State four conditions necessary for seed germination and explain how each affects the germination of tomato seeds.
18. Define a stem cutting and describe the steps for producing hardwood cuttings of bitter leaf (Vernonia amygdalina).
19. Distinguish between a rootstock and a scion in grafting and explain why cambial contact is essential for graft success.
20. Name three grafting or budding methods used in Nigerian horticulture and state one crop to which each is applied.

4.2 Nursery Management in Horticulture

4.2.1 Types and layout of horticultural nurseries

A horticultural nursery is a facility where plants are propagated and grown to an appropriate size and stage for transplanting to their permanent growing site. Types of nurseries: (1) Seed nursery beds: flat or raised beds of fine, weed-free soil in which seeds are broadcast or sown in rows at high density; seedlings are raised until they reach transplanting size; used for tomato, pepper, onion, cabbage, waterleaf, and most annual vegetables; low cost; accessible to smallholders. (2) Container nurseries: individual plants are raised in containers (polythene bags, seedling trays, or pots) filled with a growing medium; the root system is contained within the bag and the plant is transplanted with minimum root disturbance; essential for tree fruit seedlings and ornamentals that do not tolerate root disturbance; more expensive than open-bed nurseries but gives better transplanting survival. (3) Mist propagation benches: enclosed chambers with intermittent mist irrigation controlled by an electronic timer or leaf moisture sensor; maintains high relative humidity (above 90 percent) around cuttings while they develop roots; used for propagating ornamental cuttings, semi-hardwood and softwood cuttings, and microcuttings.

Nursery layout: the nursery site should be: level or gently sloping for easy drainage and irrigation; sheltered from strong winds (windbreak on the windward side); close to a reliable water source; easily accessible for routine management. A well-organised commercial nursery

includes: a propagation area (protected from direct sun; shade house or mist bench for cuttings and young seedlings); a hardening-off area (partially shaded; used for acclimatising seedlings before field transplanting); storage and chemical handling areas; and a display area for retail sales. Hygiene is critical in the nursery: all tools, containers, and benches must be sterilised (10 percent bleach solution or potassium permanganate) to prevent the spread of damping-off (Pythium, Phytophthora, Rhizoctonia) and other nursery pathogens.

Fill in the blank: Nursery _____ is a major cause of seedling death in Nigerian nurseries; it is caused by soilborne fungi (Pythium, Phytophthora, Rhizoctonia) that attack the stem at soil level; prevention requires sterilised nursery media, good drainage, and avoidance of overwatering.

4.2.2 Nursery media, containers, and seedling care

The ideal nursery medium (growing medium or substrate) for horticultural seedlings must: (1) retain adequate moisture without waterlogging; (2) provide good aeration for root development; (3) be free of weed seeds, pests, and pathogens (sterilised or pasteurised); (4) provide a small amount of nutrients to sustain early seedling growth; (5) have a suitable pH (5.5 to 6.5 for most vegetables and ornamentals). Common nursery media used in Nigeria: sieved topsoil (cheap; widely available; risk of weed seeds and pathogens; requires sterilisation by solarisation or steam); river sand (good drainage; no nutrients; usually mixed with soil or compost); decomposed organic matter/compost (adds nutrients and improves water retention; must be fully decomposed to avoid nitrogen immobilisation); coco coir (coconut fibre; excellent water retention and aeration; pH 5.5 to 6.5; increasingly used in commercial nurseries; expensive); perlite or vermiculite (volcanic mineral; lightweight; excellent aeration; no nutrients; used as a mix component). Standard seed bed mix: sieved topsoil (2 parts) + decomposed compost (1 part) + river sand (1 part); sterilised by covering with black polythene and solar heating for 2 to 4 weeks (solarisation).

Containers for nursery seedlings: flat polythene bags (3 x 5 cm to 6 x 10 cm; used for tomato, pepper, cabbage, and most annual vegetables; cheap; biodegradable alternatives available); seedling trays (plastic multi-cell trays with 50 to 200 cells per tray; standardised cell size; allow mechanised sowing and transplanting; better for large-scale commercial nurseries); small pots

(clay or plastic; 10 to 20 cm diameter; used for ornamental seedlings, perennial herbs, and succulents); large polythene bags (20 x 30 cm or larger; used for tree fruit seedling production in forestry and orchard nurseries). Seedling care: sowing seeds at correct depth (2 to 3 times seed diameter); thinning to avoid overcrowding; regular watering (morning watering preferred; reduces damping-off risk); light fertilisation with NPK 20:20:20 soluble fertiliser at 1 to 2 g/L water from 2 to 3 weeks after germination; pest and disease monitoring.

Fill in the blank: The standard nursery seed bed mix commonly used in Nigerian vegetable nurseries consists of 2 parts sieved topsoil, 1 part decomposed _____, and 1 part river sand; the mixture is solarised under black polythene film for 2 to 4 weeks to kill weed seeds, pests, and pathogens.

4.2.3 Hardening-off and transplanting procedures

Hardening-off is the gradual acclimatisation of nursery seedlings to outdoor field conditions before transplanting. Nursery seedlings are raised in relatively protected conditions (shade, controlled watering, high humidity); transplanting them directly to the open field exposes them to full sun, lower humidity, wind, and more variable soil moisture, causing transplanting shock (wilting, leaf scorch, growth check, and sometimes death). Hardening-off reduces this shock by gradually exposing seedlings to field conditions over 5 to 10 days before transplanting: progressively reducing shade, reducing irrigation frequency, stopping fertiliser application, and exposing seedlings to outdoor temperatures and wind during the day (returning to shelter at night if temperatures are extreme). Well-hardened seedlings are shorter, sturdier, and have thicker cuticles and more developed root systems than un-hardened seedlings.

Transplanting procedure: (1) Select the right growth stage (tomato: 3 to 4 true leaves, 21 to 28 days old; pepper: 4 to 5 true leaves, 28 to 35 days old; onion: 6 to 8 weeks old, pencil-thick stem; citrus: 15 to 30 cm tall, actively growing). (2) Water seedlings thoroughly the day before transplanting to reduce root damage on removal. (3) Transplant in the afternoon or on a cloudy day to minimise heat and moisture stress on the newly transplanted seedling. (4) Set the seedling at the same depth it grew in the nursery; do not bury the stem above the root collar (promotes stem rot). (5) Firm soil around the root ball to eliminate air pockets. (6) Water immediately after transplanting; apply mulch around the base to conserve moisture. (7) Provide shade for the first 3

to 5 days using palm fronds, cardboard, or shade nets if transplanting in full sun during the dry season. (8) Monitor for transplanting shock (wilting) and apply supplementary water if needed.

Fill in the blank: _____ is the gradual acclimatisation of nursery seedlings to outdoor field conditions over 5 to 10 days before transplanting; it involves progressively reducing shade and irrigation to prepare seedlings for exposure to full sun, wind, and variable soil moisture in the field.

Pilot questions 4.2

16. Define a horticultural nursery and distinguish between a seed nursery bed and a container nursery.
17. State four characteristics of an ideal nursery growing medium and name three materials commonly used in Nigerian nursery mixes.
18. Explain what damping-off is and state three measures used to prevent it in a vegetable seedling nursery.
19. Define hardening-off and describe the steps involved in hardening-off tomato seedlings before field transplanting.
20. State five steps in the correct procedure for transplanting vegetable seedlings from nursery to field.

4.3 Introduction to Ornamental Horticulture

4.3.1 Definition, scope, and importance of ornamental horticulture

Ornamental horticulture is the branch of horticulture that deals with the cultivation, management, and marketing of plants grown primarily for their aesthetic value: their flowers, foliage, form, fragrance, or other decorative qualities. Unlike pomology and olericulture (which are primarily production-oriented), ornamental horticulture is driven by visual appeal, design principles, and the human desire for beautiful environments. The scope of ornamental horticulture includes: floriculture (production of cut flowers, pot plants, and flowering bedding plants); foliage plant production (indoor and outdoor decorative foliage: palms, ferns, crotons, dracaenas); turf and lawn management (grass cultivation for sports fields, parks, and domestic lawns); arboriculture

(care of trees in urban and landscape settings); and landscape horticulture (garden design, installation, and maintenance).

Importance of ornamental horticulture in Nigeria: (1) Aesthetic and environmental improvement: ornamental plants beautify homes, offices, streets, parks, and public spaces; they improve air quality by absorbing carbon dioxide and releasing oxygen; reduce urban heat island effects; reduce noise and dust; contribute to mental health and wellbeing of urban residents. (2) Economic value: commercial floriculture (cut flowers, pot plants, landscape services) is a growing industry in Nigerian cities; landscape and gardening services employ many people in Lagos, Abuja, Port Harcourt, and other cities; nurseries producing ornamental plants are profitable small-scale enterprises. (3) Cultural and ceremonial uses: flowers and ornamental plants are used extensively in Nigerian weddings, burials, religious ceremonies, and civic celebrations; demand is high in major cities, particularly for cut roses, chrysanthemums, anthuriums, and tropical foliage. (4) Tourism: well-maintained public gardens, botanical gardens (University of Ibadan Botanical Garden; National Arboretum Abuja), and landscaped resorts attract domestic and international tourists. (5) Education and research: botanical gardens and university teaching gardens are important educational resources; ornamental plant collections support research in plant taxonomy, ecology, and horticulture.

Fill in the blank: Ornamental horticulture encompasses floriculture, foliage plant production, turf and lawn management, _____, and landscape horticulture; it improves the aesthetic quality of urban environments and supports a growing commercial industry in Nigerian cities.

4.3.2 Classification of Ornamental Plants

Ornamental plants are plants grown mainly for their decorative value in gardens, landscapes, buildings, and floral arrangements. They may be classified by life cycle and growth habit. Annuals such as marigold, zinnia, celosia, and sunflower complete their life cycle in one season, while biennials flower in the second year. Perennials such as heliconia, ixora, agapanthus, and bird of paradise survive for many years. By growth habit, ornamentals may be herbaceous plants, woody shrubs, trees, climbers, vines, succulents, or cacti. Examples include

hibiscus and croton as shrubs, Delonix regia and royal palm as trees, Allamanda and Thunbergia as climbers, and Aloe, Agave, and Opuntia as succulents.

Ornamental plants may also be classified by their function in the landscape. Ground covers such as Wedelia and lawn grasses cover bare soil and suppress weeds, while hedging plants such as Duranta, bougainvillea, and ixora provide boundaries, privacy, or wind protection. Specimen plants are used as focal points, bedding plants provide seasonal colour, and indoor plants such as Dracaena, Sansevieria, Aglaonema, and peace lily are adapted to shaded interiors. By flower use, ornamentals may be grouped into cut flowers, including roses, chrysanthemums, gladioli, gerbera, and heliconia, or pot plants such as kalanchoe, African violet, anthurium, cyclamen, and peace lily.

Fill in the blank: Ornamental plants classified as _____ covers are low-growing plants used to suppress weeds, prevent soil erosion, and cover bare ground between taller plants; examples in Nigeria include Wedelia trilobata, Rhoeo, Alternanthera, and lawn grasses.

4.3.3 Important ornamental plants in Nigeria

Flowering shrubs and climbers widely used in Nigerian gardens and landscapes: Bougainvillea (Bougainvillea spectabilis and B. glabra): one of the most popular ornamental climbers/scrambling shrubs in Nigeria; bracts (modified leaves) are the showy part (red, pink, orange, purple, white); drought-tolerant; grows in all zones; used for fences, trellises, and specimen planting. Hibiscus (Hibiscus rosa-sinensis; Chinese hibiscus): common flowering shrub (red, yellow, pink, white flowers); used for hedging and specimen planting; flowers used medicinally and for food colouring; extremely common in Nigerian school grounds, church compounds, and home gardens. Ixora (Ixora coccinea): compact evergreen shrub; clusters of small tubular red, orange, or yellow flowers; used for low hedging, border planting, and mass colour effects; prefers acid, well-drained soil. Lantana (Lantana camara): tough, drought-tolerant shrub with multi-coloured flower heads (yellow, orange, red, pink, white in the same head); attracts butterflies; invasive in disturbed habitats; requires regular pruning to maintain appearance.

Trees and palms used in Nigerian landscaping: Flame tree (Delonix regia): large deciduous tree with spectacular scarlet and orange flower display (March to May in Nigeria); commonly planted as a roadside and avenue tree; associated with the University of Ibadan campus. Jacaranda (Jacaranda mimosifolia): purple-flowered tree; deciduous; spectacular in flower; used as avenue and shade tree in Abuja and highland areas. Royal palm (Roystonea regia): stately tall palm; smooth grey trunk; used as avenue tree and formal garden feature; requires open, sunny space. African tulip tree (Spathodea campanulata; oluyin in Yoruba): native West African tree; large orange-red trumpet flowers; used as shade and ornamental tree; excellent for urban planting. Aloe vera (Aloe barbadensis): succulent used extensively in Nigerian home gardens for its medicinal properties (leaf gel for burns, skin conditions, and gastrointestinal ailments) and as an ornamental accent plant. Indoor and shade plants: Dracaena species (D. fragrans, D. marginata, D. sanderiana); Sansevieria trifasciata (snake plant; mother-in-law's tongue); Aglaonema (Chinese evergreen); Dieffenbachia (dumb cane; toxic sap; handle with care); Pothos/Epipremnum aureum (golden pothos; climbing or trailing foliage plant; tolerates low light); Peace lily (Spathiphyllum wallisii; white spathe flowers; tolerates low light; popular in offices and homes).

Fill in the blank: _____ (Delonix regia) is a large deciduous tree valued in Nigerian landscaping for its spectacular display of scarlet and orange flowers from March to May; it is widely planted as a roadside and avenue tree and is closely associated with the University of Ibadan campus.

Pilot questions 4.3

16. Define ornamental horticulture and state four reasons why it is important in Nigeria.
17. Classify ornamental plants by life cycle (annual, biennial, perennial) with two Nigerian examples of each category.
18. Classify ornamental plants by growth habit (herbaceous, shrub, tree, climber, succulent) with one Nigerian example of each.
19. Name four important flowering shrubs or trees used in Nigerian landscaping and state one characteristic feature of each.
20. Name four indoor ornamental plants suitable for use in Nigerian offices and homes and state one desirable characteristic of each.

4.4 Establishment of Ornamental Plants

4.4.1 Propagation of ornamental plants

Ornamental plants are propagated by both sexual (seed) and asexual (vegetative) methods, depending on the species and the quality required. Seed propagation of ornamentals: annual bedding plants (marigold/Tagetes, Zinnia, Celosia, Impatiens, Cosmos, Portulaca, Sunflower) are predominantly raised from seed; seeds are sown in trays or nursery beds, germinated under partial shade, and pricked out (thinned) or transplanted to individual containers or beds at 2 to 4 true-leaf stage. Hybrid (F1) seed is widely used for uniform flower colour, size, and habit in commercial production; saved seed from F1 hybrids does not breed true and should not be used. Light requirements: many ornamental seeds are small and require surface sowing or very shallow burial (Impatiens, Begonia, Petunia, Portulaca; sown on the medium surface and pressed in but not covered; these are positively photoblastic). Some ornamental seeds (Strelitzia, Heliconia, palm seeds) require soaking in warm water for 24 to 48 hours before sowing to soften the seed coat and improve germination percentage.

Vegetative propagation of ornamentals: (1) Stem cuttings: the most widely used method for woody ornamental shrubs (Bougainvillea, Hibiscus, Ixora, Duranta, Lantana, Acalypha, Croton); semi-hardwood cuttings 10 to 15 cm long with 3 to 4 nodes; lower leaves removed; base treated with IBA rooting powder; inserted into moist sand or coco coir; placed in high-humidity propagation chamber; roots develop in 2 to 6 weeks depending on species. Softwood cuttings: for herbaceous ornamentals (Impatiens, Coleus, Chrysanthemum, Pelargonium); root rapidly in 1 to 3 weeks. (2) Leaf cuttings: for succulent ornamentals (Sansevieria; single leaf sections placed upright in sand); for Begonia (leaf placed on medium, veins cut, new plantlets arise from cut veins); for African violet/Saintpaulia (leaf petiole inserted in medium; new plantlets arise at the base of the petiole). (3) Division: for clump-forming ornamentals (Strelitzia/bird of paradise; Agapanthus; ornamental ginger/Alpinia; Heliconia; ornamental grasses); the clump is dug up and divided into sections each containing roots and shoots. (4) Specialised vegetative structures: bulbs (Hippeastrum/amaryllis, Crinum, Hymenocallis; bulblets separated from mother bulb); corms (Gladiolus; cormlets); rhizomes (Canna, Ctenanthe, ornamental ginger; rhizome sections with buds).

Fill in the blank: Leaf _____ of Sansevieria (snake plant) involves cutting single leaves into 5 to 10 cm sections and inserting them upright into moist sand; new plants develop at the base of each leaf section, producing plants genetically identical to the parent.

4.4.2 Planting and establishment of ornamental gardens

The establishment of an ornamental garden involves several sequential steps: (1) Design and planning: before any soil is turned, the garden is planned on paper (site survey; measurement of area; identification of sun/shade zones, wind direction, existing trees and structures; identification of design intent: formal or informal style; plant palette selection appropriate to the site's conditions and the client's preferences; drawing a scaled planting plan). (2) Site preparation: clearing existing vegetation (manual or mechanical); soil improvement (addition of organic matter and sand to improve drainage on heavy clay soils; liming to correct pH if needed; incorporation of slow-release fertiliser or bone meal); forming of beds, paths, and lawn areas. (3) Selection and sourcing of planting material: container-grown nursery stock is preferred for landscaping because it transplants with minimal root disturbance; bare-root stock (trees dug from the ground) is also used but requires more careful handling and immediate planting.

(4) Planting: holes dug wider than the root ball (twice the width; same depth as the container); backfill with amended soil; plant at the same depth as it grew in the container (do not bury the crown); firm soil; water thoroughly; apply mulch (5 to 10 cm deep; kept away from the stem) to conserve moisture, suppress weeds, and moderate soil temperature. Spacing: respect mature plant size; allow adequate spacing for air circulation (prevents foliar disease) and light penetration; typical spacings: small bedding plants 20 to 30 cm; medium shrubs 60 to 100 cm; large shrubs and trees 2 to 5 m. (5) Establishment period: newly planted ornamentals need regular watering for the first 2 to 4 weeks while root systems establish; once established, watering can be reduced. (6) Labelling: all plants in a new garden should be labelled (botanical name, common name, planting date) for record-keeping and educational purposes.

Fill in the blank: Planting holes for ornamental trees and shrubs should be dug _____ the width of the root ball but the same depth; the extra width allows roots to penetrate the loosened backfill soil easily while keeping the plant at the correct depth to avoid crown rot.

4.4.3 Care and maintenance of established ornamentals

Pruning and training: regular pruning maintains the shape, size, and vigour of ornamental plants. Pruning objectives: (1) shaping (removing shoots to maintain the desired form of a hedge, topiary, or specimen plant); (2) deadheading (removal of spent flowers to stimulate further flowering in annuals and perennials: marigolds, Ixora, Hibiscus); (3) rejuvenation pruning (hard cutting back of old, woody, or leggy shrubs to stimulate new growth: Bougainvillea, Ixora, Hibiscus); (4) size control (limiting the size of trees and shrubs in constrained spaces); (5) health pruning (removing dead, diseased, or crossing branches). Tools: secateurs (hand pruners; for stems up to 1.5 cm diameter); loppers (for branches 1.5 to 4 cm diameter); pruning saws (for larger branches); hedge shears (for formal hedges and topiary). All cutting tools must be sharp and sterilised between plants to prevent disease transmission.

Fertilisation of established ornamentals: ornamental plants require regular feeding to maintain vigour and flowering performance. General programme: balanced NPK (15:15:15 or 20:20:20) at 100 to 200 g/m2 of bed area, applied 2 to 4 times per year, watered in after application; foliar micronutrient spray (zinc, iron, manganese) if interveinal chlorosis is observed; slow-release granular fertilisers (3 to 6 month release) are convenient for container plants and mixed beds. Flowering plants respond to higher phosphorus and potassium relative to nitrogen (a high-P/K formula such as 6:30:30 promotes flowering; excess nitrogen produces excessive leafy growth at the expense of flowers). Pest and disease management: common pests of ornamentals in Nigeria include aphids (on Hibiscus, roses, Bougainvillea; spray with systemic insecticide or neem oil), mealybugs (on Dracaena, Aglaonema, Philodendron; spray with malathion or wipe with cotton wool soaked in ethanol), spider mites (on many ornamentals in hot dry season; miticide or neem oil spray), and leaf miners (on Lantana, Chrysanthemum; systemic insecticide). Watering: most established ornamentals in Nigerian gardens require irrigation during the dry season (November to March); drip irrigation or soaker hoses around beds are most efficient; watering in the morning is preferred to reduce foliar disease risk; avoid waterlogging (raises root rot risk).

Fill in the blank: _____ is the removal of spent flowers from ornamental plants such as marigold, Ixora, and Hibiscus to stimulate the production of new flower buds and prolong the

display period; it is one of the most important routine maintenance tasks in a flowering ornamental garden.

Figure 4.1: Methods of vegetative propagation for ornamental plants used in Nigerian horticulture

Pilot questions 4.4

16. Name four methods of vegetatively propagating ornamental plants and give one example of an ornamental plant propagated by each method.
17. Describe the steps for propagating Bougainvillea from semi-hardwood stem cuttings.
18. Describe the key steps in establishing an ornamental garden from site preparation to planting.
19. Explain the purpose of deadheading in an ornamental garden and name two plants in Nigeria to which it is commonly applied.
20. Name two common pests of ornamental plants in Nigeria and state one control measure for each.

Series Summary

This Series examined **plant propagation as the process of producing new plants from seeds or vegetative parts**. Sexual propagation uses seeds and is cheap, suitable for producing many plants, and allows easy storage, but it may result in genetic variation and a longer juvenile period. Successful germination requires water, suitable temperature, oxygen, and, for some species, light. Seed dormancy may be broken through scarification, stratification, or soaking. Asexual propagation produces plants genetically similar to the parent and usually shortens the juvenile period. Major methods include stem, leaf, and root cuttings, layering, division, grafting, and budding. Grafting joins a scion to a compatible rootstock and requires close cambial contact for successful union.

The Series also covered nursery management and ornamental horticulture. **A nursery is a place where young plants are raised and cared for before transplanting.** Nursery types include seedbeds, containers, and mist-propagation benches, while good management requires a suitable growing medium, disease prevention, hardening-off, and careful transplanting. **Ornamental horticulture is the branch of horticulture concerned with plants grown for beauty, decoration, landscaping, and environmental improvement.** Ornamentals may be classified by life cycle, growth habit, or landscape function, including ground covers, hedges, specimen plants, bedding plants, and indoor plants. Their establishment and maintenance require proper site preparation, planting, watering, mulching, pruning, fertilisation, and pest control.

Glossary of Terms

- **Budding:** a grafting technique in which a single bud from the scion variety is united with a rootstock; types include T-budding (citrus, roses) and patch budding; used to produce true-to-type tree fruit and rose plants with earlier bearing.
- **Damping-off:** a nursery disease caused by soilborne fungi (Pythium, Phytophthora, Rhizoctonia) that attack seedlings at the soil surface, causing them to collapse and die; prevented by sterilised media, good drainage, and avoiding overwatering.

- **Deadheading:** the removal of spent flowers from ornamental plants to stimulate further flower bud production and prolong the display period; applied to marigold, Hibiscus, Ixora, and other flowering ornamentals in Nigerian gardens.
- **Division:** a vegetative propagation method in which clump-forming plants are dug up and separated into smaller sections, each with roots and shoots; used for Strelitzia, Heliconia, Agapanthus, and ornamental grasses.
- **Grafting:** a technique that unites the rootstock (providing root system) and scion (providing aerial characteristics) through cambial contact; used for mango, avocado, citrus, and roses; produces earlier-bearing, true-to-type plants.
- **Hardening-off:** the gradual acclimatisation of nursery seedlings to outdoor field conditions over 5 to 10 days by progressively reducing shade and irrigation before transplanting; reduces transplanting shock.
- **IBA (indole-butyric acid):** a synthetic auxin (plant growth hormone) applied at 1,000 to 3,000 ppm to the base of stem cuttings to stimulate adventitious root formation; the most widely used rooting hormone in horticultural nurseries.
- **Leaf cutting:** a propagation method using leaf or leaf sections to generate new plants; used for Sansevieria (leaf sections), Begonia (leaf with cut veins), and African violet (leaf petiole inserted in medium).
- **Marcotting (air layering):** a vegetative propagation method in which a branch is girdled, wrapped with moist sphagnum moss or coco coir, and allowed to root while still attached to the parent plant; used for citrus, guava, and avocado.
- **Nursery:** a facility where plants are propagated and grown to transplanting size; types include seed nursery beds (for vegetables), container nurseries (for tree fruits and ornamentals), and mist propagation benches (for cuttings).
- **Ornamental horticulture:** the branch of horticulture dealing with plants grown for their aesthetic value; scope includes floriculture, foliage plant production, turf management, arboriculture, and landscape horticulture.
- **Rootstock:** the root-providing plant in a graft union; selected for disease resistance, soil adaptation, vigour, or dwarfing effect; the aerial portion of the rootstock is replaced by the scion after grafting.

- **Scarification:** a pre-germination treatment used to break hard seed coat dormancy; includes mechanical scarification (nicking, filing) and chemical scarification (sulphuric acid soaking); allows water to penetrate the seed coat and trigger germination.
- **Scion:** the aerial shoot or bud from the desired parent variety that is united with the rootstock in grafting or budding; determines the aerial characteristics of the grafted plant including fruit quality, flower colour, and size.
- **Solarisation:** sterilisation of nursery soil or bed mix by covering with black or clear polythene film for 2 to 4 weeks during the hot season to raise soil temperature sufficiently to kill weed seeds, pests, and soilborne pathogens.
- **Stem cutting:** a section of stem (10 to 20 cm with 2 to 4 nodes) removed from a parent plant and rooted in a suitable medium to produce a new plant; types include hardwood (bitter leaf, moringa), semi-hardwood (Bougainvillea, Hibiscus), and softwood (Impatiens, Chrysanthemum).
- **T-budding:** a budding technique in which a T-shaped cut is made in the rootstock bark and a bud shield from the scion is inserted under the flap; the standard method for citrus and rose propagation; achieves high success rates in actively growing plants.

Concept Check Questions [Series 4]

Objective Questions

1. Seed _____ involves mechanical or chemical treatment to break hard seed coat dormancy, allowing water to penetrate the testa and trigger germination. (Linked to SLO 4.1)
2. Indole-butyric acid (IBA) at 1,000 to 3,000 ppm is applied to the base of stem _____ to stimulate adventitious root formation; it is the most widely used rooting hormone in Nigerian horticultural nurseries. (Linked to SLO 4.1)
3. In _____ budding, a T-shaped cut in the rootstock bark receives a bud shield from the scion variety; it is the standard propagation method for citrus and roses. (Linked to SLO 4.1)
4. _____ is a nursery seedling disease caused by Pythium, Phytophthora, and Rhizoctonia fungi that attack seedlings at the soil level; it is prevented by using sterilised media and avoiding overwatering. (Linked to SLO 4.2)
5. _____ is the removal of spent flowers from ornamental plants such as marigold and Hibiscus to stimulate the production of new flower buds and prolong the display period. (Linked to SLO 4.4)

Short-Answer Questions

1. State two advantages and two disadvantages of sexual propagation compared with asexual propagation. (Linked to SLO 4.1)
2. Define hardening-off and state three steps involved in hardening-off vegetable seedlings. (Linked to SLO 4.2)
3. State four characteristics of an ideal nursery growing medium. (Linked to SLO 4.2)
4. Classify ornamental plants by growth habit with one Nigerian example of each class. (Linked to SLO 4.3)
5. Describe the planting procedure for establishing ornamental shrubs in a garden bed. (Linked to SLO 4.4)

Long-Answer Questions

1. Describe the principles of sexual and asexual propagation, including stem cuttings, layering, division, grafting, and budding, with Nigerian horticultural examples. Describe the types and management of horticultural nurseries. (Linked to SLOs 4.1, 4.2)
2. Define ornamental horticulture and explain its importance in Nigeria. Classify ornamental plants and identify important examples. Describe the propagation, establishment, and maintenance of ornamental gardens. (Linked to SLOs 4.3, 4.4)

Answers to Concept Check Questions [Series 4]

Objective Questions

1. Scarification.
2. Cuttings.
3. T.
4. Damping-off.
5. Deadheading.

Short-Answer Questions

1. Advantages: low cost per plant; rapid production of large numbers. Disadvantages: genetic variability (plants not identical to parent); long juvenile period before fruiting (seedling mango 5 to 8 years vs grafted 2 to 3 years).
2. Hardening-off is the gradual acclimatisation of nursery seedlings to outdoor conditions before transplanting. Steps: (1) progressively reduce shade over 5 to 10 days; (2) reduce irrigation frequency; (3) stop fertiliser application and expose seedlings to outdoor wind and temperature during the day.
3. Good moisture retention without waterlogging. Good aeration for root development. Free of weed seeds, pests, and pathogens. Suitable pH of 5.5 to 6.5 for most vegetables and ornamentals.
4. Herbaceous (no persistent woody stem; Impatiens, Coleus). Shrub (persistent woody stems below 5 m; Hibiscus, Bougainvillea). Tree (tall woody single-stemmed; Delonix regia/flame tree, Jacaranda). Climber (climbs by twining or tendrils; Allamanda, Thunbergia). Succulent (water-storing; Aloe vera, Agave).
5. Dig hole twice the width of the root ball and the same depth. Backfill with amended soil; set plant at the same depth as in the container. Firm soil; water thoroughly; apply 5 to 10 cm mulch around the base (not touching the stem). Water regularly for 2 to 4 weeks until established.

Long-Answer Questions

1. Sexual propagation: uses seed; advantages (cheap, large numbers, easy storage); disadvantages (genetic variability, long juvenile period). Germination requires water, temperature (warm-season 25 to 30 degrees C; cool-season 15 to 20 degrees C), oxygen, and light (most light-indifferent; lettuce positively photoblastic). Dormancy broken by scarification (hard testa), stratification (cold treatment), or soaking. Asexual propagation: genetically identical, shorter juvenile period. Stem cuttings: hardwood (bitter leaf, moringa;

woody dormant stems); semi-hardwood (Bougainvillea, Hibiscus; partially matured); softwood (Impatiens, Chrysanthemum; young shoots); base treated with IBA 1,000 to 3,000 ppm; inserted in moist sand or coir; high humidity maintained. Leaf cuttings: Sansevieria (sections upright in sand), Begonia (leaf with cut veins on medium), African violet (petiole in medium). Division: clump-forming plants (Strelitzia, Heliconia, ornamental grasses) dug and separated. Layering: simple (stem bent to ground), air layering/marcotting (citrus, guava; girdled branch wrapped in moist medium). Grafting and budding: unites rootstock (roots) and scion (aerial characteristics); requires cambial contact and compatible species; methods: cleft graft (mango, avocado), veneer graft (mango; 85 to 95 percent), T-budding (citrus, roses), patch budding. Nurseries: seed beds (cheap; for annual vegetables; risk of pathogens); container nurseries (polythene bags, seedling trays; tree fruits and ornamentals; less root disturbance); mist benches (high RH for cuttings). Medium: sieved topsoil + compost + sand (2:1:1); solarised 2 to 4 weeks. Damping-off prevented by sterilised media and good drainage. Hardening-off: 5 to 10 days progressive exposure to field conditions. Transplanting: correct growth stage; afternoon; firm soil; mulch; shade 3 to 5 days.

2. Ornamental horticulture: branch dealing with plants grown for aesthetic value; scope: floriculture, foliage plants, turf, arboriculture, landscape horticulture. Importance in Nigeria: aesthetic and environmental improvement (air quality, heat island reduction, mental health); economic value (landscaping services, nursery industry, cut flower trade); ceremonial use (weddings, burials); tourism (botanical gardens, landscaped resorts). Classification by life cycle: annual (marigold/Tagetes, Zinnia, Celosia, Impatiens); biennial (foxglove/Digitalis); perennial (Strelitzia, Heliconia, Ixora, Agapanthus). By habit: herbaceous (Impatiens, Coleus); shrub (Hibiscus, Bougainvillea, Ixora, Lantana); tree (Delonix regia, Jacaranda, royal palm, Spathodea); climber (Bougainvillea, Allamanda, Thunbergia); succulent (Aloe vera, Agave). By function: ground cover (Wedelia, Alternanthera, Rhoeo); hedge/screen (Duranta, Ixora, Bougainvillea); specimen (Strelitzia, Ravenala); bedding plants (marigold, Vinca, Portulaca); indoor (Dracaena, Sansevieria, Aglaonema, Dieffenbachia, Pothos). Important ornamentals: Bougainvillea (spectacular coloured bracts; drought-tolerant); Hibiscus (red/yellow/pink flowers; medicinal use); Ixora (compact; red/orange clusters); Flame tree/Delonix regia (scarlet flowers; avenue tree; University of Ibadan campus). Propagation: seed (annual bedding plants; F1 hybrids for uniformity; small seeds sown on surface); stem cuttings (Bougainvillea, Hibiscus, Ixora; semi-hardwood; IBA treatment); leaf cuttings (Sansevieria, Begonia, African violet); division (Strelitzia, Heliconia); bulbs/corms/rhizomes (Hippeastrum, Gladiolus, Canna). Establishment: design on paper; site

prep (organic matter; liming); container stock; holes twice width of root ball; mulch; 2 to 4 weeks establishment watering. Maintenance: pruning (shaping, deadheading, rejuvenation, health); fertilisation (balanced NPK; high P/K for flowering); pest control (aphids on Hibiscus/roses: neem oil or systemic; mealybugs on Dracaena: malathion; spider mites: miticide); morning watering; dry-season irrigation.

Answers to Pilot Questions [Series 4]

Part 4.1

1. Sexual propagation uses seed produced by fertilisation. Advantages: cheap; large numbers of plants produced rapidly. Disadvantages: genetic variability (offspring not identical to parent); long juvenile period before fruiting in tree crops.
2. Water (imbibition initiates germination). Temperature (tomato germinates best at 25 to 30 degrees C; below 15 degrees C or above 35 degrees C germination fails). Oxygen (aerobic respiration required; waterlogged media inhibit germination). Light (tomato is light-indifferent; seeds germinate normally when buried at 1 to 2 cm depth).
3. A stem cutting is a section of stem (10 to 20 cm) with 2 to 4 nodes removed from the parent plant and rooted to produce a new plant. Steps for bitter leaf hardwood cuttings: collect 15 to 20 cm woody stems from healthy plants; remove most leaves; treat base with IBA powder; insert in moist sand or nursery medium; maintain shade and moisture; roots develop in 2 to 4 weeks.
4. Rootstock: provides the root system; selected for vigour, disease resistance, and soil adaptation. Scion: provides the above-ground portion and determines fruit or flower characteristics. Cambial contact is essential because the cambium (meristematic layer between bark and wood) of both rootstock and scion must unite to form new vascular tissue that allows nutrient and water flow across the graft union.
5. Cleft graft: horizontal rootstock cut with vertical slit receiving a wedge-shaped scion; used for mango. T-budding: T-shaped rootstock cut receives a bud shield; used for citrus and roses. Veneer graft: shallow matching cuts on rootstock and scion aligned and bound; used for mango; 85 to 95 percent success rate.

Part 4.2

1. A horticultural nursery is a facility where plants are propagated and grown to transplanting size. Seed nursery bed: flat or raised beds; seeds sown at high density; cheap; used for annual vegetables (tomato, onion); risk of weed seeds and pathogens. Container nursery: plants raised individually in polythene bags or trays; transplanted with minimal root disturbance; used for tree fruit seedlings and ornamentals; more expensive but higher transplanting survival.
2. Good moisture retention without waterlogging. Good aeration for root development. Free of weed seeds, pests, and pathogens. Suitable pH 5.5 to 6.5. Three materials: sieved topsoil

(cheap; risk of pathogens; requires sterilisation); decomposed compost (adds nutrients and water retention); river sand (improves drainage and aeration).

3. Damping-off is a soilborne fungal disease (Pythium, Phytophthora, Rhizoctonia) that attacks seedlings at the soil surface, causing collapse and death. Three preventive measures: use sterilised or solarised nursery medium; ensure good drainage in nursery beds and containers; avoid overwatering (waterlogged conditions favour fungal growth).
4. Hardening-off is the gradual acclimatisation of seedlings to outdoor conditions before transplanting. Steps: progressively reduce shade over 5 to 10 days; reduce irrigation frequency; stop fertiliser application; expose seedlings to outdoor temperatures and wind during the day, returning to shelter at night if temperatures are extreme.
5. Select seedlings at the correct growth stage (3 to 4 true leaves). Water seedlings thoroughly the day before. Transplant in the afternoon or on a cloudy day. Set at the same depth as in the nursery; firm soil around roots. Water immediately after planting and mulch around the base.

Part 4.3

1. Ornamental horticulture is the branch dealing with plants grown for aesthetic value. Four reasons it is important in Nigeria: (1) beautifies and improves the environment (air quality, heat island reduction); (2) economic value (landscaping services, nursery industry, cut flower trade); (3) ceremonial use (flowers for weddings, burials, and religious celebrations); (4) promotes tourism (botanical gardens and landscaped resorts).
2. Annual (complete life cycle in one season): marigold (Tagetes) and Zinnia. Biennial (flower in second year): foxglove (Digitalis) and wallflower (Cheiranthus). Perennial (persist and flower repeatedly for many years): bird of paradise (Strelitzia reginae) and Heliconia.
3. Herbaceous (no persistent woody stem): Impatiens. Shrub (woody stems below 5 m): Hibiscus rosa-sinensis. Tree (tall woody single-stemmed): flame tree (Delonix regia). Climber (climbs by twining or tendrils): Bougainvillea. Succulent (water-storing): Aloe vera.
4. Bougainvillea: spectacular coloured bracts (not petals); extremely drought-tolerant; used on fences and trellises. Hibiscus (Hibiscus rosa-sinensis): large showy flowers in many colours; very common in Nigerian school and church compounds. Flame tree (Delonix regia): spectacular scarlet and orange flower display in March to May; widely used as avenue tree. Jacaranda (Jacaranda mimosifolia): purple flowers; deciduous; used as avenue tree in Abuja.
5. Dracaena (D. fragrans, D. marginata): tolerates low light; architectural form; air-purifying. Sansevieria trifasciata (snake plant): extremely tolerant of neglect and low light; architectural upright form. Aglaonema (Chinese evergreen): tolerates deep shade; attractive variegated

foliage. Pothos (Epipremnum aureum): trailing or climbing; very tolerant of low light; rapid growth; easy to propagate from cuttings.

Part 4.4

1. Stem cuttings: Bougainvillea (semi-hardwood cuttings). Leaf cuttings: Sansevieria (leaf sections upright in sand). Division: Strelitzia/bird of paradise (clump divided with roots and shoots). Bulb separation: Hippeastrum/amaryllis (bulblets separated from mother bulb).
2. Take 10 to 15 cm semi-hardwood stem cuttings with 3 to 4 nodes from healthy Bougainvillea. Remove lower leaves; wound the base slightly. Dip base in IBA rooting powder (1,000 to 3,000 ppm). Insert in moist sand or coco coir in a container. Cover with a plastic bag or place in a shade house to maintain humidity. Roots develop in 3 to 6 weeks; transfer to larger containers once roots are established.
3. Design the garden on paper (site survey; sun/shade zones; plant selection). Prepare the site (clear vegetation; improve soil with compost; adjust pH if needed; form beds, paths, and lawn areas). Source container-grown nursery stock. Dig holes twice the width of the root ball and the same depth; set plants at the same depth as in the container; firm soil; mulch around base; water thoroughly.
4. Deadheading removes spent flowers to redirect the plant's energy from seed production to new flower bud formation, prolonging the flowering display. Two plants: marigold (Tagetes; deadhead regularly to maintain continuous flowering through the season) and Hibiscus rosa-sinensis (deadhead faded blooms daily to encourage more flowers).
5. Aphids (on Hibiscus, roses, Bougainvillea; soft-bodied insects; distort young growth): control with systemic insecticide (imidacloprid) or neem oil spray. Mealybugs (on Dracaena, Aglaonema, Philodendron; white cottony clusters in leaf axils): control with malathion spray or wiping with cotton wool soaked in ethanol.

References and Attributions [Series 4]

Textual References (Books and External Sources)

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Figures, Plates, Tables, and Boxes

- Figure 4.1: Methods of vegetative propagation for ornamental plants used in Nigerian horticulture. Attribution: AI generated. Suggested OER search string: “ornamental plant vegetative propagation stem cutting leaf cutting division bulb rhizome diagram Nigeria OER⇓.

Series 5: Landscaping Principles and Garden Development

- **Part 5.1: Principles of Landscape Design**
  - Sub Part 5.1.1: Definition and objectives of landscaping
  - Sub Part 5.1.2: Design principles: unity, balance, scale, and rhythm
  - Sub Part 5.1.3: Formal and informal garden styles
- **Part 5.2: Elements of Garden Design**
  - Sub Part 5.2.1: Hardscape elements: paths, walls, and water features
  - Sub Part 5.2.2: Softscape elements: lawns, plant beds, and trees
  - Sub Part 5.2.3: Colour, texture, and form in planting design
- **Part 5.3: Garden Development in Nigeria**
  - Sub Part 5.3.1: Botanic gardens and public parks in Nigeria
  - Sub Part 5.3.2: Residential and institutional gardens
  - Sub Part 5.3.3: Avenue and roadside planting
- **Part 5.4: Turf Establishment and Management**
  - Sub Part 5.4.1: Lawn grass species used in Nigeria
  - Sub Part 5.4.2: Turf establishment methods
  - Sub Part 5.4.3: Lawn maintenance: mowing, fertilising, and weed control

Introduction

Landscaping is the art and science of modifying and managing outdoor environments to achieve aesthetic, functional, and ecological goals. In Nigeria's rapidly urbanising cities, quality landscaping is increasingly important for the visual appearance of homes, offices, institutions, and public spaces, and for the environmental services that urban green spaces provide. The development of parks, gardens, avenue plantings, and institutional grounds requires a knowledge of design principles, plant selection, construction, and maintenance.

This Series covers the fundamental principles of landscape design, the elements that constitute a designed garden, the development of gardens and public green spaces in Nigeria, and the establishment and maintenance of turf as the foundation of most outdoor landscape settings. Together with Series 4, this Series completes the student's introduction to ornamental horticulture and equips them to participate in landscape planning and management activities.

Series Learning Outcomes

Upon completing this Series, you should be able to:

- **SLO 5.1** define landscaping and explain the design principles of unity, balance, scale, and rhythm as applied to garden design (Linked to Part 5.1),
- **SLO 5.2** describe the hardscape and softscape elements of a designed garden and explain how colour, texture, and form are used in planting design (Linked to Part 5.2),
- **SLO 5.3** describe the major botanic gardens and public parks in Nigeria, explain the design considerations for residential and institutional gardens, and describe principles for avenue and roadside planting (Linked to Part 5.3), and
- **SLO 5.4** identify the lawn grass species used in Nigeria, describe the methods of turf establishment, and explain the routine maintenance practices for established lawns (Linked to Part 5.4).

5.1 Principles of Landscape Design

5.1.1 Definition and objectives of landscaping

Landscaping is the process of planning, designing, installing, and maintaining the elements of an outdoor environment to achieve specific functional, aesthetic, and ecological objectives. It encompasses both the manipulation of the land itself (grading, drainage, paving) and the selection and arrangement of plants and other living elements within that space. Landscaping differs from gardening in scale and scope: gardening typically refers to the cultivation of plants in a domestic setting; landscaping is a professional discipline that may encompass large public parks, corporate campuses, transportation corridors, residential subdivisions, and ecological restoration projects.

Objectives of landscaping: (1) Aesthetic improvement: creating visually attractive outdoor environments that reflect the character and identity of the location; combining plants, structures, and water to produce pleasing compositions of colour, form, and texture. (2) Functional improvement: shaping outdoor spaces for human use (seating areas, children's play zones, sports fields, pedestrian circulation, car parking with shade); directing circulation by strategic planting; providing shade and shelter from wind. (3) Environmental improvement: increasing green cover in urban areas to reduce the heat island effect; improving air quality by absorbing pollutants; managing storm water through vegetated swales, rain gardens, and infiltration strips; providing habitat for birds, butterflies, and other urban wildlife. (4) Economic improvement: well-landscaped properties command higher sale and rental values; quality public landscapes improve the image of neighbourhoods and attract investment. (5) Cultural and educational: botanical gardens, heritage gardens, and theme gardens preserve and display plant collections; serve as outdoor classrooms for horticulture, ecology, and cultural history.

Fill in the blank: Landscaping differs from gardening in that it is a professional discipline concerned with planning, designing, and maintaining _____ environments of various scales, from residential gardens to public parks, corporate campuses, and roadside plantings.

5.1.2 Design principles: unity, balance, scale, and rhythm

Professional garden and landscape design is guided by a set of principles derived from the visual arts. These principles provide a framework for organising the diverse elements of a garden (plants, paths, walls, water, furniture) into a coherent, satisfying composition. (1) Unity: all elements of the garden contribute to a single, coherent visual theme or character; unity is achieved by repeating a limited palette of plants, materials, and colours throughout the design rather than using every available species and material; a garden with too many different elements appears chaotic. (2) Balance: a visual equilibrium among the elements of the garden; may be achieved through symmetry (formal balance: identical elements on either side of a central axis; typical of formal gardens) or asymmetry (informal balance: different elements of equal visual weight on either side of the composition; typical of informal or naturalistic gardens). (3) Scale: the size relationship between garden elements and human users, and between different elements within the garden; scale errors (a tiny fountain in a vast public square; a massive tree next to a small bungalow) create discomfort; elements should be proportioned to the size of the space and its users.

(4) Rhythm: the repetition of similar elements (plants, paving patterns, lighting fixtures) at regular or graduated intervals creates movement and visual interest through the garden; too much repetition becomes monotonous (rhythm without variation); too little creates chaos (variation without rhythm). (5) Emphasis (focal point): every garden composition benefits from one or more focal points that draw the eye and provide a visual anchor (a specimen tree, a fountain, a sculpture, a brightly coloured shrub at the end of a vista); focal points give the garden directionality and purpose. (6) Simplicity: a disciplined limitation of the number of different plant species, materials, and colours used in a design; simplicity produces elegance; overplanting with too many different species produces visual confusion. These principles operate together and at different scales simultaneously; a successful landscape design applies all of them cohesively.

Fill in the blank: _____ in landscape design refers to the repetition of similar design elements (plants, materials, paving patterns) at regular or graduated intervals to create visual movement and interest through the garden; it must be balanced with sufficient variation to avoid monotony.

5.1.3 Formal and informal garden styles

Garden styles reflect cultural, historical, and ecological influences and determine the overall character and layout of a landscape. Formal garden style: characterised by geometric forms (straight lines, symmetrical layouts, precise angles); clearly defined axes and vistas; clipped hedges and topiary; paved paths and formal water features (rectangular pools, fountains with geometric basins); restrained plant palette with emphasis on form and structure rather than colour diversity; associated with European Renaissance, Baroque, and Islamic garden traditions. Examples in Nigeria: formal approaches to government buildings, hotels (Federal Government buildings in Abuja; major hotel gardens in Lagos), institutional headquarters, and university administration buildings. Characteristics: high maintenance cost; requires skilled labour for clipping and shaping; impressive formal appearance; less environmentally flexible.

Informal garden style: inspired by natural landscapes; flowing, curved lines; asymmetric compositions; naturalistic plant groupings that mimic the way plants grow in nature (trees, shrubs, ground covers, and wildflowers in layered compositions); meandering paths; natural water features (ponds with irregular edges; streams); diverse and colourful plant palette; associated with English landscape tradition and contemporary ecological garden design. Examples in Nigeria: most residential gardens in southern Nigeria, university campus landscapes, botanical gardens, national parks, and eco-resort gardens. Characteristics: lower long-term maintenance (once plants establish and cover soil, weed pressure reduces); more ecologically diverse; more appropriate for most Nigerian residential and public contexts. Mixed (transitional) style: combines formal structure near the house with informal planting further from it; provides the order and clarity of formal design near the building while allowing naturalistic planting in the garden's outer zones; the most commonly recommended approach for Nigerian residential gardens.

Fill in the blank: The _____ garden style uses geometric forms, straight axes, clipped hedges, and symmetric layouts; it is associated with European Renaissance and Islamic garden traditions and is used in Nigeria for formal government buildings, hotels, and institutional headquarters.

Pilot questions 5.1

1. Define landscaping and state four objectives it serves in Nigerian cities.

2. Explain the design principles of unity and balance and give one example of each from a Nigerian garden context.
3. Distinguish between formal and informal garden styles in terms of layout, plant use, and maintenance requirements.
4. Explain why scale is an important design principle and give one example of a scale error common in Nigerian gardens.
5. State the design principle of emphasis (focal point) and give two examples of focal points used in Nigerian landscape design.

5.2 Elements of Garden Design

5.2.1 Hardscape elements: paths, walls, and water features

Hardscape refers to the non-living, hard-surfaced elements of a designed landscape: paths and walkways, walls and fences, steps, patios and terraces, edging, water features, garden furniture, and lighting. Hardscape provides the structural framework of the garden; plants (softscape) are arranged within and around this framework. Paths and walkways: the functional arteries of the garden; they direct circulation, define spatial zones, and contribute significantly to the garden's visual character. Width: primary paths (1.2 to 1.8 m; two people walking side by side); secondary paths (0.6 to 0.9 m; single person). Materials: concrete (durable; low cost; can be coloured or patterned); interlocking paving blocks (attractive; easily repaired; available in many colours; widely used in Nigerian urban gardens); granite or sandstone slabs (elegant; expensive; suited to premium residential and institutional gardens); stepping stones of concrete or flat rock (informal; naturalistic; inexpensive). Path edging (metal, plastic, brick, or treated timber) defines the boundary between path and planting bed, prevents gravel migration, and reduces grass encroachment onto paths.

Walls and fences: provide security, privacy, and spatial definition; also serve as a backdrop for climbing plants. Wall types in Nigerian gardens: block-and-plaster walls (most common; sturdy; can be rendered and painted; topped with barbed wire or broken glass for security in urban Nigeria); decorative concrete block walls (breeze block patterns allow air flow; reduce harsh enclosure); stone walls (granite or sandstone rubble; attractive; expensive; seen in high-end

residential and institutional gardens). Water features: a focal point and source of movement, sound, and wildlife habitat. Types: formal reflecting pools (geometric; still water; reflect sky and surroundings; simple to maintain); ornamental ponds (irregular shape; planted with water lilies, papyrus, and marginal plants; may support fish); fountains (circulating pump and nozzle; provide movement and sound; common in hotel lobbies and formal corporate gardens); water walls and cascades (falling water over a textured surface; dramatic; modern aesthetic). In Nigeria's climate, water features must be designed with algae control (circulation, shade, biological treatment) and mosquito management (fish stocking; BTi biological larvicide) in mind.

Fill in the blank: _____ refers to the non-living hard-surfaced elements of a designed landscape (paths, walls, water features, patios, and furniture); it provides the structural framework within which plants (softscape) are arranged.

5.2.2 Softscape elements: lawns, plant beds, and trees

Softscape refers to the living plant elements of a designed landscape. The three principal softscape elements are: (1) Lawns (turf areas): the dominant ground cover in most Nigerian formal and semi-formal gardens; provides a visual resting area (green neutral background against which colourful plants are viewed); a surface for recreation and movement; and a cooling, dust-suppressing, erosion-preventing ground cover; covered in detail in Part 5.4. (2) Plant beds (borders and island beds): defined areas in which ornamental plants are arranged in groups and masses; border beds run along a wall, fence, or path edge; island beds are freestanding in the lawn or paved area and can be viewed from all sides; beds contain a layered composition of trees and large shrubs (backdrop), medium shrubs, low shrubs, perennial ground covers, and seasonal bedding plants (foreground). (3) Trees: the largest structural elements of the softscape; provide shade (critical for human comfort in Nigerian outdoor spaces where temperatures regularly exceed 35 degrees C); structure and canopy for the garden; nesting habitat for birds; seasonal interest (flowering, fruiting, deciduous colour change).

Plant bed design: the principle of layering (tallest at back, shortest at front) ensures all plants are visible; species are grouped in masses of 3, 5, or 7 plants of the same species (odd numbers are

visually more natural than even numbers); leave adequate spacing for mature plant size; combine plants with different blooming seasons to maintain year-round interest; include evergreen structure plants to maintain the composition during non-flowering seasons. Selection of trees for the garden: consider mature height and spread (avoid large trees near foundations, overhead power lines, or drains); root system (avoid species with aggressive surface roots near paved areas: Ficus benjamina, Eucalyptus); canopy density (open canopy trees allow some light to reach garden beds below: Cassia fistula; Jacaranda; dense canopy trees create deep shade: mango, Ficus; useful for seating areas). In Nigerian urban gardens, fast-growing shade trees (Neem/Azadirachta indica; Terminalia mantaly; Khaya senegalensis) are frequently planted for rapid shade provision.

Fill in the blank: The principle of _____ in plant bed design places the tallest plants at the back of the border and the shortest at the front, ensuring all plants are visible; plants of the same species are grouped in masses of 3, 5, or 7 for a more naturalistic appearance.

5.2.3 Colour, texture, and form in planting design

Colour is one of the most powerful tools in planting design and the one most immediately noticed by garden visitors. Colour theory for garden design: (1) Colour wheel: the standard tool for understanding colour relationships; primary colours (red, yellow, blue); secondary colours (orange, green, violet); warm colours (red, orange, yellow; advance toward the viewer; create energy and excitement; appropriate at focal points); cool colours (blue, violet, green; recede from the viewer; create calm and restfulness; suitable for large masses and distant planting). (2) Colour harmonies: analogous colour schemes (adjacent colours on the wheel: yellow, orange, red; warm and vibrant; commonly used in Nigerian bedding displays of marigolds, Portulaca, and Impatiens); complementary colour schemes (opposite colours on the wheel: purple Vinca and yellow marigold; strong contrast; dramatic effect); monochromatic schemes (all one colour in varying tones: white garden with white Vinca, white Impatiens, silver-leaved plants; sophisticated and restful). (3) Seasonal colour planning: in Nigerian gardens, flowers are available in most months; the gardener plans successive blooming species to ensure continuous

colour: Celosia in harmattan; Vinca and marigolds through most of the year; Bougainvillea in the dry season; Ixora throughout the year.

Texture in the garden refers to the visual and tactile quality of plant surfaces: fine texture (small leaves, delicate stems: Casuarina, grass, ferns, Asparagus fern; light and airy appearance; use to fill spaces and create depth); coarse texture (large leaves, bold form: Heliconia, Bird of paradise/Strelitzia, Philodendron, banana; dramatic; use as focal points or accent plants). Contrasting textures create interest; combining only one texture type produces monotony. Form refers to the three-dimensional shape of individual plants and plant groups: rounded forms (most shrubs; soft, harmonious; Ixora, Duranta); columnar/upright forms (Carica papaya, tall palms, Bamboo; add height and vertical accent); weeping forms (Ficus benjamina weeping; Mussaenda; graceful, romantic); spreading/horizontal forms (Jacaranda, wide-spreading mango; create a sense of breadth and stability); prostrate/ground-hugging forms (Wedelia, Alternanthera, lawn grass; unify the composition and link other elements). Contrasting plant forms create dynamic, interesting compositions; repeating similar forms creates unity and rhythm.

Fill in the blank: _____ colours (red, orange, yellow) advance toward the viewer and create energy and excitement in planting design; they are effective at focal points and in close-up viewing areas but can be overwhelming if used over large areas.

Pilot questions 5.2

21. Define hardscape and softscape and give two examples of each in a Nigerian residential garden.
22. Describe two types of water features used in Nigerian gardens and state one design consideration for each.
23. Explain the principle of layering in plant bed design and state two other rules for successful bed composition.
24. Explain the use of colour harmony in planting design, distinguishing between analogous, complementary, and monochromatic colour schemes.
25. Distinguish between fine and coarse texture in garden plants with two Nigerian examples of each, and explain how contrasting textures improve a planting composition.

5.3 Garden Development in Nigeria

5.3.1 Botanic gardens and public parks in Nigeria

Botanic gardens are scientific institutions that maintain documented collections of living plants for the purposes of scientific research, education, conservation of plant diversity, and public display. Nigeria has several important botanic gardens: (1) University of Ibadan Botanical Garden (established 1948; one of the oldest and most important in West Africa; covers approximately 25 ha within the University of Ibadan campus; contains collections of tropical trees, economic plants, medicinal plants, ornamentals, and ecological research plots; used as a teaching resource for botany, ecology, and horticulture students; also a recreational attraction; under the Department of Botany). (2) Obafemi Awolowo University Botanical Garden (Ile-Ife; Osun State; important collection of forest plants; research resource). (3) National Arboretum Abuja (managed by FMARD; collection of trees and woody plants; demonstration garden for Nigerian and exotic tree species). (4) University of Nigeria Nsukka Botanical Garden (eastern Nigeria; important collection of forest zone plants). Public parks in Nigerian cities: Millennium Park (Abuja; large formal park with lakes, lawns, and fountain; the most prominent public park in Nigeria); Lekki Conservation Centre (Lagos; wetland conservation park with canopy walkway; managed by NCF); National Arts Theatre gardens (Lagos; formal gardens surrounding the National Arts Theatre complex); Ojota Park (Lagos); state government recreational parks in major cities (Kano, Kaduna, Port Harcourt, Enugu).

The management of public parks and botanic gardens in Nigeria faces serious challenges: inadequate and irregular government funding; vandalism and illegal activities; encroachment by buildings and roads on park land; shortage of trained horticultural staff; lack of master plans for long-term development and management; and minimal user fees that leave management dependent on government allocations. The University of Ibadan Botanical Garden has suffered significant neglect since the 1980s; many of its original labelled plant collections have been lost. Private sector-managed gardens (Lekki Conservation Centre; private botanical gardens at eco-resorts) have generally maintained higher standards due to entrance fee revenue and commercial incentives. Revitalising Nigeria's public green spaces is an important urban development priority.

Fill in the blank: The _____ of Ibadan Botanical Garden, established in 1948 and covering approximately 25 ha within the university campus, is one of the oldest and most important botanic gardens in West Africa; it serves as a teaching resource for botany, ecology, and horticulture and as a recreational attraction.

5.3.2 Residential and institutional gardens

Residential garden design in Nigeria must address several site-specific requirements: (1) Security: most urban Nigerian properties are enclosed by high perimeter walls; the garden is typically designed within these walls; the design must incorporate planting to soften the harsh visual impact of the wall (climbers on walls; shrub borders inside); decisions about gate design and driveway layout are critical to the overall garden appearance. (2) Climate: the design must provide adequate shade for outdoor living (a canopy tree or shade structure over the patio or outdoor seating area is essential in Nigerian heat above 30 degrees C); plants that thrive in the local conditions (drought-tolerant during harmattan; tolerant of heavy rain during wet season) are selected. (3) Maintenance capacity: the design must match the maintenance capacity of the household (gardeners are commonly employed in middle and upper-income Nigerian households; the garden design should suit the number and skill level of available maintenance personnel). (4) Cultural context: plant selection may reflect cultural preferences (certain plants are avoided in some communities for cultural or spiritual reasons; some plants are prized for their medicinal or culinary uses). (5) Water availability: dry-season water availability determines whether a high-maintenance irrigated lawn and flower garden or a more drought-tolerant design is appropriate.

Institutional gardens (universities, government buildings, hospitals, schools, hotels, corporate headquarters): institutional gardens must convey the character and status of the institution; serve large numbers of people; provide shade for pedestrian circulation; be maintainable with the available gardening staff and budget; and comply with relevant building and planning regulations. University campuses in Nigeria (University of Ibadan; Obafemi Awolowo University, Ile-Ife; University of Lagos; Ahmadu Bello University, Zaria; University of Nigeria Nsukka) have some of the most extensive and historically significant landscape plantings in the

country; their avenue trees (mahogany, Terminalia, mango, flamboyant/Delonix regia) define the campus character and sense of place. Hotel gardens and eco-resort landscapes (Royal Orchid Hotel, Abuja; Wheatbaker Hotel, Lagos; African Sun; Transcorp Hilton) invest significantly in high-quality landscape design and maintenance as a direct contributor to guest experience and room rates.

Fill in the blank: University campus landscapes in Nigeria (such as those of the University of Ibadan and Obafemi Awolowo University) are among the most historically significant landscape plantings in the country; their avenue trees of _____, Terminalia, mango, and flamboyant (Delonix regia) define campus character.

5.3.3 Avenue and roadside planting

Avenue planting refers to the formal arrangement of trees in rows along roads, pathways, or public spaces to create a shaded corridor, define a visual axis, and contribute to the aesthetic character of streets and approaches. Avenue trees are among the most important and long-lasting urban landscape investments: a well-chosen avenue tree, once established, provides shade, beauty, and ecological services for 50 to 100 years with minimal intervention. Criteria for avenue tree selection in Nigeria: (1) Appropriate mature height and spread: must clear overhead power lines (minimum 5 to 6 m trunk height for LV lines; 10 to 15 m for HV lines); must not overhang buildings; wide-spreading species need roads wide enough to accommodate mature canopy spread (minimum road width for large shade trees: 20 to 30 m with median strip). (2) Non-invasive root system: must not damage road surfaces, footpaths, drains, and building foundations; shallow spreading root species (Ficus species, Eucalyptus) are problematic near infrastructure; deep-rooted species (Khaya senegalensis, neem, Cassia) are preferred for road verges. (3) Fast establishment: chosen species should establish quickly with minimal aftercare to maximise the return on investment in planting. (4) Drought tolerance: avenue trees on road verges receive little irrigation after establishment and must survive on rainfall and groundwater. (5) Low litter: species that drop large fruits, heavy seed pods, or sticky resins on roads and pavements create hazards and cleaning costs.

Important avenue tree species used in Nigeria: Mahogany (Khaya senegalensis and K. ivorensis): large, spreading, semi-deciduous; valued for shade and timber; used on university campuses and

government avenues (University of Ibadan Ring Road; Abuja avenues). Neem (Azadirachta indica): fast-growing; drought-tolerant; provides dense shade; medicinal and pesticidal properties; widely planted in Sahelian and Guinea savanna cities (Kano, Kaduna, Sokoto, Abuja). Terminalia mantaly (Madagascar terminalia): small to medium tree; layered horizontal branching; good scale for residential streets; widely used in Lagos and Abuja street planting. Cassia species (C. saman, C. fistula): spreading or upright; attractive yellow flowers; Cassia saman (rain tree) provides wide shade; used in Lagos, Port Harcourt, and Warri. Royal palm (Roystonea regia): majestic formal appearance; used for formal approaches to government buildings, hotels, and airports; requires wide median strip; high planting cost but long-term elegance. Maintenance of avenue trees: young trees need watering and staking for the first 2 to 3 growing seasons; tree guards protect against vehicle damage; pruning to maintain clearance above road surface (crown lifting); removal of dead or dangerous branches.

Fill in the blank: _____ (Azadirachta indica) is the most widely planted avenue tree in Nigerian savanna cities (Kano, Kaduna, Sokoto, Abuja) because of its rapid growth, dense drought-tolerant shade, low maintenance requirement, and additional medicinal and pesticidal properties.

Figure 5.1: Formal (left) and informal (right) garden plan layouts with Nigerian examples

Pilot questions 5.3

21. Name four botanic gardens or public parks in Nigeria and state the city and one function of each.
22. State five design considerations for planning a residential garden in a typical Nigerian urban property.
23. Explain why university campus landscapes in Nigeria are considered historically significant and name two examples.
24. State five criteria for selecting avenue tree species for Nigerian city roads.
25. Name four avenue tree species used in Nigerian cities, stating one characteristic advantage of each.

5.4 Turf Establishment and Management

5.4.1 Lawn grass species used in Nigeria

Lawn grasses (turf grasses) are specialised grass species or cultivars selected for their ability to form a dense, low-growing, uniform ground cover that tolerates regular mowing and foot traffic. In Nigeria, the most commonly used lawn grasses are warm-season species adapted to tropical conditions (high temperatures 25 to 35 degrees C; high humidity; intermittent drought). Principal lawn grass species used in Nigeria: (1) Buffalo grass (Stenotaphrum secundatum; St Augustine grass): a coarse-textured, creeping grass with broad, blunt-tipped leaves; spreads by stolons (above-ground runners); shade-tolerant (tolerates up to 50 percent shade; the most shade-tolerant common Nigerian lawn grass); good establishment under trees; widely used in southern Nigeria (Lagos, Ibadan, Port Harcourt, Enugu); slightly coarser appearance than finer species but its shade tolerance makes it the default choice for gardens with significant tree cover. (2) Carpet grass (Axonopus compressus): medium-textured; creeping by stolons; forms a dense uniform sward; tolerates high traffic; good for home lawns and playing fields; widely used throughout southern Nigeria; less shade-tolerant than buffalo grass; prefers acid soils (pH 5.0 to 6.5).

(3) Bermuda grass / Ibile grass (Cynodon dactylon): fine-textured; very aggressive spreader by both stolons and rhizomes; establishes quickly; forms a tight, dense sward; excellent for sports

fields (football pitches, athletics tracks) and golf fairways; requires full sun (intolerant of shade); very drought-tolerant once established; widely used in northern Nigeria; the most important sports turf grass in Nigeria. (4) Zoysia grass (Zoysia matrella): fine to medium texture; slow establishment; very dense; extremely tolerant of foot traffic; drought-tolerant; excellent appearance; more expensive to establish than Bermuda or carpet grass; increasingly used in premium residential and hotel gardens. (5) Centipede grass (Eremochloa ophiuroides): medium texture; creeps slowly; tolerates acid, infertile soils with minimal fertilisation; used on low-maintenance verges and slopes. (6) Kikuyu grass (Pennisetum clandestinum): coarse texture; very fast-growing; aggressive; good for erosion control on slopes and embankments; used on motorway verges and steep banks in Nigeria; can become invasive in garden beds if not contained.

Fill in the blank: Buffalo grass (Stenotaphrum secundatum) is the most _____ tolerant common lawn grass in Nigeria, making it the standard choice for gardens with significant tree cover; it spreads by stolons and is widely used in southern Nigeria.

5.4.2 Turf establishment methods

There are three main methods of establishing a lawn in Nigeria: (1) Seeding: grass seed is sown directly onto a prepared seedbed; the most economical method for large areas but only practical for grass species that produce viable seed in Nigeria (Bermuda grass; centipede grass; some Zoysia cultivars); buffalo grass and carpet grass produce very little viable seed in Nigeria and are rarely established by seeding. Procedure: prepare seedbed (till to 10 to 15 cm; remove stones and clods; level surface with rake; firm with a light roller); apply basal fertiliser (superphosphate or NPK 15:15:15 at 100 to 150 kg/ha; incorporated into top 5 cm); broadcast seed at recommended rate (Bermuda grass: 5 to 15 g/m2 at 50 to 150 kg/ha; very small seed; mix with sand for even distribution); lightly rake in or roll to ensure seed-soil contact; mulch lightly with dry grass or rice straw; keep moist with sprinkler irrigation until germination (5 to 14 days) and establishment. (2) Sodding (turfing): pieces of established turf (sods; turves) are cut from a turf nursery and transplanted to the prepared site to give instant coverage; produces an established lawn within 2 to 4 weeks; much faster than seeding but significantly more expensive in Nigeria (sod must be transported quickly and planted immediately to prevent desiccation; labour-

intensive to cut and lay); used for sports fields, hotel gardens, and premium residential lawns where rapid establishment is required.

(3) Sprigging and plugging: individual grass runners (sprigs; stolen sections with 2 to 3 nodes) or small plugs of turf are planted at regular intervals across a prepared site; they spread vegetatively to fill in the bare ground between planting points; intermediate in cost and establishment speed between seeding and sodding; the standard method for buffalo grass, carpet grass, Bermuda grass, and Zoysia grass establishment in Nigerian gardens. Sprig spacing: 15 to 30 cm for faster coverage; 45 to 60 cm for slower coverage (but lower plant cost); plugs (5 x 5 cm to 15 x 15 cm turf squares) are planted at 30 to 45 cm centres. Site preparation for all methods: the site is levelled (ensuring positive drainage away from buildings at a minimum 1 to 2 percent slope); top-dressed with sandy loam topsoil to improve drainage on heavy clay sites; pH adjusted to 5.5 to 7.0; compacted layers broken by tilling; edges defined with edging board or brick before grass is planted.

Fill in the blank: _____ (turfing) involves cutting established turf from a turf nursery and transplanting it to the prepared site; it produces an established lawn within 2 to 4 weeks and is used for sports fields and premium hotel gardens where rapid establishment is more important than cost.

5.4.3 Lawn maintenance: mowing, fertilising, and weed control

Mowing: regular mowing is the single most important lawn maintenance operation; it maintains a uniform height, promotes dense lateral growth (turfgrasses respond to mowing by tillering and producing more lateral shoots), controls weeds (most broadleaf weeds do not tolerate regular mowing), and keeps the lawn aesthetically attractive. Mowing height: most Nigerian lawn grasses are mown to 3 to 7 cm; buffalo grass and carpet grass: 4 to 6 cm; Bermuda grass: 2 to 4 cm; Zoysia: 2 to 4 cm. Mowing frequency: weekly during the rainy season when grass grows rapidly (May to October); every 2 to 3 weeks during the dry season when growth slows. The one-third rule: never remove more than one-third of the leaf blade in a single mowing; removing more than one-third stresses the grass, reduces photosynthetic area, and can cause scalping (removal of leaf tissue leaving only bare stems). Mowing equipment: reel mowers (high-quality cut; require flat, firm turf); rotary mowers (versatile; handles uneven surfaces; most common in

Nigerian gardens); brush cutters (weed cutters; for large, irregular lawns in public parks and road verges; not ideal for fine turf).

Fertilisation: Nigerian lawn grasses in active growth require nitrogen (N) most critically; potassium (K) for root development and drought tolerance; phosphorus (P) primarily at establishment. Maintenance fertilisation programme: apply NPK 15:15:15 or urea at 50 to 75 kg N/ha per application, 2 to 4 times per year during the growing season (rainy season); avoid late dry-season fertilisation (promotes soft growth susceptible to harmattan desiccation); iron sulphate (FeSO4) foliar spray at 15 to 20 g/10 L water produces intense greening without excessive growth flush. Weed control: weeds in lawns are controlled by: (1) preventive measures (dense turf establishment; adequate fertilisation; correct mowing height; all reduce weed invasion); (2) manual weeding (hand pulling or using a weeding fork for broadleaf weeds such as Oxalis, Commelina, and plantain/Plantago; effective on small lawns; labour-intensive on large areas); (3) herbicides (pre-emergence herbicides applied to weed-free turf before germination season to prevent weed seed germination; post-emergence selective herbicides: 2,4-D amine or MCPA kills broadleaf weeds without damaging established grass; use with caution near garden beds as drift can damage ornamentals). Aeration: hollow-tine aeration (removing small cores of soil) or solid-tine spiking relieves soil compaction, improves water infiltration, and reduces thatch accumulation; important on heavily trafficked lawns and clay soils; done during the growing season.

Fill in the blank: The one-_____ rule of mowing states that no more than one-third of the leaf blade should be removed in a single mowing session; removing more stresses the grass, reduces photosynthetic area, and causes scalping of the turf surface.

Grass Species	Scientific Name	Texture	Shade Tolerance	Drought Tolerance	Best Use in Nigeria
Buffalo Grass	*Bouteloua dactyloides*	Medium-coarse	Moderate	High	Low-maintenance lawns, erosion control
Carpet Grass	*Axonopus compressus*	Coarse	High	Moderate	Shaded lawns, school fields, roadside cover

Bermuda Grass	*Cynodon dactylon*	Fine-medium	Low	Very high	Sports fields, golf courses, sunny lawns
Zoysia	*Zoysia japonica*	Fine	Moderate	High	Ornamental lawns, parks, medium-traffic areas
Kikuyu	*Pennisetum clandestinum*	Coarse	Low	Very high	High-traffic lawns, playing fields
Centipede Grass	*Eremochloa ophiuroides*	Medium	High	Moderate	Shaded residential lawns, low-fertility soils

Box 5.1: Comparison of lawn grass species used in Nigerian horticulture

Pilot questions 5.4

21. Name four lawn grass species used in Nigeria, state the texture of each, and give one situation where each is most appropriate.
22. Distinguish between seeding, sodding, and sprigging as methods of turf establishment in terms of cost, speed, and appropriate situations.
23. Explain the one-third mowing rule and state the recommended mowing height for buffalo grass and Bermuda grass.
24. Describe a fertilisation programme for a Nigerian residential lawn and explain why late dry-season application is avoided.
25. Describe two methods of weed control in established Nigerian lawns and state when each is most appropriate.

Series Summary

This Series examined **landscaping as the planning, design, installation, and maintenance of outdoor spaces for aesthetic, functional, environmental, economic, and cultural purposes**. The main design principles are unity, balance, scale, rhythm, emphasis, and simplicity. Landscape styles may be formal, informal, or mixed. Hardscape elements include paths, walls, paving, fountains, and ponds, while softscape elements include lawns, plant beds, shrubs, and trees. Colour, texture, and plant form are also used to create harmony, contrast, movement, and visual interest within the landscape.

The Series also covered botanic gardens, public parks, residential and institutional landscapes, avenue trees, and lawn management. Suitable avenue trees should establish quickly, tolerate drought, have non-invasive roots, and produce little litter. Common lawn grasses in Nigeria include buffalo grass, carpet grass, Bermuda grass, Zoysia, and Kikuyu grass. Lawns may be established by seeding, sodding, sprigging, or plugging and maintained through regular mowing, fertilisation, weed control, irrigation, and aeration. Effective landscape management must also consider security, water availability, cultural setting, maintenance capacity, funding, and protection from vandalism and encroachment.

Glossary of Terms

- **Aeration (lawn):** the process of removing small soil cores (hollow-tine aeration) or inserting solid tines into the turf to relieve soil compaction, improve water infiltration, and reduce thatch accumulation; important on heavily trafficked lawns.
- **Avenue planting:** the formal arrangement of trees in rows along roads or public spaces to create a shaded corridor and define a visual axis; well-chosen avenue trees provide shade and beauty for 50 to 100 years with minimal intervention.
- **Balance:** a design principle referring to visual equilibrium among landscape elements; achieved through symmetry (formal balance; identical elements on both sides of a central axis) or asymmetry (informal balance; different elements of equal visual weight).

- **Bermuda grass (Cynodon dactylon):** a fine-textured lawn grass that spreads by both stolons and rhizomes; very drought-tolerant; used for sports fields, golf fairways, and northern Nigeria lawns; requires full sun; the most important sports turf grass in Nigeria.
- **Buffalo grass (Stenotaphrum secundatum):** a coarse-textured, stolon-spreading lawn grass widely used in southern Nigerian gardens; the most shade-tolerant common Nigerian lawn grass; suitable for gardens with significant tree cover.
- **Carpet grass (Axonopus compressus):** a medium-textured creeping lawn grass widely used in southern Nigerian home lawns and playing fields; forms a dense uniform sward; tolerates high traffic; prefers acid soils.
- **Complementary colour scheme:** a planting design using two colours that are opposite each other on the colour wheel (e.g. purple and yellow); creates strong contrast and dramatic visual effect.
- **Deadheading:** see Series 4 glossary.
- **Focal point (emphasis):** a distinctive element in a garden composition (specimen tree, fountain, sculpture, colourful plant) that draws the eye and provides a visual anchor; gives the garden directionality and purpose.
- **Formal garden style:** a garden design characterised by geometric forms, straight lines, symmetric layouts, clipped hedges, and precise paving; associated with European Renaissance and Islamic garden traditions; used in Nigeria for government buildings, hotels, and institutional headquarters.
- **Hardscape:** the non-living, hard-surfaced elements of a designed landscape including paths, walls, patios, steps, water features, and furniture; provides the structural framework within which softscape (plants) is arranged.
- **Informal garden style:** a garden design characterised by flowing curved lines, asymmetric compositions, naturalistic plant groupings, meandering paths, and irregular water features; most appropriate for Nigerian residential gardens, campus landscapes, and public parks.
- **Layering (planting design):** the arrangement of plants in a bed from tallest at the back to shortest at the front, ensuring all plants are visible; a fundamental principle of plant bed design.
- **One-third mowing rule:** the principle that no more than one-third of the grass leaf blade should be removed in a single mowing; removing more stresses the grass and causes scalping.

- **Rhythm:** a landscape design principle involving the repetition of similar design elements (plants, paving patterns, lighting fixtures) at regular intervals; creates visual movement and interest; must be balanced with variation to avoid monotony.
- **Scale:** the size relationship between landscape elements and human users, and between different elements within the garden; scale errors (oversized or undersized elements) create visual discomfort.
- **Softscape:** the living plant elements of a designed landscape; includes lawns, plant beds (borders and island beds), trees, shrubs, ground covers, and seasonal bedding plants.
- **Sodding (turfing):** turf establishment by cutting established sod from a turf nursery and transplanting it to the prepared site; produces an established lawn within 2 to 4 weeks; more expensive than seeding or sprigging but gives the fastest results.
- **Unity:** a landscape design principle in which all elements of the garden contribute to a single coherent visual theme; achieved by using a limited palette of plants, materials, and colours throughout the design.
- **Zoysia grass (Zoysia matrella):** a fine to medium-textured lawn grass with slow establishment but very dense sward; extremely tolerant of foot traffic; drought-tolerant; used in premium residential and hotel gardens in Nigeria.

Concept Check Questions [Series 5]

Objective Questions

1. _____ in landscape design is the principle of repeating similar elements at regular intervals; it creates visual movement but must be balanced with variation to avoid monotony. (Linked to SLO 5.1)
2. The _____ garden style is characterised by geometric forms, straight axes, and symmetric clipped hedges; it is used in Nigeria for formal government buildings and hotels. (Linked to SLO 5.1)
3. _____ refers to the non-living hard elements of a landscape (paths, walls, water features) that provide the structural framework for the garden. (Linked to SLO 5.2)
4. Buffalo grass (Stenotaphrum secundatum) is the most _____ tolerant common lawn grass in Nigeria, making it the preferred choice for gardens with significant tree cover. (Linked to SLO 5.4)

5. The one-_____ rule states that no more than one-third of the grass leaf blade should be removed in a single mowing to avoid stressing and scalping the turf. (Linked to SLO 5.4)

Short-Answer Questions

1. Explain the design principles of unity, balance, and scale with one example of each from a Nigerian landscape. (Linked to SLO 5.1)
2. Distinguish between hardscape and softscape and give two examples of each in a Nigerian garden. (Linked to SLO 5.2)
3. State five criteria for selecting avenue trees for Nigerian city roads. (Linked to SLO 5.3)
4. Distinguish between seeding, sodding, and sprigging as turf establishment methods in terms of cost, speed, and suitability. (Linked to SLO 5.4)
5. Describe the fertilisation and weed control programme for an established Nigerian residential lawn. (Linked to SLO 5.4)

Long-Answer Questions

1. Explain the principles of landscape design (unity, balance, scale, rhythm, emphasis, simplicity) and describe formal and informal garden styles. Describe the hardscape and softscape elements of a garden and explain how colour, texture, and form guide planting design. (Linked to SLOs 5.1, 5.2)
2. Describe the botanic gardens and public parks of Nigeria, design considerations for residential and institutional gardens, avenue planting criteria and species, and the establishment and maintenance of turf in Nigerian horticulture. (Linked to SLOs 5.3, 5.4)

Answers to Concept Check Questions [Series 5]

Objective Questions

1. Rhythm.
2. Formal.
3. Hardscape.
4. Shade.
5. Third.

Short-Answer Questions

1. Unity: coherent theme using a limited plant palette. Balance: formal (symmetric planting on both sides of an axis, e.g. hotel entrance); informal (asymmetric elements of equal visual

weight). Scale: elements proportioned to space and users; planting a large royal palm in a small compound is a scale error.

2. Hardscape: non-living structural elements; examples: interlocking block path; block-and-plaster wall. Softscape: living plant elements; examples: buffalo grass lawn; Ixora shrub border.
3. Appropriate mature height (clears power lines; does not overhang buildings). Non-invasive root system (no damage to roads and drains). Fast establishment. Drought tolerance. Low litter on road surfaces.
4. Seeding: cheapest; slow; suitable for Bermuda grass on large areas. Sodding: most expensive; fastest (2 to 4 weeks); used for sports fields and hotel lawns. Sprigging: intermediate cost and speed; standard for buffalo grass, carpet grass, and Zoysia in residential gardens.
5. Fertilisation: NPK 15:15:15 or urea at 50 to 75 kg N/ha, 2 to 4 times per year during the rainy season; avoid late dry-season application. Weed control: manual weeding for small lawns; 2,4-D amine for broadleaf weeds on large lawns.

Long-Answer Questions

1. Design principles: unity (coherent theme; limited palette); balance (symmetry: formal settings; asymmetry: residential); scale (elements proportioned to space and users; large trees near small buildings are a scale error); rhythm (repetition with variation; prevents monotony); emphasis (focal points: specimen tree, fountain); simplicity (limited colours and species; produces elegance). Formal style: geometric; symmetric; clipped hedges; paved paths; government buildings and hotels; high maintenance. Informal style: curved lines; naturalistic planting; flowing lawn; residential and campus gardens; lower long-term maintenance. Hardscape: paths (interlocking blocks, concrete, stepping stones); walls (block-and-plaster; breeze block); water features (reflecting pools, ponds, fountains; mosquito and algae management needed). Softscape: lawns (ground cover, recreation, cooling); plant beds (layered: tallest back, shortest front; odd-number groups); trees (shade, structure, focal points). Colour: warm (red, orange, yellow; advance; focal points); cool (blue, violet; calm; large masses); analogous (harmonious warm scheme); complementary (dramatic contrast); monochromatic (sophisticated). Texture: fine (Casuarina, ferns; airy); coarse (Heliconia, Strelitzia; bold focal accent). Form: rounded (Ixora); columnar (palms; vertical accent); weeping (Ficus); spreading (mango); prostrate (lawn, Wedelia).
2. Botanic gardens and parks: University of Ibadan Botanical Garden (1948; 25 ha; teaching, research, recreation); OAU Ile-Ife; National Arboretum Abuja; Millennium Park Abuja; Lekki Conservation Centre Lagos. Challenges: inadequate funding; vandalism;

encroachment; shortage of staff. Residential gardens: security walls (soften with climbers); shade (essential in Nigerian heat); maintenance capacity; cultural preferences; water availability. Institutional gardens: university campuses (UI, OAU) have historically significant avenue trees of mahogany, Terminalia, mango, and flamboyant/Delonix regia. Avenue criteria: appropriate height; non-invasive roots; fast establishment; drought tolerance; low litter. Species: mahogany (Khaya; university avenues); neem (fast; savanna cities); Terminalia mantaly (small streets); Cassia saman (wide shade); royal palm (formal approaches). Lawn grasses: buffalo grass (shade-tolerant; southern residential); carpet grass (home lawns and playing fields); Bermuda/ibile (sports fields; drought-tolerant; full sun); Zoysia (premium lawns); Kikuyu (slopes and verges). Establishment: seeding (Bermuda; cheap; large areas); sodding (instant; expensive; sports and hotel); sprigging (standard for most Nigerian lawns at 15 to 45 cm spacing). Maintenance: mowing (one-third rule; 3 to 7 cm; weekly in rains; rotary mower); fertilisation (NPK 15:15:15 or urea 50 to 75 kg N/ha; 2 to 4 times/year; avoid late dry season); weed control (manual; 2,4-D amine for broadleaf weeds); aeration (hollow-tine on trafficked lawns).

Answers to Pilot Questions [Series 5]

Part 5.1

1. Landscaping is the planning, designing, installing, and maintaining of outdoor environments. Objectives: aesthetic improvement; functional improvement (shade, circulation); environmental improvement (reducing heat island effect, managing storm water); economic improvement (higher property values).
2. Unity: all elements share one coherent theme; example: using only Ixora and marigold throughout a garden instead of mixing unrelated species. Balance: symmetry (identical planting on both sides of a hotel entrance axis); asymmetry (different plants of equal visual weight on each side of a home garden path).
3. Formal: geometric layout; symmetric planting; clipped hedges; formal pools; high maintenance. Informal: curved lines; naturalistic plant groupings; flowing lawn; irregular ponds; lower long-term maintenance once established.
4. Scale ensures elements are proportioned to the space and its users; scale errors create visual discomfort. Example: planting a large royal palm in a small residential compound overwhelms the space and damages foundations.

5. Emphasis creates focal points that draw the eye and provide visual direction. Two examples: a specimen flame tree (Delonix regia) at the end of a garden vista; a fountain at the centre of a circular driveway.

Part 5.2

1. Hardscape: interlocking block path; block-and-plaster perimeter wall. Softscape: buffalo grass lawn; Bougainvillea on a trellis.
2. Ornamental pond (irregular shape; water lilies; fish; design consideration: mosquito management with fish stocking or BTi larvicide). Fountain (circulating pump; provides movement and sound; design consideration: algae control through shading and biological treatment).
3. Layering: tallest plants at the back, shortest at the front. Group plants in odd numbers (3, 5, 7) for a naturalistic appearance. Combine species with different blooming seasons for year-round colour.
4. Analogous: adjacent colours on the wheel (yellow, orange, red); harmonious and warm; e.g. marigold, Portulaca, and Impatiens. Complementary: opposite colours (purple and yellow); dramatic; e.g. purple Vinca and yellow marigold. Monochromatic: one colour in varying tones; sophisticated; e.g. white garden with white Vinca and silver-leaved plants.
5. Fine texture (small leaves; light and airy): Casuarina, ferns. Coarse texture (large bold leaves; dramatic): Heliconia, banana. Contrasting textures create visual interest; all one texture type appears monotonous.

Part 5.3

1. University of Ibadan Botanical Garden (Ibadan; teaching, research, and plant conservation). National Arboretum (Abuja; tree demonstration; managed by FMARD). Millennium Park (Abuja; public recreation). Lekki Conservation Centre (Lagos; wetland conservation and ecotourism; managed by NCF).
2. Security walls (soften with climbing plants and shrub borders). Climate (provide shade for outdoor living). Maintenance capacity (match design to available labour). Cultural preferences (respect plant taboos and preferences). Water availability (choose drought-tolerant plants if irrigation is limited).
3. University campuses have the oldest and most extensive landscape tree plantings in Nigeria, established over 50 to 100 years; they define institutional character. Two examples: University of Ibadan (mahogany and Delonix regia avenues); Obafemi Awolowo University Ile-Ife (diverse campus tree collection).

4. Appropriate mature height (clears power lines; does not overhang buildings). Non-invasive root system (no damage to roads and drains). Fast establishment with minimal aftercare. Drought tolerance (no irrigation after establishment). Low litter (no heavy fruits or pods on roads).
5. Mahogany (Khaya senegalensis): large spreading shade; long-lived; used on university avenues. Neem (Azadirachta indica): fast-growing; drought-tolerant; medicinal properties; standard in savanna cities. Terminalia mantaly: layered horizontal form; good for narrow residential streets. Cassia saman (rain tree): wide-spreading canopy; good shade; used in Lagos and Port Harcourt.

Part 5.4

1. Buffalo grass (Stenotaphrum; coarse; gardens with tree shade). Bermuda/ibile grass (Cynodon; fine; sports fields and open sunny lawns). Carpet grass (Axonopus; medium; home lawns and playing fields). Zoysia (fine; premium residential and hotel lawns).
2. Seeding: cheapest; slowest; only suitable for Bermuda grass on large areas. Sodding: most expensive; fastest (established in 2 to 4 weeks); used for sports fields and hotel lawns. Sprigging: intermediate cost and speed; standard for buffalo grass, carpet grass, and Zoysia; sprigs at 15 to 45 cm spacing fill in over several weeks.
3. One-third rule: never remove more than one-third of the leaf blade per mowing; removing more stresses grass and causes scalping. Heights: buffalo grass 4 to 6 cm; Bermuda grass 2 to 4 cm.
4. Apply NPK 15:15:15 or urea at 50 to 75 kg N/ha, 2 to 4 times per year during the rainy season. Avoid late dry-season application as it promotes soft growth vulnerable to harmattan desiccation.
5. Manual weeding: hand-pull broadleaf weeds; suitable for small lawns. Post-emergence selective herbicide (2,4-D amine): kills broadleaf weeds without damaging established grass; suitable for large lawns; apply carefully to avoid drift onto garden beds.

References and Attributions [Series 5]

Textual References (Books and External Sources)

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Figures, Plates, Tables, and Boxes

- Figure 5.1: Formal and informal garden plan layouts with Nigerian examples. Attribution: AI generated. Suggested OER search string: “formal informal garden design plan layout comparison diagram Nigeria landscape horticulture OER”.
- Box 5.1: Comparison of lawn grass species used in Nigerian horticulture. Attribution: AI generated. Suggested OER search string: “Nigerian lawn grass species comparison table shade drought tolerance turf horticulture OER”.