

UNVEILING THE DIVERSITY OF ASTER YELLOW'S PHYTOPLASMAS IN MEDICINAL FLORA: A GLOBAL PERSPECTIVE

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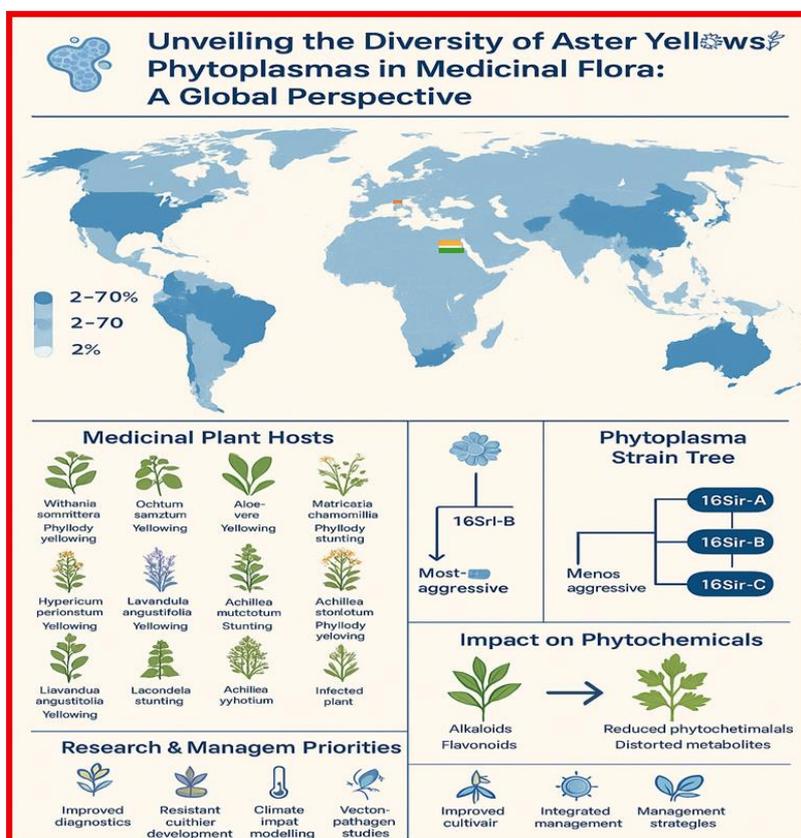
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ABSTRACT

The 16SrI group, particularly the Aster yellows Phytoplasmas, emerges as the most pervasive and genetically diverse lineage among phytoplasmas, inflicting significant Phyto-pathological damage on medicinally relevant flora. Its presence across 17 nations and pathogenicity reported in 28 medicinal species—predominantly in India—the group’s widespread dissemination and high disease incidence (ranging from 2% to 70%) underscore its global threat. The 16SrI-B subgroup, as the most polymorphic and aggressive strain, facilitates expansive host-range infections. This review synthesizes critical data on geographical prevalence, host symptomatology, and disruption of phytochemical profiles, emphasizing the destabilizing effect of 16SrI infections on pharmacologically valuable secondary metabolites and the urgent need for targeted phytoplasma management in medicinal plant systems.

KEYWORDS: Medicinal plants, Phytoplasma, Aster yellows, Disease incidence.



INTRODUCTION

Medicinal plants, prized for their *therapeutic* properties, are under constant threat from a myriad of microorganisms, compromising their quality, quantity, and even pushing some species towards extinction. Among these microbial assailants, phytoplasma has emerged as a significant pathogen. Phytoplasmas, enigmatic and elusive, are phloem-dwelling, cell wall-lacking, non-culturable prokaryotes belonging to the class Mollicutes (Bertaccini and Lee, 2018). Thriving within both plant phloem tissues and insect haemolymph, phytoplasmas manifest diverse symptoms across different plant hosts, with new manifestations continuously emerging in infected plants.

In the intricate dance of nature, insect vectors serve as conduits for the transmission of phytoplasmas. Currently, over 700 plant species, including fruits, ornamental plants, trees, and economically significant plants, stand associated with phytoplasmas globally (Bertaccini *et al.*, 2014; Marcone, 2014; Rashid *et al.*, 2018; Rao, 2021). The transmission dynamics are intricately linked to vector ecology, influenced by environmental factors such as temperature, humidity, and the availability of host plants. Among these vectors, leafhoppers and psyllids play pivotal roles, swiftly acquiring and disseminating the phytoplasma during feeding activities.

The advent of molecular tools since the early 1990s has revolutionized phytoplasma research, enabling significant strides in diagnostics and classification. The characterization of phytoplasmas has evolved to encompass 33 groups and approximately 100 sub-groups, reflecting their astonishing genomic diversity (Davis *et al.*, 2015; Zhao and Davis, 2016; Liu *et al.*, 2017). Remarkably, more than 200 medicinal plant species worldwide have been implicated in phytoplasma infections, underscoring the breadth of its impact (Rao *et al.*, 2018).

Based on sequences retrieved from Gene Bank, fourteen distinct phytoplasma groups have been identified on medicinal plants globally (Raj *et al.*, 2008a, 2009; Rao *et al.*, 2010; Chaube *et al.*, 2014; Sarwade *et al.*, 2015; Jung *et al.*, 2012; Marcone *et al.*, 2016; Shukla, 2015; Aldaghi and Bertaccini, 2015; Yang *et al.*, 2016; Alves *et al.*, 2017; Rasoulpour *et al.*, 2017; Rao *et al.*, 2017). In this review, we aim to provide an up-to-date overview of the diversity of 'Ca. *P. asteris*' associated with medicinal plants worldwide. Such insights are invaluable for phytoplasma researchers, aiding in the development of

targeted strategies to combat this pervasive pathogen and safeguard medicinal plant biodiversity.

CLASSIFICATION, AND GENOMIC CHARACTERISTICS

Before 1992, phytoplasmas were referred to as MLOs; subsequently, they were classified within the 'Ca. *Phytoplasma*' genus (Doi *et al.*, 1967; IRPCM., 2004). The advent of DNA sequencing, particularly the analysis of 16S rRNA gene sequences, has significantly advanced taxonomy and diversity studies (Drancourt *et al.*, 2000; Stackebrandt & Goebel, 1994; Stephen *et al.*, 1996; Wei & Zhao, 2022). Revisions in the threshold for 16S rRNA gene sequence identity have occurred twice, necessitating supplementary approaches such as MLSA (Wei & Zhao, 2022). Genome-wide ANI has emerged as a crucial tool for assessing species boundaries (Wei & Zhao, 2022). Presently, two classification systems are utilized, with recent guidelines refining the classification criteria (Bertaccini *et al.*, 2022). Phytoplasma classification involves phylogenetic analysis and RFLP analysis, with iPhyClassifier playing a role in swift phytoplasma identification (Davis *et al.*, 2016; Lee *et al.*, 2002; Pérez-López *et al.*, 2018; Rodrigues Jardim *et al.*, 2021; Zhao *et al.*, 2009). Some 'Ca. *Phytoplasma*' species exhibit considerable sequence identity, and species within the same group often belong to diverse subgroups (Wei & Zhao, 2022). The provisional classification of phytoplasmas serves the purpose of disease control and the exploration of their biological significance (Wei & Zhao, 2022). For example, despite specific differences, species within the 16SrXII group are collectively recognized for causing stolbur in plants (Wei & Zhao, 2022).

Research involving genetic analysis of 46 'Candidatus *Phytoplasma*' species, including the AYp subclade (also referred to as the 16SrI phytoplasma group, represented by 'Candidatus *Phytoplasma asteris*'), has been conducted (Lee *et al.*, 2004; Hogenhout *et al.*, 2008; Yang *et al.*, 2017). Subsequent examination of the 16S ribosomal RNA region has revealed the existence of multiple subgroups within the AYp subclade, their classification primarily relying on polymorphic differences within this highly conserved region (Lee *et al.*, 2004). The distribution of these AYp subgroups exhibits notable variability across different geographic regions. Lee *et al.* (2004) documented the isolation of 15 distinct AYp subgroups 16SrI-A, 16SrI-B, 16SrI-E, 16SrI-K, 16SrI-O, 16SrI-P, and 16SrI-R in the contiguous United States, with members of these subclades being classified under 'Ca. *Phytoplasma asteris*'

Table 1: List of 16Sr groups/subgroups corresponding to named Candidatus *Phytoplasma* species.

Group	'Ca. <i>Phytoplasma</i> ' Species	Accession Number of Reference Strain	Subgroup	Reference
16SrI: Aster yellows group	Ca. <i>Phytoplasma lycopersici</i> '	EF199549	16SrI-Y	Arocha <i>et al</i> 2007
	Ca. <i>Phytoplasma asteris</i> '	M30790	16SI-B	Lee <i>et al</i> 2014
	Ca. <i>Phytoplasma tritici</i> '	NZ AVA001000003	16SrI-C	Zhao <i>et al</i> 2021

Geographical distribution of medicinal plants affected by 16SrI group phytoplasma



Fig. 1: Geographical distribution of Medicinal plants (16SrI group) phytoplasma diseases in world.

Geographical distribution of medicinal plants affected by 16SrI group phytoplasma diseases spans across continents, with prevalence notably observed in Asia, the Americas, and Africa. Reports of phytoplasma (16SrI group) diseases in medicinal plants have surfaced from various regions worldwide, including India (Kumar et al., 2012a; 2012c, Tiwari et al., 2017; Raj et al., 2011, 2006a, 2006b, 2008a, 2008b, Mitra et al., 2019, 2020, M. Chaithra et al., 2015, Rao et al., 2020, 2018a, 2017, Chaturvedi et al., 2010, Tripathi et al., 2020, 2016, Debnath et al., 2020, Bhat et al., 2006, Chaube et al., 2014, 2015, Panda et al., 2019, Khan et al., 2004, Nabi et al., 2015, Maurya et al., 2014), China (Shao-shuai yu et al., 2021a, 2021b), Egypt (Mokbel et al., 2020; Omar, 2008), Iran (Souza et al. 2015), Turkey (Gazel et al., 2015), Italy (Bellardi et al., 2016, 2007, 2009, Camele et al., 1999, Salvatore et al., 1998, Paltrinieri et al., 2018, Contaldo et al., 2012), Canada (Khadhair et al., 2008), California (Marcone et al., 2000), Brazil (Eckstein et al., 2013), Europe (Marcon et al., 2000, Valiunas et al., 2016, Satta et al., 2020), U.S.A. (Lee et al., 1998), Cuba (Acosta et al., 2015, Arocha et al., 2006), Australia (Marcone et al., 2016), Czech Republic (Fránová and Šimková, 2009), America (Ganem et al., 2019, D. Mollov et al., 2014), Saudi Arabia (Alhudaib et al., 2008), Thailand (Spodee et al., 1999, Marcone et al., 2016), and Myanmar (Win et al., 2014). The pervasive presence of 16SrI group phytoplasma infections in numerous medicinally important plants underscores its dominance and global impact. The wide-ranging prevalence of aster yellows group infections across diverse climatic conditions in various countries and continents underscores its vigor and significance. This article elucidates the infection of 16SrI group phytoplasma in medicinal plants worldwide, with disease incidences ranging from 2% to 70%. Among the various medicinal plants mentioned in this review, the diverse

geographical distribution of Aster yellows group infections and their profound impact on medicinal plants emerge as alarming issues warranting serious attention.

Medicinal plants encompass a broad spectrum of wild and cultivated species that serve as vital sources of raw materials for nutraceuticals, perfumes, medicines, Flavors, and cosmetics. These plants harbour numerous bioactive phytochemical compounds renowned for their potential to enhance human and animal health. However, the escalating demand for medicinal plants and their derivatives is met with challenges posed by disease incidences, which detrimentally affect their quality, quantity, and overall productivity. Several diseases affecting medicinal plants are linked to phytoplasmas, causing substantial losses in terms of productivity, phytochemical content, and plant longevity. "Candidatus *Phytoplasma asteris*" stands out as a significant pathogen, causing diseases in several medicinal plants and resulting in severe economic repercussions. This article provides detailed descriptions of medicinal plants associated with phytoplasma (16SrI group) infections (Table 1).

HOST RANGE AND SUSCEPTIBILITY

Acalypha indica (L.), belonging to the Euphorbiaceae family, boasts diverse medicinal properties such as anti-helminthic, anticancerous, antivenom, antifungal, and neuro-protective activity. Notable for its efficacy in treating snake-bite, scabies, pyorrhoea, mental disorders, eczema, and malarial fever (Chekuri et al., 2016). In Uttar Pradesh, chlorosis, witches' broom, and stunted growth were observed in infected *Acalypha indica*, further confirmed through PCR assays associating with 'Ca. *P. asteris*', members (16SrI group) (Tiwari et al., 2017).

Cannabis sativa (L.), a member of the Cannabinaceae family, is a widely grown medicinal plant known for its narcotic resin, edible oil, and fiber. Renowned for treating neuralgia, migraine, and alcohol addiction, it possesses properties like antidepressant, topical anesthetic, and anti-asthmatic (Raj et al., 2008b; Mall et al., 2009; Maurya et al., 2017). Yellowing, witches' broom, and shortened internodes were observed in *C. sativa* plants in India, with PCR assays confirming phytoplasma association from the 16SrRNA BLAST sequence analysis (Raj et al., 2008b; Mall et al., 2009; Maurya et al., 2017).

Catharanthus roseus (L.), of the Apocynaceae family, serves as a model plant for divergent phytoplasma culture maintenance. Traditional uses include relieving muscle pain, depression, childhood leukemia, and cancer (Musetti et al., 2000, 2002; Lepka et al., 1999; Favali et al., 2008; Chaturvedi et al., 2009; Kumar and Baydgi, 2012b; Maurya et al., 2018). Phytoplasma detection worldwide includes Italian periwinkle witches'-broom and *Catharanthus* virescence from Asia, with symptoms ranging from phyllody to virescence (Marcone et al., 2000; Omar et al., 2008).

Centaurium erythraea (L.), an herbaceous medicinal plant of the Gentianaceae family, reported phyllody in Italy and is used for treating snakebite, fever, and gastrointestinal diseases. PCR assay the phytoplasma was identified as 16SrI group agent '*Ca. P. asteris*', subgroup 16SrI-B (Paltrinieri et al. 2018).

Digitalis lanata (Ehrh.), known as woolly foxglove, is prized for its cardiac glycosides used in heart disease treatment. Infected plants exhibit symptoms like stunting, witches' broom, and virescence, with lanatoside C being severely affected by the phytoplasma (Pellati et al., 2009).

Dodonaea viscosa (L.) Jacq, a flowering plant of the Sapindaceae family, displays symptoms of phytoplasma infection including leaf yellowing and severe malformation, with grafting experiments affecting the content of natural compounds (Mokbel et al., 2020).

Echinacea purpurea (L.) a member of the Asteraceae family, showcases anti-tumor and immune stimulator properties. Phytoplasma disease in Slovenia led to symptoms like plant yellowing, floral malformations, and phyllody (Radisek et al., 2008).

Grindelia robusta (Nutt). *Grindelia robusta*, or gum plant, from the Asteraceae family, exhibits perennial sedative and expectorant action. In Northern Italy, virescence and phyllody were observed in infected plants (Bertaccini et al., 2008).

Hyssopus officinalis (L.), a herbaceous perennial of the Lamiaceae family, displays phytoplasma-related

symptoms including yellowing and stunting in central Italy (Salvatore et al., 1998).

Medicago sativa (L.), an important diuretic and tonic herb, records alfalfa witches' broom disease in various countries associated with 16SrI group phytoplasmas (Marcone et al., 2016).

Melia azedarach (L.), commonly known as Chinaberry, exhibits anti-inflammatory, antioxidative, analgesic, and antidiabetic properties. Phytoplasma-infected trees show symptoms like phyllody and floral virescence in India. This was the first report of '*Candidatus Phytoplasma asteris*' (16SrI-B) affecting *M. azedarach* in India (Tripathi et al 2020). (Tripathi et al., 2020).

Momordica charantia (L.), or bitter melon, shows phyllody symptoms caused by 16SrI group phytoplasmas reported in Thailand and Myanmar (Spodee et al., 1999; Win et al., 2014).

Ocimum canum Sim, used for treating fever, colds, and parasitic infestations, exhibits little leaf and shoot proliferation symptoms in India associated with 16SrI-B subgroup phytoplasmas (Rao et al., 2017).

Ocimum basilicum (L.), known for its antibacterial properties, displays little leaf disease symptoms in Cuba associated with 16SrI group phytoplasmas (Arocha et al., 2006).

Pericampylus glaucus (Lam). exhibits symptoms like witches' broom and leaf chlorosis, with the phytoplasma strain associated with 16SrI-B subgroup (Shao-Shuai Yu et al., 2021a).

Piper nigrum (L.) or black pepper, is prized for its antimicrobial and analgesic properties. Phytoplasma infection in India causes phyllody symptoms (Bhat et al., 2006).

Plantago spp., with anti-inflammatory and antibacterial effects, exhibit symptoms like narrow and chlorotic leaves associated with 16SrI-B subgroup phytoplasmas (Fránová and Šimková, 2009; Marcone, 2011; Mori et al., 2015).

Plumbago auriculata (Lam), known for its medicinal uses, displays leaf yellowing symptoms in India, with phytoplasmas belonging to 16SrI-B subgroup (Panda et al., 2019).

Rehmannia glutinosa (Gaertn.), commonly called Chinese foxglove, shows little leaf disease symptoms associated with 16SrI-B subgroup phytoplasmas in Europe (Příbylová et al., 2013).

Sambucus nigra (L.), or elderberry, displays little leaf disease symptoms in Europe associated with 16SrI-B subgroup phytoplasmas (Příbylová et al., 2013).

These plants not only offer medicinal benefits but also serve as important indicators of phytoplasma diseases, contributing significantly to plant pathology research.

MOLECULAR AND SEROLOGICAL DIAGNOSTIC TECHNIQUES FOR ACCURATE DETECTION

Swift identification and diagnosis of phytoplasmas and phytoplasma diseases are essential for prompt control measures, averting disease spread, economic losses, and trade disruptions (Lee *et al.*, 2000). Infected plants exhibit varied symptoms like virescence, phyllody, cauliflower-like inflorescence, and witches'-broom, along with general signs such as leaf discoloration, stunting, little leaf, and stem fasciation, including asymptomatic cases (Marcone, 2014). As phytoplasmas resist *in vitro* culture, conventional methods for bacterial identification are ineffective, necessitating reliance on molecular diagnostics. Techniques like PCR, nested PCR, real-time PCR, ddPCR, LAMP, and CRISPR-based detection utilize conserved gene sequences such as 16S rRNA, *rp*, *SecY*, and *tuf* genes (Lee *et al.*, 2000). The prevalent procedure involves PCR amplification of phytoplasma DNA targeting the 16S rRNA gene, followed by sequencing and analysis with tools like iPhyClassifier to classify strains.

Although MLSA isn't yet applicable to non-culturable phytoplasmas due to limitations, it effectively discerns phytoplasma diversity and strains within groups like 16SrI. Notably, it revealed genetic variance in apple proliferation phytoplasmas and identified distinct lineages like azalea little leaf phytoplasmas based on specific genes (Marcone, 2014).

Accurate "Aster yellows" phytoplasma detection in medicinal plants relies on advanced molecular and serological methods. PCR and LAMP assays targeting phytoplasma-specific genes offer high sensitivity, with

qPCR allowing quantitative assessment. Serological techniques like ELISA and IFA enable large-scale screening, as demonstrated in sesame phyllody disease experiments. Multiplex qPCR assays combining phytoplasma and plant gene detection enhance specificity and speed, complementing immunological assays' simplicity and high throughput (Marcone, 2014).

Integrating molecular and serological approaches ensures precise surveillance and management of "Aster yellows" infection, vital for timely control and preserving medicinal plant health and productivity (Lee *et al.*, 2000).

IMPLEMENTING EFFECTIVE MANAGEMENT STRATEGIES AGAINST "ASTER YELLOWS" PHYTOPLASMA

Cultural practices, including proper sanitation, crop rotation, and field hygiene, play pivotal roles in mitigating the spread of phytoplasma diseases (Hodgetts *et al.*, 2020). Removal and destruction of infected plant materials, weed hosts, and insect vectors are essential to prevent disease dissemination. Crop rotation with non-host plants can break the disease cycle and reduce inoculum buildup in soil and plant residues, thereby minimizing disease incidence.

Integrated pest management (IPM) strategies offer holistic approaches for sustainable disease control by integrating multiple tactics, including cultural, biological, chemical, and genetic methods (Hodgetts *et al.*, 2020). Biological control agents such as predators, parasitoids, and entomopathogenic fungi can help suppress insect vectors, thereby reducing phytoplasma transmission. Additionally, targeted pesticide applications, based on monitoring and threshold levels, can be integrated with cultural practices to manage vector populations effectively. Along with this breeding of resistant varieties also is required (Fig 2).

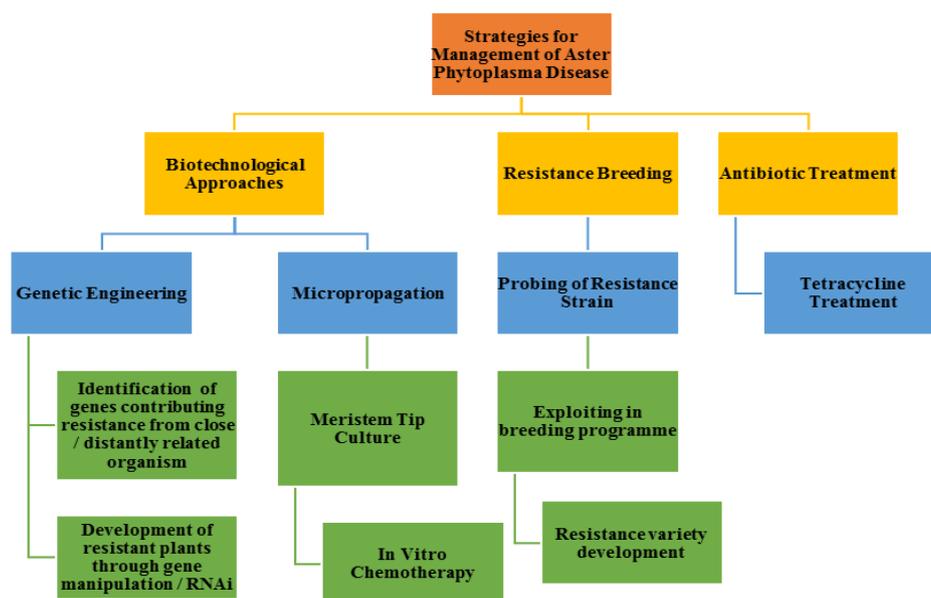


Fig. 2: Possible recent strategies available for the management of phytoplasma diseases.

CONCLUSION

This review critically examines the complex interplay between phytoplasma infections and medicinal plant health, with a strategic focus on the widespread impact of aster yellows group (16SrI) phytoplasmas. It highlights the alarming rise in infections, driven by host-vector dynamics and low host specificity, where diverse phytoplasma strains affect a wide array of plant species. The unpredictable emergence of infections in new crops and geographies underscores the accelerating threat of vector-mediated transmission. Safeguarding medicinal plant biodiversity necessitates immediate advancements in diagnostic precision, vector ecology, climate-disease modelling, and the breeding of resistant cultivars. With phytoplasmas compromising both the therapeutic and ecological value of medicinal flora, proactive, research-driven disease management is imperative to preserve these critical natural resources amid shifting environmental and epidemiological landscapes.

Table 1: Medicinal Plants and Associated Phytoplasma.						
S.No	Medicinal Plants	Host Symptoms	Geographical location	Phytoplasma Group/ Accession no.	Disease Incidence/Yield Loss	Reference
1	<i>Aclypha indica</i> (Euphorbiaceae)	Little leaf	India	16SrI-B KX139546	-	Tiwari <i>et al.</i> (2017)
2	<i>Cannabis Sativa</i> (Canabinaceae)	Witches' broom, little leaf, yellowing	India	16SrIEU439257 16SrI KX894735	-	Raj <i>et al.</i> (2008b) Maurya <i>et al.</i> (2017)
3	<i>Catharanthus roseus</i> (Apocynaceae)	Witches' broom, Shortened internodes, Virescence, little leaf, Witches' broom,	Europe Egypt India	16SrI 16SrI 16SrI KX894734	- - -	Marcone <i>et al.</i> (2000) Omar <i>et al.</i> (2008) Maurya <i>et al.</i> (2018)
4	<i>Centaurium erythraea</i> (Gentianaceae)	Virescence and phyllody	Italy	16SrI-B	-	Paltrinieri <i>et al.</i> (2018)
5	<i>Digitalis lanata</i> (Plantaginaceae)	Witches' broom, virescence	Italy	16SrI-B	-	Bellardi <i>et al.</i> (2007)
6	<i>Dodonaea viscosa</i> (Sapindaceae)	Leaf, yellowing, severe malformation,	Egypt	16SrI MT940834	-	Mokbel <i>et al.</i> (2020)
7	<i>Echinacea pupurea</i> (Asteraceae)	Leaf, yellowing, virescence & phyllody	-	16SrI-C EU416172	5-30%	Radisek <i>et al.</i> (2008)
8	<i>Grindelia robusta</i> (Asteraceae)	Virescence & phyllody	Italy	16SrI-B	-	Bellardi <i>et al.</i> (2009)
9	<i>Hyssopus officinalis</i> (Lamiaceae)	Yellowing and stunting	Italy	16SrI	-	Salvatore <i>et al.</i> (1998)
10	<i>Medicago sativa</i> (Fabaceae)	Witches' broom	America and Australia	16SrI	-	Marcone <i>et al.</i> (2016)
11	<i>Melia azedarach</i> (Meliaceae)	Phyllody & Virescent flowers	India	16SrI-B MN830223	-	Tripathi <i>et al.</i> (2020)
12	<i>Momordica charantia</i> (Cucurbitaceae)	Phyllody	Thailand & Myanmar	16SrI AB741631	-	Spoodee <i>et al.</i> (1999) Win <i>et al.</i> (2014)
13	<i>Ocimum canum</i> (Lamiaceae)	Shoot proliferation & little leaf	India	16SrI-B KX073966	5%	Rao <i>et al.</i> (2017)
14	<i>Ocimum basilicum</i> (Lamiaceae)	Little leaf disease	Cuba	16SrI DQ286577	5%	Arocha <i>et al.</i> (2006)
15	<i>Pericampylus glaucus</i> (Menispermaceae)	Witches' broom, leaf chlorosis, & leaflet	China	16SrI-B	-	Shao-shuai Yu <i>et al.</i> (2021a)
16	<i>Piper nigrum</i> (Piperaceae)	Phyllody	India	16SrI AY823413	-	Bhat <i>et al.</i> (2006)
17	<i>Plantago spp.</i> (Plantaginaceae)	Chlorotic leaves Necrosis, reduced growth and Floral abnormalities.	Czech Republic Italy	16SrI-B 16SrI-A	8-35%	Fránová & Šimková (2009) Marcone (2011)

		Yellowing				Mori <i>et al.</i> (2015)
18	<i>Plumbago auriculata</i> (<i>Plumbaginaceae</i>)	Leaf yellowing	India	16SrI-B	8-10%	Panda <i>et al.</i> (2019)
19	<i>Rehmania glutinosa</i> (Orobanchaceais)	Proliferating shoots	Europe	16SrI-B	-	Pribylova <i>et al.</i> (2001)
20	<i>Rosmarinus officinalis</i> (Lamiaceae)	Yellowing and witches' broom	Italy	16SrI-B	-	Contaldo <i>et al.</i> (2012)
21	<i>Salvadora persica</i> (<i>Salvadoraceae</i>)	Witches' broom, little leaf & leaf curling	India	16SrI-B	-	Kumar <i>et al.</i> (2012c)
22	<i>Santalum album</i> (Santalaceae)	Witches' broom, & small narrow leaves	India	16SrI-B DQ0932357	-	Khan <i>et al.</i> (2004)
23	<i>Sclerocarpus africanus</i> Jacq (<i>Asteraceae</i>)	Little leaf	India	16SrI-B KJ561783	-	Nabi <i>et al.</i> (2015)
24	<i>Thymus vulgaris</i> (Lamiaceae)	Proliferation of axillary shoots	Italy	16SrI group	20%	Bellardi <i>et al.</i> 2016)
25	<i>Vaccinium corymbosum</i> (Ericaceae)	Witches' broom	USA	16SrI-E	-	Lee <i>et al.</i> (1998)
26	<i>Valerian Officinalis</i> (Caprifoliaceae)	Typical aster yellows	Canada	16SrI-A	-	Khadhair <i>et al.</i> (2008)
27	<i>Waltheria indica</i> (<i>Malvaceae</i>)	Floral virescence, leaf chlorosis & leaflet	China	16SrI-B MW353909	70%	Shao-shuai yu <i>et al.</i> (2021b)
28	<i>Withania somnifera</i> (<i>Solanaceae</i>)	Little leaf, and witches' broom disease, Excessive branching	India	16SrI	70%	Khan <i>et al.</i> (2006b) Samad <i>et al.</i> (2006).

AUTHOR CONTRIBUTION

Dr Renu Maurya Assistant Professor has drafted the entire Paper, Prof Kalawati Shukla a senior and famed Virologist, Former Head of Department of Botany, D.D.U Gorakhpur University has edited the paper, the corresponding Author, Dr Tulika Mishra, Assistant Professor in Department of Botany, D.D.U Gorakhpur University has helped in scripting, assimilation of data and writing the paper.

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