Review

Status and Distribution of Diseases Caused by Phytoplasmas in Africa

S. A. Kazeem *, A. Zwolińska, J. Mulema, A. O. Ogunfunmilayo, S. Salihu, J. O. Nwogwugwu, I. J. Ajene, J. F. Ogunsola, A. O. Adediji, O. F. Oduwaye, K. D. Kra, M. O. Jibrin *, W. Wei *

Posted Date: 12 March 2025

doi: 10.20944/preprints202503.0864.v1

Keywords: '*Candidatus* Phytoplasma'; 16S rRNA RFLP; Africa; lethal yellow

Review

Status and Distribution of Diseases Caused by Phytoplasmas in Africa

S. A. Kazeem [1,*], A. Zwolińska [2], J. Mulema [3], A.O. Ogunfunmilayo [1], S. Salihu [4], J.O. Nwogwugwu [5], I. J. Ajene [6], J.F. Ogunsola [7], A.O. Adediji [8], O.F. Oduwaye [9], K.D. Kra [10], M.O. Jibrin [11,*] and W. Wei [12,*]

1 Post-Entry Quarantine, Diagnostic and Surveillance Station, Nigeria Agricultural Quarantine Service, Ibadan, Nigeria
2 Department of Plant Physiology, Faculty of Biology, Adam Mickiewicz University, Poznan, Poland
3 CABI, Canary Bird, 673 Limuru Road, Muthaiga, PO Box 633-00621, Nairobi, Kenya
4 National cereal research Institute, Ibadan Research Station, Oyo State, Nigeria
5 Department of Forest Conservation and Protection, Forestry Research Institute of Nigeria, Ibadan, Nigeria
6 International Centre of Insect Physiology and Ecology, Nairobi, Kenya
7 Department of Biological Sciences, Bells University of Technology, Ota, Ogun State., Nigeria
8 Research Office, Pan African University Life and Earth Sciences (including Health and Agriculture), Ibadan, Nigeria
9 Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria
10 University Nangui Abrogoua, Abidjan, Cote d'Ivoire
11 Department of Entomology and Plant Pathology, Oklahoma State University, 127 Noble Research Center, Stillwater, Oklahoma 74084, USA
12 Molecular Plant Pathology, USDA, Agricultural Reserch Service, Beltsville, MD 20705, USA
* Correspondence: kazeems2001@gmail.com; mustafa.jibrin@okstate.edu; wei.wei@usda.gov Tel.: +2348037760276; +14058540216, +13015040786

Abstract: Phytoplasma ('*Candidatus* Phytoplasma' species) diseases have been reported globally to severely limit the productivity of a wide range of economically important crops and wild plants causing different yellows-type diseases. With new molecular detection techniques, several unknown and known diseases with uncertain aetiologies or attributed to other pathogens have been identified as being caused by Phytoplasmas. In Africa, phytoplasmas have been reported in association with diseases in a broad range of host plant species. However, the few reports of phytoplasma occurrence in Africa have not been collated together to determine the status in different countries of the continent. Thus, this paper discusses the geographical distribution, detection techniques, insect vectors, alternative hosts and socio-economic impacts of phytoplasma diseases in Africa. This is to create research perspectives on the disease's aetiology in Africa for further studies towards identifying and limiting their negative effects on the continent's agricultural economy. In Africa, Phytoplasmas recorded in different countries affecting different crops belong to eight groups (16SrI, 16SrII, 16SrIII, 16SrIV, 16SrVI, 16SrXI, 16SrXIV and 16SrXXII) out of the 37 groups and over 150 subgroups reported worldwide on the basis of their 16S rRNA RFLP profile. Lethal yellow disease was the most destructive Phytoplasma reported in Africa and has a high socio-economic impact.

Keywords: '*Candidatus* Phytoplasma'; 16S rRNA RFLP; Africa; lethal yellow

1. Overview and Rationale

 doi:10.20944/preprints202503.0864.v1

Phytoplasma (‘*Candidatus* Phytoplasma’ species) diseases have been reported globally to severely limit the productivity of a wide range of economically important crops and wild plants, causing different yellow-type diseases [1–7,9,10]. Table 1 lists the phytoplasma groups reported worldwide on the basis of their 16S rRNA genes. New phytoplasma-associated diseases are continuously being discovered, mainly because of improved molecular diagnostic methods. With these detection techniques, several unknown and known diseases with uncertain aetiologies or attributed to other pathogens have been identified as being caused by Phytoplasmas. Many plant species affected by yellows-type diseases were wrongly attributed to viruses because of their infective spread, symptoms and transmission by insects [11,12].

Doi et al. (1967) reported that the aetiological agents of yellow diseases could be wall-less prokaryotes related to bacteria rather than viruses [13]. These organisms were first referred to as mycoplasma-like organisms (MLOs) because of their similarity to mycoplasmas infecting animals, which also belong to the Mollicutes class [3,14]. In contrast to mycoplasmas, MLOs were nutritionally fastidious and phylogenetically related to the Gram-positive bacteria [15,16]. The MLOs were eventually named ‘*Candidatus* phytoplasma’ after the interpretation of different molecular data [2]. These bacteria belong to the super kingdom Prokaryota; kingdom Monera; domain Bacteria; phylum Firmicutes (low G+C, Gram-positive eubacteria); class Mollicutes; and Candidatus (Ca.) genus Phytoplasma [17].

Phytoplasmas are wall-less prokaryotes, insect-vectored and phloem-limited bacteria with A+T-rich genomes that are 530–1,350 kb in size [4,16,18–21]. These bacteria differ from Gram-negative insect-vectored proteobacteria such as liberibacters, phlomobacters [9,22].

 doi:10.20944/preprints202503.0864.v1

Table 1. Phytoplasma strains reported worldwide.

Acronym	Phytoplasma strain	16Sr	Related Ca. species	Origin	DNA source
CACT		I-B	*Phytoplasma asteris*	USA	DNA
BCRD	Cactus aster yellows	I-C	*Phytoplasma asteris*	Czech.	Plant
KVE	Blackcurrant reversion disease	I-B	*Phytoplasma asteris*	UK	DNA
AYA	Clover phyllody-England	I-F	*Phytoplasma asteris*	Spain	DNA
AVUT	Apricot chlorotic leaf roll	I-M	*Phytoplasma asteris*	Germany	DNA
WBDL	Atypical aster yellows	II-B	*Phytoplasma aurantifolia*	Arabia	Plant
FBP	Lime witches'-broom	II-C	*Phytoplasma aurantifolia*	Sudan	Plant
FBPSA	Faba bean phyllody	II-C	*Phytoplasma aurantifolia*	Sudan	Plant
SOYP	Crotalaria saltiana phyllody	II-C	*Phytoplasma aurantifolia*	Thailand	Plant
TBB	Soybean phyllody	II-D	*Phytoplasma aurantifolia*	Australia Australia	Plant
SPLL	Australian tomato big bud	II-D	*Phytoplasma aurantifolia*	Fiji	DNA
IPO	Sweet potato little leaf	II-D	*Phytoplasma aurantifolia*	USA	DNA
PYLV	Ipomoea (unspecified)	III-A	*Phytoplasma pruni*	USA	DNA
GVX	Peach western X	III-A	*Phytoplasma pruni*	Italy	DNA
API	Green valley X	III-B	*Phytoplasma pruni*	USA	DNA
JRI	Euscelidius variegatus	III-H	*Phytoplasma pruni*	Tanzania	DNA
TLD	Poinsettia branching factor	IV-B	*Phytoplasma cocostanzaniae*	Ghana	DNA
CSPWD	Tanzanian lethal decline	IV-C	*Phytoplasma cocosnigeriae*	France	DNA
ULW	Ghanaian Cape St Paul wilt	V-A	*Phytoplasma ulmi*	USA	DNA
PWB	Elm witches'-broom	VI-A	*Phytoplasma trifolii*	India	Plant
BLL	Potato witches'-broom	VI-A	*Phytoplasma trifolii*	Sudan	DNA
CPS	Brinjal little leaf	VI-C	*Phytoplasma trifolii*	USA	DNA
ASHY-1	Catharanthus phyllody	VII-A	*Phytoplasma fraxini*	USA	DNA
PPWB	Ash yellows	IX	*Phytoplasma phoenicium*	Italy	DNA
AP-15	Pigeon pea witches'-broom	X-A	*Phytoplasma mali*	Germany	DNA
GSFY-1	Apple proliferation	X-B	*Phytoplasma prunorum*	Germany	DNA
ESFY	German stone fruit yellows European stone fruit yellows	X-B	*Phytoplasma prunorum*	Ethiopia	Plant
NGS	Napier grass stunt	XI	*Phytoplasma oryzae*	Jersey, UK	DNA
CPF	Cordyline phytoplasma	XII	*Phytoplasma fragariae*	Serbia	DNA
STOL	Stolbur of pepper	XII- A	*Phytoplasma solani*	USA	DNA
LYAM	Coconut lethal yellowing (Adonidiamerrillii)	IV-A	*Phytoplasma palmae*	Florida, USA	DNA
LYHV	Coconut lethal yellowing (Hyophorbeverschafeltii)	IV-A	*Phytoplasma palmae*	Florida, USA	DNA
LYPR	Coconut lethal yellowing (Phoenix rupicola) Mexican periwinkle virescence	IV-A	*Phytoplasma palmae*	Mexico	DNA
MPV		XIII	–		DNA

Source: [23,24].

 doi:10.20944/preprints202503.0864.v1

and Spiroplasmas, which are culturable in vitro [9,25]. The detection of phytoplasmas in diseased plants was previously based on electron microscope observations, symptom expressions, and transmission via insects, graft or dodder but currently uses molecular tools [25–28].

The use of molecular detection techniques has provided not only a basis for the identification of phytoplasmas but also a reliable tool for their differentiation and classification. This technique, which is based on restriction fragment length polymorphism (RFLP) analysis of the polymerase chain reaction (PCR) target gene sequence, in silico RFLP and the online *i*PhyClassifier and CpnClassiPhyR tools have been used to classify phytoplasmas that cause various diseases into groups and subgroups [29–32]. Recently, multilocus sequence analyses have been used to study the population structure of phytoplasmas [23,33–35]. Compared with those of thousands of known phytoplasma strains, only few strains have their genomes sequenced and documented [23,36].

Phytoplasmas have been reported to cause diseases in different plant species across many African countries [28,37]. The first recorded occurrence was in 1917, known as Bronze leaf wilt (now called Awka wilt disease), which causes lethal yellowing-type disease in coconut [37]. Subsequently, coconut lethal yellowing was similarly reported in different African countries [38]. This paper will attempt to identify and summarize the different status of reported phytoplasmal diseases in Africa. Hopefully, this helps to highlight the current status of plant pathogenic phytoplasmas in Africa and identify gaps for future research.

2. Symptoms and Spread of Phytoplasmal Diseases

2.1. Symptoms of Infection

Phytoplasmas cause virus-like symptoms in plants, and for many years, these diseases have been attributed to viruses [12]. Symptom expression of Phytoplasma infection alone cannot, in most cases, be used for definite identification of the causal organism. This is because symptom expression depends on the host species, growth stage of the host infection and strain of the Phytoplasma. Additionally, dual or mixed infections involving related or unrelated phytoplasmas are known to occur naturally in plants [16]. Therefore, molecular diagnosis is necessary to confirm the causal phytoplasma species since consistent isolation in axenic media is yet to be established for most phytoplasmas [16,39–42].

Phytoplasma-infected plants present symptoms that point to severe disruptions in the usual equilibrium of growth regulators or plant hormones [3,43,44]. The symptoms induced in diseased plants vary with the phytoplasma and with the stage of infection. Some plant species are tolerant or resistant to phytoplasmal infections with no or mild symptoms [44]. The protocol by Ermacora and Osler [44] provides descriptions and pictorial representatives of each symptom, factors influencing phytoplasma symptom expression and practical procedures for the diagnosis of each symptom. Wei et al. [45] developed a web-based link called the phytoplasma disease and symptom database (iPhyDSDB) to provide images and descriptive definitions of symptoms caused by phytoplasma as a reference point to match phytoplasma symptoms to aid virtual diagnosis. The most common and representative indicators of phytoplasma infection include yellowing of plants, stunting (small flowers and leaves and shortened internodes), witches' broom (bunchy growth at stem apices due to loss of apical dominance or proliferation of auxiliary or axillary shoots/buds), phyllody (development of floral parts into green leaf-like tissues) and virescence (greening of flowers due to loss of normal flower pigments) [45]. Multiple symptoms can sometimes occur on the same host due to single infection or coinfection by multiple phytoplasma species, as reported, for example, in wild grasses in East Africa (26). Symptoms also include leaf curling, crinkling or cupping upwards or downwards, purple top (reddening of leaves and stems), phloem necrosis, dieback, sterility of flowers and abnormal internode elongation [16,43,44,46,47].

 doi:10.20944/preprints202503.0864.v1

2.2. Phytoplasma Transmission

Phytoplasmas can be introduced into new geographic regions by long-distance dispersal and spread within/between fields via insect vectors, infected planting material and transovarial transmission [48,49].

2.2.1. Insect Vectors

Insect vectors are the main carriers and distributors of phytoplasmas in nature and within fields. The geographical distribution and host range of phytoplasmas are strongly dependent upon the insect vectors found in that area and whether the insects are monophagous, oligophagous or polyphagous in their feeding habits [14,16]. Monophagous and oligophagous insect species are generally more efficient vectors than polyphagous insect species are [50]. Vectors can be found on leaves, flowers, fruits, bark, and sometimes underground in the roots of host plants [48].

Phytoplasma vectors belong to the order Hemiptera and are transmitted mainly by leafhoppers (Auchenorrhyncha: Cicadellidae) and less commonly by planthoppers (Auchenorrhyncha: Fulgoromorpha) and psyllids (Sternorrhyncha: Psyllidae), which feed on the phloem sap of infected plants [16,48,50–54]. Adults and nymphs can transmit phytoplasmas since both have similar feeding behaviours [54] in a circulative-propagative manner that involves a latent period from 2-8 weeks [16,55]. The mere detection of phytoplasmas in an insect does not imply that the insect is a vector; a transmission assay is needed to provide conclusive evidence [50]. This depends on insect vector competence (the ability to acquire and transmit phytoplasmas by overcoming the insect gut and salivary gland cell barriers to becoming infectious) [50,56].

Phytoplasmas are usually transmitted by specific insect vector species, but some can transmit more than one type of phytoplasma to the same or a range of plant species in different regions [14,28,42,54]. The vector competence of more than half of the confirmed phytoplasma groups has not been determined, which has limited the identification of vectors of many phytoplasmas [42,50]. This has also affected the study of insect vector ecology and the epidemiology of plant diseases caused by phytoplasmas. Surveying vectors to determine associated phytoplasma diseases in a given region is important for quarantine/management purposes.

The screening of insect species to confirm their vector competence is usually performed via a variety of methods [42,48]. The choice of method is determined by the insect taxon, live stage of concern, and purpose of the study. Two or three methods have to be used together if there is little prior knowledge concerning the insect vector(s) [48]. Laboratory techniques for screening vectors that can be adopted to suit less equipped laboratory environments are described by Kingdom [57], Bosco and Tedeschi [58], Bertin and Bosco [59], Kruger and Fiore [48] and Pagliari et al., [60].

Methods of capturing and storing the insect vectors of phytoplasmas and criteria for choosing techniques were described by Weintraub and Jürgen [61] and Kruger and Fiore [48]. General and specific methods for raising insect vector colonies and maintaining phytoplasmas were highlighted by Kingdom [57]. Both Bosco and Tedeschi [58] and Pagliari et al., [60] described vector rearing techniques and transmission experiments using insects from phytoplasma-free laboratory colonies or field collections. The identification of all stages of insect vector species involved in phytoplasma transmission was demonstrated by Bertin and Bosco [59] via molecular identification tools where a morphological taxonomic expert is not available.

Insect vectors transmitting Grapevine yellow disease in Tunisia and South Africa [62,63] and Napier grass stunt in Kenya and Ethiopia [64–66] have been confirmed. Those suspected to transmit lethal yellowing disease of coconut in Mozambique, Ghana, and Tanzania were reported by Philippe et al. [67], Bila et al. [68], and Gurr et al. [27], respectively. The insect vector(s) for many of the reported phytoplasmas in Africa are yet to be identified, mainly because the vectors are often not studied. Thus, identifying these vectors and possibly unknown phytoplasmas for screening potential insect vectors were advocated by Trivellone and Dietrich [69] and Trivellone et al. [70]. This offers the opportunity to unravel phytoplasma species and their hosts in Africa through the monitoring and diagnosis of insect vector(s) as a target for management.

 doi:10.20944/preprints202503.0864.v1

2.2.2. Other modes of transmission

Phytoplasmas may also be transmitted from infected plants to healthy plants through the parasitic plant dodder (*Cuscuta* sp.) and grafting [71–74]. It can be spread by vegetative propagation through cuttings, tubers, rhizomes, bulbs, etc. It cannot be transmitted mechanically by inoculation with phytoplasma-containing sap.

Transovarial and seed transmission of Phytoplasmas has been demonstrated [49,75] to be possible in the introduction and spread of Phytoplasma diseases worldwide [35]. Thus, the National Plant Protection Organization of each country should now consider these modes of phytoplasma transmission in their pest risk analysis (The process of evaluating biological or other scientific and economic evidence to determine whether an organism is a pest, whether it should be regulated, and the strength of any phytosanitary measures to be taken against it (ISPM 5)) for safe movement of plants across international and national borders.

The possibility that phytoplasmas are transmitted in seed has also been demonstrated in several crops, such as coconut embryos; alfalfa (*Medicago sativa*); lime (*Citrus aurantifolia*) tomato (*Lycopersicum esculentum*), corn (*Zea mays*) and pea (*Pisum sativum*) seeds [75–79]. Some of these seeds contain phytoplasmas belonging to the ribosomal groups 16SrI, 16SrXII and 16SrII [75,76,78–81].

Transovarial transmission of phytoplasma in eggs, newly hatched nymphs and adults has been demonstrated in some insect vector/plant host combinations [49]. For example, *Scaphoideus titanus* was shown to transmit phytoplasma transovarially to *Vicia faba* seedlings. In addition, *Hishimonoides sellatiformis* and *Matsumuratettix hiroglyphicus* transovarially vectored mulberry dwarf phytoplasmas and sugarcane white leaf disease, respectively [49,82]. Phytoplasma prunorum and Phytoplasma mali, transmitted by *Cacopsylla pruni* and *Cacopsylla picta*, respectively, were also shown to have this type of phytoplasma transmission [49,83].

3. Detection and Classification of Phytoplasma

Phytoplasmas methods and protocols described in the book edited by Musetti and Pagliari [84] are useful in laboratory practices for their detection and classification. Also, the technique illustrated by ISPM 27 [14] and Pusz-Bochenska et al. [85] for field and laboratory-based assays of the pathogens and their insect vectors will be useful for less-equipped laboratories.

Currently, there are no curative control measures or identified resistant varieties. The control of vectors via synthetic insecticides and the eradication of infected plants are current management options [86]. Thus, early detection is critical for the removal of infected plants and strict quarantine measures to prevent the introduction and spread of the disease.

3.1. Detection of Phytoplasma

Initially, the identification and classification of phytoplasmas were based primarily on biological properties such as symptoms, plant host range and relationships with insect vectors [87,88]. The symptomatology of phytoplasma diseases is not sufficient as a diagnostic for identification and is not enough to distinguish among diverse phytoplasma groups. Phytoplasmas cultured in axenic media and biochemical characterization reported by Contaldo and Bertaccini [79] and Contaldo et al. [39–41] represent the possibility of detection and the confirmation of Koch's postulates. However, this prospect has not been widely accepted [16,35,42,89] preventing its use for the detection and taxonomic classification of phytoplasmas. This should be reconsidered, as it will provide the pathogenicity, biochemical and morphological aspects of classifying the phytoplasmas appropriately. In any case, there is always an open gap for future research in an attempt to further improve our understanding of the pathogen.

Other methods such as transmission electron microscopy (TEM), 4',6-diamidino-2-phenylindole (DAPI) staining under fluorescence microscopy and enzyme-linked immunosorbent assay, have been developed for the detection of phytoplasma diseases. These methods are laborious, time-consuming and unreliable. Molecular techniques using loop-mediated isothermal amplification (LAMP) and

 doi:10.20944/preprints202503.0864.v1

polymerase chain reaction (PCR) with restriction fragment length polymorphism analysis (RFLP) technology have aided in the detection and identification of diseases caused by phytoplasmas [6,7,9,90–94].

The LAMP assay should be the method of choice for the early detection, diagnosis and monitoring of phytoplasmas because of its suitability under field conditions. It requires minimal equipment, ease of use, minimal risk of sample contamination, less time for the whole process and visual confirmation of results [90–93,95,96]. Moreover, the LAMP amplification products can be confirmed by agarose gel electrophoresis if necessary. It has been used successfully with different nucleic acid extraction techniques for the detection of Napier grass stunt in Kenya and Ethiopia [90,91], coconut lethal yellow in Ghana and Mozambique [91,93], papaya dieback in Ethiopia [92,93] and grapevine yellow in South Africa [96]. However, there is a need to improve and simplify the nucleic acid extraction procedure.

Polymerase chain reaction assays such as nested and quantitative PCRs, microarrays, and next-generation sequencing are now used for the detection of phytoplasmas in both plants and insects [94]. It involves the sampling of tissues, extraction of DNA, selection of gene-specific primers that amplify a specific region of the 16S or 23S rDNA genes, PCR assays, RFLP, or sequencing and sequence analysis [94].

Tissues should be selected from insect vectors and plant parts with phloem bundles, such as veins, mid-ribs and stalks, where the bacterium is most likely to be detected. A rapid and inexpensive crude sap nucleic acid extraction method for phytoplasmas was reported by Minguzzi et al. [97]. An oligonucleotide that amplifies a specific region of the 16S or 23S rDNA genes, a spacer region between 16S and 23S, 23S, tuf, secA, secY, elongation factor EF-Tu and ribosomal proteins [4,98–100] are used to differentiate and identify phytoplasmas (Table 2). In vitro and in silico RFLP analysis of phytoplasma sequences from PCR-amplified rDNA provided a means to differentiate known and unknown phytoplasmas into phylogenetic groups and subgroups [23,30,101].

Table 2. Primers used to detect plant infected by Phytoplasmas in Africa.

Primers	Sequence (5′-3′)	Reference
P1	AAGAGTTTGATCCTGGCTCAGGATT	[107]
P4	GAAGTCTGCAACTCGACTTC	[108]
P6	CGGTAGGGATACCTTGTTACGACTTA	[107]
P7	CGTCCTTCATCGGCTCTT	[109]
R16F2n	GAAACGACTGCTAAGACTGG	[110]
R16R2	TGACGGGCGGTGTGTACAAACCCCG	[111]
LYDSR (Lethal Disease Tanzania)	GGTGCCATATATATTAGATTG	[112]
G813F (Lethal Disease Ghana)	CTAAGTGTCGGGGGTTTCC	[112]
AKSR (Lethal Disease Nigeria)	TTGAATAAGAGGAATGTGG	[112]
Rhode F (Lethal Disease Tanzania)	GAGTACTAAGTGTCGGGGCAA	[113]
Rhode R (Lethal Disease Tanzania)	AAAAACTCGCGTTTCAGCTAC	[113]

3.2. Classification system

Phytoplasmas are classified using 16S ribosomal RNA gene (rRNA) restriction fragment length polymorphism identity scores, whole-genome average nucleotide identity (ANI) or ecologically distinct host and molecular divergence [2,14].

Restriction fragment length polymorphism (RFLP) analysis of target gene differentiates sequences either into a '*Candidatus* Phytoplasma' genus based on percent sequence identity [2] or into ribosomal groups and subgroups on the basis of presence of restriction sites [30,102,103], with each group containing Roman numerals and subgroups designated by letters [104]. These classification

 doi:10.20944/preprints202503.0864.v1

systems, with the publication of Zhao et al. [105] resulted in the identification of 48 [32] or 49 [106] '*Candidatus* phytoplasma' species in 37 groups (Table 1) and more than 150 subgroups.

The RFLP analysis of the 16S ribosomal RNA (rRNA) gene has been the most commonly used method for classification. Additionally, two web-based phytoplasma classifiers namely iPhyClassifier (using rRNA sequences) [30] and CpnClassiPhyR (using the *cpn*60 gene sequence) [32], were developed for phytoplasma classification.

Several limitations have been highlighted in the use of rRNA sequences alone [4,32,99,114–116] as a classification system for phytoplasmas. These weaknesses have led to the design of classification schemes using several housekeeping genes from cpn60, rp, tuf, secY, etc. [4,115,116] and whole genome sequence-based genotypic characterization [117]. These methods provide a better resolution of closely related taxa than 16Sr methods do [4,6,99,110,114–118]. The use of more than one gene for classification is referred to as multilocal sequence typing (MLST) analysis. This approach has been used for phytoplasma subgroup differentiation and to modify earlier classifications and accurately identify new phytoplasma strains [29,32,35,106,116,119,120].

In Africa, MLST was used by Zambon et al. [121] on grapevines from South Africa and Pilet et al. [35] on coconuts from Nigeria, Mozambique and Ghana to show the genetic diversity of "Ca. Phytoplasma asteris" and "Ca. P. palmicola", respectively. Information on phytoplasmas occurring in Africa using other genes is limited; thus, this review is based mainly on the RFLP rRNA classification system. This aims to provide information on reported phytoplasmas in Africa for further study using MLST to validate their taxonomy. This suggests that MLST diagnostic studies will be highlyuseful to the phytosanitary community and other stakeholders within the region by providing appropriate markers for the surveillance and accurate reporting of phytoplasmas occurring in the continent. Also, the development of a phytoplasma classification web-based tool using several loci for the classification of phytoplasma strains is suggested. More information can be explored on the proposed amendment of IRPCM [2] guideline on the description of Candidatus Phytoplasmas by Bertaccini et al. [106]. The clarifications and amendments required in the guidelines of Bertaccini et al. [106] were highlighted by [23].

4. Phytoplasma Diseases Status in Africa

Information on phytoplasma diseases found in Africa were retrieved from literature search, web sources (www.scholar.google.com) and GenBank, which were all accessed on or before 16th September 2024 ,as well as from the online global database of Hemiptera-Phytoplasma-Plant biological interactions (http://trivellone.speciesfile.org/) [42]. In addition, information was derived from scientists working on Phytoplasma diseases through social media platforms and emails. Figure 1 shows the Phytoplasma diseases reported in Africa and their relationships. These phytoplasmas belong to the 16SrI, 16SrII, 16SrIII, 16SrIV, 16SrVI, 16SrXI, 16SrXII, 16SrXIV and 16SrXXII groups.

 doi:10.20944/preprints202503.0864.v1

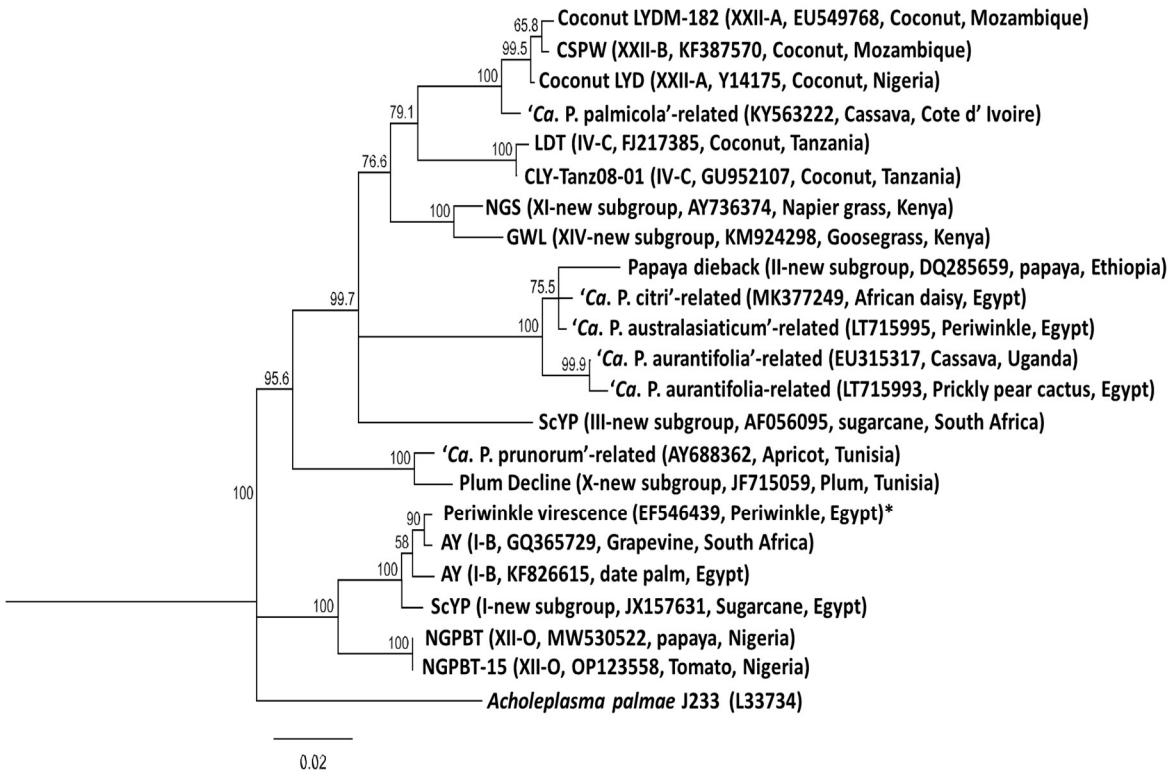


Figure 1. Phytoplasmal diseases reported in Africa.

4.1. Groups and Subgroups of Phytoplasmas in Africa

4.1.1. Grapevine Yellows Disease

Grapevine yellows disease belongs to the aster yellows phytoplasma group (16SrI). The disease was first reported in Africa on grapevines in 2004 in Tunisia and was delineated as 16SrI-B [63,122]. It was reported as a mixed phytoplasma infection of 16SrXII-A and 16SrII-B in South Africa in 2006 [80] but was confirmed to be in the aster yellow subgroup of 16SrI-B [123–125]. Symptoms reported in both countries included veinal yellowing, necrosis, thicker and downward rolling leaves, shortened internodes, drooping, incomplete lignification and flexible shoots, abortion of growth tips, and dry and shrivelled immature bunches [80,122,124]. It is transmitted via vegetative planting materials and insect vectors [62,63]. The disease was detected in leafhoppers (*Mgenia fuscovaria*, *Aconurella prolixa*, *Cicadulina anestae*, *Austroagallia sinuata* and *Austrogallia cuneata*.) [62,63] and planthopper (*Toya* sp.) [62] but are reported to be transmitted primarily by *M. fuscovaria* and possibly by *A. prolixa*. [62,126,127]. Alternative host plants of the disease were highlighted by Kruger et al.[62].

4.1.2. Phyllody/Witches Broom/Virescence

Phytoplasmas belonging to group 16SrII are known to cause phyllody and witches'-broom disease in Soyabean (*Glycine max*), eggplant (*Solanum melongena*), tomato (*Solanum lycopersicum*), squash (*Cucurbita pepo*), onion (*Allium cepa*), cactus (*Opuntia abjecta*), peanut (*Arachis hypogaea*), sunnhemp (*Crotalaria* sp.), and cotton (*Gossypium hirsutum*) in some African countries. Cotton Phyllody reported on *Gossypium hirsutum, Sida cordifolia* and *Orosius cellulosus* in Burkina Faso [128–130] as well as *Gossypium hirsutum* and *Sida cordifolia* in Mali [114,131] were previously placed in the 16SrII-F subgroup [76] but were later reclassified as 16SrII-C [114]. The strains in Egypt affecting *Solanum melongena*, *Solanum lycopersicum*, *Cucurbita pepo*, *Allium cepa* and *Opuntia abjecta* were placed in the "Ca. P. Australasia" group and 16SrII-D subgroup [132–134]. Phyllody and witches' broom in the 16SrII-C subgroup were reported on soybean in Mozambique and Malawi by Kumar et al. [135] and Tanzania [136]. Alfaro-Fernández et al. [137] placed the causal Phytoplasma of Fababean

 doi:10.20944/preprints202503.0864.v1

phyllody ("Ca. P. aurantifolia") in 16SrII-C subgroup and it affects Faba bean (*Vicia faba*), Rattlepod (*Crotalaria saltiana*) and *Cicer arietinum* in Sudan.

The phytoplasma that causes the phyllody disease of *Crotalaria saltiana* ("*Ca P.*trifolii") is in the 16SrVI-C group and was first reported in Sudan in 1962 on Periwinkle (*Catharanthus roseus*) [138]. The disease is associated with symptoms similar to those of Faba bean phyllody, with excessive proliferation of lateral shoots (witches' broom) and small, chlorotic leaves with phyllody and virescence. Symptoms of cotton phyllody include shoot proliferations with shortened internodes, reduced leaflets and petioles while those for witches' broom include phyllody, stunting, hairy root, abnormal colours on leaves and virescence [135,136]. *Orosius cellulosus* is an insect vector of this phytoplasma.

Egyptian Phytoplasma virescence on Periwinkle (EF546439) which belongs to the aster yellows phytoplasma group (16SrI), was reported by Omar et al. [139]. The diseased plant had few leaves, shortened internodes, virescence and witches' broom symptoms. In Egypt, Gad et al. [140] reported on *Gazania rigens* (Gazania or Treasure flower) Phyllody Phytoplasma (MK 377249.1), which was associated with yellowing, proliferation, virescence and few leaves, as well as reduced flower size and stunted growth symptoms.

4.1.3. Napier Grass Stunt Phytoplasma

Napier or Elephant grass (*Pennisetum purpureum*) is largely used as forage for cattle production in East Africa [141]. It is also used as biocontrol in a 'push-pull' management system for the control of cereal stem borers (*Chilo partellus* and *Busseola fusca*) and fall armyworms (*Spodoptera frugiperda*) [142–144]. Napier grass stunt (NGS) disease caused by phytoplasma is a serious disease of Napier grass resulting in 70-100% yield loss in infested farms [29,145]. The disease has been reported in Ethiopia**,** Kenya, Tanzania and Uganda [64,65,146–148].

On the basis of the 16S rDNA sequences, NGS in Ethiopia belongs to the 16Sr IIIA phytoplasma group, a member of Candidatus Phytoplasma prunorum X-disease, which is closely related to the African sugarcane yellow leaf phytoplasma (GenBank accession number AF056095) [64,65,146–148]. In Kenya**,** Tanzania and Uganda, 'Ca. Phytoplasma oryzae' or rice yellow dwarf (RYD) phytoplasma (GenBank accession number AY736374) are classified as 16SrXI group members [26,146,147]. However, discussing the refinements of the 16SrXI and 16SrXIV groups using other genes, Abeysinghe et al. [29] believed that NGS should be reclassified as a new Ca. Phytoplasma species. To date no reclassification of NGS has been performed, with 16SrXI retained by Fischer et al. [149] and Asudi, et al. [150].

Infected NGS plants have small yellow leaves with the proliferation of tillers and shortening of internodes, a bushy appearance, pale yellow-green shoots and stunted growth, which results in low or no yield and ultimately, the death of the plants [146,147,151–153]. The disease is expressed in the regrowth of Napier grass after several cuttings or grazing by animals [26,153]. Spread occurs mainly through infected plant materials and insect vectors [26,145]. Vectors that have been reported include the leafhopper, *Maiestas banda* (Kramer) (Hemiptera: Cicadellidae) in Kenya and *Leptodel phaxdymas* and *Exiti anus* in Ethiopia [64–66]. The pathogen has been detected by Obura et al. [90] and Asudi et al. [26,152] in cereals, sugarcane and several asymptomatic wild grasses, which can serve as alternative hosts.

4.1.4. Yellow Leaf Syndrome

Yellow leaf syndrome in sugarcane is associated with two pathogens: phytoplasma (Sugarcane yellow phytoplasma) and virus (Sugarcane yellow leaf luteovirus)-which cause similar symptoms [155–160]. The International Society for Plant Pathology approved the use of "leaf yellow" and "yellow leaf" to distinguish the diseases caused by phytoplasma and virus, respectively [161].

Sugarcane yellow leaf syndrome (SCYLS), referred to as "yellow wilt", was first reported in Tanzania in the 1960s, with no specific pathogen listed [155,162,163]. The disease was attributed to Phytoplasmas and was found in Egypt, Kenya, Reunion, Senegal, South Africa, Swaziland, Uganda,

 doi:10.20944/preprints202503.0864.v1

Malawi, Mauritius, Morocco, Mozambique, Zambia and Zimbabwe [156,157,164,165]. The leaf yellow from South Africa was placed in the Western X (16SrIII) group (GenBank Accession No.AF056095) [29,156] and the 16SrI-B group (GenBank Acc. No. JX15763) from Egypt [216]. The characteristic symptoms are yellow discoloration along the midrib at the abaxial surface, sometimes with the lamina still green, shortening of terminal internodes, sucrose accumulation in midribs and necrosis of leaves starting from the leaf tips and then spread through the leaf blade until the whole leaf is affected. In Africa, symptoms occur from the first three to five leaves, with visible dewlaps which often disappear with better growing conditions [165]. It is transmitted through infected planting materials and via insect vectors [166]. Its insect vector is yet to be identified in countries where leaf yellow has been reported in Africa.

4.1.5. Sugarcane Grassy Shoot

Sugarcane grassy shoot is a member of the rice yellow dwarf phytoplasma or 16SrXI group and is very closely related to the sugarcane white leaf, with a sequence similarity of more than 98% [29,167,168]. In Africa, it has been reported in Egypt (JN223446) [157] and Sudan [169]. It is transmitted by a yet-to-be identified insect vector(s) and through infected planting material in the two countries [157,169]. Infected plants produce numerous thin and slender tillers (with white or pale-yellow leaves) which gives the plant a grassy or bushy appearance and does not produce any millable canes [29].

4.1.6. Lethal Yellowing Diseases of Coconut and Cassava

Lethal yellowing diseases reported in Africa are classified into two phytoplasma groups, 16SrIV and 16SrXXII, in different subgroups (Figure 1), and three *Candidatus* Phytoplasma spp., namely, Ca. P. cocostanizae, Ca. P. Palmicola and Ca. P. Palmae [27,29,35].

Lethal Yellowing Disease of Coconut

Lethal yellowing disease (LYD) has been reported in Nigeria, Benin, Togo, Ghana, Cameroon, Kenya, Tanzania and Mozambique [29,35,170–173]. Reports of phytoplasma coconut disease date back to the early 1900s in Tanzania [35,174] and then in Nigeria in 1917 [37] and Kenya (Dowson, 1921 as cited by Pilet et al., [35]). In the 1930s, similar diseases were described in Togo, Cameroon and Ghana (Meiffren, 1951; Grimaldi and Monveiller, 1965; Chona and Addoh, 1970, all cited in Pilet et al.[35]). It was recorded in 1958 in Mozambique (de Carvalho and Mendes, 1958 cited by Eden-Green, [174]) and resulted in epidemics in the 1990s and 2014 in Mozambique and Cote d'Ivoire (Figure 2), respectively [35,175] . This disease is referred to as Awka wilt (Bronze leaf wilt) in Nigeria [37,170,176]; Cape St Paul wilt in Ghana [177] and Cote d'Ivoire [175]; Kaıncope in Togo [178]; Lethal disease in Tanzania; Lethal yellowing in Mozambique and Kribi disease in Cameroun [179].

Ca. P. Palmicola has been reported in Ghana, Nigeria, the Ivory Coast and Mozambique [29,35,38,176,180], Ca. P. cocostanizae is present in Kenya, Tanzania (16SrIV-C) [27,182] and Mozambique ((16SrIV-B and 16SrIV-C) [180,182] whereas Ca. P. palmae has not been reported in Africa [35,68]. Ca. P. Palmicola is classified into the 16SrXXIIA group i.e., Ca. P. cocos nigeriae (Akwa wilt), reported in Nigeria and Mozambique, while Cape st. Paul wilt from Ghana and Cote d'Ivoire are classified into the 16SrXXIIB group [35,38,180,183].

 doi:10.20944/preprints202503.0864.v1

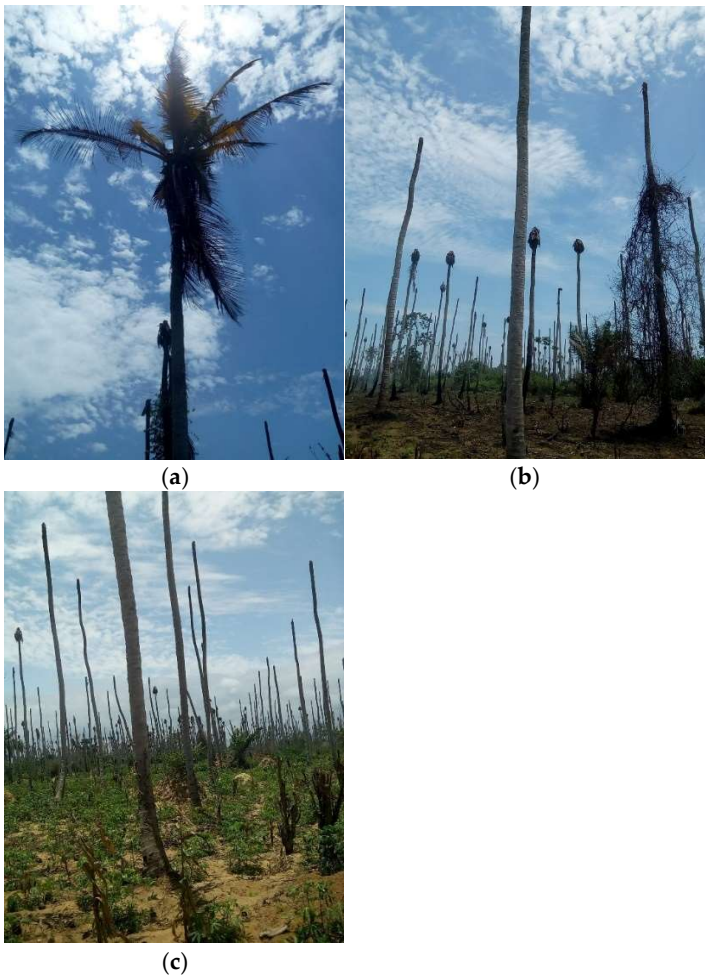


Figure 2. (a and b) Coconut Lethal Yellow Disease destruction of coconut plantations in Braffedon, Grand Lahou, Cote d'Ivoire. (c) Land is now being used for Cassava cultivation.

Symptoms start with premature nut fall and necrosis (blackening) of inflorescences, followed by yellowing of the leaves (progressing from the older to younger leaves) and rotting of spear leaves; the whole leaves turn brown and break off leaving the trunk bare. This occurs within three to six months of initial symptoms [68,184].

It is transmitted through infected planting materials and insect vectors [35,68,183] although the pathogen has been detected in the embryo [184,185], seed transmission has not been validated [35]. Myriads of insect vectors are suspected to be involved in the transmission of the pathogen in Mozambique, namely, *Diostrombusm kurangai*, *Meenoplus* sp. and *Platacantha lutea* [68]; *D. mkurangai* in Ghana; *Diostrombusm kurangai* [27,67]; *Meenoplus* sp. in Tanzania [27,67,186]; and *Nedotepa curta* in Côte d'Ivoire [187], which are reported as potential vectors but have not been proven in successful transmission trials. In other affected African countries, no insect vector has been reported or suspected thus far. Lethal yellow has been reported on oil palm (*Elaeis guineensis*) and date palm (*Borassus aethiopium*) in Mozambique (182,188) and *Manihot* spp. in Cote d'Ivoire [189] as potential alternate hosts. Other suspected alternate hosts include plant species from the families Poaceae (*Paspalum vaginatum* Sw., *Pennisetum pedicillatum* Trin.), Verbenaceae (*Stachytarpheta indica* (L.) Vahl), Plantaginaceae (*Scoparia dulcis* L.), Phyllanthaceae (*Phyllantus muellerianus* (Kuntze) Excell), Cyperacea (*Diplacrum capitatum* (Willd.) Boeckeler), Fabaceae (*Desmodium adscendus* (Sw.) DC), Euphorbiaceae (*Manihot esculenta* Crantz), *Dalbergia saxatilis* and *Baphia nitida* [183,187,190,191].

Cassava Phytoplasma

In Africa, phytoplasmas from the 16SrII and 16SrXXII groups have been reported in cassava plants. In Uganda, the restriction profiles obtained after RFLP of the PCR amplicons with the *Sau3*

 doi:10.20944/preprints202503.0864.v1

AI, *Hpa*II, and *Hae*III enzymes were similar to those of 'Ca. P. aurantifolia' (16SrII group The 16S rRNA sequences of phytoplasmas detected in cassava (EU315317) and four other nearby plant species (*Malvaviscus arborus* Cav (Malvaceae), *Codiaeum variegatum* (L.) A. Juss (Euphorbiaceae), *Hibiscus rosa-sinensis* L. (Malvaceae) and *Passiflora edulis* Sims, Passifloraceae) was 98% identical with that of the cactus witches'-broom phytoplasma (AJ293216) [65,192]. Côte d'Ivoire cassava phytoplasma of the 16SrXXII-B group, which was similar to coconut lethal yellow (CLYD) (16SrXXII-B), was recently identified in cassava from CLYD pandemic villages in Grand-Lahou, Côte d'Ivoire (KY563222) [189], indicating that it can attack another host crop (Figure 2c and 3). Infected cassava plants exhibited leaf curling and yellowing in Côte d'Ivoire [189] and leaf yellowing, chlorosis, shortening of internodes, and slight stunting in Kawanda, Uganda.

Figure 3. Cassava phytoplasma disease in Côte d'Ivoire. Source: Plant Health Unit UNA-CI.

4.1.7. Bermuda and Hyparrhenia Grass White Leaf

Bermuda grass white leaf belongs to the 16SrXIV phytoplasmas or '*Candidatus* Phytoplasama cynodontis' group (GenBank Accession number AF100412). It has been detected in Egypt, Kenya, Sudan, Tanzania and Uganda. It was found in *Cynodon dactylon* and is characterized by stunted, bushy growth and small white leaves; shortened stolons or rhizomes, proliferation of axillary shoots and dead plants [26,148,157,193,194]. Hyparrhenia grass white leaf associated with a 16SrXI phytoplasma has also been reported in Kenya [195].

4.1.8. Phytoplasma Disease of Date Palm

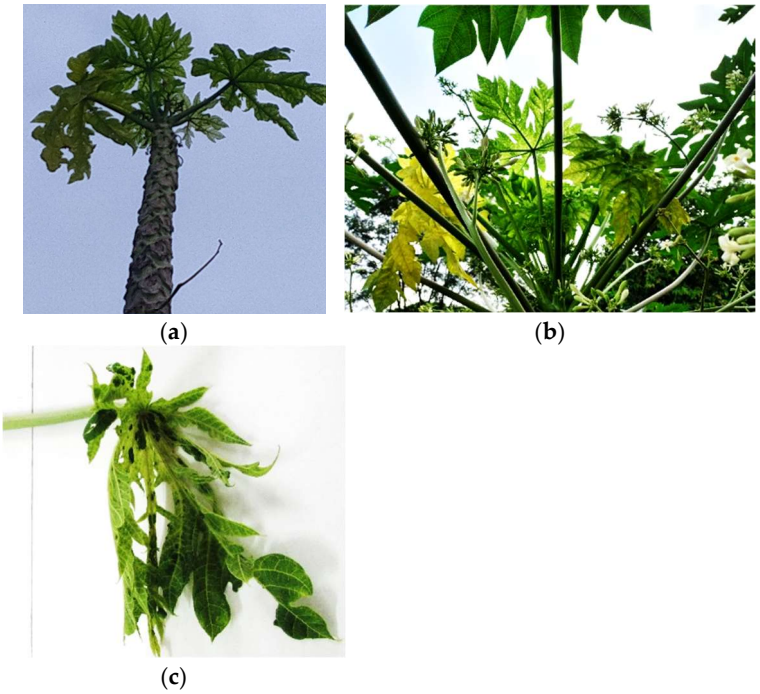
White tip dieback (WDB) (GenBank Accession number AF100411) and Slow Decline (SD) (AF268000) are phytoplasmal diseases that affect mainly immature or 5-8 years old and mature date palm (*Phoenix dactylifera* L.), respectively in Sudan [196,197]. Both of these strains belong to the 16SrXIV '*Candidatus* Phytoplasma cynodontis' group [196,197]. Severe chlorosis of the emerging spear leaf as well as tips of older frond leaflets are symptoms of WDB. The white chlorotic streaks with some necrosis extended longitudinally along the midrib, with the crown changing to dry white later. The plant dies within 6-12 months of symptom appearance [196]. Moreover, SD-infected palms die between 12 and 24 months after the first appearance of yellow leaves starting from the oldest frond and progressing to the young central fronds and spear leaves. These leaves turn white to light brown and break off, leaving the trunk bare [197]. Cronje et al. [198] also reported that young sprouts from infected SD have yellow fronds and as the crown dies, the spear leaf becomes whitish, necrotic

 doi:10.20944/preprints202503.0864.v1

and easily removed, resulting in rot-smelling basal tissues. The first report [199] confirmed the presence of streak yellows on date palm in Egypt, which was described as a member of the aster yellow phytoplasma 16SrI group (KF826615) [200]. The most common symptom is longitudinal streak yellowing along the midrib and premature drying of young and mature leaflets as well as stunted growth.

4.1.9. Phytoplasma Diseases of Papaya

Phytoplasma diseases of papaya, such as Papaya dieback, yellow crinkle, mottle, mosaic and papaya bunchy top, have been reported worldwide [65,201–205]. In Africa, papaya dieback (PDB), classified as 16SrII, has been reported in Ethiopia (Acc. No. DQ285659) [205], Papaya bunchy top (PBT) in Nigeria (Figure 4a) is designated as subgroup 16SrXII-O in the Stolbur phytoplasma group (MW530522; MW530532; MW530524) [206] and unnamed in Cote d'voire in the aster yellow subgroup of 16SrIB (PPB820865, PPB820866, PPB820867) [207] (Figure 4b and c). The symptom expression for PDB is a bright yellowing of the upper young leaves, followed by mosaic, crinkling, leaf tip necrosis, and drying of the upper leaves, leading to death of the infected plants [205]. The symptoms observed for PBT in Nigeria include leaf yellowing and crinkling, bending of the petioles and shoot at an angle, premature fruit drop and rot, necrosis of the leaf veins and leaf margins, axillary shoot proliferation in the apical crown or near the top of the plant and dieback of the entire plant or side shooting at the lower stem region [206]. This phytoplasma has also been found in tomato (OP123558) and jute mallow (OP123559) in Nigeria [208]. Symptoms observed in phytoplasma affected papaya in Cote d'voire are leaf edge curling and mosaic [207].



(**a**) (**b**) (**c**)

Figure 4. Phytoplasma diseases of papaya in (a) Nigeria and (b and c) Cote d'Ivoire Source: Plant Health Unit UNA-CI.

4.1.10. Unclassified Phytoplasma Group

Goosegrass white leaf of unknown 16Sr group has been detected in Kenya, Tanzania and Uganda [26,148,194]. In Egypt, on the basis of electron microscopy results, a phytoplasma associated with the malformation of mango fruits [209] and carrot plants (Dacus carota) transmitted by *Hebata decipiens* [210] have been reported but not yet fully characterized [133,210].

 doi:10.20944/preprints202503.0864.v1

5. Impact of phytoplasmal Disease in Africa

With improved molecular diagnostic techniques, the list of diseases caused by phytoplasmas continues to increase because those diseases previously attributed to other pathogens or of unknown aetiology are being identified and properly classified. The situation is further exacerbated by the fact that there are no viable management options when a plant is infected, and only a few vectors of phytoplasmas diseases have been identified, thus limiting preventive/control options. The phytoplasma disease pandemic experienced by some countries have brought the socio-economic importance of the disease to the fore. In Africa, only a few reports outlining their socio-economic effects exist, mainly due to inadequate studies of their epidemiology, awareness of the disease and their non-culturable nature.

The wine industry in South Africa produces approximately 3.9% of the world's wine (ranked 7th), contributing 56.5 billion rands to the GDP [211]. Approximately 87,848 ha is cultivated, with white varieties constituting 55% of the vines planted [211]. The presence of aster yellows disease threatens this industry [124,212] by reducing the quality of grapevines, and lowering the yield to death of the vines, leading to financial losses for vineyard owners and the broader economy [212,213]. Collaborations between the research Institute and viticulture industry have attempted to curtail this disease, but it remains an important quarantine pest, with delineated surveys being conducted regularly to restrict spread [126,127,212]. An epidemiology study by Carstens [212] indicated that Chenin Blanc, Chardonnay and Pinotage, which belong to some of the ten most cultivated varieties [211], have a high incidence of the disease.

Coconut lethal yellow disease (CLYD) outbreaks in some African countries resulted in the loss of millions of coconut palms [173,190,214]. The international trade of coconut seedlings has been drastically affected due to phytosanitary concerns. This has had a negative impact on the cultivation, marketing and processing of coconut as well as the diverse uses of different parts of the palm tree as sources of income, staple foods and livelihoods in affected countries [191]. Mozambique lost its ranking as the top producer of coconut in Africa to Nigeria due to CLYD after the first and second reported incidences in 1992 and 2010, respectively [188].

Pennisetum purpureum, a major fodder crop for dairy cattle in Eastern Africa has experienced a 70 -100% reduction in growth as a result of Napier grass stunt [10,64,147,151,153,154]. This has resulted in reduced livestock rearing due to scarce fodder [151,153,154,215].

6. Conclusion and Prospects

With increasing new outbreak and reports of previously uncharacterized phytoplasma diseases worldwide [3,5,11,68,78,122,124,135,136,147,175,189,207,217–219], Africa need to be alert and well prepared. Multiplicity of phytoplasmas affecting different plants in Africa has remained undetected and unreported mainly due to inadequate awareness of the pathogens and lack of molecular detection facilities in the tropics. Survey and diagnosis of the leafhopper (Auchenorrhyncha: Cicadellidae); planthopper (Auchenorrhyncha:Fulgoromorpha) and psyllid (Sternorrhyncha: Psyllidae) populations in African countries might reveal possible unknown phytoplasma species. Identification of phytoplasma and host species would improve our understanding of their epidemiology, economic impacts and contribute to the development of management strategies that prevent escalation into outbreaks and major disease such as the Napier grass stunt phytoplasma and Coconut lethal yellow diseases. Hence, further investigations are needed to identify and/or develop phytoplasma detection techniques appropriate for less developed laboratories in Africa. This will also enhance the identification of other potential insect vectors and hosts.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, SAK. and AZ.; methodology, SAK, AZ, MOJ, WW; validation, AOO, JON, SS, JFO. and AOA.; formal analysis. all authors; investigation, All authors; resources, MOJ.; data curation, ; writing—original draft preparation, All Authors; writing—review and editing, All authors; visualization, All authors.; supervision, X.X.; project administration,

 doi:10.20944/preprints202503.0864.v1

SAK, AZ, MOJ, WW.; funding acquisition, MOJ. All authors have read and agreed to the published version of the manuscript." Please turn to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

Funding: "This work was supported in part by the Multi-State Hatch grant to M. O. Jibrin".

Acknowledgments: While all efforts were made to source for credible information on reported phytoplasma diseases in Africa, we acknowledge that some reports not deliberately might have been missed owing to mainly limited access to local journals not found on the internet search engine and language barriers. We would appreciate it if such reports of phytoplasma disease not cited here could be brought to our attention for addition in subsequent publications. We apologize to the authors whose relevant work on Phytoplasma diseases were not cited owing to length constraints.

Conflicts of Interest: "The authors declare no conflicts of interest."

References

1. Lee, IM, Davis RE, Gundersen-Rindal, D.E. 2000. Phytoplasma: phytopathogenic mollicutes. *Annual Review of Microbiology* 54: 221-255.
2. IRPCM, 2004. 'Candidatus Phytoplasma', a taxon for the wall-less, non-helical prokaryotes that colonize plant phloem and insects. International Journal of Systematic and Evolutionary Microbiology 54, 1243–1255 DOI 10.1099/ijs.0.02854-0.
3. Bertaccini, A. and Duduk, B. 2009. Phytoplasma and phytoplasma diseases: a review of recent research. *Phytopathologia Mediterranea 48*(3): 355–378. http://www.jstor.org/stable/26463360.
4. Makarova, O., Contaldo, N., Paltrineri, S., Kawube, G., Bertaccini, A. and Nicolaisen, M. 2012.DNA barcoding for identification of *'Candidatus Phytoplasma'* using a fragment of the Elongation factor Tu Gene. *Plos One* 7(12): e52092.doi:10.1371/journal.pone.0052092.
5. Bertaccini, A., Duduk, B., Paltrinieri, S. and Contaldo, N. 2014. Phytoplasmas and Phytoplasma Diseases: A Severe Threat to Agriculture. *American Journal of Plant Sciences* **5**: 1763-1788. http://dx.doi.org/10.4236/ajps.2014.512191
6. Marcone, C. 2012. Advances in differentiation and classification of phytoplasmas. *Annals of Applied Biology* **160**:201-203. https://doi.org/10.1111/j.1744-7348.2012.00540.x
7. Marcone, C. 2014.Molecular biology and pathogenicity of phytoplasmas. *Annals of Biology* 165 (2): 199-221. https://doi.org/10.1111/aab.12151.
8. Marcone, C. 2019. Comparison of Different Procedures for DNA Extraction for Routine Diagnosis of Phytoplasmas P 72-81 In: Rita Musetti and Laura Pagliari (eds.), Phytoplasmas: Methods and Protocols, Methods in Molecular Biology, vol. 1875, https://doi.org/10.1007/978-1-4939-8837-2_7.
9. Liu, J, Gopurenko D, Fletcher, M.J., Johnson, A.C. and Gurr, G.M. 2017. Phytoplasmas–The "Crouching Tiger" Threat of Australian Plant Pathology. Front. Plant Sci. 8:599. doi: 10.3389/fpls.2017.00599.
10. Wambua, L., Bernd, S., Allan, O., Joseph, O. W., Olive, I., Peninah, N. W., Lavender, A., Cassandra, O., Chris, S. J., Daniel, M., Charles, M., Zeyaur, K., Joerg, J. and Anne, F. 2017. Development of field-applicable tests for rapid and sensitive detection of *Candidatus* Phytoplasma oryzae. *Molecular and Cellular Probes* 35:44-56.
11. Arocha, Y., Gonzalez, L., Peralta, E. L. and Jones, P. 1999. First Report of Virus and Phytoplasma Pathogens Associated with Yellow Leaf Syndrome of Sugarcane in Cuba. Plant Disease 1999 83:12, 1177-1177.
12. Aljanabi, S.M., Parmessur, Y., Moutia, Y., Saumtally, S. and Dookun, A. 2001. Further evidence of the association of a phytoplasma and a virus with yellow leaf syndrome in sugarcane. Plant Pathology, 50: 628-636. https://doi.org/10.1046/j.1365-3059.2001.00604.x
13. Doi, Y., Teranaka, M., Yora, K., Asuyama, H., 1967. Mycoplasma or PLT group-like microorganisms found in the phloem elements of plants infected with mulberry dwarf, potato witches' broom, aster yellows, or paulownia witches' broom. Ann. Phytopath.Soc. Jpn. 33, 259–266.
14. ISPM 27. Annex 12. 2016. Phytoplasmas. Rome, IPPC, FAO. 12pp.

 doi:10.20944/preprints202503.0864.v1

15. Weisburg, W.G., Tully, J.G., Rose, D.L., Petzel, J.P., Oyaizu, H., Mandelco, L., Sechrest J., Lawrence, T.G. and Van Etten, J. 1989. A phylogenetic analysis of the mycoplasmas:basis for their classification. *Journal of Bacteriology* 171 (2): 6455-6467.
16. Harrison N.A., Gundersen-Rinda, D., Davis, R.E., May, M. and Brown D.R. 2018. *Candidatus* Phytoplasma. in Bergey's Manual of Systematics of Archaea and Bacteria, in association with Bergey's Manual Trust. Published by John Wiley & Sons, Inc., DOI: 10.1002/9781118960608.gbm01259.pub2.
17. Hogenhout, S.A., Kenro, O., EL-Desouky, A., Shigeyuki, K., Heather, N. K. and Shigetou, N. 2008. Phytoplasmas: bacteria that manipulate plants and insects. *Molecular Plant Pathology* 9 (4):403–423. DOI: 10.1111/J.1364-3703.2008.00472.X
18. Streten, C. and Gibb, K.S. 2003. Identification of genes in the tomato big bud phytoplasma and coparison to those in sweet potato little leaf-V4 phytoplasma. *Microbiology* **149**: 1797-1805.
19. Tran-Nguyen, L.T. and Gibb, K.S. 2007. Optimizing Phytoplasma DNA purification for genome analysis. J. Biomol. Tech. 18 (2): 104-112.
20. Bertaccini, A., Contaldo, N., Calari, A., Paltrinieri, S., Windsor, H.M. and Windsor, D. 2010. Preliminary Results of Axenic Growth of Phytoplasmas from Micropropagated Infected Periwinkle Shoots. 18th Congress of the International Organization for Mycoplasmology (IOM), Chianciano Terme, 11-16 July 2010. 147-153.
21. Bendix C. and Lewis. J.D. 2018. The enemy within: phloem-limited pathogens. *Molecular Plant Pathology* **19**(1): 238–254. doi:10.1111/mpp.12526.
22. Bove, J. M. and Garnier, M. 2003. Phloem-and xylem-restricted plant pathogenic bacteria. *Plant Sci.* **164:** 423–438. 10.1016/S0168-9452(03)00032-3.
23. Wei, W. and Zhao, Y. 2022. Phytoplasma Taxonomy: Nomenclature, Classification, and Identification. Biology 11: 1119. https://doi.org/10.3390/ biology11081119.
24. Wang, R., Bai, B., Li, D., Wang, J., Huang, W., Wu, Y. and Zhao, L. 2024. Phytoplasma: A plant pathogen that cannot be ignored in agricultural production-Research progress and outlook. *Molecular Plant Pathology* 25: 10.1111/mpp.13437.
25. Gasparich, G. E. 2010. Spiroplasmas and phytoplasmas: Microbes associated with plant hosts. *Biologicals* 38 (2): 193–203.https://doi.org/10.1016/j.biologicals.2009.11.007.
26. Asudi, G. O., Van den Berg, J., Midega, C. A. O., Schneider, B., Seem¨uller, E., Pickett, J. A., and Khan, Z. R. 2016. Detection, identification, and significance of phytoplasmas in wild grasses in East Africa. Plant Dis. 100:108-115
27. Gurr, G.M., Johnson, A.C., Ash, G.J., Wilson, B.A.L, Ero, M.M., Pilotti, C.A., Dewhurst, C.F. and You, M.S. 2016. Coconut Lethal Yellowing Diseases: A Phytoplasma Threat to Palms of Global Economic and Social Significance. *Front. Plant Sci*. 7:1521. doi: 10.3389/fpls.2016.01521.
28. Kumari, S., Nagendran, K., Rai, A.B., Singh, B., Rao, G.P. and Bertaccini, A. 2019. Global Status of Phytoplasma Diseases in Vegetable Crops. *Front. Microbiol*. **10**:1349. doi: 10.3389/fmicb.2019.01349
29. Abeysinghe, S. Kanatiwela-de Silva, C., Abeysingbe, P.D., Udagama. P., Warawichanee, K., Aljafar, N., Kawicha, P. and Dickinson, M. 2016. Refinement of the Taxonomic structure of 16SrXI and 16SrXIV phytoplasmas of gramineous plants using multilocus sequencing typing. *Plant Dis*. **100**: 2001-2010.
30. Zhao, Y., Wei, W., Lee, M., Shao, J., Suo, X., and Davis, R. E. 2009. Construction of an interactive online phytoplasma classification tool, iPhyClassifier, and its application in analysis of the peach X-disease phytoplasma group (16SrIII). *International Journal of Systematic and Evolutionary Microbiology, 59*, 2582–2593.
31. Zhao, Y. and Davis, R. E. 2016. Criteria for phytoplasma 16Sr group/subgroup delineation and the need of a platform for proper registration of new groups and subgroups. *International Journal of Systematic and Evolutionary Microbiology, 66*(5), 2121–2123.
32. Muirhead, K., Pérez-López, E., Bahder, B. W. Hill, J. E and Dumonceaux T. J. 2019. The CpnClassiPhyR Facilitates Phytoplasma Classification and Taxonomy Using cpn60 Universal Target Sequences. Olivier C. Y., Pérez-López, E., and Dumonceaux T. J. (eds.) in *Sustainable Management of Phytoplasma Diseases in Crops Grown in the Tropical Belt*, Sustainability in Plant and Crop Protection 12, https://doi.org/10.1007/978-3-030-29650-6

 doi:10.20944/preprints202503.0864.v1

33. Danet, J-L, Balakishiyeva, G., Cimerman, A., Sauvion, N., Marie-Jeanne, V., Labonne, G., Laviña, A., Batlle, A., Križanac, I., Škorić, D., Ermacora, P., Ulubaş S. Ç., Caglayan, K., Jarausch, W. and Foissac, X. 2011. Multilocus sequence analysis reveals the genetic diversity of European fruit tree phytoplasmas and supports the existence of inter-species recombination. *Microbiolog* **157**: 438-50. 10.1099/mic.0.043547-0.
34. Li, Y., Piao, C-G., Tian, G-Z., Liu, Z-X., Guo, M-W., Lin, C-L. and Wang, X.-Z. 2014. Multilocus sequences confirm the close genetic relationship of four phytoplasmas of peanut witches'-broom group 16SrII-A. *J. Basic Microbiol.* **54**:818-827. https://doi.org/10.1002/jobm.201300140.
35. Pilet F, Quaicoe RN, Osagie IJ, Freire M, Foissac X. 2019. Multilocus sequence analysis reveals three distinct populations of "*Candidatus* Phytoplasma palmicola" with a specific geographical distribution on the African continent. Applied and Environmental Microbiology 85 (8): e02716-18. https://doi.org/10.1128/AEM.02716-18.
36. Quaglino, F., Kube, M., Jawhari, M., Abou-Jawdah, Y., Siewart, C., Choueiri, E., Sobh, H., Casati, P., Tedeschi, R., Lova, M.M., Alma, A. and Bianco, P.A. 2015. "*Candidatus* Phytoplasma phoenicium' associated with almond witches'-broom disease: from draft genome to genetic diversity among strain populations. *BMC Microbiol* **15**:148. https://doi.org/10.1186/s12866-015-0487-4.
37. Johnson WH. 1918. Annual report of the agricultural department of southern provinces Nigeria for the year 1917, Ibadan, Nigeria. Government Publication 14.
38. Harrison, N., Davis, R.E., Oropeza, C., Helmick, E., Narvaez, M., Eden-Green, S., Dollet, M., Dickinson, M., Konan Konan, J.L., 2014. 'Candidatus Phytoplasma palmicola', a novel taxon associated with a lethal yellowing-type disease (LYD) of coconut (Cocos nucifera L.) in Mozambique. Int. J. Syst. Evol. Microbiol. 64, 1890–1899. https://doi.org/ 10.1099/ijs.0.060053-0.
39. Contaldo, N; Bertaccini, A., Paltrinieri, S., Windsor, H.M., Windsor, D.G., 2012. Axenic culture of plant pathogenic phytoplasmas. Phytopath. Medit. 51 (3), 607–617.
40. Contaldo, N., Satta, E., Zambon, Y., Paltrinieri, S., Bertaccini, A., 2016. Development and evaluation of different complex media for phytoplasma isolation and growth. J. Microbiol. Meth. 127, 105–110
41. Contaldo, N., D'Amicoa, G., Paltrinieria, S., Diallob, H.A, Bertaccinia, A., Arocha-Rosete, Y. 2019. Molecular and biological characterization of phytoplasmas from coconut palms affected by the lethal yellowing disease in Africa. Microbiological Research 223–225 (2019) 51–57. https://doi.org/10.1016/j.micres.2019.03.011
42. Trivellone, V. 2019. An online global database of Hemiptera-Phytoplasma-Plant biological interactions. Biodiversity Data Journal 7: e32910. https://doi.org/10.3897/BDJ.7. e32910
43. Bertaccini, A. 2007. Phytoplasmas: diversity,taxonomy, and epidemiology. Front Biosci 12:673–689
44. Ermacora P and R. Osler, 2019. Symptoms of Phytoplasma Diseases In: Rita Musetti and Laura Pagliari (eds.), Phytoplasmas: Methods and Protocols, Methods in Molecular Biology, vol. 1875, https://doi.org/10.1007/978-1-4939-8837-2_5, Springer Nature 53-67.
45. Wei, W., Shao, J., Zhao, Y., Inaba, J., Ivanauskas, A., Bottner-Parker, K.D, Costanzo, S., Kim, B.M., Flowers, K. and Escobar, J. 2024**.** *i*PhyDSDB: Phytoplasma Disease and Symptom Database. *Biology*, *13*: 657. https://doi.org/10.3390/biology13090657.
46. Pracros, P., Renaudin, J., Eveillard, S., Mouras, A. and Hernould, M. 2006. Tomato flower abnormalities induced by stolbur phytoplasma infection are associated with changes of expression of floral development genes. *Molecular plant-microbe interactions* **19**(1): 62–68. https://doi.org/10.1094/MPMI-19-0062
47. Maejima, K., Iwai, R., Himeno, M., Komatsu,K., Kitazawa, Y., Fujita, N., Ishikawa, K., Fukuoka, M., Minato,N., Yamaji, Y., Oshima, K. and Namba S. 2014. Recognition of floral homeotic MADS domain transcription factors by a phytoplasmal effector,phyllogen, induces phyllody. *Plant Journal* **78**:541-554. 10.1111/tpj.
48. Kruger, K. and Fiore, N. 2019. Sampling Methods for Leafhopper, Planthopper, and Psyllid Vectors. P37-52. In:Rita Musetti and Laura Pagliari (eds.), Phytoplasmas: Methods and Protocols, Methods in Molecular Biology, vol. 1875, https://doi.org/10.1007/978-1-4939-8837-2_4. Springer Nature New York.
49. Tedeschi, R. and Bertaccini, A. 2019. Transovarial Transmission in Insect Vectors. P 115- 130 In Bertaccini, A., Weintraub, P.G., Rao, G.P. and Mori, N. Phytoplasmas: Plant Pathogenic Bacteria – II. Springer Nature Singapore Pte Ltd. https://doi.org/10.1007/978-981-13-2832-9

 doi:10.20944/preprints202503.0864.v1

50. Alma, Alberto; Federico Lessio, and Herbert Nickel 2019. Insects as Phytoplasma Vectors: Ecological and Epidemiological Aspects. P1-25 In Bertaccini, A., Weintraub, P.G., Rao, G.P. and Mori, N 2019. Phytoplasmas: Plant Pathogenic Bacteria – II. Springer Nature Singapore Pte Ltd. https://doi.org/10.1007/978-981-13-2832-9
51. Weintraub, P.G. and Beanland, L. 2006. Insect vectors of phytoplasmas. Annu Rev Entomol 51:91–111.
52. Jarausch, B. Tedeschi, R. Sauvion, N. Gross J. and Jarausch W. 2019. P 54-78 In Bertaccini, A., Weintraub, P.G., Rao, G.P. and Mori, N. Phytoplasmas: Plant Pathogenic Bacteria – II. Springer Nature Singapore Pte Ltd. https://doi.org/10.1007/978-981-13-2832-9.
53. Jović, J. Riedle-Bauer M. and Chuche J. 2019. Vector Role of Cixiids and Other Planthopper Species P 79-113 In Bertaccini, A., Weintraub, P.G., Rao, G.P. and Mori, N . Phytoplasmas: Plant Pathogenic Bacteria – II. Springer Nature Singapore Pte Ltd. https://doi.org/10.1007/978-981-13-2832-9.
54. Weintraub, P. G., Trivellone, V. and Krüger, K. 2019. The Biology and Ecology of Leafhopper Transmission of Phytoplasmas. P27 -53 In Bertaccini, A., Weintraub, P.G., Rao, G.P. and Mori, N. Phytoplasmas: Plant Pathogenic Bacteria – II. Springer Nature Singapore Pte Ltd. https://doi.org/10.1007/978-981-13-2832-9.
55. Carraro, L., Loi. N. and Ermacora, P. 2001. Transmission characteristics of the European stone fruit yellows phytoplasma and its vector *Cacopsyllapruni*. *Eur J. Plant Pathol* **107**: 695–700.
56. Ammar, E. and Hogenhout, S. 2006. Mollicutes associated with arthropods and plants. In: Kostas B, Miller T (Eds) Insect Symbiosis. CRC Press, Taylor & Francis Group, II. Boca Raton, FL, U.S.A., 97-118 pp.
57. Kingdom, H. 2013. Insect Maintenance and Transmission. .P47-59 In: Matt Dickinson and Jennifer Hodgetts (eds.), *Phytoplasma: Methods and Protocols*, Methods in Molecular Biology, vol. 938, DOI 10.1007/978-1-62703-089-2_8.
58. Bosco, D. and Tedeschi, R. 2013 Insect Vector Transmission Assays. P73-85 In: Matt Dickinson and Jennifer Hodgetts (eds.), *Phytoplasma: Methods and Protocols*, Methods in Molecular Biology, vol. 938, DOI 10.1007/978-1-62703-089-2_8.
59. Bertin, S. and Bosco, D. 2013. Molecular Identification of Phytoplasma Vector Species P87-108 In: Matt Dickinson and Jennifer Hodgetts (eds.), *Phytoplasma: Methods and Protocols*, Methods in Molecular Biology, vol. 938, DOI 10.1007/978-1-62703-089-2_8.
60. Pagliari, L., Chuche, J. Bosco, D. and Thiery, D. 2019. Phytoplasma Transmission: Insect Rearing and Infection Protocols. P21-36 In: Rita Musetti and Laura Pagliari (eds.), Phytoplasmas: Methods and Protocols, Methods in Molecular Biology, vol. 1875, https://doi.org/10.1007/978-1-4939-8837-2_7.
61. Weintraub P. and Jürgen G. 2013. Capturing Insect Vectors of Phytoplasmas. P61-72 In: Matt Dickinson and Jennifer Hodgetts (eds.), *Phytoplasma: Methods and Protocols*, Methods in Molecular Biology, vol. 938, DOI 10.1007/978-1-62703-089-2_6.
62. Kruger, K., Stiller, M., Van Wyk, D. J. and de Klerk, A. 2018. Diversity of leafhopper and plantjopper species in South African vineyards. *In*: 5th European Bois Noir Workshop, Ljubljana, Slovenia, 18-19thSeptember, 2018.
63. Nahdi, S., Bouhachem, S.B., Mahfoudhi, N., Paltrinieri, S. and Bertaccini, A. 2020. Identification of phytoplasmas and Auchenorryncha in Tunisian vineyards. *Phytopathogenic Mollicutes* 10(1):25-35.
64. Jones, P., Arocha, Y., Zerfy, T., Proud, J., Abebe, G. and Hanson, J. 2007. A stunting syndrome of Napier grass in Ethiopia is associated with a 16SrIII group phytoplasma *Plant Pathology* **56:** 345 Doi: 10.1111/j.1365-3059.2007.01525.x.
65. Arocha, Y., Pinol, B., Acosta, K., Almeida, R., Devonshire, J. Van de Meene, A., Boa., E. and Lucas, J. 2009. Detection of phytoplasma and potyvirus pathogens in papaya (*Carica papaya* L.) affected by Bunchy top symptom (BTS) in eastern Cuba. *Crop Protection* **28**: 640-646.
66. Obura, E., Midega, C. A. O., Masiga, D., Pickett, J. A., Hassan, M., Koji, S.,and Khan, Z. R. 2009. Recilia banda Kramer (Hemiptera: Cicadellidae), a vector of Napier stunt phytoplasma in Kenya. *Naturwissenschaften* **96**:1169-1176.
67. Philippe, R., Nkansah, J., Fabre, S., Quaicoe, R., Pilet, F. and Dollet, M. 2007. Search for the vector of Cape Saint Paul wilt (coconut lethal yellowing) in Ghana. *Bulletin of Insectology*. 60 (2) :179-180.

 doi:10.20944/preprints202503.0864.v1

68. Bila, J., Mondjana, A., Samils, B., Hogberg, H., Wilson, M.R. and Santos, L. 2017. First report of 'Candidatus Phytoplasma palmicola' detection in the planthopper Diostrombus mkurangai in Mozambique. *Bulletin of Insectology* **70**(1):45-48.
69. Trivellone, V. and Dietrich, C. H. 2021. Evolutionary Diversification in Insect Vector–Phytoplasma–Plant Associations, *Annals of the Entomological Society of America* 114 (2): 137–150. https://doi.org/10.1093/aesa/saaa048.
70. Trivellone, V., Wei, W., Filippin, L. and Dietrich, C. H. 2021. Screening potential insect vectors in a museum biorepository reveals undiscovered diversity of plant pathogens in natural areas. *Ecology and evolution 11*(11): 6493–6503. https://doi.org/10.1002/ece3.7502.
71. Marcone, C., Hergenhahn F., Ragozzino A., Seemuller E., 1999. Dodder transmission of pear decline, European stone fruit yellows, rubus stunt, Picris echioides yellows and cotton phyllody phytoplasmas to periwinkle. *Journal of Phytopathology* **147**: 187-92.
72. Pribylova, J. and Spak, J. 2013. Dodder transmission of phytoplasmas. In: Dickinson, M and Hodgetts, J. (Eds.) Phytoplasma: Methods and Protocols. 938:41-46. https://doi.org/10.1007/978-1-62703-089-2-4.
73. Caglayan, K., Choueiri, E. and Rao, G.P. 2023. Graft and vegetative transmission of phytoplasma-associated diseases in Asia and their management. In: Tiwari, A.K., Oshima, K., Yadav, A., Esmaeilzadeh-Hosseini, S.A., Hanboonsong, Y. and Lakhanpaul, S. (Eds) Phytoplasma Diseases in Asian Countries, Characterization, epidemiology, and management. Academic press. Vol 3:21-36. https://doi.org/10.1016/B978-0-323-91671-4.00014-9.
74. Chang, H.C. and Chen, J.C. 2024. An efficient grafting method for phytoplasma transmission in *Catharanthus roseus*. *Plant Methods* 20: 13. https://doi.org/10.1186/s13007-024-01139-w.
75. Satta, E., Paltrinieri, S. and Bertaccini, A. 2019. Phytoplasma transmission by seed. In: Phytoplasmas: Plant Pathogenic Bacteria-II. Transmission and Management of Phytoplasma Associated Diseases. Chapter 6. Eds. Bertaccini A, Weintraub PG, Rao GP, Springer, Singapore 131–147 pp.
76. Khan AJ, Botti S, Paltrinieri S, Al-Subhi AM, Bertaccini AF. 2002. Phytoplasmas in alfalfa seedlings: infected or contaminated seeds? In *Abstracts, 14th InternationalOrganization of Mycoplasmology Conference*, p. 148. Vienna, Austria.
77. Cordova I, Jones P, Harrison NA, Oropeza C. 2003. In situ PCR detection of phytoplasma DNA in embryos from coconut palms with lethal yellowing disease. *Mol. Plant Pathol*. 4:99–108.
78. Zwolińska, A., Krawczyk, K. and Pospieszny, H. 2010. First report of "stolbur" phytoplasma infecting pea plants. In Proceedings of the 18th Congress of the International Organization for Mycoplasmology (IOM), Chianciano Terme, Italy, 11-16 July 2010; Volume 11, p16.
79. Contaldo, N; and Bertaccini, A.,2019 Phytoplasma Cultivation P89-103 In: Assunta Bertaccini, Michael Kube, KenroOshima, and Govind Pratap Rao (eds) Phytoplasmas: Plant Pathogenic Bacteria - IIIhttps://doi.org/10.1007/978-981-13-9632-8 Springer Nature Singapore Pte Ltd. 2019
80. Botti, S. and Bertaccini, A. 2006. Phytoplasma infection through seed transmission: further observations. In: *Abstracts, 16th International Organization of Mycoplasmology Conference, Cambridge, UK*, p. 76.
81. Calari, A., Paltrinieri, S., Contaldo, N., Sakalieva, D.,Mori, N., Duduk, B. and Bertaccini, A. 2011. Molecular evidence of phytoplasmas in winter oilseed rape, tomato and corn seedlings. *Bulletin of insectology* **64**: S157-S158.
82. Hanboonsong, Y., Choosai, C., Panyim, S. and Damak, S. 2002. Transovarial transmission of sugarcane white leaf phytoplasma in the insect vector *Matsumuratettix hiroglyphicus* (Matsumara). *Insect molecular biology* **11**:97-103. 10.1046/j.0962-1075.2001.00314.x
83. Tedeschi, R., Ferrato, V., Rossi, J. and Alma, A. 2006. Possible phytoplasma transovarial transmission in the psyllids *Cacopsylla melanoneura* and *Cacopsylla pruni*. Plant Pathology 55 (1): 18-24.
84. Musetti R. and Pagliari L. (eds.) 2019. Phytoplasmas: Methods and Protocols, Methods in Molecular Biology, vol. 1875, https://doi.org/10.1007/978-1-4939-8837-2_7.
85. Pusz-Bochenska, K., Perez-lopez, e., Dumonceaux, T.J., Olivier, C., and Wist, T.J. 2020. A rapid, simple, laboratory and field adaptable DNA extraction and Diagnosis method suitable for insect transmitted plant pathogens and insect identification. *Plant Health progress* 21(1):63-68. https://doi.org/10.1094/PHP-09-19-0063-FI.

 doi:10.20944/preprints202503.0864.v1

86. Ustun, N., Zamharir, M.G. and Al-Sadi, A.M. 2023. Updates on phytoplasma diseases management. In: Tiwari, A.K., Oshima, K., Yadav, A., Esmaeilzadeh-Hosseini, S.A., Hanboonsong, Y. and Lakhanpaul, S. (Eds) Phytoplasma Diseases in Asian Countries, Characterization, epidemiology, and management. Academic press. Vol 3:97-123. https://doi.org/10.1016/B978-0-323-91671-4.00011-3.
87. Chiykowski, L.N. and Sinha, R.C. 1989. Differentiation of MLO disease by means of symptomatology and vector transmission. *Zentralblatt für Bakteriologie, Parasitenkunde, Infektionskrandheiten und Hygiene Supplement* **20**: 280–287.
88. Errampalli, D., Fletcher, J. and Claypool, P.L. 1991. Incidence of yellows in carrot and lettuce and characterization of mycoplasmalike organism isolates in Oklahoma. *Plant Disease* **75** (6): 579-584.
89. Cai, W., Shao, J., Zhao, Y., Davis, R.E. and Stefano, C. 2020. Draft genom Sequence of '*Candidatus* Phytoplasma pini'-related strain MDPP: A resource for comparative Genomics of Gymnosperm-infecting
90. Obura, E.; Masiga, D., Wachira, F., Gurja, B. and Khan, Z.R. 2011. Detection of phytoplasma by loop-mediated isothermal amplification of DNA (LAMP). Journal of Microbiological Methods 84: 312–316. doi:10.1016/j.mimet.2010.12.011
91. Tomlinson, J. A., Boonham, N. and Dickinson, M. 2010. Development and evaluation of a one-hour DNA extraction and loop-mediated isothermal amplification assay for rapid detection of phytoplasmas. Plant Pathology (2010) 59, 465–471. Doi: 10.1111/j.1365-3059.2009.02233.x
92. Bekele, B., Hodgetts, J., Tomlinson, J., Boonham, N., Nikolić, P., Swarbrick, P.J. and Dickinson, M.J. 2011. Use of a real-time LAMP isothermal assay for detecting 16SrII and XII phytoplasmas in fruit and weeds of the Ethiopian Rift Valley. *Plant Pathology, 60*, 345-355.
93. Hodgetts, J., Tomlinson J., Boonham, N., González-Martín, I. and Nikolić, P. 2011. Development of rapid in-field loop-mediated isothermal amplification (LAMP) assays for phytoplasmas. Bulletin of Insectology 64: S41-S42.
94. Bertaccini A. N. Fiore. A. Zamorano, A. K. Tiwari and G. P. Rao 2019. Molecular and Serological Approaches in Detection of Phytoplasmas in Plants and Insects P 105-136 In: Bertaccini, A., Kube,M., Oshima, K., and Rao, G.P. (eds) Phytoplasmas: Plant Pathogenic Bacteria – III https://doi.org/10.1007/978-981-13-9632-8 Springer Nature Singapore Pte Ltd. 2019.
95. Swarbrick P., Yankey, E.N. and Dickinson, M. 2011. Development of rapid in-field loop-mediated isothermal amplification (LAMP) assays for phytoplasmas. *Bulletin of Insectology* **64** *(Supplement):* S41-S42.
96. Alič, Š., Dermastia, M., Burger, J., Dickinson, M., Pietersen, G., Pietersen, G., and Dreo, T. (2022). Genome-Informed Design of a LAMP Assay for the Specific Detection of the Strain of '*Candidatus* Phytoplasma asteris' Phytoplasma Occurring in Grapevines in South Africa. *Plant disease*, *106*(11), 2927–2939. https://doi.org/10.1094/PDIS-10-21-2312-RE
97. Minguzzi S, Terlizzi F, Lanzoni C, Poggi Pollini C, Ratti C (2016) A Rapid Protocol of Crude RNA/DNA Extraction for RT-qPCR Detection and Quantification of 'Candidatus Phytoplasma prunorum' PLoS ONE 11(1): e0146515. doi:10.1371/journal.pone.0146515.
98. Hodgetts, J., N. Boonham, R. Mumford, N. Harrison, and M. Dickinson. 2008. Phytoplasma phylogenetics based on analysis of the secA and 23S rRNA gene sequences for improved resolution of the 'Candidatus Phyto plasma' species. Int. J. Syst. Evol. Microbiol. 58:1826–1837.
99. Lee, I-M., Zhao, Y. and Bottner, K.D. 2006. SecY Gene Sequence Anaylysis for finer differentiation of diverse strains in the Aster Yellows Phytoplasma group. *Molecular and Cellular Probes* 20: 87-91. http://dx.doi.org/10.1016/j.mcp.2005.10.001.
100. Dickinson, M., and Hodgetts, J. 2013. PCR Analysis of Phytoplasmas Based on the *secA* Gene. In: Dickinson, M., Hodgetts, J. (eds) Phytoplasma. Methods in Molecular Biology, vol 938. Humana Press, Totowa, NJ. https://doi.org/10.1007/978-1-62703-089-2_17
101. Wei, W., Lee, I.M., Davis, R.E., Suo, X. and Zhao, Y. 2008. Automated RFLP pattern comparison and similarity coefficient calculation for rapid delineation of new and distinct phytoplasma 16Sr subgroup lineages. *International Journal of Systematic and Evolutionary Microbiology* **58**:2368-2377.
102. Lee, I-M., Gundersen-Rindal, D.E., Davis R.E. and Bartoszyk I.M. 1998. Revised classification scheme of phytoplasma based on RFLP analysis of 16S rRNA and ribosomal protein gene sequences. *International Journal system Bacteriol.* **48**: 1153-1169.

 doi:10.20944/preprints202503.0864.v1

103. Wei, W., Davis, R.E., Lee, I-M and Zhao, Y. 2007. Computer-simulated RFLP analysis of 16S rRNA genes: identification of ten new phytoplasma groups. *International Journal of Systematic and Evolutionary Microbiology* **57**:1855-1867. doi.10.1099/ijs.0.065000-0.
104. Naderali, N., Nejat, N., Vadamalai, G., Davis R. E., Wei W., Harrison N. A., Kong L., Kadir J., Tan Y-H and Zhao Y. 2017. 'Candidatus Phytoplasma wodyetiae', a new taxon associated with yellow decline disease of foxtail palm (Wodyetiabifurcata) in Malaysia. Int J Syst. Evol. Microbiol. 10.1099/ijsem.0.002187.
105. Zhao, Y., Wei, W., Davis, R.E., Lee, I.M., and Bottner-Parker, K.D. 2021. The agent associated with blue dwarf disease in wheat represents a new phytoplasma taxon, 'Candidatus Phytoplasma tritici' International Journal of Systematic and Evolutionary Microbiology, p.ijsem004604.
106. Bertaccini, A.; Arocha-Rosete, Y.; Contaldo, N.; Duduk, B.; Fiore, N.; Montano, H.G.; Kube, M.; Kuo, C.H.; Martini, M.; Oshima, K.; Quaglino F., Schneider, B., Wei, W. and Zamorano, A. 2022. Revision of the 'Candidatus Phytoplasma'species description guidelines. *Int. J. Syst. Evol. Microbiol*. **72**:005353.
107. Deng, S.J. and Hiruki, C. 1991.Amplification of 16S rRNA from culturable and non-culturable mollicutes. *Journal of Microbiological Method* 14: 53-61. https://doi.org/10.1016/0167-7012(91)90007-D.
108. Kirkpatrick, B. C., Smart, C. D., Gardner, S. L., Gao, J.-L., Ahrens, U., Ma ¨urer, R., Schneider, B., Lorenz, K.-H., Seemu ¨ller, E., Harrison, N. A., Namba, S. and. Daire. X. 1994. Phylogenetic relationships of plant pathogenic MLOs established by 16/23S rDNA spacer sequences. IOM Lett.3:228–229.
109. Smart, C. D., Schneider, B., Blomquist, C. L., Guerra, L. J., Harrison, N. A., Ahrens, U., Lorenz, K. H., Seemüller, E., & Kirkpatrick, B. C. (1996). Phytoplasma-specific PCR primers based on sequences of the 16S-23S rRNA spacer region. *Applied and environmental microbiology* **62**(8): 2988–2993. https://doi.org/10.1128/aem.62.8.2988-2993.1996.
110. Gundersen, D.E. and Lee, I.-M.1996. Ultrasensitive detection of phytoplasmas by nested-PCR assays using two universal primer pairs. *Phytopathologia Mediterranea* **35** (3): 144-151.
111. Lee, I-M., Hammod, R., Davis R. and Gundersen-Rindal, D.E. 1993. Universal amplification and analysis of pathogen 16S rDNA for classification and identification of mycoplasmalike organisms. *Phytopathology* 83: 834-842. 10.1094/phyto-83-834.
112. Tymon, A.M., Jones, P. and Harrison, N.A. 1997. Detection and differentiation of African coconut phytoplasamas: RFLP analysis of PCR-amplified 16S rDNA and DNA hybridization. *Annals of Applied Biology* **131**:91-102.
113. Rohde, W., Kullaya, A., Mpunami, A.A., and Becker, D. 1993. Rapid and sensitive diagnosis of mycoplasmalike organisms associated with lethal disease of coconut palm by a specifically primed polymerase chain reaction for the amplification of 16S rDNA. *Oleagineux* **48**:319–322.
114. Martini M., Lee I.M., Bottner K.D., Zhao Y., Botti S., Bertaccini A., Harrison N.A., Carraro L., Marcone C., Khan A.J., Osler R., 2007. Ribosomal protein gene-based phylogeny for finer differentiation and classification of phytoplasmas. International *Journal of Systematic and Evolutionary Microbiology* **57**: 2037-51.
115. Pérez-López, E., Luna-Rodríguez, M., Olivier, C.Y. and Dumonceaux, T.J., 2016. The underestimated diversity of phytoplasmas in Latin America. *International Journal of Systematic and Evolutionary* Microbiology, 66(1):492-513.
116. Cho, S. T., Zwolińska, A., Huang, W., Wouters, R. H. M., Mugford, S. T., Hogenhout, S. A., and Kuo, C. H. 2020. Complete Genome Sequence of "*Candidatus* Phytoplasma asteris" RP166, a Plant Pathogen Associated with Rapeseed Phyllody Disease in Poland. *Microbiology resource announcements* **9**:35. e00760-20. https://doi.org/10.1128/MRA.00760-20.
117. Hugenholtz, P., Chuvochina, M., Oren, A., Parks, D.H. and Soo, R.M. 2021. Prokaryotic taxonomy and nomenclature in the age of big sequence data. ISME J., 15, 1879–1892.
118. Schneider, B., Gibb, K.S. and Seemüller, E. 1997. Sequence and RFLP Analysis of the Elongation Factor Tu Gene Used in Differentiation and Classification of Phytoplasmas. *Microbiology* ***143***:3381-3389.http://dx.doi.org/10.1099/00221287-143-10-3381.
119. Hodgetts, J. and Dickson, M. 2012. T-RFLP for detection and identification of phytoplasmas in plants. *Methods in Molecular Biology* 938:233-244.
120. Martini, M., Bottner-Parker, K.D. and Lee, I-M. 2019. PCR-Based Sequence Analysis on Multiple Genes Other than 16S rRNA Gene for Differentiation of Phytoplasmas. P97-115 In: Musetti, R. and Pagliari, L.

 doi:10.20944/preprints202503.0864.v1

(eds.), Phytoplasmas: Methods and Protocols, Methods in Molecular Biology, vol. 1875. https://doi.org/10.1007/978-1-4939-8837-2_7.

121. Zambon Y, Contaldo N, Richards RS, Bertaccini A, Burger J. 2015. Multigene characterization of aster yellows phytoplasmas infecting grapevine in South Africa. Phytopathogenic Mollicutes 5: S21–S22. https://doi.org/10.5958/2249-4677.2015.00008.0.
122. M'hirsi, S., Acheche, H., Fattouch, S., Boccardo, G., Marrackchi, M. and Marzouki, N. 2004. First report of phytoplasmas in the aster yellows group infecting grapevine in Tunisia. New Disease Reports 9. http:bspp.org.uk/ndr/july2004/2004-10.asp
123. IPPC, 2008. Pest reports from South Africa on Aster yellows phytoplasma on grapevine. www.ippc.int. Accessed 11th September, 2024.
124. Engelbrecht, M., Joubert, J. and Burger, J.T. 2010.First report of aster yellows phytoplasma in grapevines in South Africa. Plant Disease 94:373. Doi:10.1094/PDIS-94-3-0373A.
125. Coetzee B, Douglas-Smit N, Maree HJ, Burger JT, Krüger K, Pietersen G. 2019. Draft genome sequence of a "*Candidatus* Phytoplasma asteris"-related strain (aster yellows, subgroup 16SrI-B) from South Africa. Microbiol Resource Announc 8:e00148-19. https://doi.org/10.1128/MRA.00148-19.
126. Kruger, K., De Klerk, A., Douglas-Smit, N., Joubert, J., Pietersen, G. and Stiller, M. 2011. Aster yellows phytoplasma in grapevines:identification of vectors in South Africa *Bulletin of insectology* 64. S137-S138.
127. Pietersen, G., Pietersen, G., Jnr., Pietersen, I., and Stiller, M. 2018. Identification of *Mgenia fuscovaria* (Stal) (Hemiptera: Cicadellidae), a vector of aster yellows disease on grapevines in South Africa, and differentiation from *Mgenia augusta* (Theron) by nucleotide sequences of the mitochondrial cytochrome oxidase 1 (*cox1*) gene. *S. Afr. J. Enol. Vitic* **39** (2). http://dx.doi.org/10.21548/39-2-3157.
128. Cousin M.T., Maillet P.L., Gourret J.P., 1969. La virescence du cotonnier (Gossypium hirsutum L.) nouvelle maladie à mycoplasmes. CompteRendues Académie des Sciences, Paris, Série D 268: 2382-2384.
129. Laboucheix J., van Offeren A., Desmidts M., 1973. Etude de la transmission par Orosiuscellulosus (Lindberg) (Homoptera,Cicadellidae) de la virescence florale du cotonnier et de Sida sp.. Coton et Fibres Tropicaux 28: 461-471.
130. Delattre R., Joly A., 1981. Résultats des enquêtes sur la virescence florale du cotonniereffectuéesen Haute-Volta de 1970 à 1978. Coton et Fibres Tropicaux 36: 167-185.
131. Marzachì, C., Coulibaly, A., Coulibaly, N., Sangaré, A., Diarra, M., De Gregorio T. and Bosco, D. 2009. Cotton virescence phytoplasma and its weed reservoir in mali. *Journal of Plant Pathology* **91** (3): 717-721.
132. El-Banna, O. H. M., Mikhail, M. S., Farag, A. G., and Mohammed, A. M. S. (2007). Detection of phytoplasma in tomato and pepper plants by electron microscopy and molecular biology-based methods. Egypt J. Virol. 4, 93–111.
133. Omar, A.F. and Fossiac, X. 2012. Occurrence and incidene of phytoplasmas of the 16SrII-D subgroup on solananceous and curcurbit crops in Egypt. European Journal of Plant Pathology 133 (2):353-360.
134. El-Sisi Y., Omar A.F., Sidaros, S.A. and Elsharkawy M.M. 2017. Characterization of 16SrII-D subgroup associated phytoplasmas in new host plants in Egypt. *Archives of phytopathology and plant protection.*http://dx.doi.org/10.1080/03235408.2017.1336154.
135. Kumar, L. P., Sharma, K., Boahen, S., Tefera, H. and Tamò, M. 2011. First Report of Soybean Witches'-Broom Disease Caused by Group 16SrII Phytoplasma in Soybean in Malawi and Mozambique. *Plant Dis*. **95**(4):492. doi: 10.1094/PDIS-01-11-0016. PMID: 30743352.
136. Murithi, H., Owati, A., Madata, C. S., Joosten, M., Beed, F. and Kumar, L. P. 2015. First report of 16SrII-C subgroup phytoplasma causing phyllody and witches'-broom disease in Soybean in Tanzania: Disease notes. *Plant Disease* 99(6): 886. https://doi.org/10.1094/PDIS-11-14-1225-PDN.
137. Alfaro-Fernández, A., Ali, M. A., Abdelraheem, F. M., Saeed, E. A. E., and Font- San-Ambrosio, M. I. 2012. Molecular identification of 16SrII-D subgroup phytoplasmas associated with chickpea and faba bean in Sudan. *Eur. J. Plant Pathol*. **133**: 791–795. doi: 10.1007/s10658-012-9975-7
138. Dafalla, G.A. and Cousin, M.T. Cousin. 1988. Natural occurrence of virescence disease on *Catharanthus roseus* and *Zinna elegans* in the Gezira, Sudan. *Journal of Plant Diseases and Protection* **95** (4): 414-418.
139. Omar, A.F., Emeran, A.A. and Abass, J.M. 2008. Detection of perinwinkle virescence in Egypt. Plant Pathology Journal 7(1): 92-97.

 doi:10.20944/preprints202503.0864.v1

140. Gad, S.M., Kheder, A.A. and Awad, M.A. 2019. Detection and Molecular identification of phytoplasma associated with Gazania in Egypt. *J. of Virol. Sci*. **6**: 12-23.
141. Lukuyu, B., Ngunga, D. and Bekunda, M. 2021. Improved Napier grass varieties for smallholder farmers in East Africa. Nairobi, Kenya: ILRI.
142. Midega, CAO., Pittchar, J.O., Pickett, J.A., Hailu, G.W. and Khan, Z.R. 2018. A climate-adapted push-pull system effectively controls fall armyworm, *Spodoptera frugiperda* (J.E. Smith) in maize in East Africa. *Crop Protection* **105**: 10-15.
143. Scheidegger, L., Niassy, S., Midega, C., Chiriboga, X., Delabays, N., Lefort, F., Zurcher, R., Hailu, G., Khan, Z. and Subramanian, S. 2021. The role of *Desmodium intortum, Brachiaria* sp. and *Phaseolus vulgaris* in the management of fall armyworm *Spodoptera frugiperda* (J.E. Smith) in maize cropping system in Africa. *Pest management Science* **77**: 2350-2357. https://doi.org/10.1002/ps.6261.
144. Tsai, Y.C., Luo, P.Q., Sung, C.L., Li, Y., Hu, F.Y, Wang, C.L., Chen, Y.N., Hsu, J.H., Liao, C.E, Chang, S.R. and Chuang, W.P.2024. Evaluating local plant species for effective fall armyworm management strategies in Taiwan. *Botanical Studies* **65**: 18. https://doi.org/10.1186/s40529-024-00424-0.
145. Asudi, G. O., Muyekho, F. N., Midega, C. A. O. and Khan Z. R. 2019. Integrated Management of Napier Grass Stunt Disease in East Africa. *Sustainable Management of Phytoplasma Diseases in Crops Grown in the Tropical Belt*, Sustainability in Plant and *Crop Protection* 12: https://doi.org/10.1007/978-3-030-29650-6_5.
146. Jones, P., Devonshire, B.J., Holman, T.J. and Ajanga, S. 2004. Napier grass stunt: a new disease associated with a 16SrXI group phytoplasma in Kenya. *Plant Pathology* 53:519.
147. Nielsen, S. L., Ebong, C., Kabirizi, J., and Nicolaisen, M. 2007. First report of a 16SrXI group phytoplasma (Candidatus Phytoplasma oryzae) associated with Napier grass stunt disease in Uganda. *Plant Pathology* **56**(6): 1039–1039.
148. Asudi, G. O. 2018. The dynamics of Napier grass stunt phytoplasma in East Africa *Endocytobiosis and Cell Research* 29:13–17.
149. Fischer A, Santana-Cruz I, Wambua L, Olds C, Midega C, Dickinson M, Kawicha P, Khan Z, Masiga D, Jores J, Schneider B. 2016. Draft genome sequence of "*Candidatus* Phytoplasma oryzae" strain Mbita1, the causative agent of Napier grass stunt disease in Kenya. *Genome Announc* 4(2):e00297-16. doi:10.1128/genomeA.00297-16.
150. Asudi, G. O., Omenge, K. M., Paulmann, M. K., Reichelt, M., Grabe, V., Mithöfer, A., Oelmüller, R., & Furch, A. C. U. 2021. The Physiological and Biochemical Effects on Napier Grass Plants Following Napier Grass Stunt Phytoplasma Infection. *Phytopathology*, *111*(4), 703–712. https://doi.org/10.1094/PHYTO-08-20-0357-R
151. Kabirizi, J., Nielsen, S.L., Nicolaisen, M., Byenkya, S. and Alicai, T. 2007. Napier stunt disease in Uganda: farmers' perceptions and impact on fodder production. African Crop Science Conference Proceedings. 8:895–897.

152. Asudi, G. O., Van den Berg, J., Midega, C. A. O., Pickett, J. A., and Khan, Z. R. 2016. The significance of Napier grass stunt phytoplasma and its transmission to cereals and sugarcane. Journal of phytopathology 164:378-385.
153. Kawube, G., Talwana, H., Nicolaisen, M., Alicai, T., Otim, M., Kabirizi, J., Mukwaya, A. and Nielsen, S.L. 2015. Napier grass stunt disease prevalence, incidence, severity and genetic variability of the associated phytoplasma in Uganda. Crop Prot. 75:63–69.
154. Asudi, G.O., Van den Berg, J. Midega, C.A.O., Pittchar, J., Pickett, J. and Khan, Z. 2015. Napier grass stunt disease in East Africa: Farmers' perspectives on disease management. *Crop Protection* 71:116-124.
155. Ricaud, C. 1968. Yellow wilt of sugarcane in eastern Africa. *Sugarcane Pathol. Newsl.* **1**:45-49.
156. Cronje, C. P. R., Tymon, A. M., Jones, P. and Bailey, R. A. 1998. Association of a phytoplasma with a yellow leaf syndrome of sugarcane in Africa. *Ann. Appl. Biol*. 133:177-186. https://doi.org/10.1111/j.1744-7348.1998.tb05818.x
157. El Sayed, A.I., Soufi, Z., Wahdan, K.M. and Komor, E. 2015. Detection and characterization of phytoplasma and sugarcane yellow leaf virus associated with leaf yellowing of sugarcane. *Journal of phytopathology* **164**:4217-225. https://doi.org/10.1111/jph.12449.

 doi:10.20944/preprints202503.0864.v1

158. Scagliusi, S.M. and Lockhart, B.E.L.2000. Transmission, characterization and serology of a luteovirus associated with yellow leaf syndrome of sugarcane. *Phytopathology* **90**:120-124.
159. Marcone, C. 2002. Phytoplasma diseases of sugarcane. *Sugar Tech*. 4 (3 and 4).79-85.
160. Rutherford, R.S., Brune, A.E. and Nuss, K.J. 2004. Current status of research on sugarcane yellow leaf syndrome in Southern Africa. *Proc S Afr Sug Technol Ass* 78: 173-180.
161. Rott, P., Comstock, J.C., Croft, B.J. Kusalwong, A., Saumtally, S.A. 2005. Advances and Challenges in sugarcane pathology. Proc. Inten. Soc. Sugar Cane Technol. Congr. 25:607-614.
162. Rogers,P.F. 1969.Proceedings of a meeting on the yellow wilt condition of sugarcane. June 25th-26th, 1969. Nairobi Kenya: East Africa Specialist Committee on Sugarcane Research.
163. Arocha, Y., López, M., Fernández, M., Piñol, B., Horta, D., Peralta, E. L., Almeida, R., Carvajal, O., Picornell, S., Wilson, M. R. and Jones, P. 2005. Plant pathology 54 (5):634-642. https://doi.org/10.1111/j.1365-3059.2005.01242.x.
164. Abdelmajid, N., Mohamed, A., Cronje, P., & Jones, P. (1999). First Report of Yellow Leaf Syndrome of Sugarcane in Morocco. *Plant disease*, *83*(4), 398. https://doi.org/10.1094/PDIS.1999.83.4.398C
165. Lockhart, B.E.L. and Cronjé, P.R., 2000. Yellow leaf syndrome. In: Rott, P. Bailey, R.A. Croft, B.J., Comstock, J.C. Saumtally, A.S. (eds). *Guide to Sugarcane Diseases*. France: CIRAD, 291 – 5.
166. Nithya, K., Kirdat, K., Parameswari, B., Tiwarekar, B., Tiwari, A.K., Rao, G.P., Nikpay, A., Hoat, T.X., Viswanathan, R. and Yadav, A. 2023. Updates on phytoplasma diseases associated with sugarcane in Asia. In: Tiwari, A.K., Oshima, K., Yadav, A., Esmaeilzadeh-Hosseini, S.A., Hanboonsong, Y. and Lakhanpaul, S. (Eds) Phytoplasma Diseases in Asian Countries, Characterization, epidemiology, and management. Academic press. Vol 2:215-232. https://doi.org/10.1016/B978-0-323-91897-8.00008-3.
167. Nithya, K., Parameswari, B. and Viswanathan, R. 2020. Mixed infection of sugarcane yellow leaf virus and grassy shoot phytoplasma in yellow leaf affected Indian sugarcane cultivars. The Plant pathology journal 36 (4): 10.5423/PPJ.OA.06.2020.0092.
168. Kirdat, K., Tiwarekar, B., Thorat, V., Narawade, N., Dhotre, D., Sathe, S., Shouche, Y. and Yadav, A. 2020. Draft genome sequences of two phytoplasma strains associated with sugarcane grassy shoot (SCGS) and Bermuda grass white leaf (BGWL) diseases. Mol. Plant-Microbe Interact. 33:715-717. 10.1094/MPMI-01-0005-A.
169. Viswanathan, R. 2000. Grassy shoot. In: Rott, P., Bailey, R.A., Comstock, J.C., Croft, B.J. and Saumtally, A.S. (eds.) A guide to Sugarcane diseases. Centre de cooperation international en recherche agronomique pour le development (CIRAD) and International Society of Sugar Cane Technologists (ISSCT) Montpellier. P215-220.
170. Ekpo, E.N. and Ojomo, E.E. 1990. The spread of lethal coconut diseases in West Africa: incidence of akwa disease or bronze leaf wilt in the Ishan area of Bendel State of Nigeria. *Principes* 34 (3): 143-146.
171. Mpunami, A., Tymon, A., Jones, P. and Dickinson, M.J. 1999. Genetic diversity in the coconut lethal yellowing disease phytoplasmas of East Africa. Plant Pathol 48:109 –114. https://doi.org/10.1046/j.1365-3059.1999.00314.x.
172. Dollet, M., Quaicoe, R., and Pillet, F. 2009. Review of coconut "lethal yellowing" type diseases. Diversity, variability and diagnosis. *Oilseed fats crops lipids* 16:97-101.
173. Eziashi, E. and Omamor, I. 2010. Lethal yellowing disease of the coconut palms (Cocos nucifera L.): An Overwiew of the crises. Afr. J. Biotechnol. 9: 9122-9127.
174. Eden-Green, S.J. 1997. History, distribution and research on coconut lethal yellowing-like diseases of palms. In: Eden-Green, S.J. and Ofori, F.(eds.) Proceedings of the International workshop on lethal yellowing-like diseases of coconut, Elmina, Ghana. NRI: Chatham, UK. P9-25.
175. Konan Konan, J.L., Allou, K., Atta Diallo, H., Yao, S. D., Koua, B., Kouassi, N., Benabid, R., Michelutti, R., Scott, J.A. and Arocha-Rosete, Y., 2013. First report on the molecular identification of the phytoplasma associated with a lethal yellowing-type disease of coconut palms in Cote d'Ivoire. *New Disease Reports* **28**:3. https://doi.org/10.5197/j.2044-0588.2013.028.003.
176. Osagie, I.J., Ojomo, E.E. and Pilet, F. 2015. Occurrence of Awka wilt disease of coconut in Nigeria for one century. Phytopathogenic Mollicutes 5: S61–S62. https://doi.org/10.5958/2249-4677.2015.00025.0.

 doi:10.20944/preprints202503.0864.v1

177. Ofori F. and Nkansah-Poku J. 1997. Cape Saint Paul wilt disease of coconut in Ghana: History of its occurrence and spread. In: Eden-Green S.J. and Ofori F. (eds). Proceedings of an International Workshop on Lethal Yellowing-Like Diseases of Coconut, Elmina, Ghana, November 1995. Chatham, UK: NRI, P27-32.
178. Dabek, A.J., Johnson, C.G. and Harries, H.C. 1976. Mycoplasma-like organisms associated with Kaincope and Cape St. Paul wilt diseases of coconut palms in West Africa. PANS:22 (3): 354-358. https://doi.org/10.1080/09670877609412071.
179. Dollet, M., Gianotti, J., Renard, J-L and Ghosh, S.K. 1977. Study of a lethal yellowing of coconut trees in Cameroon: Kribi disease. Observations of mycoplasma-type organisms. *Oleagieux* 32 (7):317-322.
180. Bila J, Mondjana A, Samils B, Hogberg N. 2015. High diversity, expanding populations and purifying selection in phytoplasmas causing coconut lethal yellowing in Mozambique. *Plant Pathol* **64**:597– 604. https://doi.org/10.1111/ppa.12306.
181. Cordova, I., Oropeza, C., Puch-Hau, C., Harrison, N., Colli-Rodriguez, A., Narvaez, M., Nic-Matos, G., Reyes, C. and Saenz, L. 2014. A real-time PCR assay for detection of coconut lethal yellowing phytoplasmas of group 16S IV subgroups A,D and E found in the Americas. *J. Plant Pathology* **96**: 343-352
182. Bila, J. Hogberg, N., Mondjana, A and Samils, B. 2015. African fan palm (*Borassus aethiopum*) and Oil palm (*Elaeis guineensis*) are alternate host of coconut lethal yellowing phytoplasma in Mozambique. *African Journal of Biotechnology* 14 (52):3359-3367.
183. Danyo, 2011. Review of scientific research into the Cape Saint Paul wilt disease of coconut in Ghana. *African Journal of Agricultural Research* 6(19): doi.10.5897/AJAR11.139.
184. Nipah, J. O., Jones, P. and Dickinson, M. J. 2007. Detection of lethal yellowing phytoplasma in embryos from coconut palms infected with cape St Paul wilt disease in Ghana. *Plant Pathol.* **56**(5): 777–784.
185. Oropeza, C., Cordova, I., Puch-Hau, C., Castillo, R., Chan, J. and Sáenz, L. 2017. Detection of lethal yellowing phytoplasma in coconut plantlets obtained through in vitro germination of zygotic embryos from the seeds of infected palms. *Annals of Applied Biology*, *171*(1), 28–36.
186. Mpunami, A., Tymon, A., Jones, P. and Dickinson, M.J. 2000. Identification of potential vectors of the coconut lethal disease phytoplasma. Plant Pathology 49 (3): 355–361. https://doi.org/10.1046/j.1365-3059.2000.00460.x.
187. Kwadjo, K. E., Beugré,N.'D. I., Dietrich,C. H., Kodjo, A. T. T., Diallo, H. A., Yankey,N., Dery,S., Wilson, M., Konan Konan, J. L., Contaldo, N., Paltrinieri, S. Bertaccini, A. and Arocha-Rosete, Y.2018. Identification of Nedotepa curta Dmitriev as a potential vector of the Côte d'Ivoire lethal yellowing phytoplasma in coconut palms sole or in mixed infection with a 'Candidatus Phytoplasma asteris'-related strain. *Crop Protection* **110**:48-56. https://doi.org/10.1016/j.cropro.2017.12.015.
188. Bila, J. 2016. Coconut lethal yellowing phytoplasma disease in Mozambique. Doctoral Thesis, Swedish University of Agricural Sciences, Uppsal.
189. Kra KD, Toualy YMN, Kouamé AC, Diallo HA, Arocha-Rosete Y, 2017. First report of a phytoplasma affecting cassava orchards in Cote d'Ivoire..*New Disease Reports* 35, 21. http://dx.doi.org/10.5197/j.2044-0588.2017.035.021
190. Arocha-Rosete, Y., Diallo, H.A., Konan Konan, J.L., Yankey, N., Saleh, M., Pilet, F., Contaldo, N., Paltrinieri, S., Bertaccini, A. and Scott, J. 2017. Detection and differentiation of the coconut lethal yellowing phytoplasma in coconut growing villages of Grand-Lahou, Côte d'Ivoire. *Annals of Applied Biology* **170**: 333–347. http://dx.doi.org/10.1111/aab.12333.
191. Bila, J., Mondjana, A., Samils, B., Santos, L. and Hogberg, N. 2019. Integrated Management of Coconut Lethal Yellowing Phytoplasma Disease in Mozambique: Current Challenges and Future Perspectives. *Sustainable Management of Phytoplasma Diseases in Crops Grown in the Tropical Belt*, Sustainability in Plant and Crop Protection 12. https://doi.org/10.1007/978-3-030-29650-6_11.
192. Álvarez E., 2019. Phytoplasma Diseases Affecting Cassava. Olivier, C. Y.. Tim J. Dumonceaux and Edel Pérez-López (eds.), *Sustainable Management of Phytoplasma Diseases in Crops Grown in the Tropical Belt*, Sustainability in Plant and Crop Protection 12, https://doi.org/10.1007/978-3-030-29650-6_7.
193. Arocha, Y and Jones, P. 2010. Phytoplasma disease of Graminae.I: Weintraub P, and Jones, P. (Eds.). Phytoplasmas: genome, plants hosts and vectors. Wallingford, UK: CABI International. P170-187.

 doi:10.20944/preprints202503.0864.v1

194. Obura, E., Masiga, D., Midega, C. A. O., Wachira, F., Pickett, J. A., Deng, A. L.,and Khan, Z. R. *2010.First report of a phytoplasma associated with Bermuda grass white leaf disease in Kenya* New Dis. Rep. 21:23
195. Obura, E., Masiga, D., Midega, C. A. O., Otim, M., Wachira, F., Pickett, J., and Khan, Z. R. 2011. Hyparrhenia grass white leaf disease, associated with a 16SrXI phytoplasma, newly reported in Kenya. New Dis. Rep. 24:17.
196. Cronje, P., Dabek, A.J., Jones, P. and Tymon, A.M. 2000. First report of a phytoplasma associated with a disease of date palms in North Africa. *Plant Pathology* 49(6): 801-801. https://doi.org/10.1046/j.1365-3059.2000.00504.x
197. Cronje, P., Dabek, A.J., Jones, P. and Tymon, A.M. 2000. Slow decline: a new disease of matured date palms in North Africa associated with phytoplasma. *Plant Pathology* 49(6): 804-804. https://doi.org/10.1046/j.1365-3059.2000.00507.x.
198. Cronjé, P., Dabek, A. J., Jones, P. and Tymon, A. M.2008. First report of a phytoplasma associated with a disease of date palms in North Africa. Plant Pathology 49(6) 801-801.https://doi.org/10.1046/j.1365-3059.2000.00504.x.
199. Ammar, M.I. Amer, M.A. and Rashed, M.F. 2005. Detection of phytoplasma associated with yellow streak disease of date palms in Egypt. Egyptian J. Virol. 2:74-86.
200. Alkhazinder, M., 2014.Detection and molecular identification of Aster Yellows phytoplasma in date palm in Egypt. Journal of Phytopathology. Doi:10.1111/jph.12241
201. Guthrie, J.N., White, D.T., Walsh, K.B. and Scott, P.T. 1998. Epidemiology of phytoplasma associated papaya diseases in Queensland, Australia. Plant Diseases 82: 1107-1111.
202. Padovan, A. and Gibb, K. 2001. Epidemiology of phytoplasma diseases in papaya in Northern Australia. Journal of Phytopathol. 149: 649-658.
203. Elder, R., Milne, J., Reid, D., Guthrie, J. and Persley, D. 2002. Temporal incidence of three phytoplasma associated diseases of Carica papaya and their potential hemipteran vectors in central and south-east Queensland. Aust. Plant. Pathol.31: 165-176.
204. Gera, A., Mawassi, M., Zeidan, M., Spiegel, S. and Bar-Joseph, M. An isolate of 'Candidatus Phytoplasma australiense' group associated with Nivun Haamir dieback disease of papaya in Israel. Plant Pathology 54(4):560 – 560. 10.1111/j.1365-3059.2005.01236.x.
205. Arocha, Y., Bekele, B., Tadesse, D. and Jones, P. 2007. First report of a 16SrII group associated with die-back diseases of papaya and citrus in Ethiopia. Plant Pathology 56:1039.
206. Kazeem, S.A., Inaba, J., Zhao, Y., Zwolińska, A., Ogunfunmilayo, A.O., Arogundade, O. and Wei, W. 2021. Molecular identification and characterization of 'Candidatus Phytoplasma convolvuli'-related strains (representing a new 16SrXII-O subgroup) associated with papaya bunchy top disease in Nigeria. *Crop Protection* 148: https://doi.org/10.1016/j.cropro.2021.105731.
207. Lobognon N.P.A., Kra, K.D. and Toualy, M-N. 2014. First Detection of Ca. phytoplasma asteris in Papaya orchards in Ivory Coast. *Pakistan Journal of phytopathology* 36 (2):347-358. doi.10.33866/phytopathol.036.02.1207.
208. Inaba, J., Kazeem, S.A., Zhao, Y., Zwolińska, A., Ogunfunmilayo, A.O., Arogundade, O. and Wei, W. 2023. Tomato and Jute Mallow are Two New Hosts of Papaya Bunchy Top Phytoplasma, a 'Candidatus Phytoplasma convolvuli'-Related Strain in Nigeria. *Plant Disease* **107** (6): 1937. 10.1094/PDIS-09-22-2192-PDN.
209. El-Banna, O.H.M. and El-Deeb, S.H. 2007. Phytoplasma associated with mango malformation disease in Egypt. Journal of Phytopathology: 157:639-641.
210. Amr, M., Kheder, A., Ahmed, G., El-Habbaa and Mahdy, A. 2024. Identification and molecular characterization of phytoplasma associated carrot plant (Daucus carota L.) in Qalyubia Governorate, Egypt. *Annals of Agricultural Science, Moshtohor* **62**:21-36. doi.10.21608/ASSJM.2024.283796.1276.
211. SA wine Industry Statistics 2023. South Africa Wine Industry Information and systems SAWIS. www.sawis.co.za and wosa.co.za. Accessed 1st September, 2024.
212. Carstens, R. 2014. The incidence and distribution of grapevine yellows diseases in South African vineyards. M.Sc Thesis Stellenbosch University. 95p.

 doi:10.20944/preprints202503.0864.v1

213. Kruger, K. 2020. Grapevine Yellows management in South Africa: Manangement Strategies for Aster yellows phytoplasma in grapevine in South Africa. Tropicsafe Technical Innovative Factsheet. www.tropicsafe.eu.
214. Yankey, E. N., Aidoo, O.F., and Sossah, F. L. 2024. A critical review of Cape Saint Paul Wilt Disease: A devastating phytoplasma-associated infection affecting coconut trees in Ghana. Crop Protection 184:https://doi.org/10.1016/j.cropro.2024.106830.
215. Khan ZR, Midega CAO, Nyang'au MI, Murage A, Pittchar J, Agutu L,Amudavi DM, Pickett JA. (2014) Farmers' knowledge and perceptions of the stunting disease of Napier grass in western Kenya. Plant Pathol. 63(6):1426–1435.
216. El Sayed, A. I. and Boulila, M., 2014. Molecular Identification and phylogenetic analysis of sugarcane yellow leaf Phytoplasma (SCYLP) in Egypt. *J. Phytopathol.* 162: 89-97. 10.1111/jph.12156.
217. Jibrin, M. O., Olson, J. Wallace, S., Walker, N. and Marek, S.M. 2024. First Report of '*Candidatus* Phytoplasma asteris'-Related Strains (Subgroup 16SrI-A) Associated With Aster Yellows on Chrysanthemums in Oklahoma. *Plant Disease* 108 (11): 3406. https://doi.org/10.1094/PDIS-03-24-0693-PDN.
218. Singh, K., Ranebennur,H., Rawat,K., Chalam, V.C., Gupta,S., Choudhary, M., Meena, V.S., Shekhawat, N., Sharma, M., Chawla, M.P., Kumar, M., Singh, P. K. and Singh G. P. First Report of '*Candidatus* Phytoplasma asteris' (16SrI-B Subgroup) Associated with Stunting and Little Leaves of Guar (*Cyamopsis tetragonoloba*) in World. *Plant Disease* xxx. https://doi.org/10.1094/PDIS-07-24-1493-PDN.
219. Dutta, D.S., Kalita, M.K. and Nath, P.D. (2024). First report of *Candidatus* Phytoplasma trifolii (16SrVI-D) associated with little leaf disease of *Nyctanthes arbor-tristis* in the world. *J Plant Pathol* **106**: 1403–1404. https://doi.org/10.1007/s42161-024-01635-x.