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Checklist of pests and diseases of fruits and vegetables in Bamenda, North West Region, Cameroon

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Abstract

Fruits and vegetables are an integral part of human diet attributed to their appealing flavour, taste, nutrients and health-promoting properties. However, in Cameroon, the agricultural system is constantly dealing with a decrease in fruit and vegetable yield due to diseases and pests' infestation. The aim of this study was to identify diseases and pests of fruits and vegetables in farms and markets in Mezam Division. North West Region of Cameroon. A field survey was conducted in randomly selected farms in Mezam, Bamenda while a market survey was carried at Mile 3 Nkwen and the Bamenda food markets in December 2022 and January 2023 with the participation of secondary school Biology teachers as trainees. They were taught on the signs and symptoms of diseases caused by fungi, bacteria, and viruses on fruits and vegetables by plant pathologists while insect pests' identification was taught by agriculture entomologists from the University of Bamenda. Pictures of infected vegetable and fruit parts were taken; host plant was identified and the pathogens causing disease was identified based on signs and symptoms and results presented on tables. Also, Infected vegetables and fruits samples were cultured in PDA and pure cultures were identified by use of cultural characters. Insect identification was done with the aid of photographs and by the use of a dichotomous key which was used to determine the orders of the different insect pests. High number of vegetables and fruits were found to be infected by fungi, bacterial and viral pathogens. The symptoms observed in farms and markets ranged from fusarium wilt caused by *Fusarium oxysporum* on *Passifora edulis*, bacteria canker of *Persea americana* to leaf spot disease caused by *Pleospora* spp. on *Talinum fruticosum*. The insect pests identified were *Dacus punctatifrons*, *Helicoverpa armigera*, *Podagrica* spp., *Bemisia tabaci* and aphids. Some of these insect pests serve as vectors of plant diseases.

Keywords – Diseases – Farms – Identification – Markets – Pests – Signs and Symptoms

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Introduction

Fruits and vegetables are an important source of food for both humans and animals, and their consumption has increased significantly in recent years. (Adedeji et al. 2020), which can be defined to an array of factors, including increased awareness of their benefits for health (Padayachee et al. 2017). Most people are more aware of what they eat and tend to eat healthy, often preferring organic foods (Gherini 2018). Fruits and vegetables are living entities that comprise a vast group of plant foods that differ greatly in content of energy and nutrients (Yousuf et al. 2020). They are also a rich source of dietary fiber. Fruit and vegetables form an important part of the human diet and in addition form the basis of a healthy diet. They are considered suitable for health and contain essential vitamins, minerals, and other phytochemicals that can help in the smooth functioning of the human body and can help fight some diseases (Van Duyn & Pivonka 2000). Consuming adequate quantities of fruits and vegetables will benefit an individual in maintaining a healthy lifestyle (Yousuf et al. 2020).

The issue of food loss and waste is a major challenge worldwide (Principato et al. 2021). Nearly half of the cultivated fruits and vegetables are lost between production and consumption (FAO 2011) and about 45% of the world's fruits and vegetables are wasted (FAO 2015). Despite the substantial waste during transportation and processing, a major loss in fruits and vegetables occurs during storage. Bacteria and fungi are the main causes of contamination (Buchholz & Kostić 2018, Padmaperuma et al. 2020). Various fungi, mainly belonging to the genera *Alternaria*, *Aspergillus*, *Botrytis*, *Colletotrichum*, *Fusarium*, *Monilia*, *Penicillium* and *Rhizopus* produce mycotoxins such as aflatoxin (AFS), ochratoxin A (OTA), patulin (PAT), Alternaria toxins (ATs) and fumonisin (FBS), which are nephrotoxic, genotoxic, teratogenic, carcinogenic and cytotoxic (Andersen et al. 2004, Saleh & Al-Thani 2019, Raduly et al. 2020). Pathogenic fungi cause plant diseases such as anthracnose, leaf spot, rust, wilt, blight, coils, scab, gall, canker, damping-off, root rot, mildew, and dieback. Systemic foliar pathogens diminish crop quality and yield of commercial crops (Iqbal et al. 2018). Bacteria such as *Clostridium*, *Clavibacter*, *Streptomyces*, *Xanthomonas*, *Erwinia*, *Listeria*, *Salmonella* and *Escherichia* have been reported to cause the highest proportion of food spoilage (Boudon et al. 2005, Perez et al. 2016). Diseases caused by pathogenic microorganisms affect the quality, reduce shelf life, and lead to substantial economic losses. Insect pests cause direct losses to cultivated crops. They colonize the stems or leaves and the developing pods or fruits. Infested leaves are destroyed and yellowed by the pest sucking activities. Plants become desiccated and may eventually die, fruits numbers are reduced and the size too (Shannang 2007). Insects are also considered as important vector of viruses on cultivated crops (Biddle & Cattlin 2007). Farmers in the tropics are face with considerable plant protection-related risks that seriously threaten agricultural production safety and sustainable food supply (Ratnadass et al. 2021). In order to prevent agricultural disaster occurrence, as well as ensure farmlands' quality and productivity, there is a need to identify pests and diseases of crops accurately, take pest management decisions such as applying pesticides or implementing other management strategies (cultural, biological) which impacts the food production chain (Zheng et al. 2019, Kong et al. 2021).

Pest and disease damage to crops, as well as pesticide applications, can cause (i) Food insecurity and reduced income; (ii) Adverse effects on human and environmental health (which also affects other actors in crop value chains, e.g. agricultural workers, labourers, and consumers); and (iii) export restrictions due to quarantine pests and diseases and maximum limits on pesticide residues (Sikora et al. 2019). Production is often increased to compensate losses, together with innovative packaging technologies, as well as control measures such as physical or use of synthetic chemicals, applied to overcome challenges. Post-harvest treatments include wax coatings with chemicals, applications of growth regulators and diverse synthetic inputs (Kusstatscher et al. 2020). The use of these chemicals poses health and environmental hazards. Over the years, many studies have embarked on finding safe and effective to the use of these synthetic chemical fungicides to reduce losses. Even though numerous biological measures have been developed, biological products have never reached broad usage due to their limited applicability (Sharma et al. 2009,

Droby et al. 2009, 2016). Another cause of enormous damage to fruits and vegetables are insects. Insect pests are considered to be responsible for approximately 10–20% of yield losses in significant crops worldwide and about 50% of annual production in developing countries (Badii et al. 2015). Detecting these insect pests before they enter the supply chain is still a major challenge for the food industry (Lezoche et al. 2020). The improper postharvest environment regarding temperature, relative humidity or water activity and light damages the physiology of fruits and vegetables. Apart from the environment, the possible wounds during harvesting, transportation, preservation and marketing allow the pathogens to invade the hosts. High nutrients, high moisture and low pH in fruit and vegetables provide a suitable environment for the growth of pathogens (Droby et al. 1992). Therefore, fruits and vegetables face various diseases caused by pathogens after harvest. Secondary school Biology teachers need to understand the signs and symptoms of diseases caused by fungi, bacterial and viruses, know how to identify pests of fruits and vegetables and learn how to collect diseased samples, prepare media, isolate the pathogen through culturing and obtain pure cultures of the pathogen for identification. This will help the teachers better teach their students. The objective of the study was to identify diseases and pests of friuts and vegetables in farms and markets in Mezam, Bamenda by documenting the signs and symptoms, culture the diseased samples to identify the pathogens and to produce a checklists for diseases and pests of fruits and vegetables in Cameroon.

Materials & Methods

Description of study site

Bamenda is situated between longitude 10^{o} 08' 10^{o} 12' E and latitude 5^{o} 55' 6^{o} 00' N, alt 1229 m asl. Bamenda covers a surface area of 71.23 square kilometers. The morphology of Bamenda is characterized by a gentle sloping Upstation area separated from an undulating to flat Down Town area by an escarpment which is about 7 km long with trend N37^{o} and about 150 m high (Gwanfobe et al. 1983). The slopes along the escarpment are more than 35^{o}. The climate is the humid tropical highland type characterized by two seasons a rainy season and a dry season. The vegetation is characterized by short stunted tress that is the savannah type. The soils are ferralitic, vertisols and andosols, which are easily eroded and cannot support dense vegetation and intense agricultural activities. River Mezam is the main river which drains Bamenda. The hydrography presents a characteristic dendritic drainage pattern. Farming is the main activity carried out here which is mostly crop based farming, pure pastoralism and mixed crop livestock (Gwanfobe et al. 1983).

Field Sampling

Field survey was carried out in randomly selected farms and markets in Mezam Division in December 2022 and January 2023 by Secondary school Biology teachers who were taught the signs and symptoms and cultural identification of diseases caused by fungi, bacteria and viruses on fruits and vegetables by plant pathologists. Additionally, they were taught on how to identify insect pests of fruits and vegetables by agriculture entomologists. The trainees observed fruits and vegetables around different markets and farms around Bamenda. They took pictures and collected diseased fruits and vegetables for cultural identification in the Biological Science Laboratory of the University of Bamenda. Insects found on fruits and vegetables were collected with the aid of sweep nets and some through handpicking while others like aphids were collected by harvesting the plant part on which they were found. They were as well taken to the Biological Science Laboratory of the University of Bamenda for identification.

Pathogen Isolation and Identification

About 5mm infected part of vegetable and fruit were cut with the use of sterile razorblade and the portions were put in small nets, surface sterilized by immersing in 10% sodium hypochlorite solution for 3 minutes and rinsed in distilled water, followed by rinsing with 70% alcohol for 1 minute. They were then rinsed in sterile distilled water and finally tap water, then plated upon

the solidified PDA medium in labeled Petri dishes. The plates were sealed with parafilm wax and incubated at room temperature (25 °C) in the dark for 7 days. After 7 days, fungi that grew on the inoculants were sub-cultured on fresh PDA plates at room temperature. This was according to the protocol of Leslie & Summerrel (2008). For the isolation of pure culture of fungal and bacteria isolates, the isolated fungal and bacterial cultures were transferred into fresh pre-sterilized Petri plates separately and incubated until fungal and bacterial colonies appeared. The separated colonies were subculture on new PDA Petri plates to obtain the pure fungal culture. The fungal colonies obtained were then identified based on cultural characters.

Insect Identification

For the identification of insect pests of fruits and vegetables, trainees were trained on how to collect insects in the field with emphasis on different collection equipment by agriculture entomologists of the University of Bamenda. Flying insects were collected with the aid of sweep nets and some through handpicking while insects like aphids and whiteflies were collected by harvesting the plant part on which they were found. In the field photographs of the insect pests as well as their damaged signs were taken. After collection, the insects were taken to the Biological Science Laboratory of the University of Bamenda for identification. The identification was with the aid of photographs by Vurela et al. (2003) and a dichotomous key by James (2000) was used to determine the orders of the different insect pests.

Results & Discussion

Table 1 and Table 2 showed the diseases and pests of fruits and vegetables on the host plants, the pathogens involved, the signs and symptoms and the locality of the farms and markets. The pictures of the signs and symptoms for each sample observed in the farms and markets are shown on Figs 1 to 18. The signs and symptoms observed in the field ranged from fusarium wilt caused by *Fusarium oxysporum* on *Passifora edulis* to leaf spot disease caused by *Pleospora* spp. on *Talinum fruticosum*.

Table 1 Diseases and pests of fruits and vegetables in the farms, the pathogens involved, the signs and symptoms and the locality of the farmlands.

SN	Fruits and Vegetables	Symptoms and Pathogen involved	Description of signs and symptoms of pathogen	Locality of farmland
1	Adam fruit (*Passifora edulis*)	Fusarium wilt *Fusarium oxysporum*	Wilting of fruits before the fruits mature.	BHS Mankon
2	Amaranthus (*Amaranthus hybridus*)	Leaf chlorosis *Ageratum enation virus* (AEV)	Yellowing and curling of leaves, vein enation on the lower side of leaves and shortening of internodes. There are also dark spots on older leaves and stunting of growth of the plants.	Atunibah Bambui
3	Anchia (*Solanum macrocapon*)	Green stink bug Infestation of *Solanum* spp.	The bug helps in disease transmission and also feeds on the fruits making them to get rotten.	Atunibah Bambui
4	Anchia (*Solanum macrocapon*)	Fruit rot Fungi *Phytophthora* spp.	Infected fruits have change in normal coloration. Also, there is rot with different backgrounds.	Atunibah Bambui
5	Avocado (*Persea americana*)	Bacterial canker *Pseudomonas syringae*	Small water-soaked lesions are found that eventually turn brown and dry up. The lesions are coalescing and form larger areas making the fruits unmarketable. The disease can also cause premature drop of fruits.	Nkwen food Market

Table 1 Continued.

SN	Fruits and Vegetables	Symptoms and Pathogen involved	Description of signs and symptoms of pathogen	Locality of farmland
6	Avocado (*Persea americana*)	Anthracnose *Collectotrichum gloeosporioides*	Lesions on the leaves are small dark, water-soaked spots that eventually enlarge and turns black or brown. Spots can coalesce causing yellowing of leaves which drop prematuring.	BHS Mankon Orchard
8	Beans (*Phaseolus vulgaris*)	Bacterial blight of beans *Xanthomonas axonopodis* pv phaseoli	Spots on the leaves become enlarge and turn necrotic and brown. Also leaves are distorted with partial yellowing.	Atunibah Bambui
9	Bell pepper (*Capsicum annum*)	Viral infection. Pepper leaf curl virus (PepLCV)	Symptoms include: stunting of the plant, curling and reduction in the size of the leaves, mottling of the foliage and fruits.	Atunibah Bambui
10	Bitter leaf (*Vernonia amygdalina*)	Rust of bitter. *Puccinia vernoniae*	Necrotic lesions on the under surface of the leaf with rusty appearance	Mile 3 Nkwen (garden)
11	Bitterleaf (*Vernonia amygdalina*)	Viral infection. Vein-banding on leaves	Folding of leaves with stunted growth of the plant	Upper Bayele
12	Bitter leaf (*Vernonia amygdalina*)	Black Aphids (*Aphis* spp.)	Small, black and soft-bodied sucking insects that pierce plant tissues, thus tearing the leaves in the cause of drawing juices	Upper Bayelle
13	Cabbage (*Brassica oleracea*)	Turnip mosaic virus	- Ringspots in young leaves - Yellow and brownish spots surrounded by circular or irregular necrotic rings. - Deformed and stunted plants.	Mile 3 Nkwen (garden)
14	Cabbage (*Brassica oleracea*)	Lepidopteran caterpillars	The caterpillars feed on the cabbage leaves leaving holes, affected areas turns yellow	Bambui
15	Cabbage (*Brassica oleracea*)	Sclerotinia rot *Sclerotia sclerotiorum*	Externally invaded leaf tissues appear dark and become soft and watery.	Bambui
16	Cassava (*Manihot esculenta*)	Cassava mosaic disease Cassava mosaic virus	Mottling and twisting of leaves. Reduction in leaf size. Intermingling of coloration (green and yellow) that shows mosaic appearance. Stunted growth of the plant.	Mile 3 Nkwen (farm)
17	Celery (*Apiumgraveolens*)	Early blight *Cercospora apii*	Brown spots on the leaves. There is also yellowing of the leaves.	Bambui
18	Chinese cabbage (*Brassica juncea)*	Aphids on Chinese cabbage	Dark brown aphids with solid back. These are vectors for the transmission of viruses	Upper Bayelle
19	Chinese cabbage (*Brassica rapa* subsp. pekinesis)	Powdery mildew *Erysiphe cruciferarum*	Whitish spores on the upper surface of leaf in the form of powder. Leaf become pale green.	Mile 3 Nkwen (garden)
20	Citrus (*Citrus sinensis*)	Bacterial brown leaf spot *Burkholderia andropogonis*	Gray spots with yellowish-brown borders.	Atunibah Bambui
21	Citrus (*Citrus sinensis*)	Citrus Black spot *Guignardia citricarpo*	Black spots on fruits.	Upper Bayelle

Table 1 Continued.

SN	Fruits and Vegetables	Symptoms and Pathogen involved	Description of signs and symptoms of pathogen	Locality of farmland
22	Citrus (*Citrus reticulate*)	Bacterial gall - Agrobacterium, Rhodococcusor - *Pseudomonas* spp.	Leaves appear yellowish with swellings/galls. - Galls appear as small, round whitish, soft overgrowth on leaves. - Gall tumours found on upper surface of infected leaves.	Bambui
23	Cocoa (*Theobroma cacao*)	Aphids	- Presence of aphids on the leaves, fruit and stem. - Curling or folding of leaves.	Fon's street Bamenda
24	Cocoa (*Theobroma cacao*)	Cocoa ring spot	- Rings of black spots on fruits surrounded by greenish lesions	Upper Bayelle
25	Cocoyam (*Xanthosoma sagittifolium*)	Leaf blight *Xanthosoma campestris*	Leaves shows patches which become necrotic, showing symptoms of blight.	COLTECH Bambili
26	Cowpea (*Vigna unguiculata*)	Mosaic: Bean MosaicVirus	Severe blistering and distortion of leaflets. Mosaic	Mile 3 Nkwen (garden)
27	Cucumber (*Cucumis sativus*)	Bacterial wilt *Erwinia tracheiphila*	- Leaves are yellowish and wilt during the day and progresses to the vine. - Severe wilting of vines, followed by rapid death of the plant. - Leaves are infested with pest on its lower surface.	Atunibah Bambui
28	Cucumber (*Cucumis sativus*)	Mosaic: Cucumber mosaic virus	- Light greenish coloration of leaves intermingled with yellow. - Leaf Crinkling	COLTECH Bambili
29	Cucumber (*Cucumis sativus*)	Mosaic: Cucumber mosaic virus	- Yellowing of leaves, fruit shrinks,	Bambui
30	Foleri (*Naegleria fowleri*)	White flies (*Bemisia tabaci*)	- White flies on fruits, which serves as vectors of virus transmission	Ntarinkon
31	Garden egg (*Solanum melongena*)	Leaf spot (*Cercospora capsica*)	Brown spots appear on the leaf and some on the margins of the leaf.	Bambui
32	Garden egg (*Solanum melongena*)	Anthracnose (*Colletrotichum gloesporioides*)	Dark sunken spots. - Dead or rotting areas on fruits.	Mile three (farm)
33	Garden egg (*Solanum melongena*)	Fusarium wilt (*Fusarium oxysporum*)	Young leaves as well as branches soon wilt and die.	Bambui
34	Guava (*Psidium guajava*)	Red rust (Cephaleuros virescens)	Small to large spots on leaves. - Spots are darkish green to brown or dark. - Drying of leaves.	Mile three (farm)
35	Guava (*Psidium guajava*)	Guava bud moth (webworm) *Stictea ejectana*	Larvae living in the rolled and webbed terminal leaves where they chewed the leaves and causes damage (death).	Bambui
36	Guava (*Psidium guajava*)	Guava Canker *Physalopara psidii*	Lesion crowed on fruits surface that can turn yellow.	Upper Bayelle
37	Guava (*Psidium guajava*)	Whiteflies	Insects lower leaf surface in association with brown Aphids.	Bambui
38	Maize (*Zea mays*)	Downy mildew *Peronosclerospora sacchari*	Brown powdery growth on the lower surface of leaf.	Bambui

Table 1 Continued.

SN	Fruits and Vegetables	Symptoms and Pathogen involved	Description of signs and symptoms of pathogen	Locality of farmland
39	Maize (*Zea mays*)	Corn smut *Ustilago maydis*	Large darkish to whitish outgrowth (gall) on maize ears that prevent grain development.	Upper Bayelle
40	Maize (*Zea mays*)	Corn smut *Ustilago maydis*	Brown galls on ears which expands and becomes black	Mile 3 Nkwen (farm)
41	Mango (*Mangifera N indica*)	Sooty mould (Meliolamangifera)	Forms thick, black coating on foliage or leaves which turns black	Mile three (farm)
42	Okongobong (*Telferia occidentalis*)	White rust *Phoma sorghina*	Leaves which are translucent white, turn brown and shatter, Leaving the leaves with perforations.	Mile 3 Nkwen (garden)
43	Okongobong (*Telfaria occidentalis*)	Insect infestation	Twisted fruits and leaves. White patches on leave margin.	BHS Mankon farmland
44	Parsley (*Petroselinum crispum*)	Leaf spot *Septoria petroselini*	Yellow and brown spots appear on the leaves. - This was suspected to be cause by a fungi infection.	Bambui
45	Pawpaw (*Carica papaya*)	Cercospora Disease *Cercospora* spp.	Leaf spots appear Black and circular	Bambui
46	Pawpaw (*Carica papaya*)	Pawpaw black spot Asperisporium caricae	Circular brown lesions on fruits. Irregular hard dark spots.	Atunibah Bambui
47	Pawpaw (*Carica papaya*)	Powdery mildrew: *Oidium caricaepapayae*	White mycelia on fruits and leaves, fruits with bumps, sap flowing out.	Mile 3 Nkwen
48	Pawpaw (*Carica papaya*)	Botrytis disease *Botrytis* spp.	Secondary soft rot on young fruits. Blossom end of fruit rot and may give room for secondary infection.	Bambui
49	Pawpaw (*Carica papaya*)	Papaya ring spot virus	Dark rings on fruit with white powdery ring.	Bambui
50	Pepper (*Capsicum annuum*)	Mushy spots on pepper: *Fusarium solani*	Appearance of soft, dark brown or black lesions on the stem and nodes - Also, fruit rot.	Mile 3 Nkwen (garden)
51	Pineapple (*Ananas comosus*)	Mealybug - Dark Spots *Ceratocystis paradoxa*	leaves appear yellowish. - Dark spots on leaves and fruit. - Chlorosis	New road Nkwen Bamenda
52	Plum (*Dacryodes edulis*)	Viral Infection Anthracnose *Collectotrichum* spp.	Twisting of young leaves. Brown spots on leaves.	BHS Mankon Orchard
53	Pumpkin (*Cucurbita maxima*)	Powdery mildew *Phyllactinia* spp.	- Spots or patches of white to greyish powdery mildew growth on leaves.	Mile 3 Nkwen
54	Pumpkin (*Cucurbita maxima*)	Mosiac Cucumber mosaic virus	Leaf with light green colour, stunted fruit and leaves growth. - Wilt	Bambui
55	Pumpkin (*Cucurbita* sp.)	Bacteria spot *Xanthomonas campestris* pv *curcurbitae*	Brown spots on the pumpkin leaves	Mile 3 Nkwen
56	Soursop (*Annona muricata*)	Radicular rot (*Rosellinia* spp. and *Phytophthora* spp.	Yellowish of younger leaves, folding on the stem. Brown fruits with zigzag crack lines, yellowing of leaf toward the petiole with black spots on the whole plant.	Mile 3 Nkwen

Table 1 Continued.

SN	Fruits and Vegetables	Symptoms and Pathogen involved	Description of signs and symptoms of pathogen	Locality of farmland
57	Taro (*Colocasia esculenta*)	Black spot of Taro *Phytophthora colocasiae*	Small irregular brown spots on leaves that turns black.	Mile 3 Nkwen
58	Taro (*Colocasia esculenta*)	Leaf blight: *Phytophthora colocasiae*	Small yellow areas on upper surface of leaf, which expand and become brown with irregular margins.	Bambui
59	Taro (*Colocasia esculenta*)	Leaf blight: *Phytophthora colocasiae*	Yellowing (chlorosis) of leaves which soon dry up and become necrotic.	UpperBayelle
60	Taro (*Colocasia antiqoarium*)	Leaf blight *Phytophthora colocasia*	Blight of leaf lamina. - Dark, ring like-lesions that rapidly expand to form large brown spots.	Bambui
61	Tomato (*Solanum lycopersicum*)	Fusarium wilt *Fusarium oxysporum* f. sp. *lycopersici*	It affects the entire plant. - Leaves are brown and dry out and stem is discoloured. - Plant wilts.	Atunibah Bambui
62	Tomato (*Solanum lycopersicum*)	Late blight *Phytophthora infestans*	Leaves first appear small, then with water-soaked areas which rapidly becomes enlarge with brown necrotic lesions	Bambui
63	Tree tomato (*Solanum betaceum*)	Bacteria: Erwinia or *Pseudomonas* spp.	Dark spots on fruit which frequently enlarge and merge to form rot.	BHS Mankon orchard
64	Water leaf (*Talinum fruticosum*)	Leaf spot disease *Alternaria* spp.	Round spots on leaves. - Spots might range from small to large.	Mile 3 Nkwen (garden)

Table 2 Diseases and Pests from fruits and vegetables assessed in markets in Bamenda.

SN	Fruits and Vegetables	Symptoms and Pathogen involved	Description of signs and symptoms of pathogen	Locality of farmland
1	Adam fruit (*Passifora edulis*)	Anthracnose *Collectotrichum* spp.	Small, well-defined dried pink spots on the surface of ripening fruits.	Bamenda food market
2	Apple (*Malus pumila)*	Bacterial infection *Erwinia*, *Pectobacterium*	Flesh of apple gets soft.	Mile 8 Mankon
3	Avocado (*Persea americana*)	Avocado Scab (*Venturiapyrina* sp.)	Dry scaly brown spots that gradually increases on the fruit. The pathogen is not deep-seated.	Nkwen food market
4	Banana (*Musa paradisiaca*)	Black spot, rot *Erwina*	Soft dark rot, mould.	Bambui
5	Bell pepper (*Capsicum annum*)	Black spots (*Diplocarpon rosae*)	Black spots on fruit, rot.	Bambui
6	Bell pepper (*Capsicum annum*)	Soft rot (Bacteria) *Erwinia* spp., *Pseudomonas*, *Bacillus*, *Xanthomonas*	Soft rot with mycelium growth.	Ntarinkon market
7	Cabbage (*Brassica oleracea*)	Leaf spot of cabbage *Alternaria brassicicola*	Small patches of black spots found on cabbage leaves.	Atunibah Bambui
8	Carrot (*Daucus carota)*	White mould (*Sclerotia* spp.)	White fluffy mycelia growth on fruit.	Bambui

Table 2 Continued.

SN	Fruits and Vegetables	Symptoms and Pathogen involved	Description of signs and symptoms of pathogen	Locality of farmland
			- Large compact resting bodies or white sclerotia develop at first but later become black.	
9	Carrot (*Daucus carota)*	Soft rot (*Erwinia* spp.)	Begin as small water-soaked lesions which enlarge rapidly in diameter and depth. - Affected area become soft and mushy.	Bambui
10	Carrot (*Daucus carota*)	Black patches and black rot *Thielaviopsis basicola*	Carrot was found with black mold on its surface.	AtunibahBambui
11	Carrot (*Daucus carota*)	Tip rot, caused by poor drainage in the field and small cracks that develop on root tips.	Longitudinal cracking of tubers.	Mile 4 market
12	Celery (*Apium graveolens*)	Celery blight *Septoria apiicola*	Folding of leaves.	FoodmarketBamenda
13	Chili pepper (*Capsicum annum*)	Black spots (*Diplocarpon rosae*)	Black spots on fruit, rot.	Food Market Bamenda
14	Citrus (*Citrus sinensis*)	Citrus rust mite, *Phyllocoptruta oleivora*	Brown lesion on fruits extending to other regions.	Food market
15	Citrus (*Citrus sinensis*)	*Citrus Elsinoe anthracnose* (Elsinoespp.)	Sunken dark coloured lesion on fruit, which becomes covered with spores.	Food market
16	Citrus (*Citrus sinensis*)	Powdery mildew *Oidium citri* and *O. tingitaninum*	Whitish powdery molds on surface of fruit.	Food market
17	Lemon (*Citrus limon*)	Citrus black spot Guignardia citricarpa	Citrus black spot and canker of fruit.	Ntarinkon market
18	Mandarine Orange (*Citrus reticulata*)	Rhizopus soft rot Rhizopus spp.	Infected portions appear brown in colour, water soaked and very soft.	Bambui
19	Egg plant (*Solanum melongena*)	Black Spot Cercosporamelongenae	A black spot on fruit.	New road Nkwen Bamenda
20	Eggplant (*Solanum melongena*) Aubergine	Eggplant scab Cladosporium	Scaly dry patches on fruit.	Nkwen market
21	Garden egg (*Solanum melongena*)	Blossom end rot caused by lack of calcium and or uneven watering	Small water-soaked area on end of unripe fruit. - Lesion enlarges and turns sunken. Black and leathery in appearance.	Mile 4 market
22	Grape (*Citrus paradisi*)	Sooty mold Fungi *Capnodium*	Black soot on the surface of grape fruit.	Atunibah Bambui
23	Grape (*Citrus paradisi*)	Soft rot of grape *Phomopsis viticolasacc*	Fruit decomposition and affected region is soft.	Atunibah Bambui
24	Grape (*Citrus paradisi*)	Black spot disease or anthracnose *Elsinoe ampelina*	First symptom is small light orange-yellow or red brown spots appearing on the fruit skin.	Food market
25	Irish potato (*Solanum tuberosum*)	Bacterial infection (*Pectobacterium carotovorum*)	A round circle formed on the tuber which is soft and upon cutting it shows it leads to rot inside the tuber.	Atunibah Bambui

Table 2 Continued.

SN	Fruits and Vegetables	Symptoms and Pathogen involved	Description of signs and symptoms of pathogen	Locality of farmland
26	Kolanuts (*Cola accuminata*)	Insect infestation fruit fly	Furrow like perforation on the inner softer tissues. - Also, white mould observed of the chaffs left from the feeding of the insect (secondary infection) indicating fungi attack.	Bambui
27	Okro (*Abelmosschusesculentus*)	Anthracnose *Colletotrichum* spp.	Brown sunken spot that rots.	Food Market Bamenda
28	Okro (*Abelmosschusesculentus*)		An okra fruit being attacked by pest. - Pest feeds on okra causing it to attacked by a bacteria pathogen.	Bambui
29	Onion (*Alium cepa)*	Bacterial rot *Pectobacterium carotovorum*	Infected bulb, soft rot	Mile 8 Mankon
30	Pawpaw (*Carica papaya*)	Papaya Anthracnose *Colletotrichum gloesosporioides*	Wet watery lesion on fruit with a brown spot that enlarges.	Food Market Bamenda
31	Pawpaw (*Carica papaya*)	Sooty mold Fungus (Powdery mildew) Green spot soft rot	Presence of dark spots, black powder, fruit is crinkled maybe as a result of a viral infection. - Green spots are spotted around the fruit.	Ntarinkon market
32	Pepper (*Capsicum annuum*)	Mushy spots on pepper	Exposed sides of pepper become papery.	Ntarinkon market
33	Plantain (*Musa paradisiaca*)	Birds	Plantain fruit destroyed by pest possible birds causing the plantain to destroyed.	Food Market Bamenda
34	Plum (*Dacryodes edulis*)	Plum scab (caused by *Venturia pirina*)	Circular, velvety, olive-black spots on fruit.	Foncha junction
35	Soursop (*Annona muricata*)	Anthracnose *Colletotrichum* spp.	Scaly dry patch on fruit. Cracking of fruit.	Foncha junction
36	Soursop (*Annona muricata*)	Med fly	- Dry dark rot, mould.	Food Market Bamenda
37	Tomato (*Solanum lycopersicum*)	Tomato rot *Alternaria* spp.	Spot appear sunken and have a black, velvety surface layer of fungus growth and spores. - Small lesion at surface may indicate extensive spread of infection inside fruits.	Food Market Bamenda
38	Tomato (*Solanum lycopersicum*)	Rot *Erwina caratovora*	Soft rot, white mould.	Food Market Bamenda
39	Tomato (*Solanum lycopersicum*)	Tomato Anthracnose *Collectotrichum coccodes*	Dark concentric rings form in the center of the lesions; the rings actually consist of numerous small fruiting structures known as acervuli of the fungus.	Nkwen food market
40	Water leaf (*Talinum fruticosum*)	Leaf spot disease (*Pleospora* spp.)	Dark green spots on underside of leaves. - Spots later become brown or reddish on the upper side of the leaves and eventually become black.	Mile 4 market

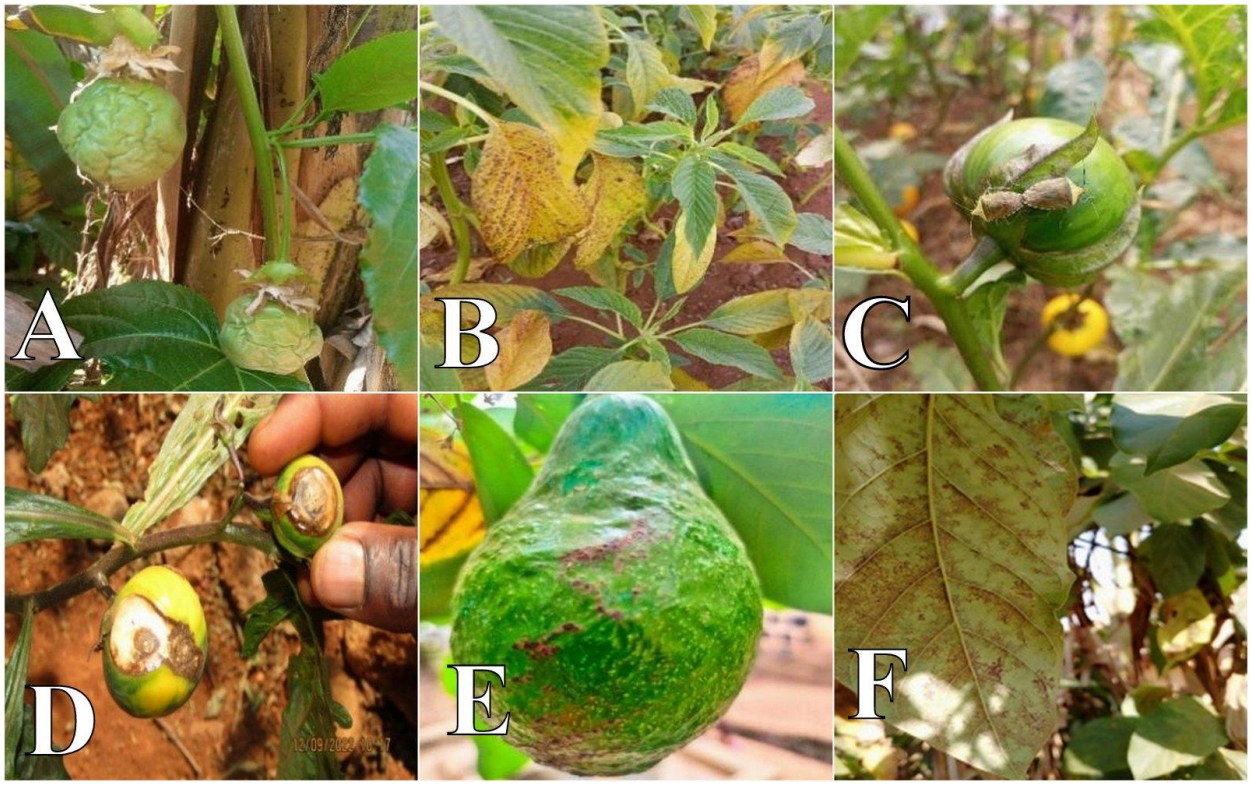

Fig. 1 – Pest and disease symptoms. A Fusarium wilt, *Fusarium oxysporum*. B Leaf chlorosis *Ageratum enation virus* (AEV). C Green stink bug Infestation of *Solanum* spp. D Fruit rot Fungi *Phytophthora* spp. E Bacterial Canker *Pseudomonas syringae*. F Anthracnose *Collectotrichum gloeosporioides* on farmlands in Bamenda.

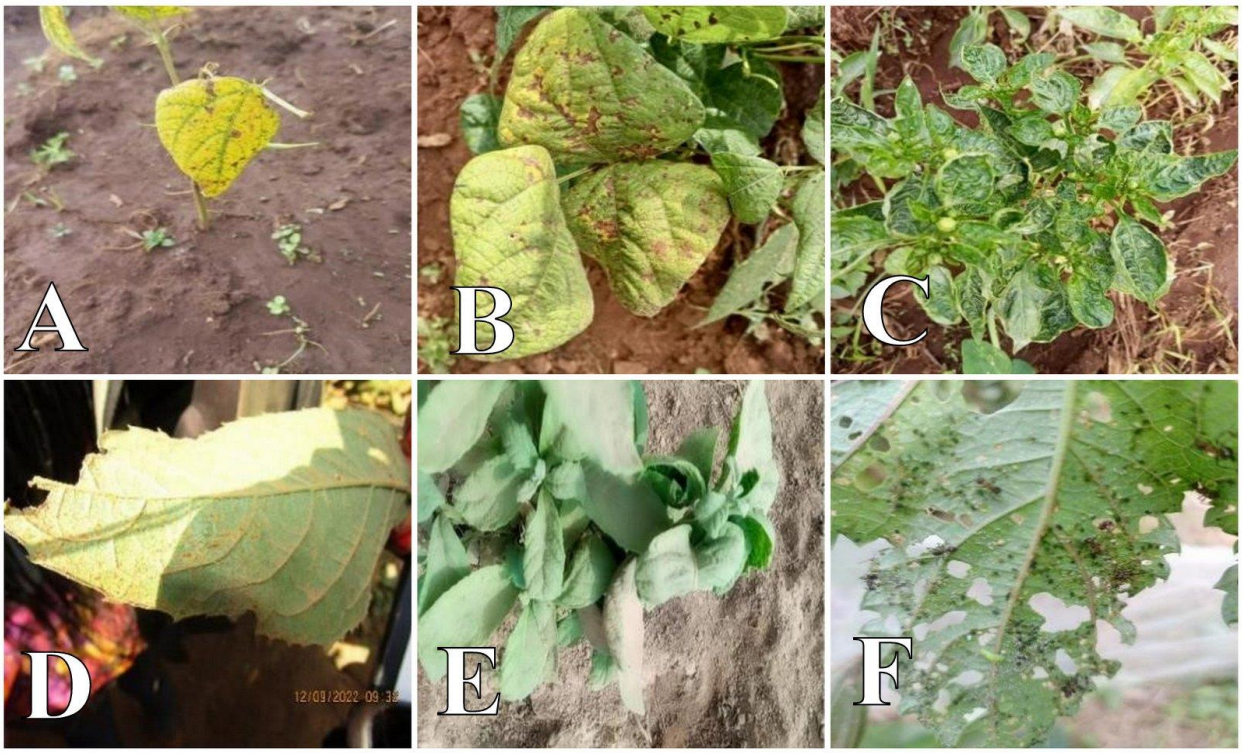

Fig. 2 – Pest and disease symptoms. A Bacterial blight of beans. B *Xanthomonas axonopodis* pv phaseoli. C Viral infection: pepper leaf curl virus (PepLCV). D Rust of bitter leaf *Puccinia* vernoniae. E Viral infection: Vein-banding on leaves. F Black Aphids (Aphis spp.) on bitter leaf on farmlands in Bamenda.

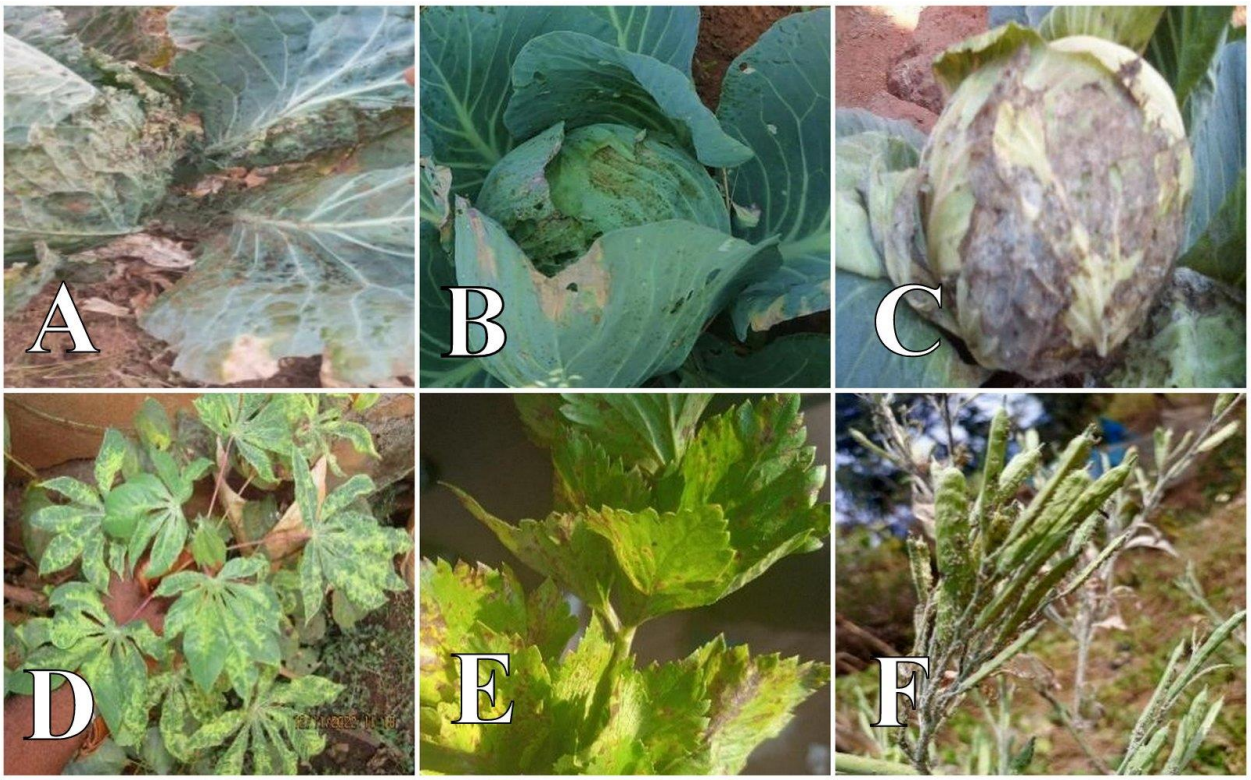

Fig. 3 – Pest and disease symptoms. A Turnip mosaic virus. B Lepidopteran Caterpillars. C *Sclerotinia* rot *Sclerotia sclerotiorum*. D Cassava mosaic virus. E Early blight *Cercospora apii*. F Aphids on Chinese cabbage on farmlands in Bamenda.

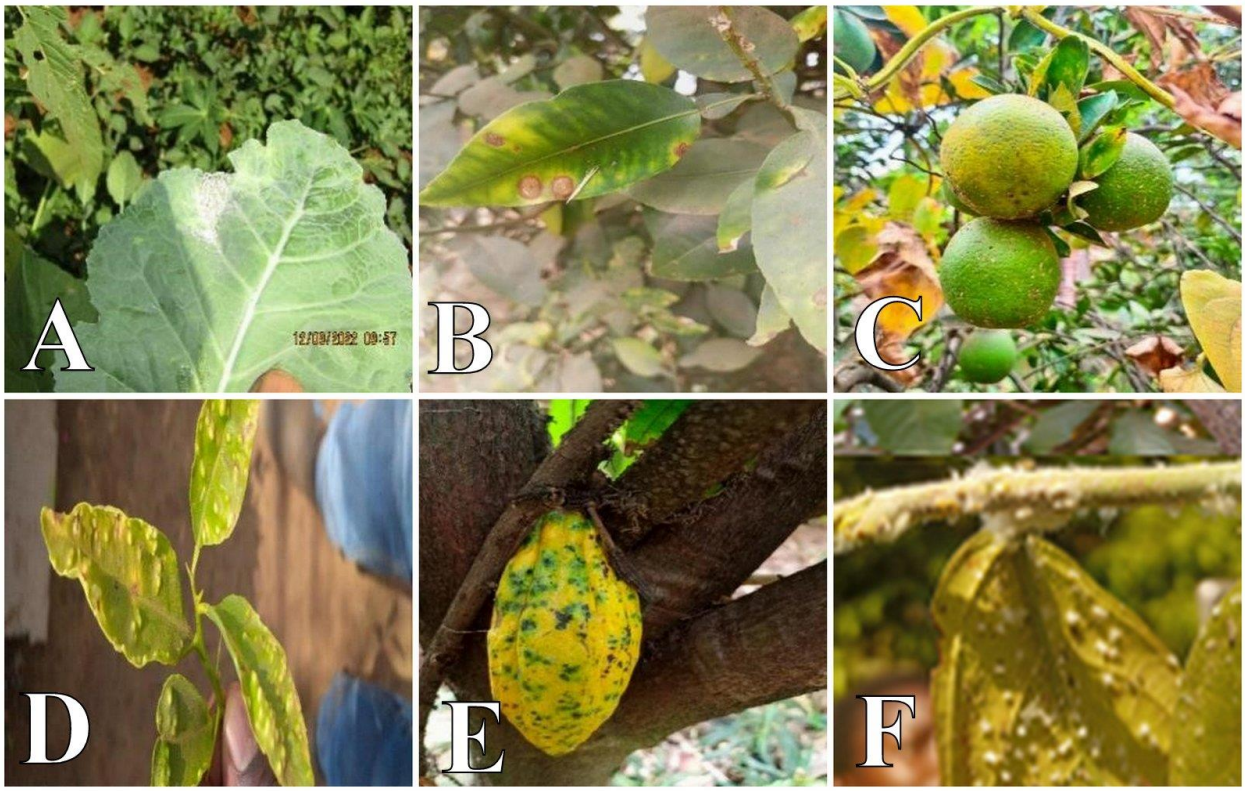

Fig. 4 – Pest and disease symptoms. A Powdery mildew *Erysiphe cruciferarum*. B Bacterial brown leaf spot *Burkholderiaandropo gonis*. C Citrus Black spot *Guignardia citricarpo*. D Bacterial Gall-Agrobacterium. E Rhodococcusor – *Pseudomonas* spp. F Aphids and Cocoa ring spot on farmlands in Bamenda.

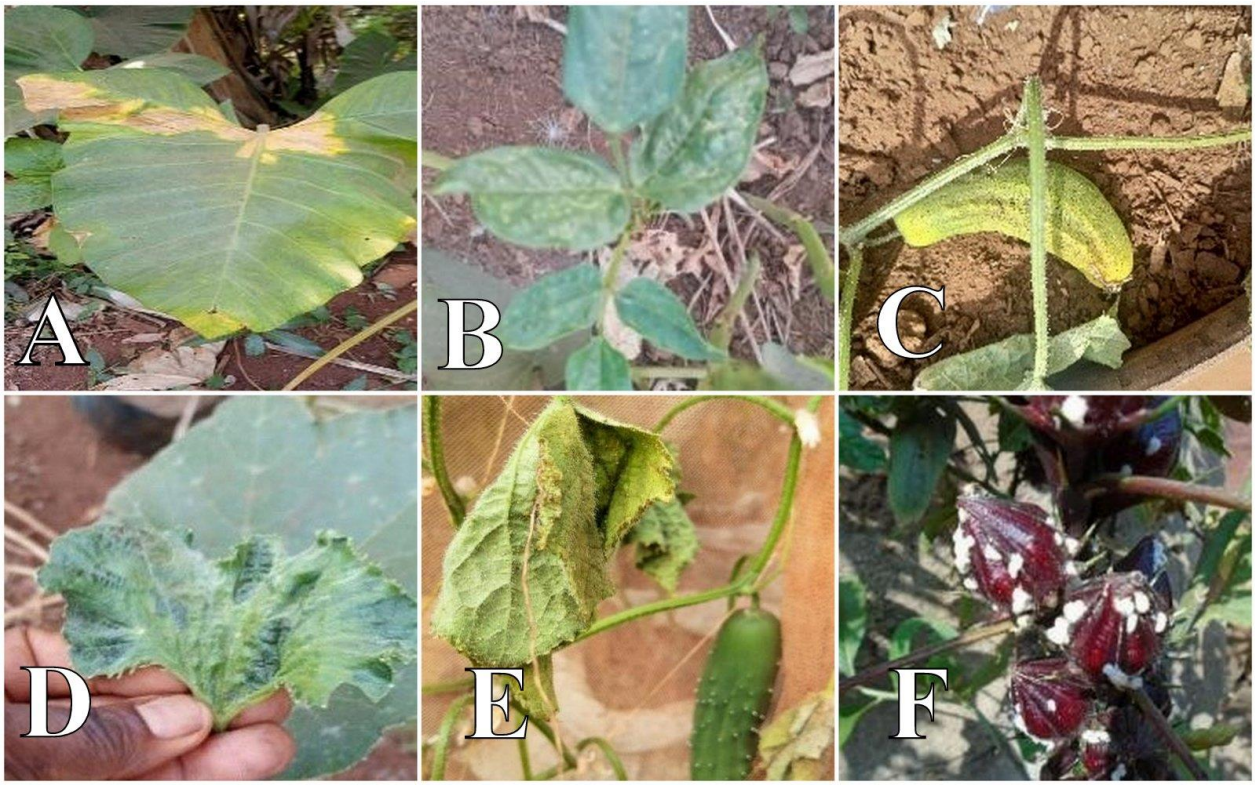

Fig. 5 – Pest and disease symptoms. A Leaf blight *Xanthosoma Campestris*. B Mosaic: Bean Mosaic Virus. C Bacterial wilt *Erwinia tracheiphila*. D Mosaic: Cucumber mosaic virus. E Mosaic: Cucumber mosaic virus. F White flies (*Bemisia tabaci*) on farmlands in Bamenda.

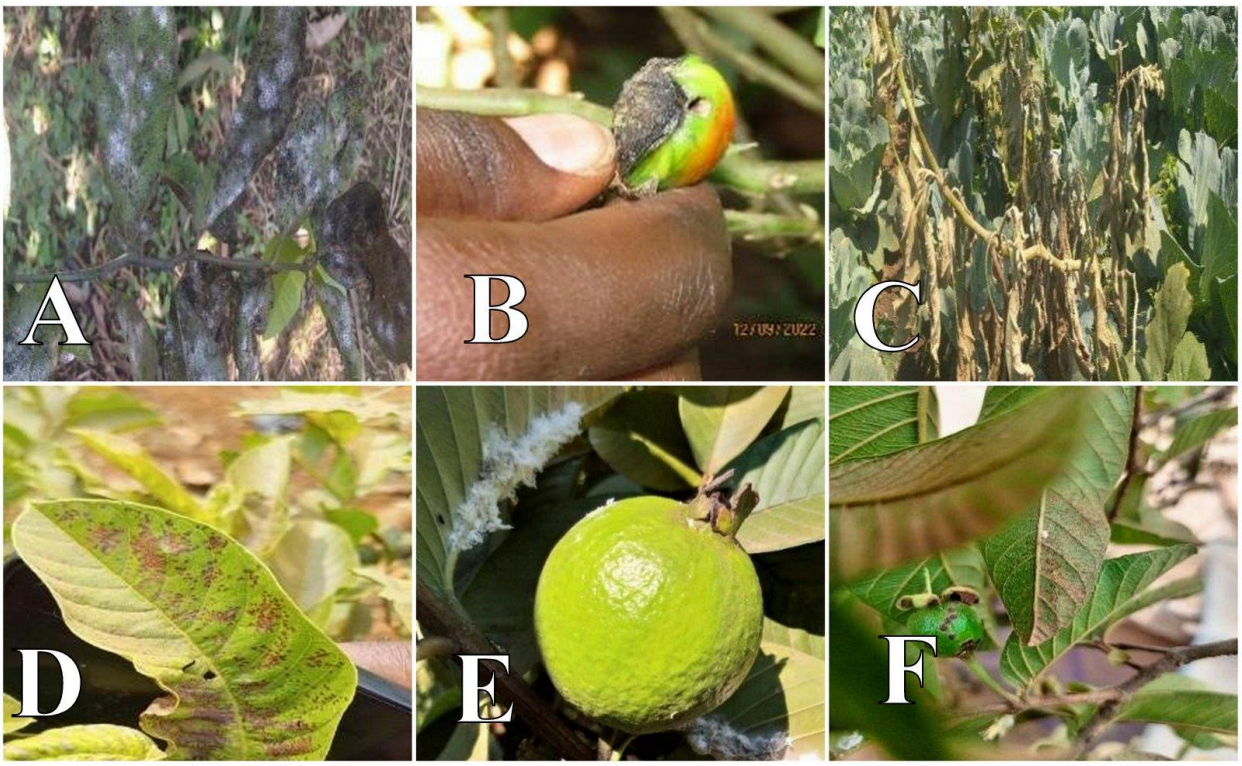

Fig. 6 – Pest and disease symptoms. A Leaf spot (*Cercospora capsica*). B Anthracnose (*Colletrotichum gloesporioides*) on eggplant. C Fusarium wilt of vegetable (*Fusarium oxysporum*). D Red rust (*Cephaleuros virescens*), on Guava. E Guava bud moth (webworm) *Stictea ejectana*. F Guava Canker *Physalopara psidii* on farmlands in Bamenda.

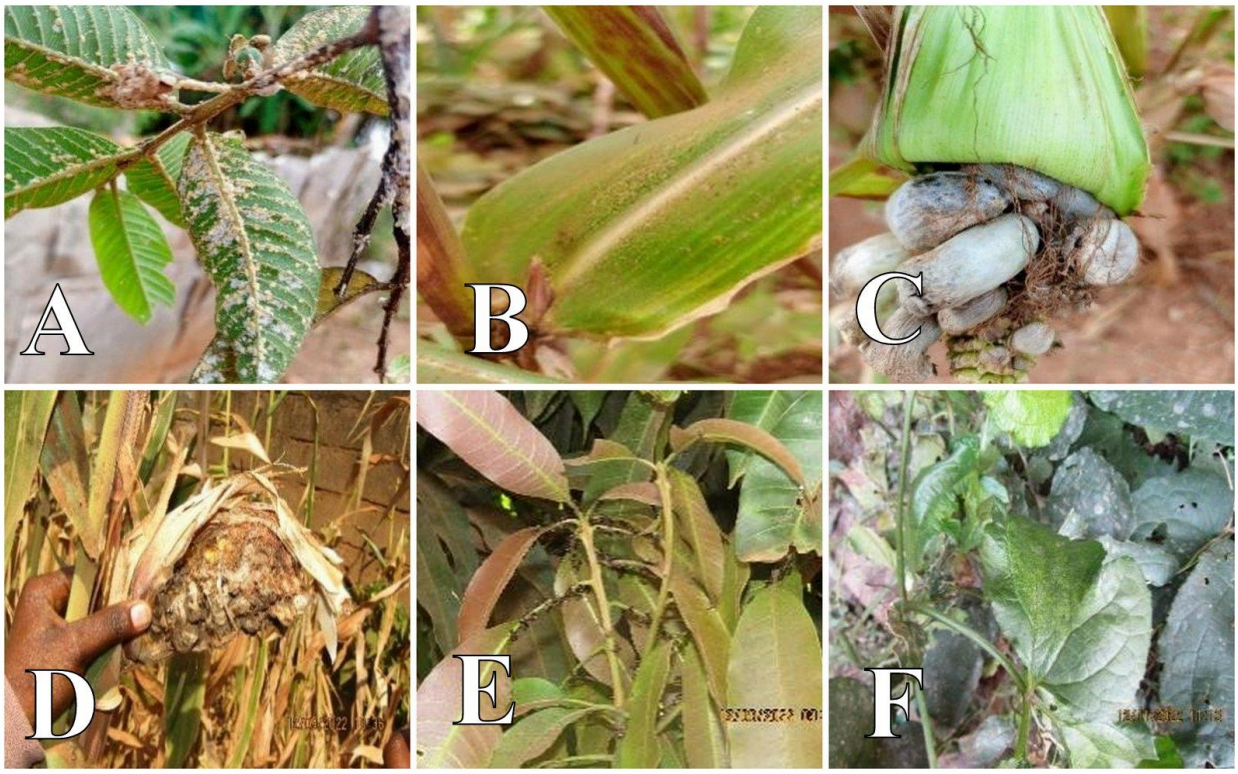

Fig. 7 – Pest and disease symptoms. A Whiteflies on Guava. B Downy mildew *Peronosclerospora sacchari*. C Corn smut *Ustilago maydis*. D Corn smut in advanced stage *Ustilago maydis*. E Sooty mould (*Meliola mangifera*). F White rust *Phoma sorghina* on farmlands in Bamenda.

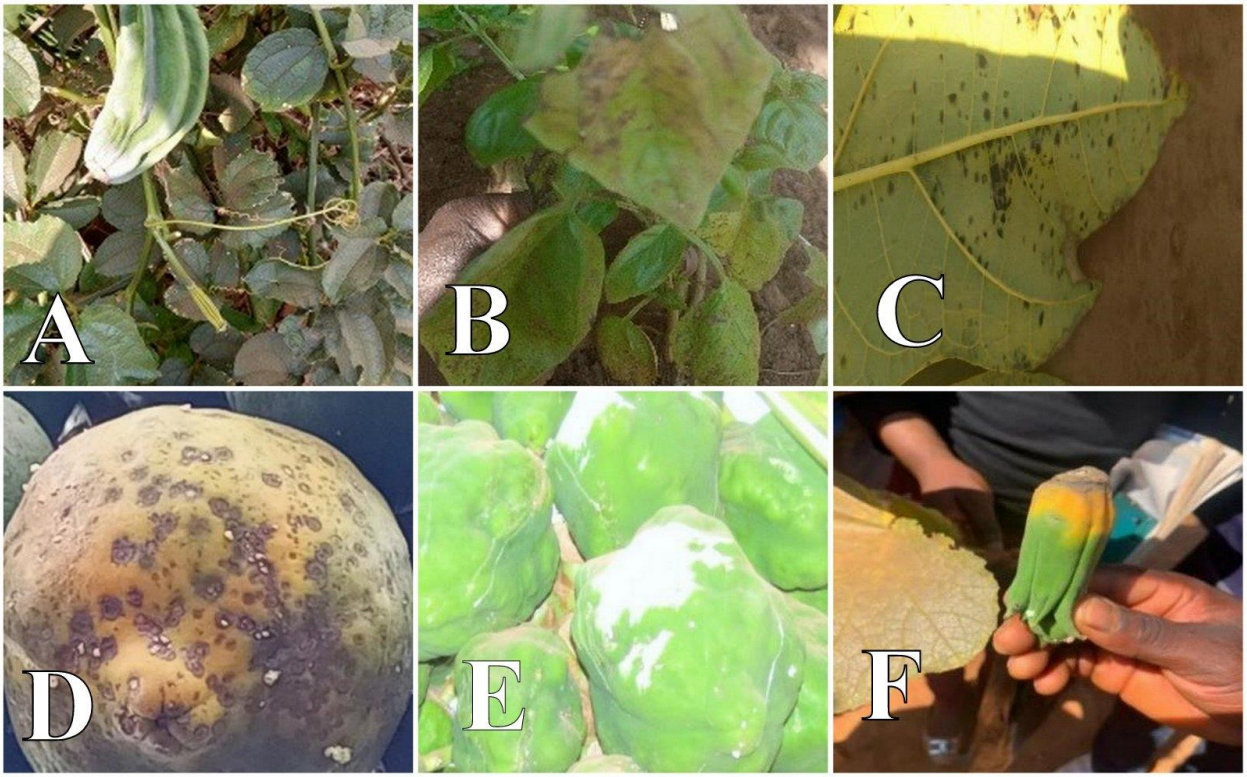

Fig. 8 – Pest and disease symptoms. A Insect infestation on vegetable. B Leaf spot *Septoria petroselini*. C Cercospora symptom on vegetable *Cercospora* spp. D Pawpaw black spot *Asperisporium caricae*. E Powdery mildew on Pawpaw *Oidium caricaepapayae*. F Botrytis disease *Botrytis* spp. on farmlands in Bamenda.

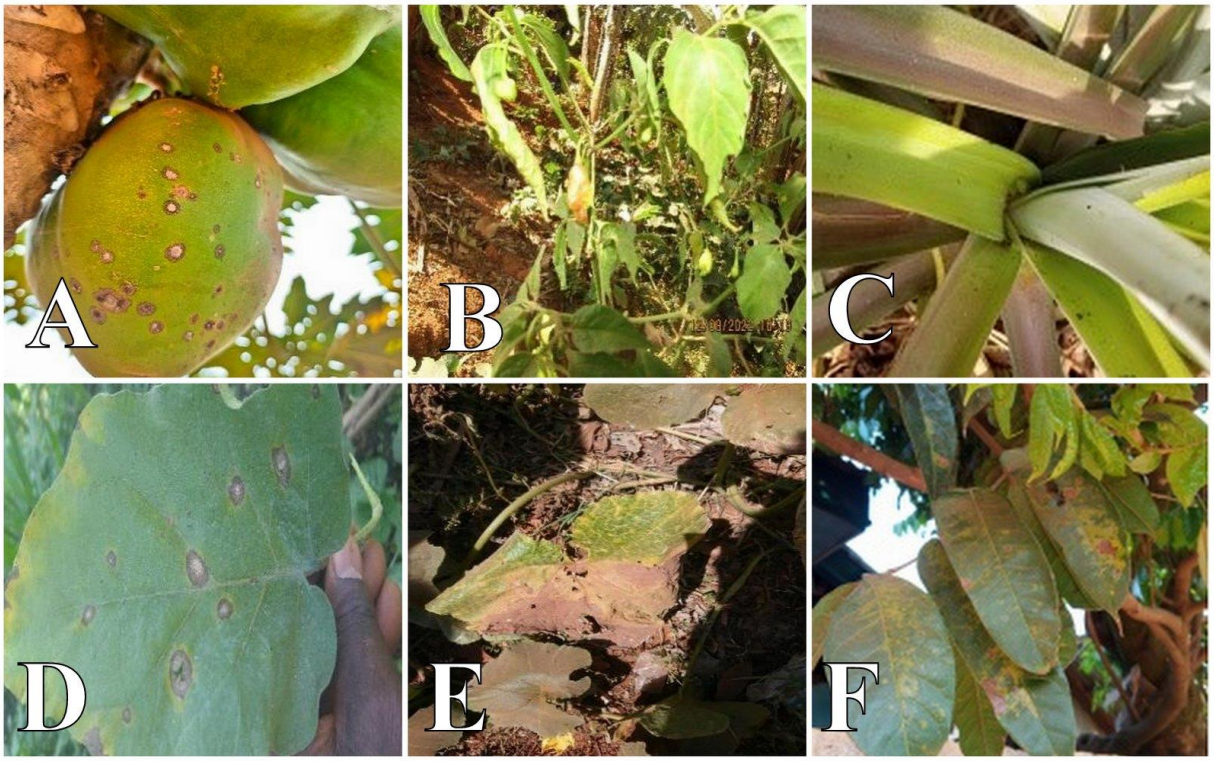

Fig. 9 – Pest and disease symptoms. A Papaya ring spot virus. B Mushy spots on pepper: *Fusariun solani*. C Mealybug - Dark Spots *Ceratocystis paradoxa*. D Viral Infection Anthracnose *Collectotrichum* spp. E Powdery mildew *Phyllactinia* spp. F Mosiac virus on plum on farmlands in Bamenda.

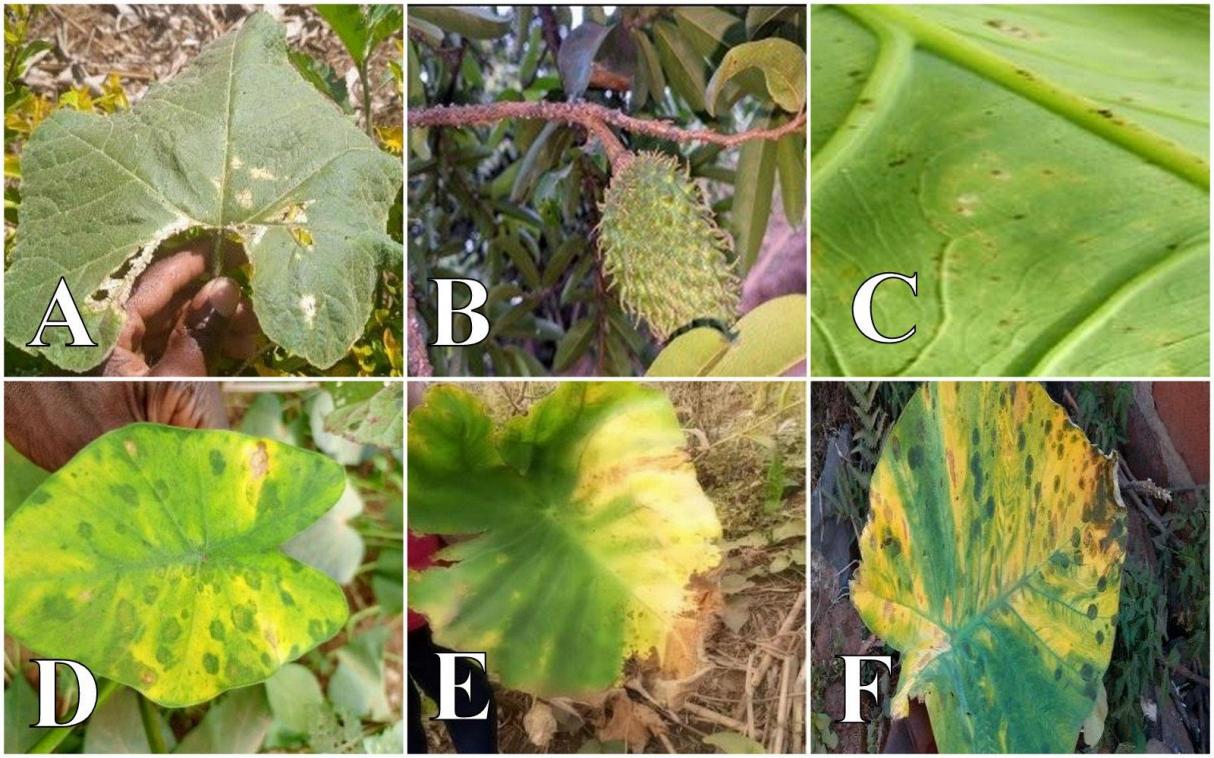

Fig. 10 – Pest and disease symptoms. A Radicular rot (*Rosellinia* spp. B *Phytophthora* spp. C Black spot of Taro *Phytophthora colocasiae*. D Leaf blight of Taro *Phytophthora colocasia*. E Leaf blight of Taro *Phytophthora colocasia*. F Fusarium wilt *Fusarium oxysporum* sp. *lycopersici* on farmlands in Bamenda.

Fig. 11 – Pest and disease symptoms. A Late blight with high severity on Tomatoes *Phytophthora infestans*. B Late blight with mild severity on Tomatoes *Phytophthora infestans*. C Bacteria blight: *Erwinia* or *Pseudomonas* spp. D Leaf spot of waterleaf *Alternaria* spp. on farmlands in Bamenda.

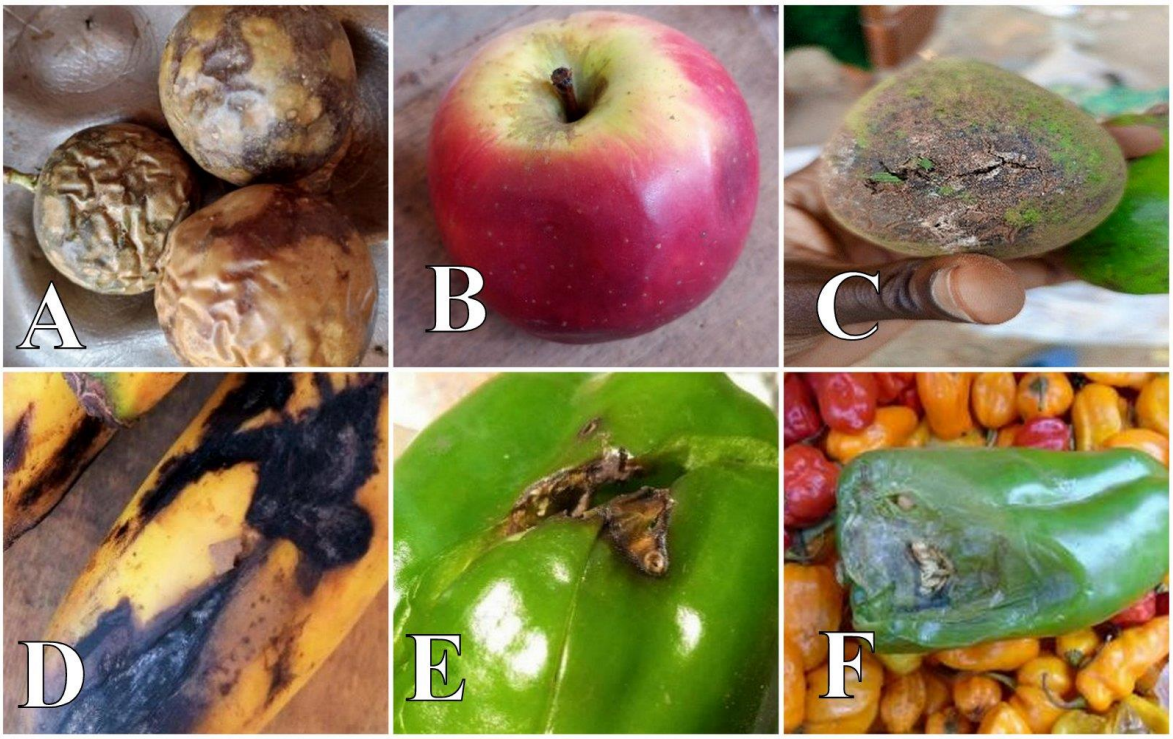

Fig. 12 – Pest and disease symptoms. A Anthracnose *Collectotrichum* spp. B Bacterial infection *Erwinia, Pectobacterium*. C Avocado Scab (*Venturia pyrina* sp.). D Black spot, rot *Erwina*. E Black spots (*Diplocarpon rosae*). F Soft rot (Bacteria) *Erwinia* spp., *Pseudomonas*, *Bacillus*, *Xanthomonas* in markets in Bamenda.

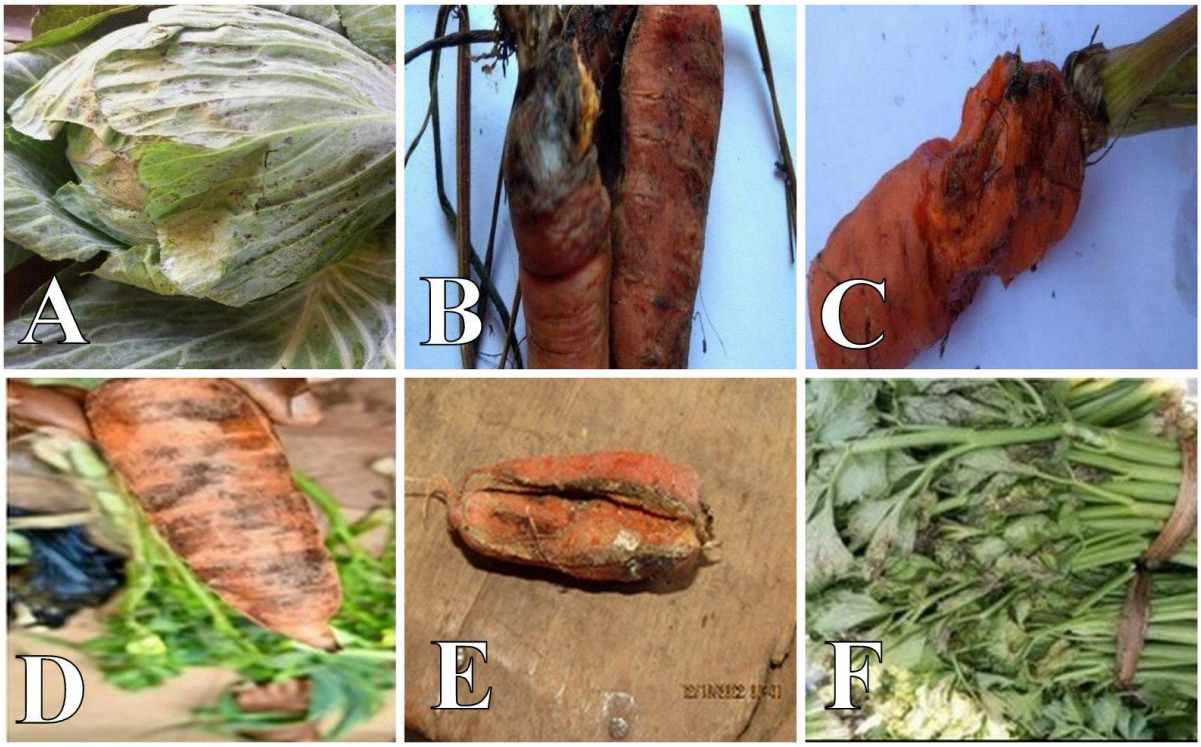

Fig. 13 – Pest and disease symptoms. A Leaf spot of cabbage *Alternaria brassicicola*. B White mould (*Sclerotia* spp.). C Soft rot (*Erwinia* spp.). D Black patches and black rot *Thielaviopsis basicola*. E Tip rot, caused by poor drainage in the field and small cracks that develop on root tips. F Celery blight *Septoria apiicola* in markets in Bamenda.

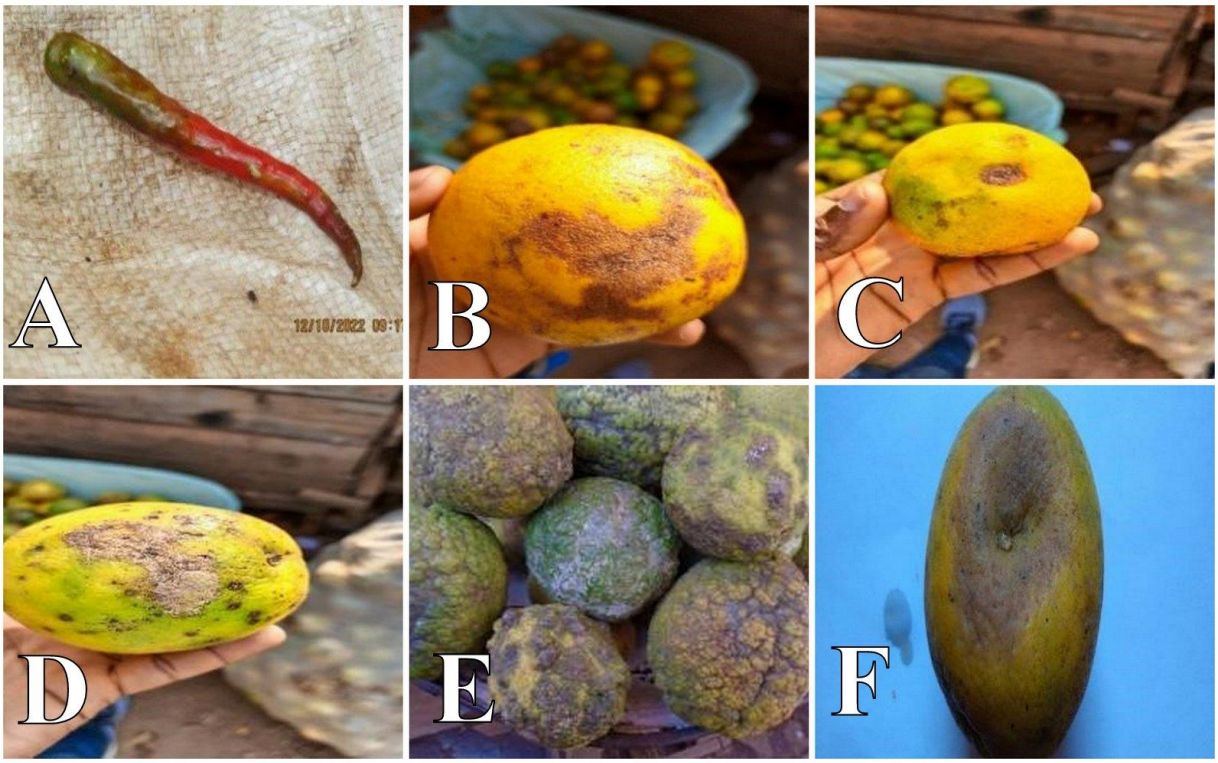

Fig. 14 – Pest and disease symptoms. A Black spot on pepper (*Ceratitis capitata*). B Citrus rust mite, *Phyllocoptruta oleivora*. C Citrus Elsinoe anthracnose (*Elsinoe* spp.). D Powdery mildew *Oidium citri* and *O. tingitaninum*. E Citrus black spot *Guignardia citricarpa*. F Rhizopus soft rot *Rhizopus* spp. in markets in Bamenda.

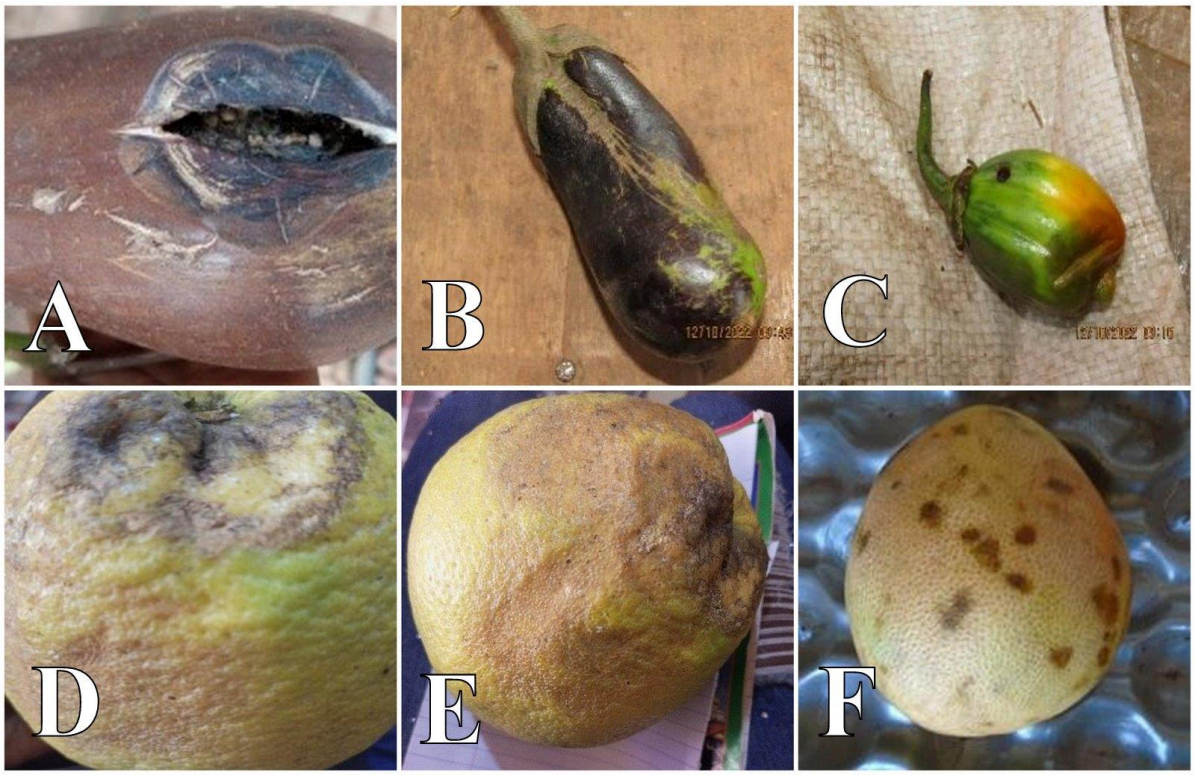

Fig. 15 – Pests and diseases symptoms. A Black spot *Cercospora melongenae*. B Eggplant scab *Cladosporium*. C Blossom end rot caused by lack of calcium and or uneven watering. D Sooty mold Fungi *Capnodium*. E Soft rot of grape *Phomopsis viticolasacc*. F Black spot disease or anthracnose *Elsinoe ampelina* in markets in Bamenda.

Fig. 16 – Pest and disease symptoms. A Bacterial infection (*Pectobacterium carotovorum*). B Insect infestation by Fruit fly. C Anthracnose Colletotrichum spp. D Pest on Okra. E Bacterial rot *Pectobacterium carotovorum*. F Papaya Anthracnose *Colletotrichum gloesosporioides* in markets in Bamenda.

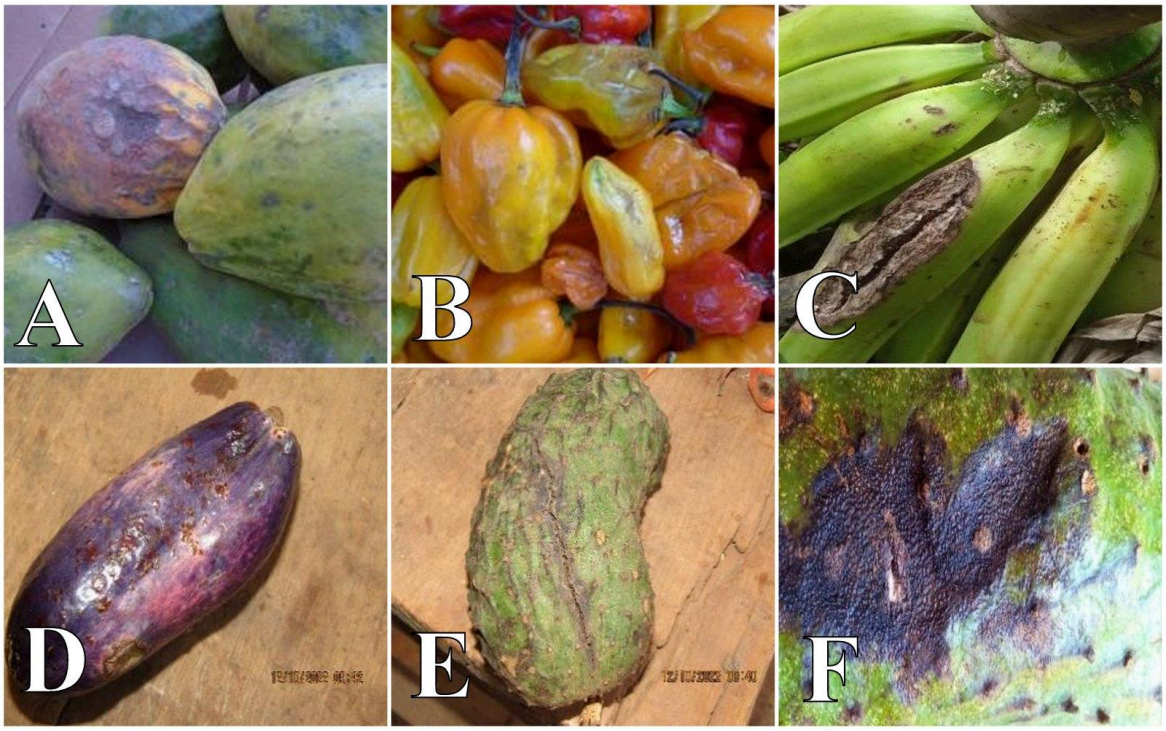

Fig. 17 – Pest and disease symptoms. A Sooty mold Fungus (Powdery mildew). B Green spot soft rot mushy spots on pepper. C Birds mark on plantain. D Plum scab (caused by *Venturia pirina*). E Anthracnose *Colletotrichum* spp. F Med fly on Soursop in markets in Bamenda.

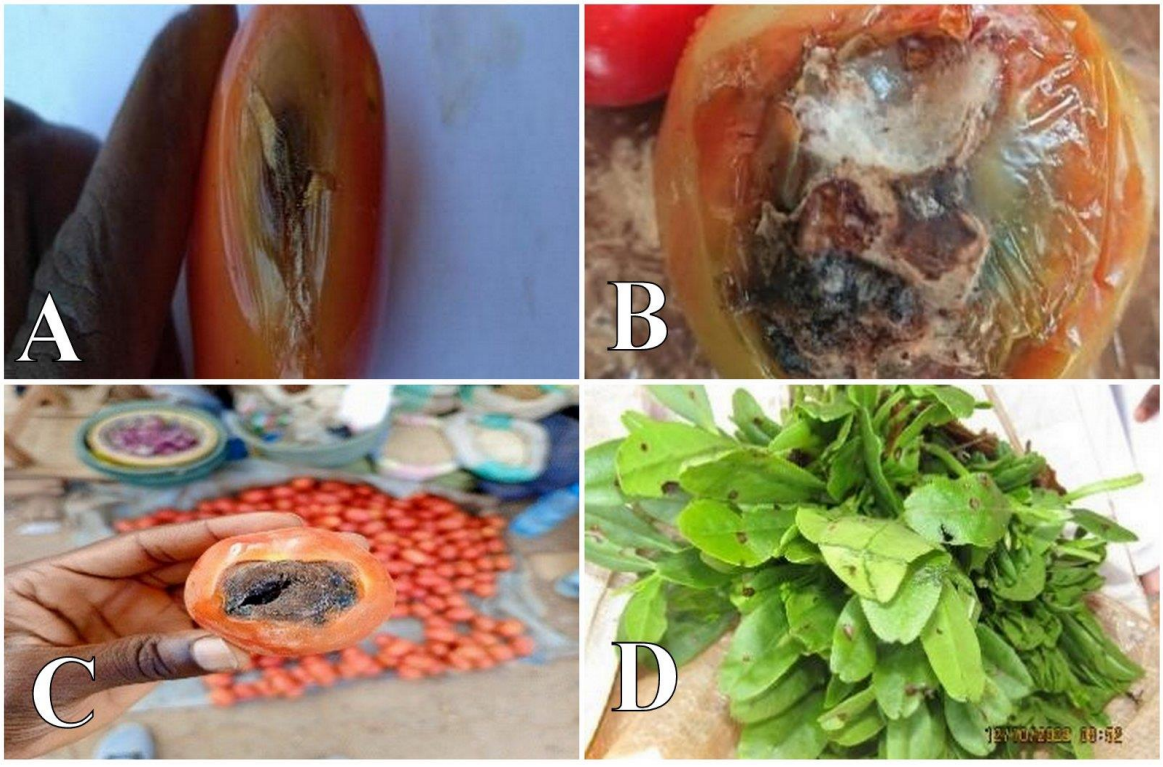

Fig. 18 – Pest and disease symptoms. A Tomato rot *Alternaria* spp. B Tomato rot *Erwina caratovora*. C Tomato Anthracnose *Collectotrichum coccodes*. D Leaf spot disease (*Pleospora* spp.) in markets in Bamenda.

In both farms and markets, the fruits and vegetables were affected by diseases/disorders such as fusarium wilt, leaf chlorosis, fruit rot, bacterial canker, bacterial blight, rust, early blight,

powdery mildew, mosaic, leaf spot and botrytis disease. These diseases were caused by fungi, bacteria and viruses. This is in line with several research works which indicated that diseases that affected fruits and vegetables were black spot (Lindh et al. 2021), rot caused by *Erwina* (Tiwari et al. 2022), Carrot crack disease (Methun et al. 2021), carrot soft rot caused by *Erwinia* spp. (Chandrashekar et al. 2023), carrot white mould caused by *Sclerotia* spp. (Ojaghian et al. 2020), carrot black patches and black rot (Javed & Javaid 2021), Celery blight caused by *Cercospora apii* (Singh et al. 2020), powdery mildew of citrus (El Kahlout & Abu-Naser 2019), citrus rust (Puspitarini & Endarto 2021), citrus elsinoe anthracnose caused by *Elsinoe* spp. (Zhao et al. 2020), rhizopus soft rot caused by *Rhizopus* spp. (and eggplant scab (Al-Karaawi & Al-Waily 2023), black spot of eggplant (Naibe 2021), garden egg blossom end rot (Bush et al. 2016), soft rot of grape (Achari & Devappa 2021), grape soothy mold (Achari & Devappa 2021), circular depression and rotting in potato (Trafder 2021), bacterial rot of onion (Belo et al. 2023), anthracnose of okro (Mitra et al. 2021), powdery mildew of pawpaw (Seress et al. 2021), pawpaw anthracnose (Kugui 2020), mushy spots on pepper (Wasendorf et al. 2022), Plum scab (Yakuba et al. 2021), soursop scab (Yakuba et al. 2021), tomato anthracnose (Shahriar et al. 2023), tomatoes rot caused by *Erwina* (Zhou et al. 2023), tomato rot caused by *Alternaria* spp. (Ogolla et al. 2023) and waterleaf leaf spot disease caused by *Pleospora* spp. (Zhan et al. 2023). The insect pests identified were *Dacus punctatifrons*, *Helicoverpa armigera*, *Podagrica* spp., *Bemisia tabaci* and aphids. Some of these insect pests serve as vectors of plant diseases. According to Fajinmi & Fajinmi (2010) flea beetles are involved in the transmission of okra mosaic virus in okra.

Specific description of some insect pests of fruits and vegetables in Bamenda are:

Tomato fruit fly (*Dacus punctatifrons*)

Dacus punctatifrons Karsh (Diptera: Tephritidae) is a fruit fly pest observed in farms and markets in Nkwen and Bambui (Fig. 19). This fruit fly belongs to the sub family Dacinae. It is an orange-brown fly with a medial black stripe on the scutum attacking pepper, tomatoes garden egg and cucumber (Fig. 20). The adult females have a long extensible ovipositor, which they use to insert their eggs within an intact unripe tomato fruit, which in turn hatch into larvae (Ntonifor & Okolle 2006). These larvae feed on the pulp of fruits (Fig. 21) as was seen on tomatoes and cucumber. When the larvae are mature, they drop to the ground, wriggle into the soil where they transform into pupae and later get transformed in to adults that attack other tomato fruits. This fly is distributed throughout the tropics and sub-tropical regions of the world and appears to be endemic to the tropical and sub-tropical rain forest. The fly has also been reported on Cucurbits host plants in other areas of Cameroon; for instance, it was reported as prominent pest on tomatoes in the Centre and Southern regions of Cameroon where at times its high infestations cause some farmers to abandon entire tomato fields (Tindo & Tamo 1999).

Fruit worm (*Helicoverpa armigera*)

Another insect pest identified on tomato and cabbage (*B. oleracea)* in Bamenda was the fruit worm, *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae) as shown in Fig. 22. It is one of the most destructive agricultural pests in the world. This moth is a major pest, because the larva can feed on a wide range of economically important crops including cotton, corn, tomato, legumes and tobacco (King 1994, Shanower & Romeis 1999). Due to its heavy infestation, it can damage a complete field crop causing enormous losses (Prasad & Purohit 2009). Damage by this worm starts soon after the fruiting period of the crop when the newly hatched larvae bore into the fruit and feed inside to render the fruit unfit for human consumption. Also, the newly hatched larvae feed on the petals as well as the young fruits and this may lead to the drying out of the fruit let. In some cases, feeding areas on the fruit may become enlarged as the fruit grows and this feeding area may show up on mature fruit as uniformly shallow circular or oval sunken areas with brownish coloration (Khanam et al. 2003, Ghosh et al. 2010).

Fig. 19 – *D. punctatifrons* adults.

Fig. 20 – Signs of *D. punctatifrons.* A Tomato. B Pepper. C Garden egg.

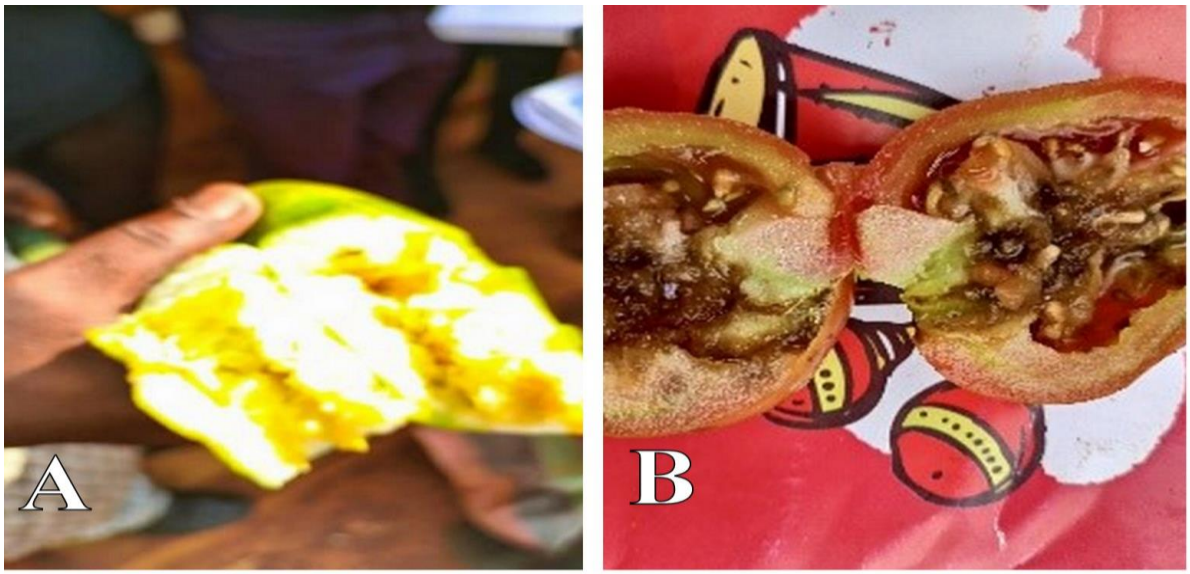

Fig. 21 – *D. punctatifrons* infestation. A Decaying cucumber. B Decaying tomato.

Fig. 22 – *H. armigera* damaging effects. A Tomato. B Cabbage.

Flea beetles (*Podagrica* spp.)

Flee beetle (*Podagrica* spp.) is an insect pest of okra (*Abelmoschus esculentus* L. Moench) observed in farms in Bamenda (Fig. 23). Flea beetles (*Podagrica* spp.) are mainly leaf eaters and have biting and chewing type of mouthparts. They are observed to commence their infestation on okra plants from the stage of germination throughout all stages of its growth (Ahmed et al. 2007, Pitan & Adewole 2011). They produce a characteristic injury known as "shot holing" (Egwuatu 1982) and occasionally damage flowers, shrubs and even trees. The crop is susceptible to various pests of which flea beetle causes heavy damage (Ghosh 2014). The flea beetles have also been implicated in the transmission of okra mosaic virus in okra (Fajinmi & Fajinmi 2010).

Fig. 23 – Flea beetles (*Podagrica* spp.) damaging effects. A Pods. B Leaves of okra.

Whitefly (*Bemisia tabaci*)

Whitefly, *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) are small sucking insects of vegetables, ornamental plants and field crops and can cause losses up to100% on tomato in tropical and subtropical regions (Lourenção et al. 2008). The larvae and adults feed on the underside of leaves by sucking leaf sap and the fly also causes irregular ripening of fruit or even death (Naika et al. 2005, Touhidull & Shunxiang 2007). Their regular ripening disorder of fruits is characterized externally by inhibited or incomplete ripening of longitudinal sections of fruit and internally by an increase in the amount of white tissue (Schuster et al. 1989). *Bemisia tabaci* being obligate phloem feeders as adult and nymph stages causes chlorosis on infected leaves (Jiang et al. 2000, Zhang et

al. 2004). The fly is also involved in the transmission of the Tomato yellow leaf curl virus (TYLCV) present in many tropical and subtropical countries especially West Africa, Mediterranean basin, Caribbean countries and South-eastern Asia. In Bamenda, it was seen on bitter leaf (*Vernonia amygdalina*) with some of its leaves folded and curled (Fig. 24).

Fig. 24 – Bitter leaf (*Vernonia amygdalina*) infested by whiteflies.

Aphids

Aphids (Homoptera: Aphididae) feed on phloem sap and are major agricultural and horticultural pests throughout the world. For instance, *Myzus persicae* is widespread and polyphagous and its host plant include tomato, beans, sweet potato as well as various ornamentals (Patterson et al. 2007). Aphids can have a dramatic negative impact on their host plants partly due to their capacity for extremely rapid population growth (Dixon 1987). Aphids reproduce rapidly and have been shown to adapt quickly to host-plant phenology and ecology, as well as plant physiology and biochemistry (Patterson et al. 2007). They can result in direct damage to crops through feeding on phloem tissue; they can also contribute to severe indirect damage by acting as primary vectors of many plant viruses. They ingest phloem sap from their hosts through narrow piercing-sucking mouthparts called stylets. During probing, aphids' stylets transiently puncture epidermal, mesophyll and parenchyma cells, and this mechanical damage may influence plant responses to infestation (Delahau 2005). They were identified on bitter leaf (Fig. 25) and African black night shade (Fig. 26) whose leaves were curled in Bambui, Bambili and Nkwen.

Fig. 25 – Bitter leaf (*Vernonia amygdalina*). A Aphids. B Curled leaves due to their infestation.

Fig. 26 – Black night shade (*Solanum scabrum*). A Aphids. B Curled leaves due to their infestation.

Conclusion

Pathogens and pest's infestation on fruits and vegetables is broad and their detection could be ineffective. This results in the reduction in the value of produce because they enter the supply chain without detection and control. This study explored the different pests and diseases infecting fruits and vegetables in this region by documenting the signs and symptoms which was diverse. Also, various bacterial and fungi pathogens were identified by cultural method. Agricultural production is at a scale and stage where subjective assessment is insufficient to meet the scale of quality needed by the industry. Molecular identification is necessary to compliment signs and symptoms assessment of pests and diseases as well as their cultural and morphological identification. Integrated management and control of pests and diseases is required.

Acknowledgements

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