

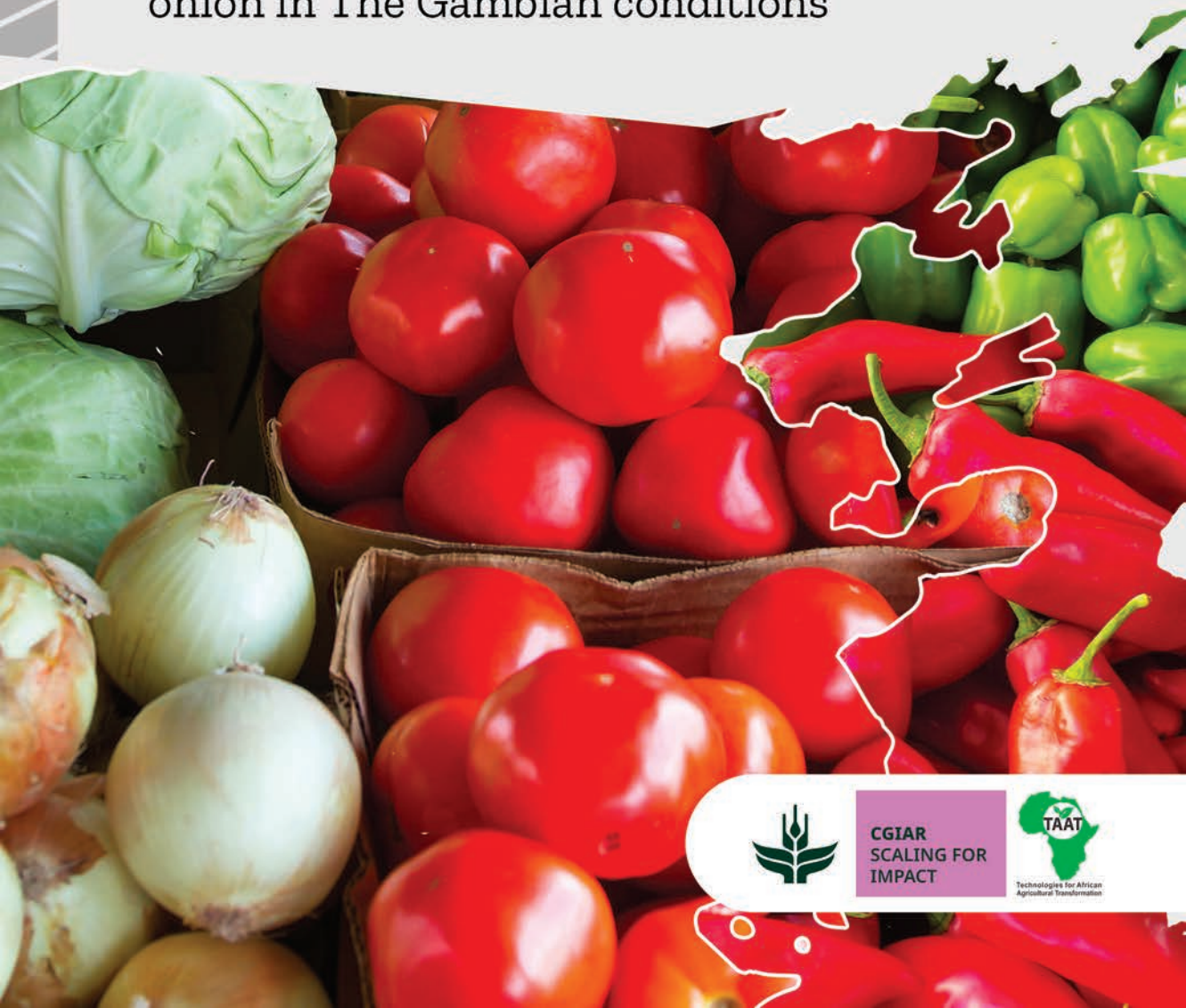


World Vegetable Center



Good Agronomic practices for safe and sustainable vegetable production:

case of cabbage, tomato, peppers, and onion in The Gambian conditions



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Technologies for African
Agricultural Transformation

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Summary

This training manual provides comprehensive practical guidance on Good Agronomic Practices (GAP) for the safe, profitable, and sustainable production of cabbage, tomato, pepper, and onion under Gambian conditions. It begins with an overview of the importance of vegetables for nutrition, income generation, employment, and climate resilience in The Gambia, while highlighting the key role of extension officers in supporting farmers and strengthening the vegetable sector.

The manual covers core technical areas including seed quality and variety selection, nursery establishment, soil fertility and crop nutrition management, composting, organic and inorganic fertilizer use, nutrient deficiency diagnosis, irrigation methods, and water-saving practices. It also provides crop-

specific modules detailing agro-ecological requirements, planting practices, nutrient and water management, major pests and diseases, harvesting, post-harvest handling, and key extension messages for each target crop.

In addition, the guide addresses integrated pest and disease management, packaging and storage technologies such as Zero-Energy Cool Chambers (ZECC), food safety, and farmer training methods including demonstrations, field days, and monitoring adoption. Overall, the manual is designed to strengthen extension services, improve vegetable productivity and quality, reduce post-harvest losses, and promote climate-smart vegetable production systems that enhance food security, nutrition, and rural livelihoods in The Gambia.

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List of acronyms

Acronyms Definition

BSF	Black soldier fly
Ca	Calcium
Cm	Centimeter
FAO	Food and Agriculture Organisation
GAP	Good Agronomic Practices
GDP	Gross Domestic Product
ha	Hectare
IPM	Integrated pest management
IPDM	Integrated pest and diseases management
K	Potassium
KCl	Muriate of potash
LYSV	Leek yellow stripe virus
m	Metter
Mg	Magnesium
NGOs	Non-governmental organisation
N	Nitrogen
OYDV	Onion yellow dwarf virus
P	Phosphorus
SSP	Single superphosphate
t	tons
TSP	Triple superphosphate
ToMV	Tomato mosaic virus
TYLCV	Tomato Yellow Leaf Curl Virus
ZECC	Zero-Energy Cool Chambers
Zn	Zinc

Table of contents

6	Summary
7	Acknowledgements
8	List of acronyms
9	Table of contents

14 CHAPTER I: General Introduction

14	1.1. Importance of vegetables in The Gambia
15	1.2. Role of extension officers
15	1.3. Purpose, scope, and audience of this document

16 CHAPTER II: Overview and agricultural practices for vegetables

16	2.1. Overview of vegetable production in Gambia
16	2.1.1. Production systems and seasons
16	2.1.2. Importance of cabbage, tomato and onion
17	2.1.3. Key constraints and opportunities
17	2.2. Good agricultural practices (GAP) for vegetables

19 CHAPTER III: Core technical modules

19	3.1. Seed quality and variety selection
19	3.1.1. Importance of seed quality
20	3.1.2. Seed sources and certification
20	3.1.3. Seed selection criteria
20	3.2. Nursery establishment and management
23	3.3. Soil fertility and crop nutrition management
23	3.3.1. Soil preparation and amendments
24	3.3.2. Organic fertilizers and application
26	3.3.2.1. Composting process
30	3.3.2.2. Application methods of organic fertilizers
31	3.3.3. Inorganic fertilizers and application methods

34	3.3.4. Nutrient deficiency diagnosis
36	3.3.5. Integrated soil fertility management
36	3.4. Water and irrigation management
36	3.4.1. Irrigation methods
39	3.4.2. Scheduling and frequency
39	3.4.3. Water-saving practices

40 CHAPTER IV: Crop-specific production modules

40	4.1. Cabbage - Brassica oleracea var. capitata
40	4.1.1. Description and importance
41	4.1.2. Agro-ecological requirements
42	4.1.3. Variety and seed selection
46	4.1.4. Nursery, land preparation and transplanting
47	4.1.5. Nutrient and water management
48	4.1.6. Pests and diseases of cabbage
52	4.1.7. Maturity and harvesting of cabbage
53	4.1.8. Key extension messages
55	4.2. Tomato
55	4.2.1. Description and importance
56	4.2.2. Agro-ecological requirements
56	4.2.3. Variety and seed selection
60	4.2.4. Nursery, land preparation and transplanting
62	4.2.5. Nutrient and water management
63	4.2.6. Major pests and diseases of tomato
69	4.2.7. Harvesting, post-harvest handling and storage
70	4.2.8. Key extension messages
71	4.3. Onion - Allium cepa
71	4.3.1. Crop description and importance
72	4.3.2. Agro-ecological requirements
73	4.3.3. Variety and seed selection
76	4.3.4. Nursery, land preparation and transplanting
78	4.3.5. Nutrient and water management
78	4.3.6. Major pests and diseases
82	4.3.7. Harvesting, post-harvest handling and storage
83	4.3.8. Key extension messages

84	4.4. Pepper - Capsicum spp.
84	4.4.1. Description and importance
85	4.4.2. Agro-ecological requirements
86	4.4.3. Variety and seed selection
88	4.4.4. Nursery, land preparation and transplanting
90	4.4.5. Nutrient and water management
91	4.4.6. Major pests and diseases
94	4.4.7. Harvesting, post-harvest handling and storage
95	4.4.8. Key extension messages
97	4.5. Integrated pest and disease management (IPDM)
97	4.5.1. Pest and disease identification
97	4.5.2. Cultural practices
99	4.4.3. Biological control
101	4.4.4. Chemical control and safe pesticide use
102	4.4.5. Principles of Integrated pest management (IPM)

104 CHAPTER V: Post-harvest technologies, food safety and extension delivery

104	5.1. Packaging technologies
104	5.2. Conservation technologies: case of Zero-Energy cool chambers
106	5.3. Food safety and quality management
106	5.3.1. Hygiene practices
106	5.3.2. Chemical residue risks
106	5.3.3. Consumer health protection
106	5.4. Extension methods and farmer training
106	5.4.1. Adult learning principles
107	5.4.2. Demonstrations and field days
107	5.4.3. Using the manual in training
108	5.4.4. Monitoring adoption and feedback

109 Conclusion

110 References

List of figures

- 21 Figure 1: Diversity of nurseries
- 22 Figure 1: Diversity of nurseries (*End*)
- 23 Figure 2: Beds raising during soil preparation step
- 25 Figure 3: Types of organic fertilizers
- 26 Figure 4: Animal organic matter suitable for composting
- 27 Figure 4: Animal organic matter suitable for composting (*End*)
- 27 Figure 5: Crops residues suitable for composting
- 28 Figure 6: Pile formation for composting
- 29 Figure 7 : End of composting
- 30 Figure 8: Application method for organic fertilizers
- 31 Figure 9: Examples of some mineral fertilizers
- 32 Figure 10: Examples of some mineral fertilizers
- 33 Figure 11: Application methods of mineral fertilizers
- 34 Figure 11: Application methods of mineral fertilizers (*End*)
- 37 Figure 12: Power source for irrigation: a motor pump using domestic gas
- 37 Figure 13: Various irrigation systems
- 38 Figure 13: Various irrigation systems (*End*)
- 39 Figure 14: Drip irrigation bundled with chameleon sensors for tomato production
- 40 Figure 15: organic mulching applied for okra (a) and tomato (b) production
- 41 Figure 16: Cabbage plant
- 47 Figure 17: Cabbage planting spacing for healthy growth
- 51 Figure 18: Some major pests and their characteristic damage symptoms
- 52 Figure 18: Some major pests and their characteristic damage symptoms (*End*)
- 53 Figure 19: Characteristic damage symptoms of major diseases
- 55 Figure 20: Morphological appearance of a tomato plant (a) and fruit (b)
- 62 Figure 21: Tomato planting spacing for healthy growth
- 67 Figure 22: Main insect pests of tomato and their characteristic damage
- 68 Figure 23: Characteristic symptoms of the main diseases of tomato
- 71 Figure 24: *Allium cepa* - Vegetative morphology and bulbs
- 77 Figure 25: Onion planting spacing for healthy growth and optimal yield
- 81 Figure 26 : Main insect pests of onions and their characteristic damage
- 82 Figure 27 : Characteristic symptoms of the main onion diseases
- 85 Figure 28: Capsicum spp., a) plant morphology, and fruit (b,c)
- 90 Figure 29: Capsicum Onion planting spacing for healthy growth and optimal yield
- 93 Figure 30: Main insect pests of capsicum and their characteristic damage
- 94 Figure 31: Characteristic symptoms of the main diseases of capsicum
- 99 Figure 32 : Examples of crop associations
- 100 Figure 33: Main predators for pests' management in biological control
- 105 Figure 34: ZECC technology for fresh vegetable conservation
- 107 Figure 35: farmers visiting tomato plots during field day

List of tables

- 35 Table 1: Common nutrient deficiency symptoms in vegetable crops
- 42 Table 2: Climate, soil, and altitude requirements for cabbage production
- 44 Table 3: Main cabbage varieties cultivated in West Africa: Agronomic characteristics, yield potential and disease tolerance
- 46 Table 4: Nursery management, land preparation and transplanting practices for cabbage Production
- 48 Table 5: Nutrient and water management for optimal cabbage production
- 49 Table 6: Synthesis of major pests and diseases of cabbage in West Africa: Symptoms and management and management
- 54 Table 7: Recommendations across activities
- 56 Table 8: Climate, soil, and altitude requirements for tomato
- 58 Table 9: Characteristic of some tomato varieties cultivated in West Africa
- 61 Table 10: Tomato nursery, land preparation, and transplanting guidelines
- 63 Table 11: Nutrient and water requirements of tomato
- 64 Table 12: Synthesis of major pests and diseases of tomato in West Africa: Symptoms and management and management
- 69 Table 13: Harvesting, post-harvest handling and storage of tomato
- 70 Table 14: key message for extension
- 72 Table 15: Agro-ecological requirements for onion production
- 74 Table 16: Characteristic of some onion varieties cultivated in West Africa
- 76 Table 17: Nursery, land preparation, and transplanting practices for Onion
- 78 Table 18: Nutrient and water management practices for Onion
- 79 Table 19: Synthesis of major pests and diseases of Onion in West Africa: Symptoms and management
- 83 Table 20: Onion harvesting and storage guidelines
- 83 Table 21: Key extension messages for onion production
- 86 Table 22: Agro-ecological requirements for *capsicum* production
- 88 Table 24: Nursery, land preparation, and transplanting practices for *Capsicum*
- 88 Table 23: Characteristic of some capsicum varieties cultivated in West Africa
- 91 Table 25: Nutrient and water management practices for *Capsicum*
- 92 Table 26: Major pests and diseases of *Capsicum* in West Africa – symptoms and management tips
- 95 Table 27: Harvesting, post-harvest handling and storage of *capsicum*
- 96 Table 28: Key extension messages for *Capsicum* cultivation
- 98 Table 29: Main cultural practices for pest and disease management in crops
- 101 Table 30: Type of biological control

CHAPTER I:

General Introduction

1.1. Importance of vegetables in The Gambia

Vegetable crops play a critical role in food and nutrition security, livelihoods, and socio-economic development in The Gambia. They are a principal source of essential vitamins, minerals, proteins, and bioactive compounds required for healthy diets, particularly for rural and peri-urban populations. Crops such as onion, tomato, pepper, cabbage, and traditional leafy vegetables contribute significantly to household income, employment, and foreign exchange earnings, with women and youth being the primary actors in vegetable production and marketing.

Agriculture accounts for approximately 28% of national Gross Domestic Products (GDPs), and nearly 70% of the population is actively engaged in the sector, largely under smallholder and subsistence systems. While staple crops such as groundnut, millet, and maize dominate production systems, horticulture has emerged as a government priority due to its potential to address food insecurity, income generation, and micronutrient deficiencies. Despite this importance, domestic vegetable production declined from 24.6% to 16.3% between 1988 and 2018, highlighting growing reliance on imports and increased vulnerability of local food systems.

Vegetable production offers strong opportunities for crop diversification and intensification, which are key strategies for building resilience to climate change. The Gambia's semi-arid climate, characterized by long dry seasons, rising temperatures, and increasing climate variability, has adversely affected crop productivity, soil fertility, and pest and disease pressure. Vegetables, particularly tomato and onion, are highly sensitive to heat stress, waterlogging, and water scarcity, leading to yield losses, poor quality produce, and reduced farmer incomes when best agronomic practices are not applied.

Recognizing these challenges, the Government of The Gambia, in collaboration with NGOs, donor agencies, and FAO, has prioritized fruit and vegetable production as part of climate adaptation and livelihood diversification strategies. Improved access to quality seed, irrigation, soil fertility management, integrated pest management, and extension services has been shown to enhance productivity and resilience, while reducing climate-related risks. Diversified and climate-smart vegetable production systems also generate co-benefits, including improved soil health, water conservation, biodiversity management, and enhanced household nutrition. In sum, strengthening vegetable production systems through improved technologies, extension support, and inclusive value chains is essential for improving food and nutrition security, empowering women and youth, increasing rural incomes, and enhancing climate resilience in The Gambia.

1.2. Role of extension officers

Agricultural extension officers play a pivotal role in the development of the vegetable sector in The Gambia by serving as the main link between research, policy, and farmers. They support farmers in adopting Good Agricultural Practices (GAP) across the vegetable value chain from seed and nursery management to crop production, pest and disease control, irrigation, and post-harvest handling; thereby improving productivity, quality, and food safety. Extension officers also promote climate-smart and diversified vegetable production systems to enhance resilience to climate variability, reduce production risks, and stabilize incomes. In addition, they facilitate access to improved technologies, strengthen market linkages, and support collective action among farmers, with particular emphasis on women and youth who are central to vegetable production. Through continuous field monitoring, data collection, and stakeholder coordination, extension officers contribute to scaling proven innovations, reducing post-harvest losses, and strengthening the overall sustainability and competitiveness of the Gambian vegetable sector.

1.3. Purpose, scope, and audience of this document

This manual aims to strengthen the technical and advisory capacity of agricultural extension officers in The Gambia to support improved vegetable production systems. It provides practical, field-oriented guidance on the production of cabbage, tomato, pepper, and onion, covering the full production cycle from seed selection and nursery management to crop production, pest and disease management, harvesting, and post-harvest handling. The manual focuses on Good Agricultural Practices (GAP) and climate-smart approaches adapted to Gambian conditions, with emphasis on improving productivity, quality, food safety, and farmer resilience. It is primarily intended for agricultural extension officers in public services, NGOs, and development projects, and may also serve as a reference for trainers, lead farmers, and students involved in vegetable production and extension.

CHAPTER II: Overview and agricultural practices for vegetables

2.1. Overview of vegetable production in Gambia

2.1.1. Production systems and seasons

Vegetable production in The Gambia is dominated by smallholder and family farming systems, with vegetables often integrated into mixed cropping systems alongside staple crops to support household food security and income generation. Major vegetables grown include onion, tomato, cabbage, pepper, and leafy greens, cultivated mainly in river valleys, lowlands, and irrigated perimeters. Production is strongly influenced by seasonality, with the dry season (October – May) representing the principal period for vegetable cultivation due to the availability of irrigation water from the River Gambia and boreholes, enabling the production of high-value crops when rainfall is limited. During the rainy season (June – September) ingenious vegetables like Okra, Roselle and some African Leafy are mainly cultivated in community vegetable gardens and backyards complemented by irrigation to allow year-round supply. Women and

community groups play a central role in vegetable production and marketing, supported by initiatives promoting drip irrigation, solar-powered pumping, and improved post-harvest practices. While market-oriented vegetable production is expanding with improved access to inputs and extension services, the sector continues to face challenges related to climate variability, post-harvest losses, storage and transport constraints, limited value addition, and access to finance, highlighting the need for strengthened extension support and climate-smart production systems.

2.1.2. Importance of cabbage, tomato and onion

Cabbage, tomato, and onion are among the most important vegetable crops in The Gambia, playing a central role in nutrition, diets, income generation, and food security. Nutritionally, these crops supply essential vitamins and minerals (vitamin C, dietary fiber, vitamin K, and folate) contributing to immune function, digestion, and overall health in a population that relies heavily on locally produced foods. Dietarily, they form the backbone of everyday Gambian cuisine: onions are indispensable in almost all meals, tomatoes provide flavor and acidity in stews such as Domoda and Benachin, and cabbage contributes fresh vegetables for salads and side dishes, enhancing dietary diversity amid rapid urbanization and population growth. Economically, the production and marketing of cabbage, tomato, and onion generate substantial

income for smallholder farmers, especially women, in regions such as the Central River, North Bank, Western, and Lower River areas. Nationally, annual production is estimated at about 20,000 t of onions and 8,000 t of tomatoes, with cabbage contributing additional cash-crop value, although imports still cover seasonal supply gaps. From a food security perspective, these vegetables strengthen household nutrition and local markets, reduce dependence on imports and are increasingly promoted through irrigation schemes and community gardens as climate-resilient crops that support rural livelihoods and poverty reduction.

2.1.3. Key constraints and opportunities

Vegetable production systems for tomato, onion, and cabbage in The Gambia face a combination of structural, climatic, and market-related constraints, but also offer strong opportunities for growth. Major constraints include post-harvest losses of up to 30%, driven by inadequate storage facilities, poor transportation, and the absence of cold-chain infrastructure, with tomatoes and cabbage being particularly vulnerable due to their perishability. Productivity is further limited by restricted access to quality seed, fertilizers, modern equipment, and pest management knowledge, alongside increasing climate variability characterized by erratic rainfall, droughts, and heat stress. Pests and diseases combined with labor-intensive production practices and unreliable irrigation during the dry season, further depress yields and increase production costs, while seasonal imports

contribute to price volatility. Despite these challenges, significant opportunities exist through investment in improved irrigation systems (drip and solar-powered), agro-processing (tomato paste, dried onions), and better storage technologies, which can reduce losses, add value, and stabilize incomes, particularly for women-led farming systems. Strengthening market linkages, expanding year-round production, and tapping into growing urban and regional demand present viable pathways for enhancing the competitiveness and resilience of the vegetable sector in The Gambia.

2.2. Good agricultural practices (GAP) for vegetables

Good Agricultural Practices (GAP) provide a practical framework for ensuring safe, high-quality, and environmentally sustainable vegetable production, and are particularly important in The Gambia where crops such as tomato, onion, and cabbage are affected by climate variability and high post-harvest losses. GAP emphasize sound soil and water management, including soil testing, crop rotation, and the use of organic amendments such as compost to maintain soil fertility and reduce pest pressure in riverine and irrigated production areas, alongside efficient irrigation systems (e.g. drip and solar-powered) to conserve water and support dry-season production. Integrated pest and disease management (IPM) is a core principle, promoting regular field scouting, resistant varieties, natural and biological control options, and good field hygiene to manage key pests such as *Tuta absoluta* in tomato and diseases affecting onion and cabbage, while

minimizing reliance on chemical pesticides. GAP also stresses proper harvest and post-harvest handling, including harvesting at optimal maturity, gentle handling, sorting, and the use of ventilated storage or shade drying to reduce losses (up to 30%) and improve market quality. In addition, worker health and safety and basic record-keeping are essential GAP elements, ensuring safe pesticide use, protection of farmers (particularly women involved in community gardens), traceability of inputs and outputs, and compliance with food safety and market standards.



CHAPTER III:

Core technical modules

3.1. Seed quality and variety selection

3.1.1. Importance of seed quality

Seed quality is the foundation of successful vegetable production because it directly determines crop establishment, growth uniformity, yield potential, and final market quality. In cabbage, tomato, and onion production systems in The Gambia, the use of poor-quality seed often results in low germination rates, weak seedlings, uneven plant stands, and increased vulnerability to pests, diseases, and climatic stress. High-quality seed ensures strong early plant development, which allows crops to compete better with weeds, use nutrients efficiently, and produce uniform harvests that meet market standards. Quality seed combines several key attributes: genetic purity, which guarantees the desired

traits (yield, maturity period, and disease tolerance), physical purity, meaning the seed is free from debris, damaged grains, and weed seeds; and physiological quality, reflected in high germination and seed vigor.

When farmers use certified or well-selected seed, they reduce the risk of crop failure and avoid additional costs associated with replanting, excessive pesticide use, or poor-quality produce. In the Gambian context, where climate variability, heat stress, and pest pressure are increasing, selecting quality seed becomes even more critical. Improved and adapted varieties can offer tolerance to key constraints, helping farmers maintain productivity during dry seasons and under irrigated systems. Furthermore, good seed quality contributes to better post-harvest performance (uniform bulb size in onion, firm fruits in tomato, and compact heads in cabbage) which improves shelf life, reduces losses, and increases market value.

3.1.2. Seed sources and certification

Access to reliable seed sources is essential to ensure good germination, varietal purity, and consistent crop performance. In The Gambia, farmers obtain vegetable seeds mainly from certified agro-dealers, seed companies, development projects, and local markets, although seed quality may vary widely among sources. Extension officers should encourage farmers to prioritize certified seed, which is produced and tested under quality control systems to guarantee genetic purity, high germination rates, and freedom from major seed-borne diseases. Certified seed is typically labeled with key information such as variety name, lot number, germination percentage, and expiry date. While farmer-saved or informal seed may be available, it should be used cautiously due to potential risks of low vigor and inconsistent performance. Promoting the use of certified and properly labeled seed helps improve productivity, reduce crop failures, and ensure compliance with food safety and market standards.

3.1.3. Seed selection criteria

Selecting the right variety is critical for improving productivity, crop resilience, and market value. Extension officers should guide farmers to consider several key factors when choosing

varieties of cabbage, tomato, and onion:

- **Adaptation to local agro-ecological conditions:** Choose varieties suited to The Gambia's climate, particularly heat tolerance and performance under dry-season irrigation.
- **Resistance or tolerance to pests and diseases:** Prefer varieties with tolerance to common problems such as *Tuta absoluta* in tomato or insect pests in cabbage to reduce crop losses and pesticide use.
- **Yield potential and maturity period:** Select varieties with good productivity and appropriate maturity duration to fit the cropping calendar and market windows.
- **Market preference and quality traits:** Consider fruit size, shape, color, head firmness (cabbage), bulb size and storage ability (onion), and shelf life to meet consumer and trader demands.
- **Production system suitability:** Ensure varieties perform well under local management practices, including irrigation systems and available inputs.

3.2. Nursery establishment and management

Successful vegetable production begins with proper nursery establishment. The nursery should be located on a well-drained, fertile site close to a reliable water source and protected from flooding, strong winds, and livestock. Raised beds, nursery boxes, baskets or

seed trays are used to improve drainage, root development, and ease of management for cabbage, tomato, and onion seedlings. Seeds should be sown shallowly in rows or evenly spaced holes, lightly covered with fine soil or compost, and clearly labeled with crop and variety information. Incorporating well-decomposed compost into the nursery soil helps improve structure, nutrient availability, and early seedling vigor.



Nursery raising in nursery boxes



Nursery raising on ground



Nursery raising in baskets



Nursery raising in godets

Figure 1: Diversity of nurseries



Nursery raising in the alveoli

Figure 1: Diversity of nurseries (End)

Effective nursery management focuses on maintaining optimal conditions for healthy and uniform seedlings. Regular, light watering using a fine watering can or drip system keeps the soil moist without causing waterlogging, while temporary shading protects young seedlings from heat stress and is gradually reduced before transplanting to harden the plants. Balanced nutrition can be provided through compost or light starter fertilizers to support early growth. Good hygiene practices (clean tools, proper spacing, and regular monitoring) help prevent pests and diseases such as damping-off. Integrated pest management measures, including removal of infected plants and use of biopesticides when necessary, ensure strong, disease-free seedlings ready for successful field establishment.



3.3. Soil fertility and crop nutrition management

3.3.1. Soil preparation and amendments

Proper soil preparation is essential to create a favorable environment for root development, nutrient uptake, and healthy growth of cabbage, tomato, and onion. Land preparation should begin with clearing crop residues and weeds, followed by ploughing or digging to loosen the soil to a depth of about 20-30 cm. This improves aeration, drainage, and root penetration. In areas prone to waterlogging, raised beds or ridges should be formed to enhance drainage and reduce disease risk. Where soils are compacted, deep cultivation or incorporation of organic matter helps improve soil structure and water infiltration.



Figure 2: Beds raising during soil preparation step

Before planting, farmers should assess soil fertility through simple soil testing, when possible, to determine nutrient status and pH. The application of organic amendments, such as well-decomposed compost or animal manure, is strongly recommended to improve soil organic matter, enhance microbial activity, and increase water-holding capacity. Organic materials should be applied several weeks before planting to allow proper decomposition and avoid nutrient imbalances.

In addition to organic inputs, soil amendments such as lime, gypsum or biochar may be used where soil acidity or salinity limits crop performance. Mulching with plant residues can further conserve soil moisture, regulate temperature, and suppress weed growth. A combination of good land preparation, organic amendments, and appropriate soil management practices provides a strong foundation for efficient nutrient use and sustainable vegetable production.

3.3.2. Organic fertilizers and application

In cabbage, tomato, and onion cultivation, the use of organic inputs helps increase soil organic matter, improve water-holding capacity, stimulate beneficial soil microorganisms, and promote gradual nutrient release throughout the crop cycle. Organic fertilizers are particularly valuable in sandy or low-fertility soils common in many vegetable-growing areas, where they help maintain long-term soil productivity. A wide range of organic fertilizers can be used in vegetable production. Well-decomposed animal manures, (poultry manure, cattle manure, sheep or goat manure, and pig manure, etc.) are widely available and provide essential nutrients including nitrogen, phosphorus, and potassium. Compost made from crop residues, household organic waste, kitchen scraps, or green biomass improves soil structure and provides balanced nutrition. Other organic inputs include green manures and cover crops (legumes incorporated into the soil), vermicompost, biochar, and plant-based amendments such as neem cake or other seed cakes. Where available, black soldier fly (BSF) compost, farmyard manure, and agro-industrial by-products can also be valuable nutrient sources.



Poultry manure in pack



Soybean meal



Cow dung



Compost

Figure 3: Types of organic fertilizers

3.3.2.1. Composting process

Composting is a key practice that transforms organic materials into a stable, nutrient-rich soil amendment. Farmers can prepare compost by combining plant residues, animal manure, and kitchen waste in layers, maintaining adequate moisture, and turning the pile regularly to ensure proper decomposition. Well-prepared compost is dark, crumbly, and free from foul odors. It should be applied and incorporated into the soil before planting to improve soil fertility and reduce nutrient losses. Combining organic fertilizers with good crop management practices (organic mulching, crop rotation, and integrated nutrient management) supports healthier soils, improved crop growth, and more resilient vegetable production systems.

Composting is a simple and effective method of converting organic waste into a nutrient-rich soil amendment that improves soil fertility, structure, and moisture retention. Proper composting helps recycle farm residues, reduce waste, and provide a sustainable source of nutrients for vegetable crops such as cabbage, tomato, and onion.

→ Selection of materials

Good compost requires a balanced mixture of green materials (rich in nitrogen) and brown materials (rich in carbon).

- *Green materials:* fresh plant residues, vegetable scraps, green leaves, manure, kitchen waste.
- *Brown materials:* dry leaves, straw, maize stalks, rice husks, sawdust, and dried grass.
- Avoid diseased plants, plastics, or chemically treated materials.



Cow manure



Cow dung

Figure 4: Animal organic matter suitable for composting



Poultry manure



Guano

Figure 4: Animal organic matter suitable for composting (End)



Plant debris



Soybean meal

Figure 5: Crops residues suitable for composting

→ Site selection and preparation

Choose a shaded, well-drained area close to a water source. Compost can be prepared in a pile, pit, or bin depending on available space. The base layer should allow air circulation, for example by placing small branches or coarse materials at the bottom.

→ Layering and pile formation

Build the compost pile in layers:

- A layer of dry materials;
- A layer of green materials or manure;
- A thin layer of soil or finished compost to introduce microorganisms;
- Repeat layers until the pile reaches about 1-1.5 m height;
- Moisten each layer lightly.



Figure 6: Pile formation for composting

→ Moisture and aeration management

Maintain adequate moisture by watering the pile when it becomes dry. Turn the compost every 2-3 weeks using a fork or shovel to introduce oxygen, speed up decomposition, and prevent bad odors. Proper aeration helps beneficial microbes break down organic matter efficiently.

→ Decomposition and maturity

The composting process usually takes 6-10 weeks depending on materials and weather conditions. Well-matured compost is dark brown, crumbly, and has an earthy smell. It should no longer feel hot or contain recognizable plant residues.



Ongoing composting



Matured compost ready for use

Figure 7 : End of composting

3.3.2.2. Application methods of organic fertilizers

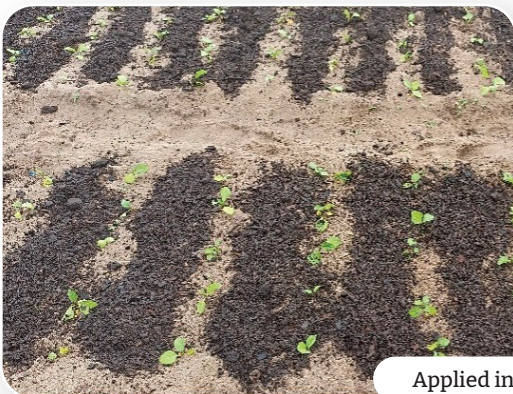
Organic fertilizers play a key role in sustainable soil fertility management by improving soil structure, enhancing microbial activity, and providing essential nutrients for plant growth. Their effectiveness, however, largely depends on the method and timing of application. Appropriate application techniques help ensure better nutrient availability, reduce losses through leaching or volatilization, and promote efficient uptake by crops. Depending on the type of organic fertilizer and the production system, different application methods can be used, including broadcasting, band placement, incorporation into the soil, and localized application near the root zone. The main methods of applying organic fertilizers are presented below.



Incorporation during the land preparation



Crown application



Applied in line (strip)



Figure 8: Application method for organic fertilizers

3.3.3. Inorganic fertilizers and application methods

Inorganic fertilizers support rapid growth, high yields, and improved crop quality in cabbage, tomato, and onion production systems. The most commonly used fertilizers include NPK compound fertilizers, and urea. These fertilizers supply essential nutrients (nitrogen for vegetative growth, phosphorus for root development and early establishment, and potassium for crop strength, disease tolerance, and produce quality fruits). Proper fertilizer use should be guided by soil testing where possible and adapted to crop growth stages and local conditions.



Figure 9: Examples of some mineral fertilizers

NB: Magnesium sulphate, calcium sulphate, and potassium sources such as potassium sulphate and ammonium sulphate are important fertilizers for improving vegetable growth, yield, and quality. Magnesium sulphate supplies magnesium for chlorophyll formation and photosynthesis, calcium sulphate improves root growth and prevents calcium deficiencies, while potassium sulphate enhances fruit quality, firmness, and stress tolerance. Ammonium sulphate provides readily available nitrogen and sulphur for vigorous plant growth and protein formation.

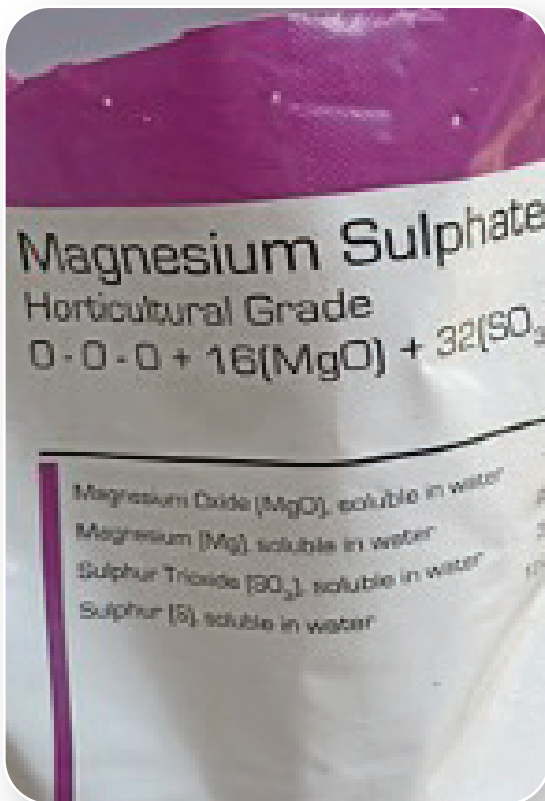


Figure 10: Examples of some mineral fertilizers

→ Application methods

- Different application methods help improve nutrient efficiency and reduce losses:
- Basal application: fertilizers are applied and incorporated into the soil during land preparation or at planting. This method is commonly used for phosphorus and part of nitrogen and potassium to support early root growth.
- Top dressing: nitrogen fertilizers such as urea are applied in small split doses during crop growth to meet increasing nutrient demand and minimize leaching losses.
- Band placement or side dressing: fertilizer is placed a few centimeters away from the plant root zone to improve nutrient uptake and avoid root burn
- Fertigation: soluble fertilizers are applied through irrigation water to ensure uniform distribution and efficient nutrient use. More appropriate for drip irrigation systems.
- Foliar feeding: liquid fertilizers are sprayed on leaves to correct nutrient deficiencies quickly, especially during stress periods.



Application in top



Urea application in

Figure 11: Application methods of mineral fertilizers



Foliar application of micro-nutrients, bio-stimulants,

Figure 11: Application methods of mineral fertilizers (End)

3.3.4. Nutrient deficiency diagnosis

Early identification of nutrient deficiencies helps maintain healthy growth and prevent yield losses in cabbage, tomato, peppers and onion. Extension officers should encourage regular field observation to detect symptoms such as yellowing leaves (nitrogen deficiency), purpling or poor root growth (phosphorus deficiency), and leaf edge scorching or weak plants (potassium deficiency). Deficiencies often appear first on older leaves when mobile nutrients are lacking (Table 1).

Table 1: Common nutrient deficiency symptoms in vegetable crops

Elements	Symptoms of the deficiencies
Nitrogen (N)	<ul style="list-style-type: none"> – Older leaves turn pale green to yellow (uniform chlorosis). – Plants appear stunted with slow growth and thin stems. – Reduced leaf size and overall poor vigor. – Symptoms usually start from the lower leaves and move upward.
Phosphorus (P)	<ul style="list-style-type: none"> – Plants grow slowly with weak root development. – Leaves may show a dark green or purplish tint, especially in cool conditions. – Delayed flowering and maturity. – Seedlings often appear small and less vigorous.
Potassium (K)	<ul style="list-style-type: none"> – Leaf margins turn yellow, then brown or scorched, starting from older leaves. – Plants become weak and prone to lodging, pests, and diseases. – Poor fruit quality in tomato and reduced head or bulb firmness in cabbage and onion. – Increased sensitivity to drought and heat stress.
Calcium (Ca)	<ul style="list-style-type: none"> – Young leaves become distorted, curled, or necrotic at tips. – Poor root growth and weak stems. – Blossom-end rot in tomato fruits. – Growing points may die under severe deficiency
Magnesium (Mg)	<ul style="list-style-type: none"> – Interveinal yellowing on older leaves while veins remain green. – Leaves may develop reddish or brown spots later. – Premature leaf drop. – Reduced photosynthesis and weak growth.
Sulphur (S)	<ul style="list-style-type: none"> – General yellowing of young leaves first. – Plants remain small and thin. – Delayed growth and maturity. – Similar to nitrogen deficiency but appears on younger leaves.
Iron (Fe)	<ul style="list-style-type: none"> – Interveinal chlorosis on young leaves first. – Leaves become pale yellow to almost white in severe cases. – Veins often remain green. – Reduced growth under severe deficiency.

Elements	Symptoms of the deficiencies
Boron (B)	<ul style="list-style-type: none"> – Death of growing points or poor new leaf development. – Brittle, thick, or cracked leaves/stems. – Poor flowering and fruit set. – Hollow stems or internal disorders in some crops.
Manganese (Mn)	<ul style="list-style-type: none"> – Interveinal chlorosis with small brown specks on young to middle leaves. – Reduced leaf size. – Poor growth and weak plants. – Symptoms often appear in high pH soils.

3.3.5. Integrated soil fertility management

Integrated Soil Fertility Management (ISFM) is an approach that combines organic and mineral fertilizers to improve crop management practices to maintain soil productivity and ensure efficient nutrient use. In cabbage, tomato, and onion production, ISFM promotes balanced fertilization by applying compost or well-decomposed manure together with recommended inorganic fertilizers, allowing both immediate nutrient supply and long-term soil health improvement. Practices such as crop rotation, organic mulching, proper irrigation, and timely weeding help conserve soil moisture, reduce nutrient losses, and enhance root development. By integrating organic and inorganic nutrient sources with good agronomic practices, ISFM improves soil structure, increases nutrient availability, reduces production costs, and

enhances resilience of vegetable systems under climate variability.

3.4. Water and irrigation management

3.4.1. Irrigation methods

Farmers commonly use manual watering with watering cans, especially in small gardens and community vegetable plots. Water is usually obtained from shallow wells, boreholes, or nearby rivers such as the River Gambia. In larger farms or organized schemes, motor pumps or solar-powered pumps are increasingly used to lift water for irrigation. Furrow irrigation is also practiced where land is slightly sloped, allowing water to flow between crop rows



Figure 12: Power source for irrigation: a motor pump using domestic gas



Hose-pier irrigation



Sprinkler irrigation

Figure 13: Various irrigation systems



Perforated tape irrigation

Figure 13: Various irrigation systems *(End)*

NB: Drip irrigation bundled with chameleon sensors delivers water directly to plant roots, reduces water loss through evaporation, and improves water-use efficiency for crops like tomato, onion, and cabbage.

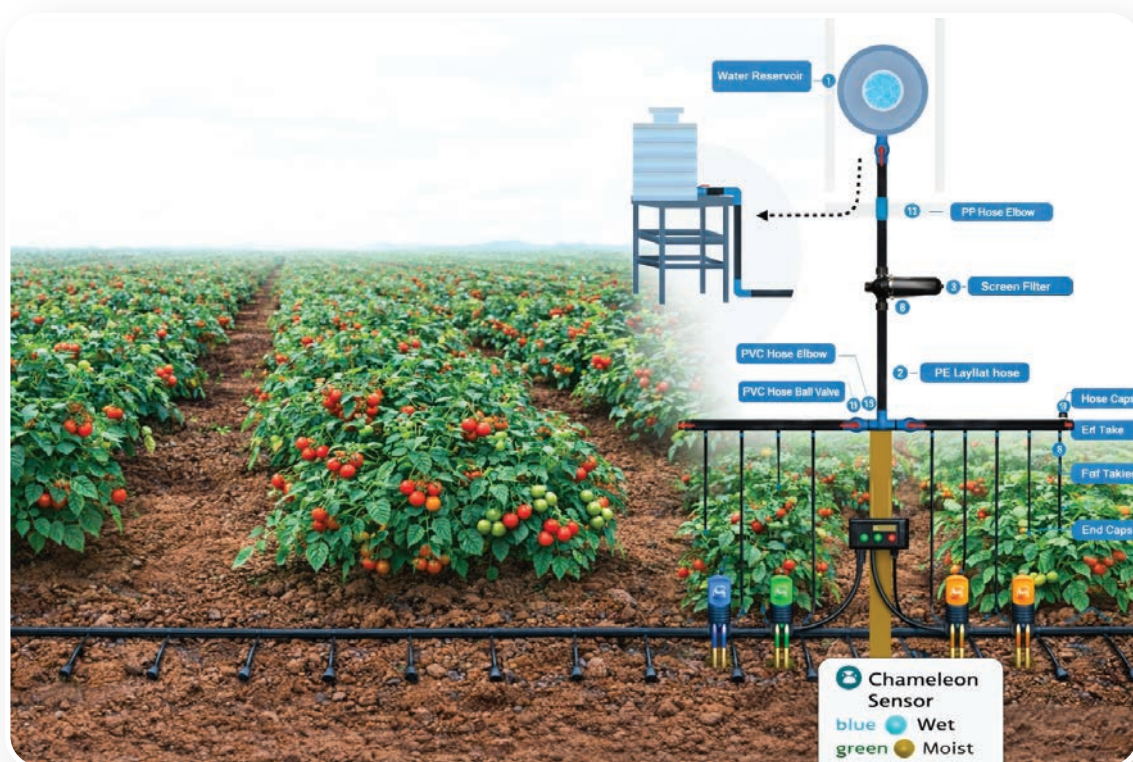


Figure 14: Drip irrigation bundled with chameleon sensors for tomato production

3.4.2. Scheduling and frequency

Proper irrigation scheduling ensures that crops receive adequate water at the right time without wasting resources. In vegetable production, irrigation frequency depends on soil type, crop stage, and weather conditions. Sandy soils common in many Gambian vegetable areas require more frequent watering because they drain quickly. Young seedlings require light but frequent watering, often once or twice per day in hot conditions. As plants grow, watering can be reduced to every 2-3 days, ensuring that the soil remains moist but not waterlogged. Critical growth stages (flowering and fruit development (tomato), bulb formation (onion), and head formation (cabbage)) require consistent moisture to avoid yield losses.

3.4.3. Water-saving practices

Farmers can adopt several water-saving practices to improve irrigation efficiency. Organic mulching using crop residues, (dried grass) helps to reduce soil evaporation and maintain soil moisture. Drip irrigation systems deliver water directly to the root zone and can reduce water use significantly compared to surface irrigation. Proper land leveling and raised beds improve water distribution and prevent runoff. Farmers should also control weeds regularly, as weeds compete with crops for water and nutrients. In addition, rainwater harvesting and small water storage systems can help farmers collect and store water for dry periods. These practices not only conserve water but also improve crop productivity and resilience to climate variability.



Figure 15: organic mulching applied for okra (a) and tomato (b) production

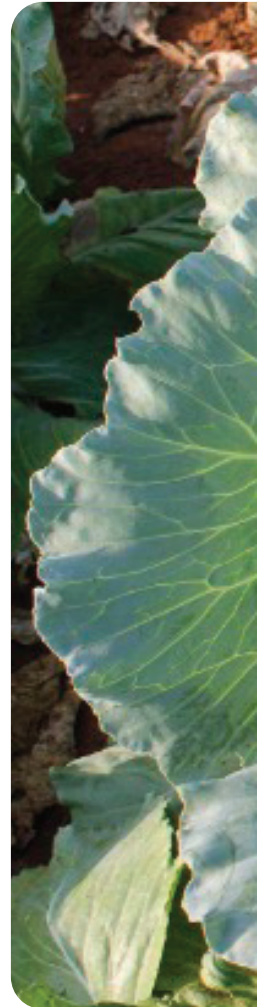
CHAPTER IV: Crop-specific production modules

4.1. Cabbage - *Brassica oleracea var. capitata*

4.1.1. Description and importance

Cabbage is a leafy vegetable in the Brassicaceae family. It is a cool-season biennial crop that is typically grown as an annual for its compact head, which is formed by tightly overlapping leaves. The plant develops a short, thick stem on which large, broad leaves are arranged in a rosette pattern before forming a dense head. It is cultivated in several countries, including China, India, and Russia, which are among the leading producers. Cabbage is rich in vitamins C and K, dietary fiber, antioxidants,

and essential minerals, such as potassium and calcium. Its high nutritional value makes it an essential part of a balanced diet and contributes to food security. Cabbage is one of the most important vegetable crops globally from an economic standpoint. Under rainfed conditions, yields of 25 to 35 ton/ha fresh heads are normal, with a maximum of about 50 ton/ha when sprayed and well-fertilized. Overall, cabbage is an economically valuable, nutritionally rich, and widely cultivated vegetable crop that contributes significantly to food security, farmer livelihoods, and agricultural diversification worldwide.



4.1.2. Agro-ecological requirements

Cabbage is a cool-season crop that thrives under specific climate and soil conditions. Understanding its temperature, soil fertility, and altitude preferences is essential to ensure proper growth, optimal head formation, and high yields. The table below summarizes the key requirements for successful cabbage cultivation.



Figure 16: Cabbage plant

Table 2: Climate, soil, and altitude requirements for cabbage production

Aspect	Key requirements / Tips
Climate	<ul style="list-style-type: none"> - Cool-season crop: performs best at 20 - 26 °C °C. - Optimal germination: 20–25 °C; head formation: 15–18 °C. - Temperatures >25 °C reduce head quality; - <5 °C may cause premature bolting. - Excessive heat can split heads or cause tipburn. - Full sun is essential; long days with high heat can impair head formation.
Soil	<ul style="list-style-type: none"> - Fertile, well-drained loamy soils with good moisture retention. - Avoid waterlogged heavy clays (risk of root diseases) and very sandy soils (low nutrient retention). - Optimal pH: 6.0–6.8; pH <5.5 increases clubroot risk. - High nutrient needs: N for vegetative growth, P for roots, K for head firmness and stress tolerance. - Organic matter is essential for soil structure and fertility.
Altitude	<ul style="list-style-type: none"> - Can be grown from lowland to highland. - In tropical regions, higher altitudes with cooler temperatures favor head formation and better yields.

4.1.3. Variety and seed selection

The selection of cabbage varieties and seeds is a critical factor influencing crop performance, adaptability, and market value. Variety choice should consider agro-climatic conditions, market preferences, and resistance to major pests and diseases. Cabbage cultivars differ in maturity period (early, medium, or late), head size, shape, compactness, and color (green, red, or savoy types), as well as in their tolerance to temperature stress. In tropical and subtropical regions, heat-tolerant and bolt-resistant varieties are generally preferred, while cooler environments favor cultivars

adapted to low temperatures for proper head formation. The use of varieties with resistance or tolerance to key diseases such as black rot and clubroot helps improve yield stability and reduces reliance on pesticides. In addition, high-quality seed is essential for successful crop establishment and should possess high genetic and physical purity with germination rates typically above 85%. Certified seeds obtained from reliable suppliers minimize the risk of seed-borne diseases and varietal mixtures. Proper storage under cool and dry conditions maintains seed viability, and seed treatment - either chemical or biological - can protect seedlings from soil-borne pathogens during the early stages of growth.



Table 3: Main cabbage varieties cultivated in West Africa: Agronomic characteristics, yield potential and disease tolerance

Variety	Type	Cycle (days after transplanting)	Average yield (t/ha)	Storage aptitude
Copenhagen Market	Open pollinated	70–80	25–35	Medium (2–3 weeks)
Tropicana F1	Hybrid	70–80	40–55	Good
Gloria F1	Hybrid	80–90	45–60	Very good (4–5 weeks)
Green Coronet F1	Hybrid	75–85	40–50	Good
KK Cross	Hybrid	65–75	35–45	Medium
Sugarloaf	Open pollinated	75–90	25–35	Medium
Oxheart	Open pollinated	70–85	20–30	Low to medium
Golden Acre	Open pollinated	65–75	25–35	Medium
Farao F1	Hybrid	65–75	40–50	Good
Hurricane F1	Hybrid	80–95	45–60	Very good
Atlas F1	Hybrid	75–85	40–55	Good
Cheers F1	Hybrid	80–90	45–55	Very good
Red Acre	Open pollinated	75–85	20–30	Good
Brunswick	Open pollinated	85–100	30–40	Good

Climate adaptation (season)	Tolerance to pests and diseases
Cool dry season	<ul style="list-style-type: none"> – Moderate tolerance to black rot – Susceptible to diamondback moth
Dry and warm season	<ul style="list-style-type: none"> – Tolerant to heat stress – Moderate tolerance to caterpillars
Cool dry season	<ul style="list-style-type: none"> – Resistant to fusarium yellows – Moderate tolerance to pests
Dry season	<ul style="list-style-type: none"> – Moderate resistance to black rot – Adapted to tropical climates
Dry season	<ul style="list-style-type: none"> – Moderate tolerance to insect pests – Susceptible to bacterial diseases
Cool season	<ul style="list-style-type: none"> – Moderate tolerance to aphids; – Susceptible to black rot
Dry season	<ul style="list-style-type: none"> – Heat tolerant – Susceptible to cabbage worms
Cool dry season	<ul style="list-style-type: none"> – Moderate tolerance to pests – Susceptible to black rot
Dry season	<ul style="list-style-type: none"> – Good tolerance to heat and some foliar diseases
Cool season	<ul style="list-style-type: none"> – Good resistance to fusarium and black rot
Dry season	<ul style="list-style-type: none"> – Moderate tolerance to insects and bacterial diseases
Cool dry season	<ul style="list-style-type: none"> – Resistant to fusarium yellows – Moderate tolerance to caterpillars
Cool season	<ul style="list-style-type: none"> – Moderate resistance to pests – Susceptible to bacterial diseases
Cool season	<ul style="list-style-type: none"> – Moderate tolerance to cold and some pests

4.1.4. Nursery, land preparation and transplanting

Successful cabbage production largely depends on proper crop establishment, which involves raising healthy seedlings, preparing suitable soil conditions, and carrying out careful transplanting. Because cabbage is commonly grown through transplanting rather than direct seeding, effective nursery management is essential to produce vigorous seedlings capable of adapting quickly to field conditions. In addition, proper land preparation improves soil structure, fertility, and drainage, thereby facilitating root development and optimal plant growth. Careful transplanting practices further reduce plant stress and ensure uniform crop establishment. Together, these practices play a crucial role in determining plant survival, crop performance, and ultimately cabbage yield and quality.

Table 4: Nursery management, land preparation and transplanting practices for cabbage Production

Production stage	Key practices
Nursery management	<ul style="list-style-type: none"> – Sow seeds in raised beds or trays with fertile, well-drained substrate rich in organic matter – maintain regular watering, adequate light, and protection from pests and heavy rain; ensure fine seedbed and proper spacing – harden seedlings before transplanting. – Seedlings are ready after 3–5 weeks when they have 4–6 true leaves.
Land preparation	<ul style="list-style-type: none"> – Plough and harrow soil to obtain a fine tilth – incorporate well-decomposed organic manure – prepare raised beds or ridges in poorly drained soils – level the field and conduct soil testing before planting.
Transplanting	<ul style="list-style-type: none"> – Transplant in late afternoon or cool weather; carefully remove seedlings to avoid root damage – plant at recommended spacing (45–60 cm between plants and 60–75 cm between rows) – irrigate immediately after planting and monitor plants during the first two weeks.

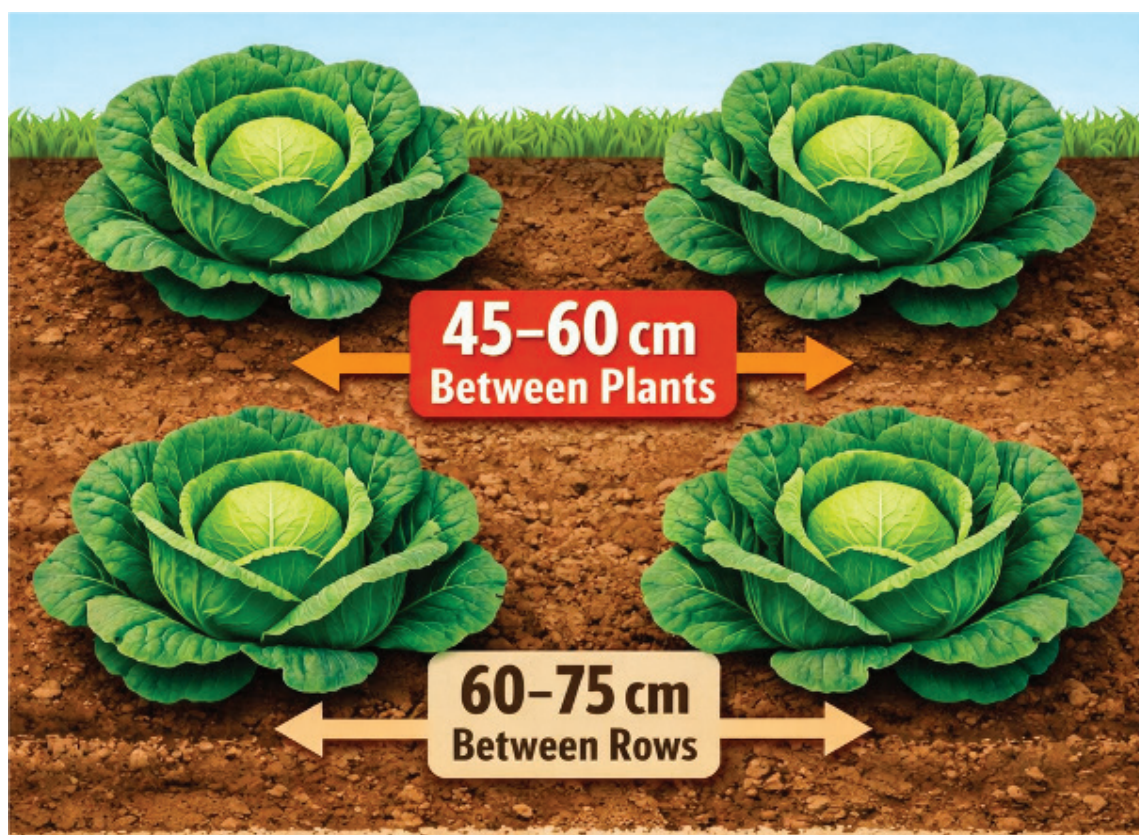


Figure 17: Cabbage planting spacing for healthy growth

4.1.5. Nutrient and water management

Cabbage requires careful nutrient and water management to achieve high yield and quality. Nitrogen supports leaf growth, phosphorus aids root establishment, and potassium enhances head firmness and stress tolerance, while calcium, magnesium, and boron prevent physiological disorders. Combining organic amendments with balanced fertilizers and splitting nitrogen applications optimizes nutrient use. Consistent water supply, especially during transplanting and head formation, is crucial, as drought reduces head size and quality, while overwatering promotes diseases. Efficient irrigation, proper drainage, and scheduling based on growth stage and climate ensure uniform growth, disease reduction, and optimal productivity.

Table 5: Nutrient and water management for optimal cabbage production

Management aspect	Key practices
Nutrient	<ul style="list-style-type: none"> – Apply balanced N, P, K based on soil test – Nitrogen critical for leaf growth; split applications recommended – Phosphorus for early root establishment – Potassium for head firmness, stress tolerance, disease resistance – Secondary nutrients (Ca, Mg) to prevent physiological disorders – micronutrients (B) for proper head development – Combine organic amendments (compost/manure) with mineral fertilizers
Water	<ul style="list-style-type: none"> – Maintain consistent soil moisture, especially during transplant establishment and head formation – Total water requirement: 380–500 mm per season – Avoid drought stress and waterlogging – Use efficient irrigation (e.g., drip) and proper drainage – Schedule irrigation based on crop stage and climate

4.1.6. Pests and diseases of cabbage

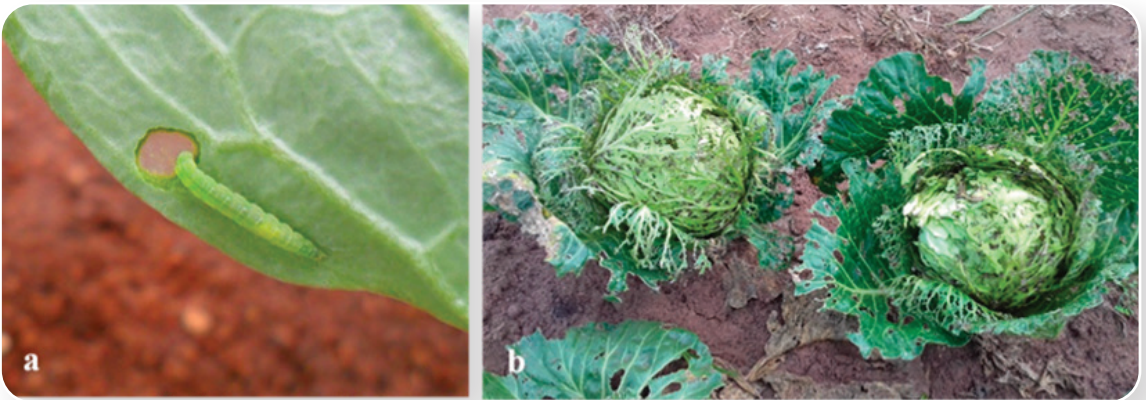
Cabbage production is frequently affected by a wide range of insect pests and diseases that can significantly reduce crop growth, yield, and market quality. Insect pests mainly damage cabbage by feeding on leaves, boring into plant tissues, or transmitting plant pathogens, which can weaken plants and reduce head formation. In addition, several fungal, bacterial, and viral diseases may develop under favorable environmental conditions, leading to leaf lesions, rotting, wilting, or deformation of the cabbage head. Effective management of these constraints relies on early detection, regular field monitoring, and the implementation of integrated pest management strategies combining cultural, biological, and, when necessary, chemical control methods. The most common pests and diseases affecting cabbage are presented below.

Table 6: Synthesis of major pests and diseases of cabbage in West Africa: Symptoms and management and management

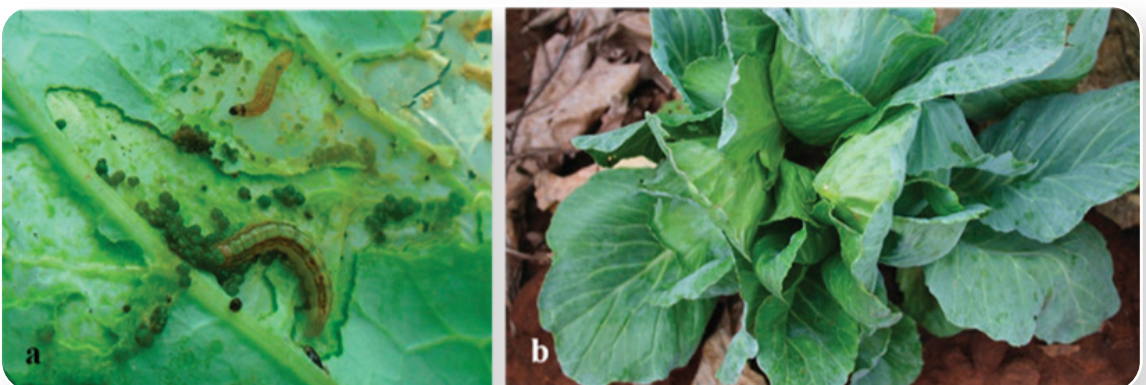
Catew-gory	Pest / Disease	Scientific Name	Symptoms / Damage	Management Tips
Insect Pests	Diamond-back moth	<i>Plutella xylostella</i>	<ul style="list-style-type: none"> – Larvae feed on leaves, creating holes; – reduce photosynthesis and yield 	<ul style="list-style-type: none"> – Monitor regularly and remove infested leaves – encourage natural enemies – apply insecticides only if threshold reached
	Cutworms	<i>Agrotis</i> spp.	Seedlings cut at soil level	<ul style="list-style-type: none"> – Handpick or trap – maintain weed-free fields
	Greater cabbage moth	<i>Crocidolomia pavonana</i>	Leaf feeding, holes and defoliation	<ul style="list-style-type: none"> – Encourage parasitoids – selective insecticides if needed
	Cabbage webworm	<i>Hellula undalis</i>	Leaf damage tunnels in stems	<ul style="list-style-type: none"> – Remove infested parts – use pheromone traps – apply biopesticides
	White butterfly	<i>Pieris rapae</i>	Larvae feed on leaves reduce leaf area	<ul style="list-style-type: none"> – Handpick larvae – encourage predators – apply insecticides if necessary
	Crossstriped cabbageworm	<i>Evergestis rimosalis</i>	Defoliation, skeletonized leaves	<ul style="list-style-type: none"> – Monitor and remove larvae – biological control if available
	Mediterranean climbing cutworm	<i>Spodoptera littoralis</i>	Leaf and stem damage	<ul style="list-style-type: none"> – Cultural control and natural enemies used – insecticides if needed
	Onion armyworm	<i>Spodoptera exigua</i>	Irregular leaf feeding; defoliation	<ul style="list-style-type: none"> – Remove larvae – encourage natural predators – selective insecticides

Category	Pest / Disease	Scientific Name	Symptoms / Damage	Management Tips
Diseases	Cabbage root fly	<i>Delia radicum</i>	<ul style="list-style-type: none"> - Larvae feed on roots; stunted growth 	<ul style="list-style-type: none"> - Crop rotation and remove infested plants; - Apply barriers if possible
	Cabbage aphids	<i>Brevicoryne brassicae</i>	<ul style="list-style-type: none"> - Cluster on leaves; - Yellowing; - Transmit viruses 	<ul style="list-style-type: none"> - Use water sprays - Encourage ladybirds - Insecticidal soap if needed
	Potato aphid	<i>Myzus persicae</i>	<ul style="list-style-type: none"> - Leaf curling, - Yellowing; - Virus vector 	<ul style="list-style-type: none"> - Monitor; biological control - Safe insecticides if threshold reached
	Flea beetles	<i>Phyllotreta</i> spp.	<ul style="list-style-type: none"> - Small holes in leaves; - Seedlings severely affected 	<ul style="list-style-type: none"> - Use row covers - Apply neem or biopesticides - maintain weed-free field
	Cabbage looper	<i>Trichoplusia ni</i>	<ul style="list-style-type: none"> - Leaf feeding; - Reduced leaf area 	<ul style="list-style-type: none"> - Monitor; encourage parasitoids; - Biopesticides or selective insecticides
	Black rot	<i>Xanthomonas campestris</i> pv. <i>campestris</i>	<ul style="list-style-type: none"> - V-shaped yellow lesions on leaves; - Vascular discoloration 	<ul style="list-style-type: none"> - Use disease-free seeds; - Rotate crops and remove infected plants; - Copper-based bactericides
	Clubroot	<i>Plasmodiophora brassicae</i>	<ul style="list-style-type: none"> - Root swelling; - Wilting; - Stunted growth 	<ul style="list-style-type: none"> - Use resistant varieties; - Lime soil to increase pH; - Rotate crops
	Downy mildew	<i>Hyaloperonospora brassicae</i>	Pale, fuzzy growth on leaves under humid conditions	<ul style="list-style-type: none"> - Improve air circulation; - Fungicide application; - Remove infected leaves

Category	Pest / Disease	Scientific Name	Symptoms / Damage	Management Tips
	Damping-off	<i>Pythium spp.</i> , <i>Rhizoctonia spp.</i>	<ul style="list-style-type: none"> - Seedlings collapse - Poor germination 	<ul style="list-style-type: none"> - Use well-drained soil; - Sterilize seedbeds; - Fungicide treatment of seeds
	Dark leaf spot	<i>Alternaria brassicae</i>	<ul style="list-style-type: none"> - Dark spots on leaves - Reduced photosynthesis 	<ul style="list-style-type: none"> - Remove infected debris; - apply fungicides if severe
	Ring spot	<i>Mycosphaerella brassicicola</i>	<ul style="list-style-type: none"> - Circular leaf lesions - Leaf drop 	<ul style="list-style-type: none"> - Sanitation, fungicide application; - Rotate crops
	Downy mildew of crucifers	<i>Peronospora parasitica</i>	Leaf yellowing, fuzzy growth under humid conditions	<ul style="list-style-type: none"> - Improve ventilation; - Remove infected leaves; - preventive fungicide spray



Plutella xylostella : a) Larva b) damage symptom



Hellula undalis : a) Larva b) damage symptom

Figure 18: Some major pests and their characteristic damage symptoms



Crocidolomia pavonana : a) Larva b) damage symptom



Cabbage aphids: a) Adult b) damage symptom

Figure 18: Some major pests and their characteristic damage symptoms (End)

4.1.7. Maturity and harvesting of cabbage

Harvesting vegetables at the correct stage of maturity is essential to ensure good quality, longer shelf life, and reduced post-harvest losses, as harvesting too early leads to poor size and flavor while harvesting too late reduces storage potential and market value. For cabbage, heads should be harvested when firm, compact, and at marketable size, as over-mature heads may crack and immature heads remain loose and lightweight. Using proper maturity indices reduces losses, improves market quality, and ensures better returns, and extension officers should train farmers to monitor crop development carefully and harvest at the appropriate stage.



Xanthomonas campestris pv. *Campestris* – Symptom on leaf (a) and on head (b)



Sclerotinia sclerotiorum



Alternaria brassicae

Figure 19: Characteristic damage symptoms of major diseases

4.1.8. Key extension messages

Cabbage is a high-value vegetable widely grown in West Africa, but achieving good yield and quality requires careful attention to crop management. Smallholder farmers often face challenges such as pests, diseases, and inconsistent water or nutrient supply. Extension messages provide simple, practical guidance to improve crop establishment, growth, and post-harvest handling. By following these key recommendations (Table 7), farmers can enhance plant survival, increase productivity, and produce high-quality cabbage suitable for local markets.

Table 7: Recommendations across activities

Activities	Key recommendations
Variety selection	– Choose high-yielding, pest- and disease-resistant varieties suited to your climate and market.
Seed quality	– Use certified, disease-free seeds with high germination for uniform seedlings
Nursery management	– Sow in well-drained, fertile beds or trays; – water adequately, protect from pests, and harden seedlings before transplanting.
Land preparation	– Prepare fine tilth, incorporate organic manure, ensure proper drainage to prevent waterlogging.
Transplanting	– Plant healthy seedlings at recommended spacing – Irrigate immediately to support establishment.
Nutrient management	– Apply balanced fertilizers (N, P, K) and supplement with compost or manure – Split N applications as needed.
Water management	– Maintain consistent soil moisture, especially during head formation – Avoid water stress and waterlogging
Pest management	– Monitor for diamondback moth, aphids, cutworms, and others – Use cultural, biological, and selective chemical control.
Disease management	– Use resistant varieties, disease-free seeds, rotate crops, maintain sanitation, and apply fungicides/bactericides when necessary.
Harvesting	– Cut heads when firm and compact – Avoid bruising – Remove damaged leaves and soil residues.
Post-Harvest handling	– Handle gently, clean heads, and minimize physical damage to reduce decay.
Storage	– Store at 0–5°C with 90–95% humidity; – Ensure ventilation – Can last 4–12 weeks depending on variety.
Field hygiene & Rotation	– Remove crop residues and rotate with non-cruciferous crops to reduce pest and disease pressure.

4.2. Tomato

4.2.1. Description and importance

Tomato (*Solanum lycopersicum* L.) is an herbaceous plant of the Solanaceae family, typically cultivated as an annual crop with determinate or indeterminate growth depending on the variety. It has branched stems, compound pinnate leaves, yellow hermaphroditic flowers, and produces fleshy berries that vary in size, shape, and color. Originating in western

South America and domesticated in Central America, tomato is now grown worldwide under open-field and protected conditions. It thrives in well-drained, fertile soils (pH 5.5–7.5) with moderate temperatures (20–27 °C) and adequate sunlight, but is sensitive to frost, waterlogging, and high heat during flowering. Nutritionally, it is rich in vitamins C and A, potassium, and antioxidants such as lycopene. Economically, tomato is important for fresh markets, agro-processing, and income generation, making it a strategic crop for food security, nutrition, and smallholder livelihoods.



Figure 20: Morphological appearance of a tomato plant (a) and fruit (b)

4.2.2. Agro-ecological requirements

Tomato is a warm-season crop that requires specific climate, soil, and altitude conditions to grow well and produce high-quality fruit. Understanding these requirements helps farmers optimize growth, improve yield, and reduce the risk of physiological disorders. The table below summarizes the key factors for successful tomato cultivation.

Table 8: Climate, soil, and altitude requirements for tomato

Aspect	Key requirements / Tips
Climate	<ul style="list-style-type: none"> – Warm-season crop; optimal temperature: 20–27 °C. – Night temperature for flowering/fruit: 15–20 °C. – Temperatures >32–35 °C reduce pollen viability, cause flower abortion and blossom drop. – Requires high light intensity; prolonged cloudiness reduces yield and fruit quality
Soil	<ul style="list-style-type: none"> – Well-drained, fertile soils with loamy or sandy-loam texture. – Optimal pH: 5.5–7.5. – Avoid waterlogging to prevent root diseases. – High organic matter improves soil structure, nutrient availability, and microbial activity.
Altitude	<ul style="list-style-type: none"> – Can be grown from sea level to highlands if temperature remains optimal. – Match varietal selection to local climate and disease pressure.

4.2.3. Variety and seed selection

The selection of an appropriate variety and high-quality seed is a key step in tomato production. A well-adapted variety suited to local agro-climatic conditions, the production system, and the target market can significantly improve yield, fruit quality, and tolerance to pests and diseases. Tomato varieties differ in growth habits (determinate or indeterminate) and seed type (open-pollinated or hybrid), each offering specific advantages in terms of adaptation, productivity, and management. The use of pest- and disease-tolerant varieties is also an important preventive strategy within Integrated Pest Management (IPM). In addition, the use of high-quality seeds with high germination capacity, varietal purity, and freedom from pathogens ensures uniform crop establishment, vigorous seedlings, and sustainable crop performance.



Table 9: Characteristic of some tomato varieties cultivated in West Africa

Variety Name	Variety Type	Fruit Color	Fruit Shape	Yield (t/ha)
Calypso	Open-pollinated	Red	Globe	~60
Floradade	Open-pollinated	Red	Globe	25–60
Elgon	Open-pollinated	—	—	~25
Icrixina	Landrace/local	Presumed red	Globe	High*
AVT01710 (Accession)	Local/Multi-location	—	—	~40.9
VIO43614 (Accession)	Local/Multi-location	—	—	~20
Konica	Local/OP	Red	Globe	Lower
Tropimech	Local/Common	Red	Globe	Variable
Petomech	Local/Common	Red	Globe	Variable
Caraibo	Local/Common	Red	Globe	Variable
Mongal F1	Hybrid (F1)	Red	Globe	Variable
HA 3060	Hybrid potential	Red	Globe	Not specified
Atak	Hybrid potential	Red	Globe	Not specified
Bybal / Bybel	Hybrid potential	Red	Globe	Not specified
Lety F1	Hybrid	Red	Globe	Not specified

Crop Cycle (days)	Storage Duration	Production Season	Pest/Disease Tolerance/Resistance
~140	Moderate	Rainy/dry	<ul style="list-style-type: none"> – Tolerant to early blight, stemphylium, Verticillium & Fusarium; – susceptible to cotton bollworm & whitefly.
120–140	Moderate	Rainy/dry	<ul style="list-style-type: none"> – Resistant to early blight, stemphylium & Fusarium; – susceptible to cotton bollworm & whitefly.
~90	—	Rainy/dry	– Not specified in regional data.
—	—	All seasons	<ul style="list-style-type: none"> – Good performance; – most affected by tomato yellow leaf curl but still high yield.
—	—	Rainy	<ul style="list-style-type: none"> – High yield; – performance varies by season.
—	—	Dry	– Moderate yield, season-dependent.
—	—	Rainy/dry	– Susceptible to bacterial wilt and bacterial leaf spot.
—	—	Rainy/dry	<ul style="list-style-type: none"> – Susceptible to viral diseases; – widely cultivated.
—	—	Rainy/dry	<ul style="list-style-type: none"> – Susceptible to viral diseases; – widely cultivated.
—	—	Rainy/dry	<ul style="list-style-type: none"> – Susceptible to viral diseases; – widely cultivated.
~100–120*	Moderate	Dry & rainy	<ul style="list-style-type: none"> – Susceptibility varies; – commonly preferred for fresh markets.
—	—	All seasons	– Resistant in trials (ToLCD, other diseases).
—	—	All seasons	– Lower virus severity/greater yield than Roma VF in trials.
—	—	All seasons	– Lower virus severity in trials.
—	—	All seasons	– Selected for viral tolerance.

Variety Name	Variety Type	Fruit Color	Fruit Shape	Yield (t/ha)
TLCV 15	Improved OP / hybrid	Red	Globe	Not specified
Roma VF	Open-pollinated	Red (plum)	Pear/oblong	Variable

4.2.4. Nursery, land preparation and transplanting

Successful tomato production begins with careful nursery management, proper land preparation, and correct transplanting practices. Healthy seedlings, well-prepared soil, and appropriate planting techniques ensure strong early growth, improve yield potential, and reduce susceptibility to pests and diseases. The table below summarizes key practices for each stage of tomato establishment.

Crop Cycle (days)	Storage Duration	Production Season	– Pest/Disease Tolerance/Resistance
–	–	Seasonal	– Grown in limited areas with tolerance to leaf curl viruses.
~80–90*	Good	Rainy/dry	– Resistance to Verticillium & Fusarium; – susceptible to ToLCD in W Africa.

Table 10: Tomato nursery, land preparation, and transplanting guidelines

Aspect	Key practices / Tips
Nursery Management	<ul style="list-style-type: none"> – Sow seeds in sterilized substrate or well-prepared nursery beds with organic matter. – Ensure well-drained, sunny nursery areas protected from heavy rain and pests. – Water regularly but moderately to prevent damping-off. – Seedlings ready for transplanting after 3–4 weeks, 10–15 cm tall with 4–6 true leaves. – Select uniform, disease-free seedlings for better field establishment.
Land Preparation	<ul style="list-style-type: none"> – Clear field of crop residues and weeds. - Plough and harrow to obtain fine tilth. – Use raised beds in waterlogged areas for drainage and root health. – Incorporate well-decomposed organic manure or compost to improve fertility and structure. – Implement crop rotation and soil health management to reduce soil-borne diseases.
Transplanting	<ul style="list-style-type: none"> – Transplant during cooler periods (early morning or late afternoon). – Respect spacing for air circulation, light, and disease prevention; adjust by variety/system. – Plant seedlings at the same depth as nursery; irrigate immediately. – Apply mulch to conserve moisture, suppress weeds, and regulate temperature. – Proper transplanting enhances early vigor, yield, and pest resilience.

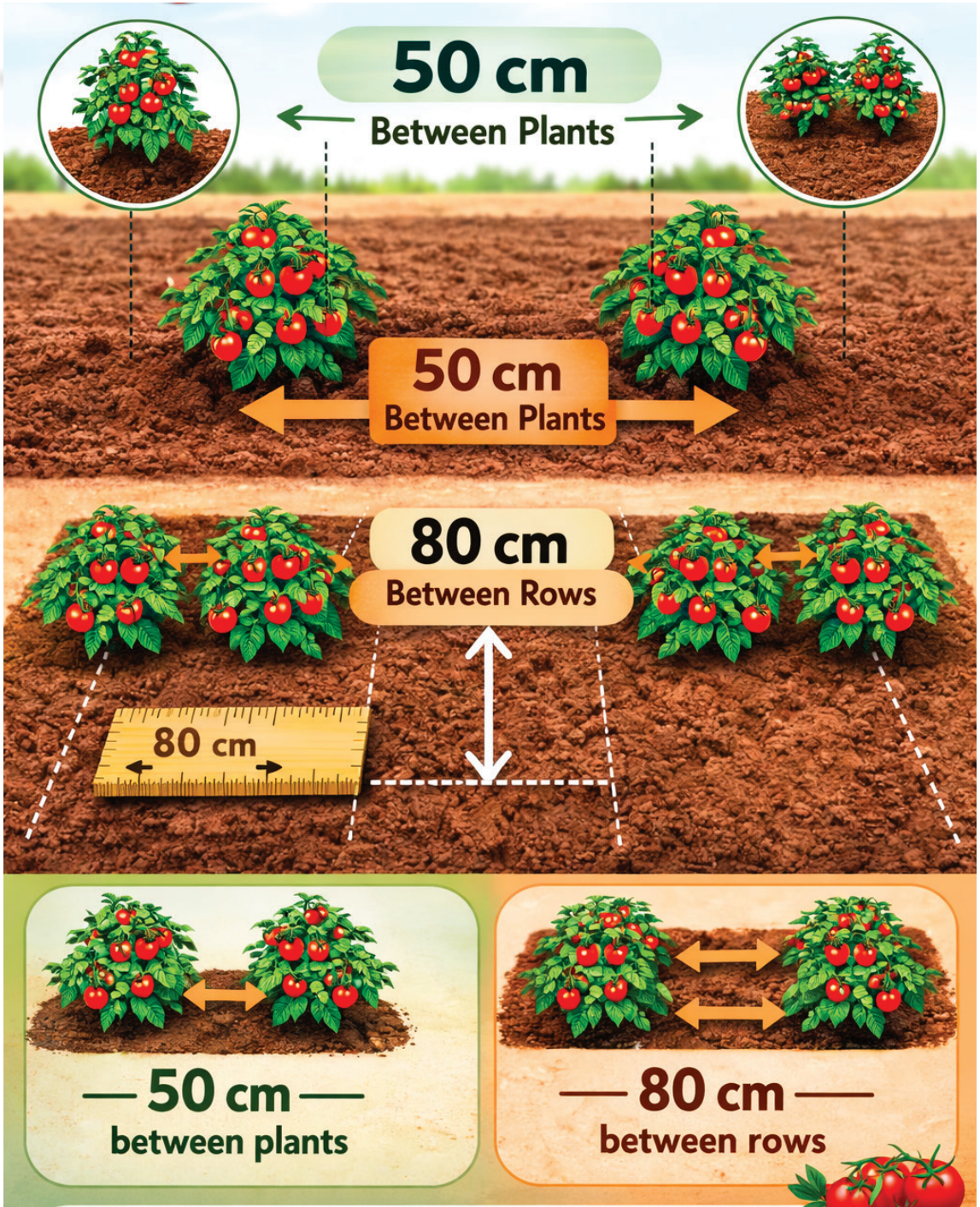


Figure 21: Tomato planting spacing for healthy growth

4.2.5. Nutrient and water management

Organic fertilizers play a key role in sustainable soil fertility management by improving soil structure, enhancing microbial activity, and providing essential nutrients for plant growth. Their effectiveness, however, largely depends on the method and timing of application.

Appropriate application techniques help ensure better nutrient availability, reduce losses through leaching or volatilization, and promote efficient uptake by crops. Depending on the type of organic fertilizer and the production system, different application methods can be used, including broadcasting, band placement, incorporation into the soil, and localized application near the root zone. The main methods of applying organic fertilizers are presented below.

Table 11: Nutrient and water requirements of tomato

Aspect	Description
Nutrient requirements	<ul style="list-style-type: none"> – Nitrogen (N): supports vegetative growth (excess may cause excessive foliage and increase pest susceptibility). – Phosphorus (P): promotes root development and early plant growth. – Potassium (K): essential for fruit development, firmness, and improved disease tolerance. – Calcium (Ca): helps prevent physiological disorders such as blossom-end rot.
Water requirements	<ul style="list-style-type: none"> – Tomatoes have moderate to high water requirements depending on the growth stage. Critical stages: flowering and fruit enlargement. – Total water needs: approximately 400–800 mm per crop cycle, depending on climatic conditions and the production system.

NB: Agroecological practices, such as mulching, organic amendments, and drip irrigation, enhance water and nutrient efficiency, reduce dependency on synthetic inputs, and support plant health. Properly managed nutrient and water supply strengthens plant resistance to pests and diseases, thereby contributing to sustainable and productive tomato cropping systems.

4.2.6. Major pests and diseases of tomato

Tomato production is constrained by numerous insect pests and diseases that can significantly reduce plant vigor, yield, and fruit quality. These biotic stresses affect different stages of crop development, from seedlings to fruiting plants. Insect pests mainly damage the crop through defoliation, sap feeding, or direct fruit attack, while many species also act as vectors of viral diseases. In

addition, tomatoes are highly susceptible to several fungal, bacterial, and viral pathogens that can cause severe epidemics under favorable environmental conditions. Effective management of these constraints requires early identification, regular field monitoring, and the implementation of integrated pest management (IPM) strategies combining cultural, biological, and, when necessary, chemical control measures. The main pests and diseases affecting tomato production are summarized in the table and figure below.

Table 12: Synthesis of major pests and diseases of tomato in West Africa: Symptoms and management and management

Category	Pests / Diseases	Scientific Name(s)	Symptoms and Damage	Key Management Notes
Pests	Cotton bollworm	<i>Helicoverpa armigera</i>	Larvae feed on leaves, flowers, and fruits, creating holes and causing direct fruit damage that reduces marketable yield.	<ul style="list-style-type: none"> – Monitor pest populations; – integrate biological, cultural, and chemical control methods.
	Egyptian cotton leafworm	<i>Spodoptera littoralis</i>	Larvae defoliate plants by feeding on leaves and sometimes fruits, leading to severe foliage loss and reduced plant vigor.	<ul style="list-style-type: none"> – Monitor regularly;
	Whiteflies	<i>Bemisia tabaci</i> , <i>Trialeurodes vaporariorum</i>	Sap-sucking causes leaf yellowing, wilting, and honeydew deposition that promotes sooty mold; also vectors viral diseases.	<ul style="list-style-type: none"> – Monitor populations; – conserve natural enemies;
	Aphids	<i>Aphis gossypii</i> , <i>Myzus persicae</i>	Colonies suck plant sap causing leaf curling, stunted growth, and honeydew accumulation; can transmit viruses.	<ul style="list-style-type: none"> – Promote natural predators; – apply biopesticides or selective insecticides when thresholds are exceeded.
	Spider mites	<i>Tetranychus urticae</i> , <i>Aculops lycopersici</i>	Feeding causes chlorotic spots, leaf bronzing, and premature leaf drop, especially under hot and dry conditions.	<ul style="list-style-type: none"> – Maintain adequate humidity; encourage predatory mites; – avoid excessive use of acaricides.

Category	Pests / Diseases	Scientific Name(s)	Symptoms and Damage	Key Management Notes
Diseases	Root-knot nematodes	<i>Meloidogyne</i> spp.	Formation of root galls leading to impaired water and nutrient uptake, stunted growth, and reduced yield.	<ul style="list-style-type: none"> – Practice crop rotation; – apply soil solarization; use resistant varieties where available.
	Fusarium wilt	<i>Fusarium oxysporum</i>	Progressive yellowing of lower leaves, vascular browning, wilting, and eventual plant death.	<ul style="list-style-type: none"> – Use resistant varieties; – rotate crops; – practice soil solarization.
	Verticillium wilt	<i>Verticillium dahliae</i>	Leaf yellowing, wilting, and vascular discoloration leading to reduced plant vigor and yield.	<ul style="list-style-type: none"> – Implement crop rotation; – apply soil amendments; use resistant cultivars.
	Early blight	<i>Alternaria solani</i>	Dark concentric lesions on leaves (“target spots”), leading to premature defoliation and reduced fruit production.	<ul style="list-style-type: none"> – Remove infected plant debris; apply biological control agents or fungicides when necessary.
	Late blight	<i>Phytophthora infestans</i>	Water-soaked lesions on leaves and stems that rapidly expand, causing plant collapse and fruit rot under humid conditions.	<ul style="list-style-type: none"> – Ensure proper drainage; – remove infected plants promptly; apply recommended fungicides.

Category	Pests / Diseases	Scientific Name(s)	Symptoms and Damage	Key Management Notes
	Bacterial wilt	<i>Ralstonia solanacearum</i>	Sudden wilting of plants without yellowing; brown discoloration in vascular tissues.	<ul style="list-style-type: none"> – Use healthy seedlings; – rotate crops; – avoid waterlogged conditions.
	Bacterial spot	<i>Xanthomonas spp.</i>	Small dark lesions on leaves and fruits that may enlarge and cause leaf drop and reduced fruit quality.	<ul style="list-style-type: none"> – Remove infected plants; – maintain field sanitation; – apply copper-based products if required.
	Tomato yellow leaf curl virus (TYLCV)	<i>TYLCV</i>	Leaf curling, chlorosis, stunted growth, and severe yield reduction.	<ul style="list-style-type: none"> – Control whitefly vectors; use resistant varieties; – remove infected plants.
	Tomato mosaic virus (ToMV)	<i>ToMV</i>	Mosaic patterns, leaf distortion, and reduced plant growth and fruit quality.	<ul style="list-style-type: none"> – Use disease-free seeds; – disinfect tools; – remove infected plants.



Helicoverpa armigera : a) larva b) damage symptom



Spodoptera armigera - Larva and damage symptom

Tetranychus urticae - Damage symptom



Phthorimaea absoluta: a) larva and b) damage symptom

Figure 22: Main insect pests of tomato and their characteristic damage



Symptom of *Xanthomonas* spp



Symptom of *Scelotium* spp



Tomato yellow leaf curl virus



Symptom of *Fusarium oxysporum*



Symptom of *Colletotrichum* spp



Symptom of *Ralstonia solanacearum*

Figure 23: Characteristic symptoms of the main diseases of tomato

4.2.7. Harvesting, post-harvest handling and storage

Proper harvesting and post-harvest management are essential to maintain tomato fruit quality and reduce post-harvest losses. Tomatoes are highly perishable and require careful handling from harvest to storage. Harvesting at the correct maturity stage, followed by appropriate sorting, packaging, and storage conditions, helps preserve fruit firmness, flavor, and market value. Maturity is determined by fruit color and firmness: fruits harvested at the breaker or turning stage (green to light pink or red) are suitable for distant markets, whereas fully red fruits are best for immediate local sale; fruits should be firm, well-sized, and free from cracks or pest damage.

Table 13: Harvesting, post-harvest handling and storage of tomato

Stage	Aspect	Key Practices / Recommendations	Purpose / Benefits
Harvesting	Timing	Harvest fruits when they are fully mature but still firm, at the stage when the fruit has developed its characteristic color (red, orange, or yellow depending on the variety).	Ensures good fruit quality and optimal flavor.
	Frequency	Harvest regularly every 2–3 days to prevent over-ripening and fruit drop.	Maintains fruit quality and reduces field losses.
	Method	Pick fruits by hand using gentle twisting or cut with pruning scissors; Avoid pulling the fruit.	Prevents damage to the fruit and plant, maintaining future productivity.
Post-Harvest Handling	Sorting	Sort fruits according to maturity, size, and absence of visible damage or disease; Remove damaged or diseased fruits.	Reduces post-harvest losses and improves market quality.
	Cleaning	Remove soil and debris gently; Avoid excessive washing unless fruits are properly dried afterward.	Prevents fungal growth and maintains fruit quality.
	Packaging	Use ventilated crates or baskets and avoid excessive stacking.	Reduces bruising and allows proper air circulation.
	Temperature	Store at 12–18 °C; Avoid temperatures below 10 °C to prevent chilling injury.	Preserves flavor, texture, and shelf life.

Stage	Aspect	Key Practices / Recommendations	Purpose / Benefits
Storage	Humidity	Maintain 85–90 % relative humidity.	Prevents fruit dehydration and shriveling.
	Storage duration	Tomatoes can be stored 1–2 weeks under good conditions; Longer storage possible in cool rooms or ventilated facilities.	Extends shelf life and reduces post-harvest losses.
	Agroecological tips	Store in shaded, well-ventilated areas and away from ethylene-producing fruits such as bananas.	Slows ripening and maintains fruit quality with low energy input.

4.2.8. Key extension messages

The principal extension messages in tomato production are presented in a table 14.

Table 14: key message for extension

Aspect	Key messages / Practices
Variety & Seed Selection	<ul style="list-style-type: none"> – Choose high-yielding, disease-resistant varieties suited to your area. – Use certified seeds or healthy seedlings.
Land Preparation & Planting	<ul style="list-style-type: none"> – Prepare well-drained, fertile soil. – Plant in rows with proper spacing (50–60 cm between plants, 70–90 cm between rows). – Transplant carefully to avoid root damage.
Water & Nutrient Management	<ul style="list-style-type: none"> – Water regularly, especially during flowering and fruiting. Avoid overwatering; water in the morning. Apply a mix of organic compost and balanced fertilizers.
Pest & Disease Management	<ul style="list-style-type: none"> – Inspect plants regularly. – Promote natural enemies and use biological control. – Apply pesticides safely and only when necessary.
Harvesting & Post-Harvest Handling	<ul style="list-style-type: none"> – Harvest when fruits are fully colored and firm. Handle gently to avoid bruising. – Store in ventilated crates in shaded, cool areas.
Agroecological Practices	<ul style="list-style-type: none"> – Mulch to conserve moisture and reduce weeds. Rotate crops to prevent soil-borne diseases. – Use companion planting (e.g., basil, marigold) to reduce pests.

4.3. Onion - *Allium cepa*

4.3.1. Crop description and importance

Onion is a bulb-forming herbaceous biennial in the amaryllis family (Amaryllidaceae). Native to southwestern Asia, it is now cultivated worldwide as one of the most important vegetable crops, valued for its distinctive flavor, nutritional uses, and cultural significance in cuisines across the globe.



Figure 24: *Allium cepa* - Vegetative morphology and bulbs

4.3.2. Agro-ecological requirements

Successful onion production depends largely on the suitability of environmental conditions, including climate, soil characteristics, and altitude. These factors strongly influence seed germination, vegetative growth, bulb formation, and final yield. Onion is particularly sensitive to temperature, day length (photoperiod), and soil conditions because of its shallow root system and specific requirements for bulb development. Understanding the key agro-ecological requirements of the crop allows farmers and extension agents to select appropriate production areas, adopt suitable management practices, and choose varieties adapted to local conditions, thereby improving productivity and bulb quality.

Table 15: Agro-ecological requirements for onion production

Agro-ecological factor	Key conditions	Importance for onion growth
Climate requirements	<ul style="list-style-type: none"> – Moderate temperatures between 13–24 °C; optimal germination at 20–25 °C. – Bulb formation is influenced by photoperiod and temperature. – High temperatures and drought reduce bulb size, while prolonged cold may induce bolting. 	<ul style="list-style-type: none"> – Ensures proper germination, vegetative growth, and bulb development. – Selecting varieties adapted to day length (short-day or long-day) is essential for successful production.
Soil requirements	<ul style="list-style-type: none"> – Fertile, well-drained sandy loam or loamy soils with good structure. – Optimal soil pH: 6.0–7.0. – High organic matter content recommended. 	<ul style="list-style-type: none"> – Promotes proper bulb expansion, root development, and nutrient availability. – Poor drainage or heavy clay soils increase the risk of waterlogging and diseases.
Altitude	<ul style="list-style-type: none"> – Adapted from sea level up to about 2,000 m above sea level, depending on variety and climate. 	<ul style="list-style-type: none"> – Cooler highland areas in tropical regions often favor onion production, while appropriate variety selection ensures adaptation to local temperature and photoperiod conditions.

4.3.3. Variety and seed selection

The selection of suitable onion varieties depends on climatic conditions, photoperiod requirements, market demand, and tolerance to pests and diseases. Onion cultivars are generally classified as short-day, intermediate-day, or long-day types based on the day length needed to initiate bulb formation, with short-day varieties being most adapted to tropical and subtropical regions. Varieties also differ in bulb color, shape, pungency, maturity period, and storage capacity, which influence market preference and post-harvest value (Table 16). Choosing high-yielding and well-adapted varieties can significantly improve productivity and reduce crop losses. In addition, the use of high-quality seeds with high purity and germination rates (above 80–85%) is essential for uniform crop establishment. Certified and properly stored seeds help prevent seed-borne diseases and ensure vigorous seedling development.



Table 16: Characteristic of some onion varieties cultivated in West Africa

Variety	Cycle to Maturity (days)	Yield potential (t/ha)	Bulb colour	Bulb shape
Blanc de Galmi	120–140	20–30	White	Round
Blanc de Soumarana	120–180	30–40	White	Oval
Jaune Hâtif de Valence	130–150	30–40	Pale yellow	Oval-long
Violet de Galmi	120–130	40–45	Violet	Round and flat at the extremities
Local malanville	120-125	28	Deep violet	Round
Gandiol+	110–115	40–45		Flattened globe Medium size
Super Yali	95–115	–		Globe shaped with thin collars
Noflaye	105–110	25–40		Flattened
Rouge de Tana	100–105	Data not specific	Red	Thick dishes
Local Gambian Varieties	Varies by ecotype	Moderate		
Red Creole	130-160	15-25	Red	Round
Texas Grano/ Hybrid Reds	Not listed	High		

Storability	Others characteristics
Medium	<ul style="list-style-type: none"> - Susceptible to Fusarium, Aspergillus, - Xanthomonas and the pink root rot; - Susceptible to Thrips and Termites; - Resistant to the root-knot nematode.
Medium	<ul style="list-style-type: none"> - Susceptible to Fusarium, Aspergillus, Xanthomonas and the pink root, rot, - Susceptible to thrips and termites - Resistant to the root-knot, nematode; - Good deshydration, aptitude.
Medium	<ul style="list-style-type: none"> - Susceptible to Fusarium, to Sclerotinium and to Aspergillus - Susceptible to Thrips - Poor early flowering
Good	<ul style="list-style-type: none"> - Susceptible to Fusarium, Aspergillus Xanthomonas and to the pink root rot - Resistant to the root-knot nematode - Very early maturing - Very hot taste appreciated by consumers
Poor	<ul style="list-style-type: none"> - Tolerant to an excess of water during - The growing season
Good	<ul style="list-style-type: none"> - Flattened bulbs - Good uniformity and storage
Good	<ul style="list-style-type: none"> - Good drought tolerance and storage potential; tolerant to several stresses
Good	<ul style="list-style-type: none"> - Uniform bulb shape and size - Good storage performance
-	<ul style="list-style-type: none"> - Local commercial variety
Moderate	<ul style="list-style-type: none"> - Adapted to local climate - Moderate yield and storage
Poor	<ul style="list-style-type: none"> - Tolerance to the pink root rot - Susceptible to Thrips
-	<ul style="list-style-type: none"> - Commercial varieties with good market demand

4.3.4. Nursery, land preparation and transplanting

Proper nursery management, land preparation, and careful transplanting are essential steps for successful onion production (Table 17; Figure 25). Following these practices ensures healthy seedlings, good establishment in the field, and optimum bulb growth, ultimately leading to higher yields and reduced crop losses.

Table 17: Nursery, land preparation, and transplanting practices for Onion

Stage	Key practices / Tips
Nursery	<ul style="list-style-type: none"> – Sow seeds thinly in well-drained, fertile nursery beds – Cover lightly with soil and water gently – Maintain consistent moisture and protect seedlings from pests – Seedlings are ready for transplanting after 4–6 weeks, when 10–15 cm tall with several true leaves.
Land preparation	<ul style="list-style-type: none"> – Choose well-drained, fertile soil with pH 6–7 – Remove weeds and debris, plow or dig to fine tilth – Incorporate organic compost or manure – Use raised beds or ridges to improve drainage
Transplanting	<ul style="list-style-type: none"> – Transplant seedlings carefully to avoid root damage – Space plants 10–15 cm apart in rows, with 30–40 cm between rows – Transplant in cooler parts of the day – Water immediately after transplanting and monitor seedlings for pests and stress

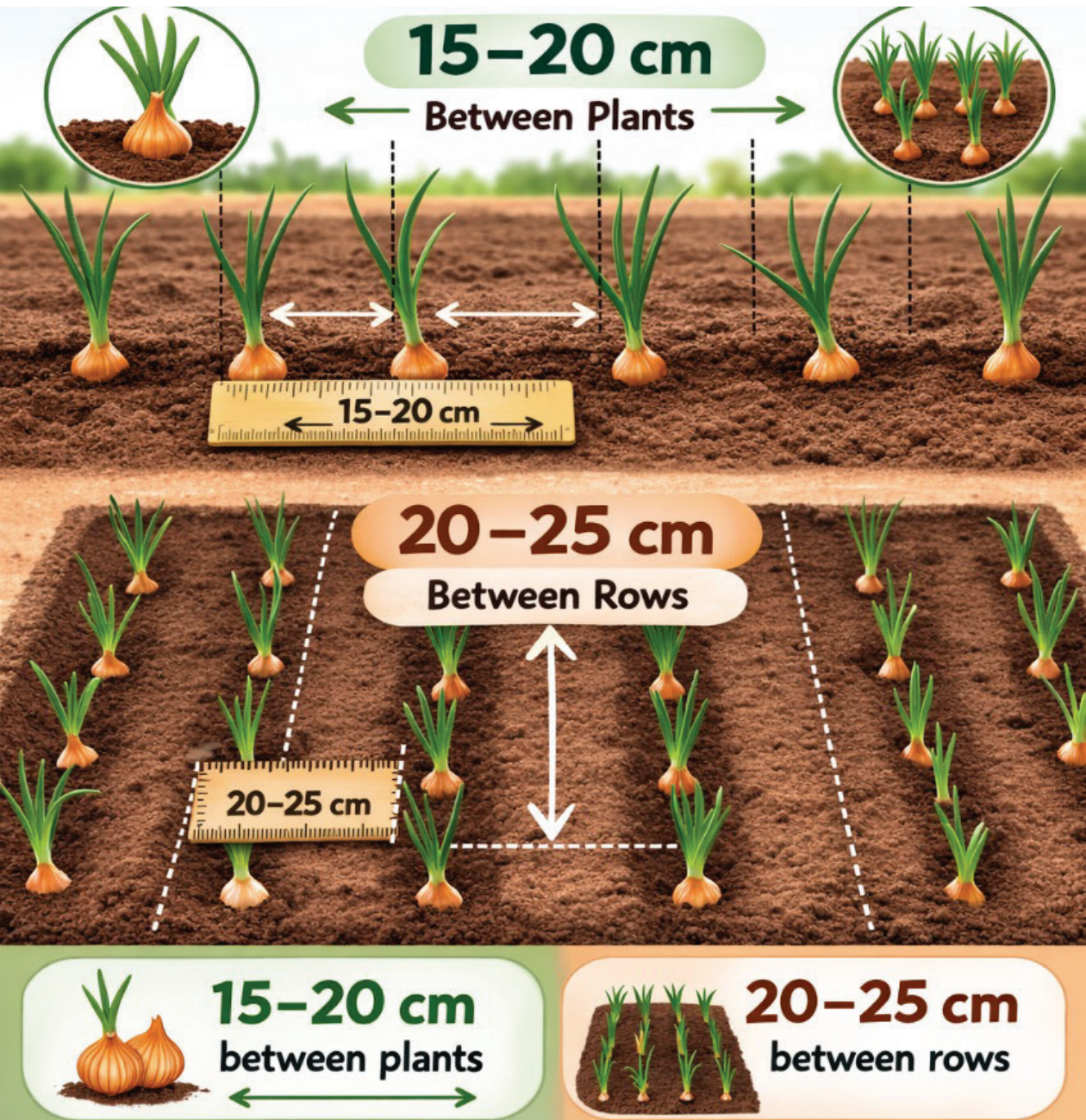


Figure 25: Onion planting spacing for healthy growth and optimal yield

4.3.5. Nutrient and water management

Proper nutrient and water management are essential for healthy onion growth and optimal bulb yield. Applying the right fertilizers and ensuring consistent, adequate irrigation help maintain plant vigor, improve bulb size, and reduce the risk of pests and diseases. The table below summarizes key practices farmers should follow.

Table 18: Nutrient and water management practices for Onion

Aspect	Key practices / Tips
Nutrient Management	<ul style="list-style-type: none"> – Apply well-decomposed organic compost or manure before planting. – Supplement with N, P, K fertilizers according to soil needs. – Avoid excessive nitrogen to prevent too much leaf growth. – Use foliar micronutrients (Zn, Mg, B) if deficient. – Conduct soil tests to guide fertilizer application.
Water Management	<ul style="list-style-type: none"> – Provide regular, adequate irrigation, especially during bulb initiation and enlargement. – Use light, frequent watering rather than heavy irrigation. – Apply mulch to conserve moisture and control weeds. – Ensure proper drainage to avoid standing water and reduce disease risk.

4.3.6. Major pests and diseases

In West Africa, onion is susceptible to a wide range of insect pests as well as fungal, bacterial, and viral diseases, all of which can cause significant yield losses and reduce bulb quality if not properly managed. These pests and diseases are summarized in the table 19 and figure 26 -27.

Table 19: Synthesis of major pests and diseases of Onion in West Africa: Symptoms and management

Category	Pest / Disease	Scientific Name	Symptoms / Damage	Management Tips
Insect Pests	Onion thrips	<i>Thrips tabaci</i>	<ul style="list-style-type: none"> – Silvery streaks on leaves; – Reduced photosynthesis; – Smaller bulbs 	<ul style="list-style-type: none"> – Monitor regularly; – Remove plant residues; – Encourage natural enemies; – Apply insecticides only if necessary
	Cutworms	<i>Agrotis spp.</i>	<ul style="list-style-type: none"> – Seedlings cut at soil level 	<ul style="list-style-type: none"> – Handpick or trap; – Maintain weed-free fields; – Use physical barriers around seedlings
	Bulb mites	<i>Rhizoglyphus spp.</i>	<ul style="list-style-type: none"> – Bulb decay, predisposition to fungal infections 	<ul style="list-style-type: none"> – Use clean seed bulbs; – Store bulbs in dry conditions; – Rotate crops
	Leafminers	<i>Liriomyza spp.</i>	<ul style="list-style-type: none"> – Mines in leaves, reduced leaf area 	<ul style="list-style-type: none"> – Remove infested leaves; – Encourage parasitoids; – Apply biopesticides if needed
	Beet armyworm	<i>Spodoptera exigua</i>	<ul style="list-style-type: none"> – Larvae feed on leaves, creating irregular holes; – Severe defoliation reduces photosynthesis and bulb size; – May attack seedlings 	<ul style="list-style-type: none"> – Remove and destroy infested leaves; – Keep fields weed-free; – Rotate crops; – Encourage natural enemies; – Apply selective insecticides only if threshold reached
Diseases	Fusarium wilt	<i>Fusarium oxysporum f. sp. cepae</i>	<ul style="list-style-type: none"> – Yellowing and wilting of leaves; stunted growth 	<ul style="list-style-type: none"> – Use disease-free seeds; – Rotate crops; – Solarize soil if possible

Category	Pest / Disease	Scientific Name	Symptoms / Damage	Management Tips
Diseases	Anthracnose	<i>Colletotrichum spp</i>	<ul style="list-style-type: none"> – Sunken dark lesions on leaves and bulbs; – May lead to leaf dieback and bulb rot in storage 	<ul style="list-style-type: none"> – Remove and destroy infected plant parts; – Avoid overhead irrigation; – Use tolerant varieties; – Apply recommended fungicides; – Sanitize tools and storage areas
	Purple blotch	<i>Alternaria porri</i>	<ul style="list-style-type: none"> – Purplish lesions on leaves and stems 	<ul style="list-style-type: none"> – Remove infected debris; – Apply fungicides if severe; – Avoid overhead watering
	Downy mildew	<i>Peronospora destructor</i>	<ul style="list-style-type: none"> – Pale patches on leaves; – Fuzzy growth under humid conditions 	<ul style="list-style-type: none"> – Ensure good ventilation; – Remove infected leaves; – Use fungicides when necessary
	Bacterial soft rot	<i>Erwinia carotovora</i>	<ul style="list-style-type: none"> – Bulb decay, especially in storage 	<ul style="list-style-type: none"> – Use clean bulbs; – Avoid waterlogging; – Store in dry conditions
	Bacterial blight	<i>Pseudomonas spp.</i>	<ul style="list-style-type: none"> – Water-soaked lesions on leaves; stunted growth 	<ul style="list-style-type: none"> – Sanitize tools; – Remove infected plants; – Apply copper-based bactericides if needed
	Onion yellow dwarf virus	OYDV	<ul style="list-style-type: none"> – Stunted plants; – Yellowing of leaves; – Reduced bulb size 	<ul style="list-style-type: none"> – Use virus-free seeds; – Remove infected plants; – Control aphid vectors
	Leek yellow stripe virus	LYSV	<ul style="list-style-type: none"> – Chlorosis and reduced vigor 	<ul style="list-style-type: none"> – Plant resistant varieties; – Control aphid vectors; – Remove infected plants



Spodoptera exigua – a) larva and b) damage



Thrips tabaci – a) adult and b) damage

<https://extension.usu.edu/planthealth/research/onion-thrips>

Figure 26 : Main insect pests of onions and their characteristic damage



Colletotrichum spp



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Fusarium Oxysporum F.Sp. Cepae



Onion yellow dwarf virus

Figure 27 : Characteristic symptoms of the main onion diseases

4.3.7. Harvesting, post-harvest handling and storage

Proper harvesting, handling, and storage of onion are essential to maintain bulb quality, reduce post-harvest losses, and ensure longer shelf life. The following table summarizes key practices that farmers should follow at each stage, from field harvesting to storage.

Table 20: Onion harvesting and storage guidelines

Aspect	Key practices / Tips
Harvesting	<ul style="list-style-type: none"> – Harvest when foliage starts to yellow and fall over, indicating bulb maturity. – Use a hoe or fork to lift bulbs carefully to avoid damage. – Dry bulbs in the shade for a few hours before moving to curing or storage.
Post-Harvest Handling	<ul style="list-style-type: none"> – Remove excess soil and damaged leaves. – Sort bulbs by size and quality, discarding diseased or damaged ones. – Avoid washing unless necessary. – Handle gently to prevent bruising.
Storage	<ul style="list-style-type: none"> – Store in well-ventilated, dry, shaded areas. – Ideal temperature: 12–20 °C; humidity: 65–75%. – Use mesh bags, crates, or ventilated bins. – Avoid storing near potatoes or wet crops. – Inspect regularly and remove any rotten or sprouting bulbs.

4.3.8. Key extension messages

Successful onion production depends on good practices at every stage, from variety selection to harvesting and storage. The following table summarizes the key messages and recommendations that farmers should follow to improve yield, reduce losses, and maintain bulb quality.

Table 21: Key extension messages for onion production

Aspect	Key messages / Practices
Variety & Seed Selection	<ul style="list-style-type: none"> – Use high-yielding, disease-resistant varieties suited to the local climate. – Use certified seeds or healthy seedlings.
Land Preparation & Planting	<ul style="list-style-type: none"> – Prepare well-drained, fertile soil. – Plant in rows with proper spacing. – Handle seedlings carefully during transplanting.

Aspect	Key messages / Practices
Water & Nutrient Management	<ul style="list-style-type: none"> – Provide regular irrigation, especially during bulb initiation and enlargement. – Apply balanced fertilizers and organic compost. – Avoid overwatering.
Pest & Disease Management	<ul style="list-style-type: none"> – Inspect crops regularly for pests and diseases. – Promote natural enemies. – Apply chemical control only when necessary, following safety guidelines.
Harvesting & Post-Harvest Handling	<ul style="list-style-type: none"> – Harvest when foliage yellows. – Sort, clean, and handle bulbs gently. – Store in well-ventilated, dry, shaded areas.
Agroecological Practices	<ul style="list-style-type: none"> – Rotate crops to prevent soil-borne diseases. – Use mulch to conserve moisture and suppress weeds. – Employ companion planting to reduce pest pressure naturally.

4.4. Pepper - *Capsicum spp.*

4.4.1. Description and importance

Capsicum (Figure 28) belongs to the Solanaceae family and is closely related to important crops such as tomatoes and potatoes. It includes a wide range of varieties, from mild and crunchy bell peppers (*Capsicum spp.*) to highly pungent types such as chili peppers. The genus originated in Central and South America, where it has been cultivated for thousands of years before spreading worldwide. Capsicum fruits are rich in bioactive compounds, including carotenoids, phenolic compounds, and essential vitamins. In spicy varieties, the characteristic heat is due to capsaicinoids, which are responsible for their pungency.



Figure 28: Capsicum spp., a) plant morphology, and fruit (b,c)

4.4.2. Agro-ecological requirements

Capsicum production is strongly influenced by agro-ecological conditions, which determine plant growth, yield, and fruit quality. Understanding these requirements is essential for selecting suitable production areas and adopting appropriate management practices. Key factors such as climate, water availability, soil characteristics, light, and altitude play a crucial role in ensuring optimal crop performance and sustainable production.

Table 22: Agro-ecological requirements for *capsicum* production

Agro-ecological factor	Key conditions	Importance for capsicum growth
Climate requirements	<ul style="list-style-type: none"> – Warm temperatures between 20–30 °C; sensitive below 15 °C and above 35 °C. – Requires moderate humidity and is highly sensitive to frost. – Optimal under tropical and subtropical climates with good sunlight exposure. 	<ul style="list-style-type: none"> – Ensures optimal germination, flowering, and fruit set. – Extreme temperatures can cause flower drop, poor fruit development, and reduced yield.
Soil requirements	<ul style="list-style-type: none"> – Well-drained, fertile sandy loam or loamy soils. – Rich in organic matter. – Optimal soil pH: 5.5–7.0. 	<ul style="list-style-type: none"> – Supports root development, nutrient uptake, and plant vigor. – Poor drainage increases susceptibility to diseases and limits productivity.
Altitude	<ul style="list-style-type: none"> – Can be grown from lowlands up to about 2,000 m, depending on variety and climate. 	<ul style="list-style-type: none"> – Influences temperature conditions and crop adaptation. – Proper variety selection ensures optimal performance across different altitudes.

4.4.3. Variety and seed selection

The selection of appropriate Capsicum varieties and high-quality seeds is a crucial step for achieving optimal yield, fruit quality, and resilience to biotic and abiotic stresses. Capsicum includes a wide diversity of species and cultivars, mainly *Capsicum annuum*, *Capsicum chinense*, and *Capsicum frutescens*, which differ in fruit size, shape, color, pungency, and adaptability to specific

agroecological conditions. The choice of variety should therefore be guided by market preferences (fresh consumption, processing, or drying), climatic suitability, and resistance or tolerance to major pests and diseases such as viruses, anthracnose, and insect pests.

In addition, selecting certified, healthy, and viable seeds is essential to ensure good germination, uniform plant establishment, and reduced risk of seed-borne diseases. Seeds

should be sourced from reliable suppliers or improved varieties developed by research institutions, as these often offer better performance, higher productivity, and improved resistance traits. In agroecological systems, farmers may also use locally adapted varieties, which are often more resilient to environmental stresses and require fewer external inputs. Overall, the combined choice of suitable varieties and high-quality seeds constitutes a fundamental component of sustainable Capsicum production systems.



Table 23: Characteristic of some capsicum varieties cultivated in West Africa

Variety Name	Variety Type	Fruit Color	Fruit Shape	Yield (t/ha)
Bird's Eye Chili (Piment oiseau)	Hot pepper	Red (sometimes green)	Small, elongated	3–8
Scotch Bonnet	Hot pepper	Red / Yellow / Orange	Round, wrinkled	5–10
Cayenne	Hot pepper	Red	Long, thin	6–12
Local Chili (C. frutescens types)	Hot pepper	Red	Small, pointed	2–6
Habanero (local types)	Hot pepper	Orange / Red	Lantern-shaped	5–9
California Wonder	Sweet pepper	Green → Red	Blocky (bell shape)	10–20
Yolo Wonder	Sweet pepper	Green → Red	Blocky	8–18
African Bird Pepper (Piri-piri)	Hot pepper	Red	Small, thin	3–7
Kpakpo Shito (Ghana type)	Mild-hot pepper	Green / Red	Small, round	4–8

4.4.4. Nursery, land preparation and transplanting

The table below summarizes the key steps and best practices for successfully establishing a capsicum crop, from raising healthy seedlings in the nursery to preparing the field and transplanting for optimal growth and yield.

Table 24: Nursery, land preparation, and transplanting practices for *Capsicum*

Stage	Key practices / Tips
Nursery	<ul style="list-style-type: none"> – Sow seeds thinly in well-drained, raised nursery beds enriched with compost or FYM – Treat seeds before sowing to prevent diseases – Cover lightly with fine soil and water gently – Maintain consistent moisture and provide partial shade if needed – Protect seedlings from damping-off and pests – Seedlings are ready in 25–35 days at 4–5 true leaf stage (10–15 cm tall)

Crop Cycle (days)	Storage Duration	Production Season	Pest/Disease Tolerance/Resistance
70–90	Short (1–2 weeks fresh)	Year-round (irrigated)	High tolerance to heat and pests
90–120	Medium (2–3 weeks)	Rainy & dry season	Moderate resistance, sensitive to excess moisture
80–100	Good (drying possible)	Mainly dry season	Moderate tolerance, good adaptability
75–95	Short	Year-round	Well adapted to local conditions
90–110	Medium	Rainy season preferred	Moderate resistance
90–120	Medium (2–3 weeks)	Dry season (irrigation)	Sensitive to pests/diseases
85–110	Medium	Dry season	Moderate resistance
70–90	Short	Year-round	High tolerance to heat and drought
80–100	Short	Rainy season	Moderate tolerance

Land preparation

- Choose well-drained loamy soil with pH 6.0–7.0
- Plough 2–3 times to achieve fine tilth and remove weeds/debris
- Incorporate 20–25 tons FYM or compost per hectare
- Apply recommended basal fertilizers based on soil test
- Prepare raised beds or ridges and furrows for good drainage

Transplanting

- Transplant healthy seedlings (25–35 days old) carefully to avoid root damage
- Maintain spacing of 45 × 45 cm or 60 × 45 cm depending on variety
- Transplant during late afternoon or cloudy weather
- Water immediately after transplanting
- Provide light shade if necessary and replace missing plants within a week
- Avoid deep planting; keep collar above soil level



Figure 29: Capsicum Onion planting spacing for healthy growth and optimal yield

4.4.5. Nutrient and water management

Proper nutrient and water management is essential for achieving high yield and quality in capsicum cultivation. Balanced application of macro- and micronutrients supports healthy plant growth, flowering, and fruit development, while preventing disorders such as Blossom end rot. Efficient irrigation practices, including regular and uniform watering, help maintain optimal soil moisture, reduce plant stress, and improve productivity. Integrating fertigation, mulching, and proper drainage ensures sustainable and efficient crop management.

Table 25: Nutrient and water management practices for *Capsicum*

Aspect	Key practices / Tips
Nutrient Management	<ul style="list-style-type: none"> – Apply well-decomposed compost (20–25 t/ha) before transplanting. – Apply balanced N, P, K fertilizers based on crop stage (more N in vegetative, more K in fruiting). – Split fertilizer doses through fertigation or top dressing. – Avoid excess nitrogen to prevent excessive vegetative growth and poor fruiting. – Apply calcium (e.g., calcium nitrate) to prevent Blossom end rot. Use foliar sprays of micronutrients (Zn, Mg, B) every 10–15 days if needed. – Maintain soil pH between 6.0–6.8 for optimal nutrient uptake. – Conduct soil testing to guide precise fertilizer application.
Water Management	<ul style="list-style-type: none"> – Provide regular and uniform irrigation, especially during flowering and fruit development stages. – Use drip irrigation for efficient water use and fertigation. – Apply light and frequent irrigation rather than heavy watering. – Maintain consistent soil moisture to avoid fruit cracking and disorders. – Use mulching to conserve moisture and control weeds. – Ensure proper drainage to prevent waterlogging and root diseases. – Avoid irregular watering to reduce risks of Blossom end rot. – Adjust irrigation based on crop stage (higher during fruiting stage).

4.4.6. Major pests and diseases

Capsicum production is constrained by a wide range of pests and diseases (Table 26). The most economically damaging problems in capsicum are whiteflies and viral diseases, followed by fruit borers and fungal diseases. These can cause significant yield and income losses if not managed early. Farmers should prioritize regular monitoring, vector control, and good field sanitation as part of an integrated pest management (IPM) strategy

Table 26: Major pests and diseases of *Capsicum* in West Africa – symptoms and management tips

Category	Pest/Disease Name	Scientific Name	Symptoms/ Damage	Management / Control Measures
Pest	Aphids	<i>Aphis gossypii</i>	Leaf curling, yellowing, honeydew, virus transmission	Neem sprays, biological control, avoid excess nitrogen
	Whiteflies	<i>Bemisia tabaci</i>	Yellowing, stunting, virus transmission	Sticky traps, nets, resistant varieties
	Thrips	<i>Thrips tabaci</i>	Silvering of leaves, flower drop	Biopesticides, field sanitation
	Helicoverpa armigera	<i>Helicoverpa armigera</i>	Fruit boring, internal damage	Pheromone traps, handpicking, Bt
	Spider mites	<i>Tetranychus urticae</i>	Leaf speckling, webbing	Maintain humidity, use acaricides
Disease	Phytophthora blight	<i>Phytophthora capsici</i>	Wilting, stem and fruit rot	Good drainage, crop rotation
	Anthraco-nose	<i>Colletotrichum</i> spp.	Sunken dark lesions on fruits	Fungicides, remove infected fruits
	Bacterial wilt	<i>Ralstonia solanacearum</i>	Sudden wilting	Resistant varieties, rotation
	Bacterial leaf spot	<i>Xanthomonas</i> spp.	Leaf spots, defoliation	Certified seeds, copper sprays
	Chili leaf curl virus	<i>Virus (Begomovirus group)</i>	Leaf curling, stunting	Control whiteflies, rogue plants



Aphis gossypii



Damage of aphid



Helicoverpa armigera



© Stephen Ausmus

Bemisia tabaci

Figure 30: Main insect pests of capsicum and their characteristic damage



Colletotrichum spp.



Chili leaf curl virus



Bacterial wilt

Figure 31: Characteristic symptoms of the main diseases of capsicum

4.4.7. Harvesting, post-harvest handling and storage

Proper harvesting and post-harvest handling are crucial to maintain the quality and market value of capsicum. Harvesting at the right maturity stage ensures better shelf life and consumer acceptance. Careful handling, grading, and packaging help reduce physical damage and post-harvest losses. Maintaining optimal storage conditions, including appropriate temperature and humidity, significantly extends shelf life while preserving freshness and nutritional quality.

Table 27: Harvesting, post-harvest handling and storage of *capsicum*

Aspect	Key practices / Tips
Harvesting	<ul style="list-style-type: none"> – Harvest fruits at mature green stage for longer shelf life or at full color stage (red/yellow) for better taste and nutrition. – First harvest usually occurs 60–90 days after transplanting depending on variety. – Pick fruits manually using a sharp knife or scissors to avoid plant damage. – Harvest at regular intervals (3–7 days) to encourage continuous fruiting. – Avoid harvesting during wet conditions to reduce disease spread.
Post-Harvest Handling	<ul style="list-style-type: none"> – Handle fruits carefully to avoid bruising and mechanical damage. – Remove damaged, diseased, or overripe fruits during sorting. – Clean fruits gently and dry before packing. – Grade fruits based on size, color, and quality. – Use ventilated crates or cartons for packaging. – Avoid direct sunlight exposure after harvest.
Storage	<ul style="list-style-type: none"> – Store capsicum at 7–10°C with 85–95% relative humidity. – Avoid temperatures below 7°C to prevent chilling injury. – Under proper storage, fruits can last 2–3 weeks. – Maintain good ventilation to reduce moisture buildup and decay. – Do not store with ethylene-producing fruits (like Banana) as it accelerates ripening.

4.4.8. Key extension messages

Key extension messages for capsicum focus on adopting improved cultivation practices from nursery to marketing. Using quality seedlings, balanced nutrition, efficient irrigation, and proper pest management ensures healthy crop growth and higher yields. Timely harvesting and careful post-harvest handling help maintain quality and increase market value, ultimately improving farmers' income.

Table 28: Key extension messages for *Capsicum* cultivation

Aspect	Key practices / Tips
Variety Selection	<ul style="list-style-type: none"> – Choose high-yielding, disease-resistant varieties suitable for local climate. – Prefer hybrid varieties for better productivity and uniform fruits.
Nursery Management	<ul style="list-style-type: none"> – Raise healthy seedlings in a well-prepared nursery or pro-trays. – Use sterilized growing media to prevent diseases. – Transplant healthy, 4–6-week-old seedlings.
Land Preparation & Planting	<ul style="list-style-type: none"> – Prepare well-drained, fertile soil rich in organic matter. – Maintain proper spacing for good aeration and growth. – Use mulching to conserve moisture and control weeds.
Nutrient Management	<ul style="list-style-type: none"> – Apply balanced fertilizers based on soil test results. – Split fertilizer doses and use fertigation if possible. – Avoid excess nitrogen; ensure adequate calcium to prevent Blossom end rot.
Water Management	<ul style="list-style-type: none"> – Provide regular and uniform irrigation, especially during flowering and fruiting. – Use drip irrigation for efficient water use. – Avoid water stress and waterlogging.
Weed Management	<ul style="list-style-type: none"> – Control weeds early to reduce competition. – Use mulching or manual weeding.
Pest & Disease Management	<ul style="list-style-type: none"> – Regularly monitor for pests and diseases. – Use integrated pest management (IPM) practices. – Remove and destroy infected plants or fruits.
Harvesting	<ul style="list-style-type: none"> – Harvest at proper maturity stage (green or fully colored). – Pick fruits regularly to promote continuous yield.
Post-Harvest Handling	<ul style="list-style-type: none"> – Handle fruits carefully to avoid damage. – Grade and pack properly for better market value.
Marketing	<ul style="list-style-type: none"> – Sell produce based on size, color, and quality grading. – Target local and high-value markets for better returns.

4.5. Integrated pest and disease management (IPDM)

4.5.1. Pest and disease identification

Identifying pests and diseases is essential for effective crop protection and sustainable agricultural production. It involves recognizing harmful organisms such as insects, mites, nematodes, fungi, bacteria, and viruses, as well as interpreting the symptoms and signs they cause on plants. Accurate identification is crucial because each pest or pathogen requires specific management strategies; misidentification may result in ineffective control measures, unnecessary pesticide use, higher production costs, and environmental risks.

Pest identification relies on observing morphological characteristics and damage patterns, including body shape, size, color, presence of wings, mouthparts, and the pest's developmental stage. Different feeding behaviors produce distinct damage symptoms, such as defoliation from chewing insects or leaf yellowing and curling from sap-sucking insects. Disease identification, on the other

hand, focuses on diagnosing abnormal plant conditions caused by pathogens. It requires distinguishing between symptoms (plant responses such as chlorosis, wilting, or necrosis) and signs (physical presence of the pathogen, such as mycelium or bacterial exudates).

The diagnostic process generally involves field observation, proper sample collection, identification using field guides or taxonomic keys, and sometimes laboratory confirmation. Accurate diagnosis ultimately supports informed decision-making and the implementation of appropriate and economically justified pest and disease management strategies.

4.5.2. Cultural practices

Cultural methods are a key component of Integrated Pest Management (IPM). They involve modifying farming practices and the crop environment to reduce the development and spread of pests and diseases while improving plant health and resilience. The main cultural practices used for pest and disease management are presented in table 22.

Table 29: Main cultural practices for pest and disease management in crops

Cultural Practice	Description and purpose
Crop rotation	Alternating different crops on the same field over successive seasons to break the life cycle of crop-specific pests and pathogens, particularly soil-borne fungi, nematodes, and insects.
Use of resistant or tolerant varieties	Selecting crop varieties with genetic resistance or tolerance to certain pests and diseases in order to reduce damage and limit the need for chemical control.
Use of healthy seeds and planting material	Planting certified or disease-free seeds to prevent the introduction and spread of seed-borne fungal, bacterial, or viral pathogens.
Balanced fertilization	Applying nutrients in appropriate amounts to maintain plant vigor and resilience, since excessive fertilization (especially nitrogen) may increase pest and disease susceptibility.
Irrigation management	Regulating water supply to avoid conditions favorable to disease development, such as excessive humidity that promotes fungal and bacterial infections.
Weed management	Controlling weeds that may serve as alternative hosts for pests and pathogens, thereby reducing infestation sources in the field.
Removal of crop residues	Removing or properly destroying plant residues after harvest to eliminate pest habitats and pathogen inoculum that may survive on crop debris.
Planting date and plant density management	Adjusting planting time and plant spacing to avoid peak pest populations and improve air circulation within the crop canopy, reducing disease development.
Crop diversification and intercropping	Growing different crops together or in rotation to disrupt pest host location and promote beneficial organisms that help regulate pest populations.

4.4.3. Biological control

Biological control uses natural enemies, such as predators, parasitoids, and entomopathogens, to regulate pest populations. Predators consume multiple prey, while parasitoids develop within a host and ultimately kill it. Entomopathogens, including bacteria, fungi, and viruses, also play a significant role. *Bacillus thuringiensis* (Bt), a bacterium that is widely used against lepidopteran larvae because of its insecticidal crystal proteins.



Basilic - Amaranth



Basilic - Cabbage



Basilic - Okra



Basilic - Crotalaira

Figure 32 : Examples of crop associations



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Trichogramma sp*Apanteles spp**Aphidius spp**Ischiodon aegyptius**Cheilomenes sulphurea - Adult**C. sulphurea - Larva**Rhynocoris albopitus*Earwing (*Forocula spp.*)*Afrilus purpureus**Nesidiocoris tenuis**Mantis religiosa**Chrysoperla sp***Figure 33: Main predators for pests' management in biological control**

Biological control can be classified as classical (introduction of exotic natural enemies), augmentative (mass release), or conservation (protection of existing beneficial organisms). Conservation biological control is emphasized in Integrated Pest Management (IPM) programs because reducing broad-spectrum pesticide use enhances the survival and effectiveness of natural enemies.

Table 30: Type of biological control

Type of biological control	Description and example
Conservation biological control	Practices that protect and enhance the activity of natural enemies in the field, such as planting flowering plants, reducing pesticide use, and maintaining habitat diversity.
Augmentative biological control	The mass rearing and periodic release of natural enemies to increase their population in the field, for example releasing <i>Trichogramma</i> wasps to control caterpillar pests.
Classical biological control	Introduction of natural enemies from the pest's region of origin to control invasive pests in a new environment.

4.4.4. Chemical control and safe pesticide use

Chemical control plays an important role in Integrated Pest Management (IPM), especially when pest populations exceed economic thresholds and preventive measures are ineffective. It involves applying synthetic or naturally derived pesticides to rapidly and effectively reduce pest populations. However, since pesticides can pose risks to human health, non-target organisms, and the environment, their use must adhere to strict safety, regulatory, and technical guidelines.

Chemical control includes several categories of pesticides, including insecticides, fungicides, herbicides, nematicides, etc. These products

act through various modes of action, including contact, inhalation, ingestion, fumigant, repellent and growth regulation. Selecting the proper product requires accurately identifying the pest, knowing the active ingredient, understanding resistance risks, and being aware of potential effects on beneficial organisms. Rotating pesticides with different modes of action is recommended to delay the development of resistance, which is a major challenge in modern agriculture.

Safe pesticide use begins with reading and strictly following the instructions on the label, which provide essential information such as dosage, active ingredient, category of pesticide, target pest or disease, crop, application timing, pre-harvest intervals, re-entry intervals, and hazard classification.

Using appropriate personal protective equipment (PPE), including gloves, masks, goggles, long-sleeved clothing, and boots, is critical to minimizing exposure during mixing, loading, and spraying. Calibrating spraying equipment ensures accurate dosage and prevents under- or overapplication, both of which can have economic and environmental consequences. To prevent accidental poisoning and contamination, pesticides must be stored in locked, well-ventilated facilities away from food and water sources.

Environmental protection is also central to the safe use of pesticides. To reduce drift and runoff, applicators must avoid spraying near water bodies or pollinator habitats, and they should not spray during windy conditions. Integrated approaches recommend applying pesticides only when monitoring indicates that economic thresholds have been reached. This targeted application minimizes unnecessary treatments and preserves natural enemies, promoting agroecosystem balance.

Finally, properly disposing of pesticide containers and leftover solutions is essential. Empty containers should be triple-rinsed and disposed of according to national regulations to prevent environmental contamination and illegal reuse. Training and capacity building for farmers and applicators significantly improves compliance with safety standards and reduces health risks related to pesticides.

4.4.5. Principles of Integrated pest management (IPM)

IPM is a sustainable, ecosystem-based approach to pest control. It combines various management strategies and practices to keep pest populations below levels that cause economic damage while minimizing risks to human health, beneficial organisms, and the environment.

The FAO defines IPM as the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations. It combines biological, chemical, physical and crop specific (cultural) management strategies and practices to grow healthy crops and minimize the use of pesticides, reducing or minimizing risks posed by pesticides to human health and the environment for sustainable pest management. The United States Environmental Protection Agency similarly defines IPM as an effective, environmentally sensitive approach that relies on a combination of common-sense practices.

IPM is based on several key principles: prevention, monitoring and accurate identification, economic thresholds to guide decision-making, non-chemical methods, pesticides selection, reduced pesticide use, ant-resistance strategies and evaluation.

· **Principle 1: Prevention and suppression**

Preventive measures are designed to reduce the likelihood of pest outbreaks before they occur. These include crop rotation, use of resistant varieties, appropriate planting dates, field sanitation, soil health management, and conservation of natural enemies. Prevention is considered the foundation of IPM because it reduces the need for curative interventions.

· **Principle 2: Monitoring and accurate identification**

Regular field scouting and systematic observation are essential to determine pest presence, population density, and crop damage levels. Accurate identification of pests, diseases, and beneficial organisms ensures that control measures are properly targeted. Monitoring may involve visual inspection, traps, sampling techniques, and, when necessary, laboratory diagnosis. Without reliable identification and monitoring, management decisions may be ineffective or unnecessary.

· **Principle 3: Decision-making on monitoring and thresholds**

Control actions should only be implemented when pest populations exceed a level at which economic losses are likely to surpass the cost of control. This threshold-based decision-making prevents routine or calendar-based pesticide applications and reduces unnecessary chemical use. Economic thresholds vary depending on crop type, growth stage, pest species, and market conditions.

· **Principle 4: Non-chemical methods**

The combination of non-chemical methods that may be individually less efficient than pesticides can generate valuable synergies

· **Principle 5: Pesticide selection**

Development of new biological agents and products and the use of existing databases offer options for the selection of products minimizing impact on health, the environment, and biological regulation of pests

· **Principle 6: Reduced pesticide use**

Reduced pesticide use can be effectively combined with other tactics.

· **Principle 7: anti-resistance strategies**

Addressing the root causes of pesticide resistance is the best way to find sustainable crop protection solutions.

· **Principle 8: Evaluation and continuous improvement**

After implementing control measures, farmers and practitioners must assess their effectiveness and adapt strategies accordingly. Record keeping, data analysis, and farmer training contribute to the continuous refinement of IPM programs. Adaptive management ensures that pest control remains effective under changing environmental and agronomic conditions.

CHAPTER V:

Post-harvest technologies, food safety and extension delivery

5.1. Packaging technologies

In Gambian smallholder systems, common packaging includes woven baskets, sacks, and cartons, but these often cause compression damage (especially for tomatoes). Extension officers should promote improvements using locally accessible options such as clean ventilated baskets lined with soft material (paper, dry leaves) and avoiding overfilling. Where feasible, adoption of stackable plastic crates can significantly reduce bruising and losses; this approach is already widely used in parts of Kenya, Rwanda, Ghana, and Senegal for tomato and other perishables. Several practical technologies used in other African countries can be introduced or scaled in The Gambia:

- Reusable plastic crates: widely adopted across East and Southern Africa for tomatoes and leafy vegetables to reduce crushing losses.
- Simple packhouses/collection centers: used in Kenya and Rwanda; basic shaded structures with sorting tables, water access for cleaning, and organized loading areas.
- Mesh bags and ventilated onion nets: commonly used in West Africa for onions to improve ventilation and reduce rot during transport.
- Low-cost grading tables and sorting benches: used by farmer groups in Ghana and Nigeria to standardize quality and improve market prices.

5.2. Conservation technologies: case of Zero-Energy cool chambers

Technologies such as Zero-Energy Cool Chambers (ZECC), already used across some African countries (Nigeria, Kenya, Sudan, etc.) can be introduced in The Gambia to extend shelf life without electricity. This low-cost structure reduces temperature through evaporative cooling and is suitable for farmer groups and community gardens. Below the step-by-step to construct a ZECC:

– Select a suitable site

Choose a shaded, well-ventilated area close to a reliable water source. The site should be slightly elevated to prevent flooding and have good drainage.

– Prepare the foundation

Mark the dimensions of the chamber (commonly about 2 m × 1 m × 1 m). Level the ground and create a firm base using a layer of sand or bricks to provide stability and drainage.

– Build the double brick walls

Construct two parallel brick walls leaving a 10-15 cm gap between them. Use cement mortar for stability. This double-wall structure is essential for the cooling effect.

– Fill the gap with sand

Fill the space between the two walls with clean river sand. This sand will hold water and enable evaporative cooling.

– Install the floor

The floor of the chamber can be made with bricks or a layer of sand, ensuring good drainage and preventing water accumulation.

– **Provide a cover**

Place a bamboo frame, wooden frame, or metal frame on top and cover it with wet jute sacks, straw mats, or cloth. This helps maintain cool temperatures inside the chamber.

– **Moisten the sand regularly**

Pour water on the sand between the walls two to three times a day to keep it moist.

Evaporation from the wet sand lowers the temperature inside the chamber.

– **Place vegetables inside crates**

Store vegetables such as tomato, cabbage, and onion in plastic crates or baskets inside the chamber. Avoid stacking produce directly on the floor to ensure good air circulation.



Figure 34: ZEC technology for fresh vegetable conservation

5.3. Food safety and quality management

5.3.1. Hygiene practices

Tomato, onion, and cabbage are often consumed fresh or lightly cooked, making proper hygiene essential to reduce foodborne illnesses, protect consumer health, and maintain market confidence. Farmers and workers should practice good personal hygiene, including regular handwashing, wearing clean clothing, and avoiding handling produce when sick. Harvesting tools, crates, and containers must be cleaned regularly and stored in clean, dry places to prevent contamination. Sorting and packing should be carried out on clean surfaces under shade, and vegetables should not be placed directly on bare soil. Only clean water should be used for washing produce, while damaged or rotten vegetables should be removed promptly. Livestock should also be kept away from production and packing areas to avoid contamination.

5.3.2. Chemical residue risks

Chemical residue risks occur when pesticides remain on vegetables at unsafe levels due to excessive or improper use. In crops such as tomato, cabbage, and onion, practices like frequent spraying, incorrect dosages, mixing pesticides without guidance, using unregistered products, or ignoring the pre-harvest interval can lead to harmful residues and market rejection. To reduce these risks, farmers should use only registered products, follow label instructions on dosage and application, respect the pre-harvest interval, adopt Integrated Pest Management (IPM) practices, and keep simple records of pesticide use.

5.3.3. Consumer health protection

Vegetables such as tomato, cabbage, and onion are widely consumed fresh, making food safety essential to prevent contamination and protect public health. Applying Good Agricultural Practices (GAP) including proper hygiene, safe water use, responsible pesticide application, and careful post-harvest handling helps ensure safe produce. Farmers should avoid unregistered chemicals, respect pre-harvest intervals, and maintain clean equipment, packaging, and transport conditions. Basic record-keeping and traceability further strengthen consumer protection and help build market confidence in safely produced vegetables.

5.4. Extension methods and farmer training

5.4.1. Adult learning principles

Effective farmer training should follow adult learning principles that emphasize practical, experience-based, and problem-oriented approaches. Farmers learn best when training is relevant, participatory, and focused on solving real production challenges. Demonstrations, field practice, discussions, and observation are more effective than long lectures. Extension officers should use simple language, encourage dialogue, and integrate farmers' local knowledge while using practical examples from crops such as cabbage, tomato, and onion to improve understanding and adoption of improved practices.

5.4.2. Demonstrations and field days

Demonstrations and field days are effective extension methods that allow farmers to observe and evaluate improved practices under real field conditions. They provide hands-on learning opportunities where farmers can compare new technologies with traditional practices and discuss results. Well-planned demonstrations and field days focused on crops such as cabbage, tomato, and onion help to promote practices like improved nursery management, fertilizer use, integrated pest management, and post-harvest handling. These activities encourage peer learning, build farmer confidence, and accelerate the adoption of improved vegetable production technologies.



Figure 35: farmers visiting tomato plots during field day

5.4.3. Using the manual in training

This manual is a practical guide to support extension officers in planning and delivering farmer training on cabbage, tomato, and onion production. It should be used to organize key messages, guide demonstrations, and adapt training to local conditions and farmers' needs rather than being read word-for-word. The manual can also serve as a reference during follow-up visits to address challenges and reinforce recommended practices, helping improve the adoption of vegetable production technologies.



5.4.4. Monitoring adoption and feedback

Monitoring adoption and collecting farmer feedback are important to ensure that training leads to real improvements in vegetable production. Extension officers should regularly follow up through farm visits, discussions, and simple observations to assess whether recommended practices are being applied. Tracking indicators such as improved nursery beds, drip irrigation use, proper onion curing, or better packaging helps measure impact, while farmer feedback helps identify constraints and adjust recommendations to better meet farmers' needs.

Conclusion

This manual provides practical guidance for improving the sustainable production of cabbage, tomato, and onion in The Gambia. It emphasizes the application of Good Agricultural Practices (GAP) throughout the production cycle, including seed selection, nursery management, soil fertility management, irrigation, pest and disease control, harvesting, and post-harvest handling. Applying these practices helps farmers improve productivity, product quality, and food safety while reducing production risks and post-harvest losses, and increasing resilience to climate variability.

Agricultural extension officers play a key role in supporting farmers to adopt these practices through training, demonstrations, and field follow-up. Their work helps promote improved technologies and climate-smart farming approaches that strengthen the vegetable value chain. Supporting farmers, particularly women and youth who are highly involved in vegetable production, contributes to better nutrition, higher incomes, and stronger rural livelihoods.

The development of a resilient vegetable sector in The Gambia requires collaboration among farmers, extension services, research institutions, development partners, and the private sector. By improving access to knowledge, quality inputs, and sustainable production practices, vegetable production can contribute significantly to food security, economic development, and climate-resilient agriculture.

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