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Review Article

Weeds and ruderal plants as potential sources of inoculum for vegetable diseases in northern Sinaloa

Rubén Félix-Gastélum*, [1]Universidad Autónoma de Occidente, Unidad Regional Los Mochis, Departamento de Ciencias Naturales y Exactas, Bulevard Macario Gaxiola y Carretera Internacional s/n, CP 81223. Los Mochis, Sinaloa; **Gabriel Herrera- Rodríguez**, Junta Local de Sanidad Vegetal del Valle del Fuerte. Lázaro Cárdenas, PTE. 315, Colonia Centro, Los Mochis Sinaloa, CP. 81200, México**;** [1]**Karla Yeriana Leyva-Madrigal,** [1]**Guadalupe Arlene Mora-Romero**.

***Corresponding Author**:
Rubén Félix-Gastélum
ruben.felix@uadeo.mx

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ABSTRACT

Weeds and ruderal plants of the families Cucurbitaceae and Solanaceae are addressed as potential sources of inoculum for the development of viral diseases such as *Tomato apex necrosis virus* (ToANV), zucchini (*Zucchini yellow mosaic virus* (ZYMV), *Watermelon mosaic virus* (WMV)*, Papaya ring spot virus* (PRSV-W) and *Cucumber mosaic virus* (CMV). Reference is made to weeds and ruderal plants as potential sources of inoculum, including wild sunflower for powdery mildew (*Golovinomyces spadiceus*), wild tobacco for foliar blight (*Alternaria* spp.), black nightshade for leaf spot (*Curvularia moehlemvekiae*)*,* Johnson grass for foliar blight (*Alternaria* sp.), and wild castor bean for foliar blight (*Alternaria ricini*) and wild melon for downy mildew (*Pseudoperonospora cubensis*). Future lines of multidisciplinary research focusing on the determination of pathogenicity in cultivated plants of viruses and fungi associated with wild plants and vice versa are proposed; the spatial-temporal distribution of wild plants that may serve as sources of inoculum, as well as the of potential insect vectors of viral diseases, should also be studied. The implementation of modern molecular techniques, such as High Throughput Sequencing, for the detection of phytopathogens is important. All this will contribute to the implementation of environmentally friendly strategies for disease control in agricultural crops in Sinaloa, for the benefit of the vegetable growers.

Keywords: inoculum, vectors, managements of diseases.

Introduction

In Sinaloa, a wide range of vegetables are grown, of which Solanaceous and Cucurbitaceous crops stand out. The first group includes the potato (*Solanum tuberosum*), tomato (*Solanum lycopersicum*), pepper (*Capsicum annum*) and husk tomatoes (*Physalis philadelphica*), which, in the fall-winter season of 2022, covered a surface of 11,975.1; 11,541.2; 15,172.4 and 7,317.9 ha, respectively. Meanwhile, cucurbitaceous crops are represented by different types of pumpkin and cucumber that cover a surface of de 2,686.2 and 3,874.9 ha in the same growing season. The annual value of the production of solanaceous crops reached 13,618,770,410 pesos, while cucurbitaceous crops reached 2,511,114,370 pesos (SIAP, 2022).

From an agronomic point of view, weeds are considered a significant threat to agricultural production, since they compete for nutrients, space, water and light with cultivated plants (Zimdahl, 1980; Dille *et al*., 2016). On the other hand, although ruderal plants do not compete with the growth of crops, they become undesirable, since they grow along roadsides and in vacant lots in towns and cities, as well alongside railways and in the embankments of drains and channels, limiting the flow of water during heavy rainfalls, causing the accumulation of sediments, which leads to floodings. In addition, both plant types can be sources of inoculum for the development of diseases in economically important crops. These types of plants can act as hosts for plant pathogens and vector insects that spread diseases from these to economically important crops. The symptoms caused by diverse diseases are more evident in cultivated plants than in wild ones, due to several factors: a) The greater genetic diversity in wild plants than in cultivated plants, b) heterogeneity of the wild populations and the limited contact between plants of the same species, c) natural selection in time, which leads to a species becoming resistant or tolerant to a certain pathogen, and d) the natural elimination of wild plants susceptible to highly virulent pathogens (Wisler and Norris, 2000). There are many records of cases in which wild plants are involved as sources of inoculants of diseases caused by viruses (Duffus, 1971; Yazdkhastia *et al*., 2021; Korbecka-Glinka, 2021) and fungi (SAGARPA-SENASICA, 2016; Gerling *et al*., 2022).

This study addresses of viral and fungal diseases that have been found in weeds and ruderal plants and which display a potential for spreading to horticultural crops in northern Sinaloa.

Viral diseases. In the complexity of the epidemiology of viral agents, wild and cultivated plants, as sources of inoculum for the development of diseases (Table 1), as well as the insect population and its motility, are important elements for the incidence of this type of diseases. Weeds and ruderals can be infected by viruses introduced to an area of cultivated plants, and then serve as a permanent source of

Table 1. Viruses causing diseases in cucurbits and tomato in Sinaloa and other parts of the world.

Virus	Genus	Vector	Mode of transmision	Presente in Sinaloa	Reference
Watermelon mosaic virus (WMV)	*Potyvirus*	*Aphis gossypi, Aphis craccivora*	Non persistent	Yes	Zitter *et al*., 1996
Papaya ringspot virus (PRSV)	*Potyvirus*	*Mysus pérsicae, macrosifum euphorbiae*	Non persistent	Yes	Zitter *et al*., 1996
Zucchini yellow mosaic virus (ZYMV)	*Potyvirus*	*Aphis gossypi, Aphis craccivora*	Non persistent	Yes	Zitter *et al*., 1996
Cuccumber mosaic virus (CMV)	*Cucumovirus*	*Mysus pérsicae, macrosifum euphorbiae*	Non persistent	Yes	Zitter *et al*., 1996
Squash mosaic virus (SqMV)	*Comovirus*	*Acalyma, Erivittata, Diabrotica, Undecimpunctata, Henosepilachna, Vigintioctopunctata.*	Vector transmission occurs for 20 days after adquisición	Not	Tolín e*t al*., 2016
Tomato severe rugose virus (ToSRV)	*Begomovirus*	*Bemisia tabaci*	Circulative	Not	Zitter *et al.,* 1996.
Chino del tomate virus (CdTV)	*Begomovirus*	*Bemisia tabaci*	Circulative	Yes	Brown, 1988
Sinaloa tomato leaf curl virus (ToMoV)	*Begomovirus*	*Bemisia tabaci*	Circulative	Yes	Idris y Brown, 1998
Tomato yellow leaf curl virus (TYLCV)	*Begomovirus*	*Bemisia tabaci*	Circulative	Yes	Ascencio-Ibañez *et al*., 1999.
Tomato marchitez virus (ToMarV)	*Torradovirus*	*Bemisia tabaci*	Semi-persistent	Yes	Turina *et al*., 2007.
Tomato chlorosis virus (ToCV)	*Crinivirus*	*Trialeurodes abutilonea*/*Bemisia tabaco*/*T. vaporariorum*	Semi-persistent	Yes	Alvarez-Ruiz *et al*., 2007.

inoculum for other cultivated plants (Broadbent, 1964). Although this aspect remains unexplored in Sinaloa, the possibility that many of the viruses that currently cause diseases in vegetable crops entered via seeds or other ways to spread diseases is not discarded, as well as the viruses being transmitted from cultivated plants to wild plants, where insect vectors play a crucial role in the development of epidemics.

Potential sources of viral diseases in tomatoes for processing. The viral diseases in processing tomatoes significantly limited the production in northern Sinaloa in the 1990s. Studies in which geostatistical tools were used indicated a high correlation between the presence of weeds and ruderals of the families Malvaceae, Sterculiaceae, Euophorbiaceae, Nyctaginaceae and Leguminaceae, with symptoms induced by geminivirus. Addditonally, species of the family Solanaceae displayed incidence of *Tobacco etch virus* (TEV), *Pepper mottle virus* (PepMoV), *Cucumber mosaic virus* (CMV) and *Tomato spotted wilt virus* (TSWV). The presence of symptomatic plants and populations of whiteflies, aphids and thrips was highly correlated with the incidence of these viruses in tomatoes for processing. Furthermore, Geographic Information Systems (GeoEAS; USEPA-LV.EAD, Las Vegas, NV), studies on the analysis of risk variables (Myers, 1991), as well as the application of the 5x5 km grid using the Kriging system for risk estimation (Isaaks MJ. 1989; Myers, 1991) helped on determining sectors of northern Sinaloa with incidences ranging between 0 and 2% and others with incidences between 25 and 100% of viral diseases in tomato. Based on this information, a management system was designed and validated for viral diseases in the crop, which consisted of the selection of the irrigation districts with the lower risk of incidence of this type of disease, and where the planting stage was considered, along with the elimination of weeds and ruderals in an area of 200 m adjacent to the vegetable plantations, in the districts that displayed a high risk of incidence of these diseases (Nelson *et al*., 1994). During the time of the development of this study, 7,000 ha of sugarcane (*Saccharum officinarum*) were planted in northern Sinaloa, which displayed large weed populations infected with the *Tobacco etch virus* (TEV), the *cucumber mosaic virus* (CMV) transmitted by aphids, *geminivirus* complex transmitted by whiteflies, the *Tomato spotted wilt virus* (TSWV) transmitted by thrips, and the *Tomato mosaic virus* (TMV) with an unknown vector. Meanwhile, the weeds were colonized by the insect vectors mentioned above, which transmitted them to tomato plantations for processing. Nowadays, sugarcane is not being planted in the area, and undoubtedly, the level of risk of incidence of viral diseases has decreased. However, in recent years, the *Tomato apex necrosis virus* (ToANV) (Barajas-Ortiz, 2013) and the *Zucchini yellow mosaic virus* (Félix-Gastelum *et al*., 2007) have emerged, which justifies regional studies, such as the one carried out in the 1990s and the subsequent implantation of this system for the management of viral diseases in vegetable plantations.

The *Tomato apex necrosis virus* in tomato and *tomatillo.* In the past 10 years, studies have been carried out on the detection of the *Tomato apex necrosis virus* (ToANV). The disease caused losses in 100% of tomato and husk tomatoes transplants in the El Fuerte and del Carrizo Valleys on 400 and 300 ha surfaces with both crops in the 2011-2012 and 2012-2013 cycles. The damages were observed mainly in the transplanting of susceptible hybrids established in September. Despite the small whitefly (*Bemisia tabaci*) populations, the populations of wild plants with viral symptoms were large due to summer rains, indicating a high efficiency of the whitefly as a vector. Symptoms in tomato consist on necrosis of young plant and fruit buds (Figures 1 A and B). In husk tomatoes, symptoms initially appear as a mosaic in leaves and in advanced stages of the disease, they become entirely yellow (Figure 1C), followed by the plant in general (Figure 1), with effects on the vigor

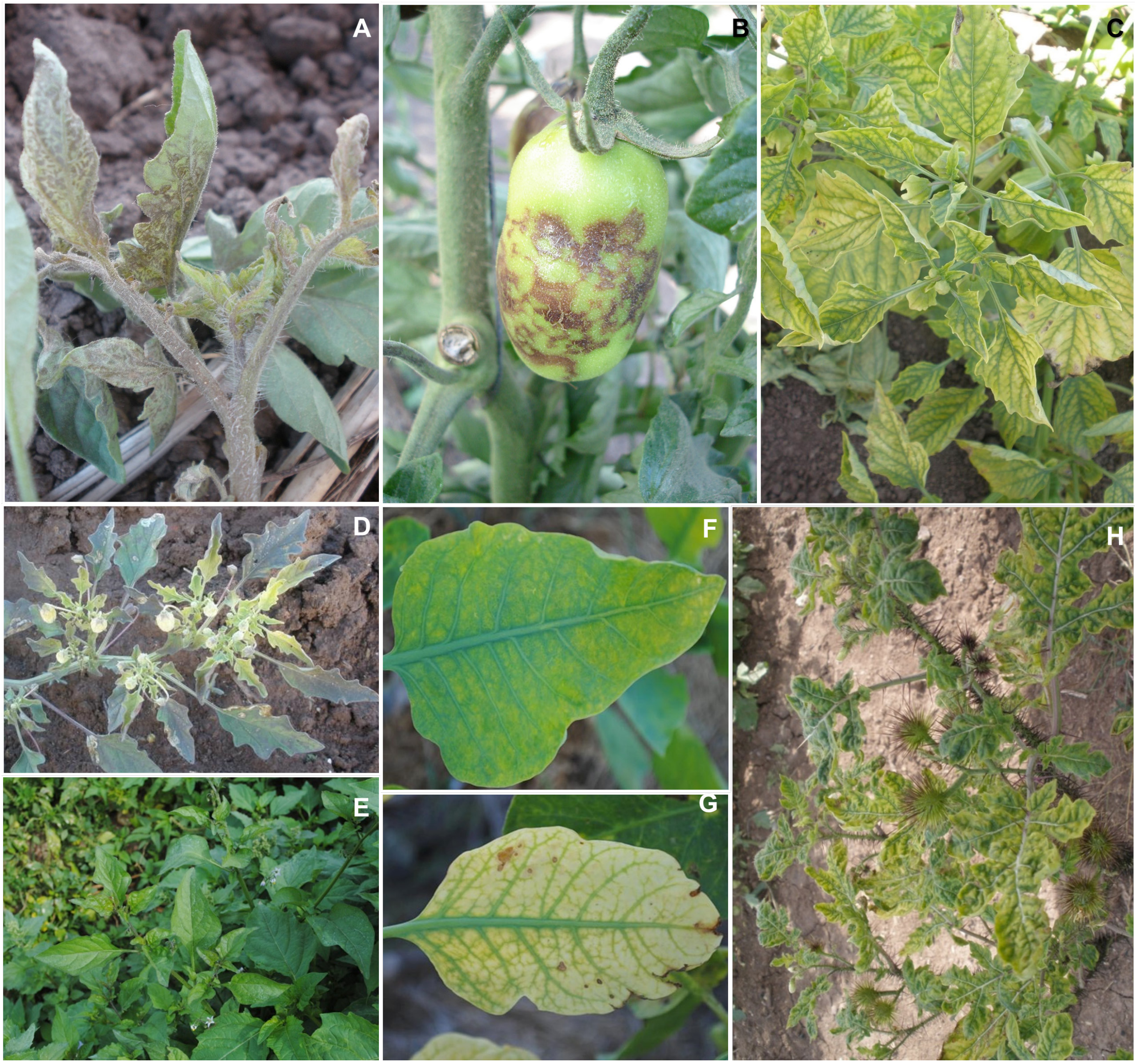

Figure 1. Symptoms induced by *Tomato apex necrosis virus* (ToANV). A) Necrosis in young growth of tomato; B) Necrosis in tomato fruit; C) interveinal chlorosis in leaves of husk tomato; D) Yellowing in wild husk tomato (*Physallis* sp.); E) Slight yellowing and deformation of initial leaves in black nightshade (*Solanum nigrum*); F) Initial symptoms of interveinal chlorosis; G) Intense chlorosis and vein greening of wild tobacco (*Nicotiana glauca*) leaves; H) General yellowing in black nightshade (*Solanum asureum*).

and limiting the production and quality of this vegetable, to the extent in which farmers destroy the crop in order to plant maize (*Zea mays*) or sorghum (*Sorghum bicolor*) (Espinoza-Castillo, 2013).

The ToANV has been detected in weeds and ruderals of the family Solanaceae using serological and RT-PCR tests, such as wild tomatillo (*Physalis* sp.) (Figure

1D), black nightshade (*Solanum nigrum*) (Figure 1E), jimsonweed (*Datura* sp.), wild tobacco (*Nicotiana glauca*) (Figures 1F and G) and nightshade (*Solanum asureum*) (Figure 1H). Additional tests indicated that whiteflies transmit the virus to tomatillo and tomato from wild plants (mentioned earlier) (Espinoza-Castillo, 2013). These findings coincide with previous results that indicate that the virus is transmitted by whiteflies (Barajas-Ortiz, 2013). These potential sources of inoculum are widely distributed in northern Sinaloa and frequently display viral symptoms, which coincides with large vector populations and husk tomatoes and tomato crops. The management of this disease has focused on the use of virus-tolerant tomato varieties and the management of whitefly using systemic insecticides in applied through pressurized irrigation systems and the elimination of plants as potential sources of inoculum, which is precisely followed up by the la Local Plant Health Board of the Valley del Fuerte.

Wild Cucurbitaceae as sources of inoculum for viral diseases in zucchini squash. Preliminary studies in the El Valle del Fuerte indicate that in zucchini, the infections that take place are caused by the Z*ucchini yellow mosaic virus* (ZYMV) (Figure 2A and B), the *Watermelon mosaic virus* (WMV), the *Papaya ring spot virus* (PRSV-W) and the *Cucumber mosaic virus* (CMV), both individually and as coinfections in commercial plots with this crop. Meanwhile, wild tobacco (*Nicotiana glauca*), wild cantaloupe (*Cucumis melo* var. *Dudaim*), bitter melon (*Momordica charantia*) and prickly cucumber (*Cucumis dipsaceus*) plants displayed the same viruses (Félix-Gastelum *et al*., 2007). Finding these viruses in weeds and ruderals indicates that these can act as sources of inoculum for the development of viral diseases in other cucurbitaceous crops planted in the region, which must be proven through inoculation tests under greenhouse conditions with insect species previously reported as vectors for this type of virus. Studies in Mexico indicate that *N. glauca* is a CMV reservoir, which coincides with studies in Greece, where the same ruderal is a source of inoculum for the same virus (Volvas and Di Franco, 2004).

Diseases caused by fungi. Fungal diseases in weeds and ruderals have received less attention than cultivated plants, since they cause economic losses in the latter, whereas wild plants frequently remain unnoticed in natural environments. Some plants act as alternate hosts, which is essential in the life cycles of diseases. In this regard, wheat rust stands out, caused by *Puccinia graminis* f. sp. *tritici*, which infects the alternate host (*Berberis vulgaris*) with basidiospores and genetic exchange takes place, to form aecia and aeciospores that infect the wheat plant once again. This allows the biological cycle to repeat itself (Leonard and Szabo, 2005). It is also known that in Germany, on the edges of “kettle holes,” different species

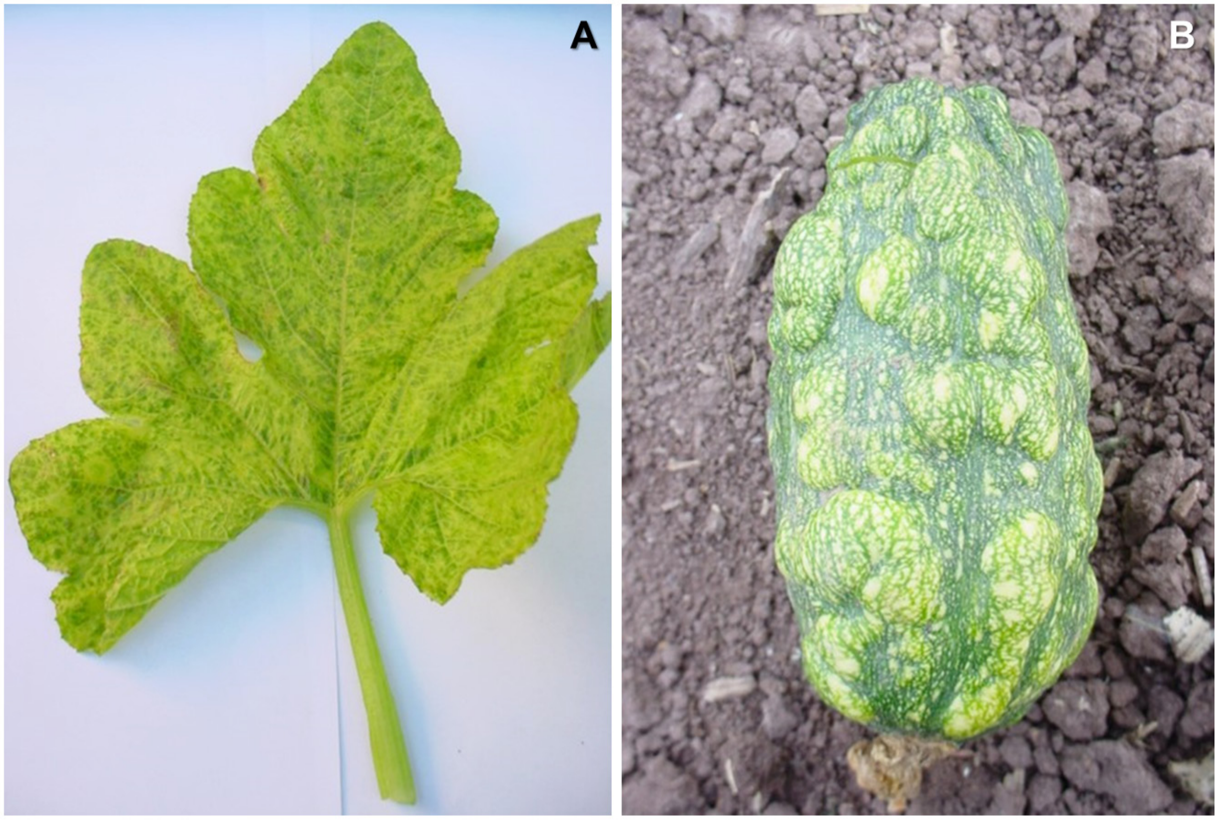

Figure 2. Symptoms induced by the virus Z*ucchini yellows mosaic virus* (ZYMV). A) Yellowing in Zucchini squash var. Grey leaf; B) Symptoms of deformation of the fruit of the same host caused by the same virus.

of Poaceae and herbaceous plants grow, which are infected by up to 12 species of *Fusarium* in the autumn-winter, and which have the potential to cause diseases in agricultural crops (Gerling *et al*., 2022). Similarly, *Phomopsis* sp., *Phomopsis longicolla* and *Diaporthe phaseolorum,* isolated from the weeds *Eclipta postrata*, *Ipomea lacunosa* and *Desmenthus illinoensi*s caused diseases in hypocotyls, pods and seeds in soybean plants (*Glycine max*) (Mengistu *et al*., 2007). The following describes weeds and ruderals as potential sources of inoculum for the development of fungal leaf diseases in Sinaloa.

Powdery mildew (*Golovinomyces spadiceus*) on wild sunflower (*Helianthus annus*). Studies on the powdery mildew on wild sunflower (Figure 3D) indicated that *G. spadiceus* is the causal agent of the disease in Sinaloa and it caused the disease in commercial sunflower in artificial inoculations (Félix-Gastélum *et al*., 2019). This study is important, since wild sunflower can serve as a source of inoculum for the development of the disease in cultivated sunflower. It is important

Figure 3. Symptoms induced by fungus in weeds. A) Light to dark brown lesions and browning of the leaf sheath in Johnsongrass (*Sorghum halepense*) plants, caused by *Curvularia muehlenbeckiae*; B) Symptoms of powdery mildew caused by *Golovinomyces spadiceos* in a wild sunflower leaf (*Helianthus annus*); Irregular to circular brown spots, on a leaf of castor bean plant (*Ricinus comunis*) caused by *Alternaria* sp. Irregular to circular brown spots, on a leaf of castor bean plant (*Ricinus comunis*) caused by *Alternaria* sp.; F) Symptoms of downy mildew caused by *Pseudoperonospora cubensis* in wild melon (*Cucumis melo* var. Dudaim).

to emphasize that wild sunflower grows as a weed, competing with maize (*Zea mays*), bean (*Phaseolus vulgaris*) and other crops, as well as growing as a ruderal plant on the edges of roads, embankments and slopes of drains and canals in the winter and early spring, coinciding with the commercial sunflower cultivations in the region.

Foliar blight (*Alternaria* spp.) in wild tobacco (*Nicotiana glauca*). Wild tobacco is a perennial solanaceous plant that grows alongside of, embankments and slopes of irrigation channels and drains, as well as in vacant agricultural fields. This ruderal appears as light to dark brown lesions in irregular shapes on leaves (Figure 3B) during the autumn-winter cycle. The severity of the disease increases when the daily periods of wet foliage range from 15 to 18 h and temperatures fluctuate between 14 and 28 °C; under these conditions, defoliation of the basal third of plants occurs. Preliminary studies showed that an unidentified species of *Alternaria* (Simmons, 2007) is the causal agent of the disease (Apodaca-Orduño, 2016). In artificial inoculations, the fungus proved to be pathogenic in tomatoes, causing light to dark brown lesions with concentric rings (Figure 3C), similar to those of early blight caused by *A. solani* (Sánchez-Castro, 1998) y *A. tomatophila* (Jones *et al*., 2017). These results show that wild tobacco is a potential source of inoculum for the development of early blight in tomato, caused by a new species of *Alternaria* in Mexico and other parts of the world.

Leaf blight in coyote tobacco (*Nicotiana trigonophylla*) and black nightshade (*Solanum nigrum*). Coyote tobacco and black nightshade are annual plants that grow during the autumn and winter, mainly appear as weeds and rarely, as ruderals. In recent years, these plants displayed irregular, light to dark brown lesions measuring 3.0 to 5.0 mm. With the progress of the disease, the lesions acquire an irregular shape and can cover up to 50% of the infected leaf. When the lesions coalesce and cover up to a third of the leaf, defoliation begins, mainly on the basal leaves of the plants. Two species of *Alternaria* belonging to the section *Alternata* and *Curvularia muehlenbeckiae* (Guerra-Meza, 2021) were consistently isolated, yet their pathogenicity has been proven in them or in cultivated Solanaceae.

Leaf blight (*Alternaria* sp.) of Johnson grass (*Sorghum halepense*). Johnson grass is an annual Poaceae that is found as a weed and ruderal all year round in Sinaloa. In the autumn, winter and spring, the plants display light to dark brown interveinal lesions measuring 1.0 a 2.0 cm (Figure 3). The lesions increase their size until they cover 50% of the area of the leaf. Studies carried out in Sinaloa indicate that the disease is caused by *Curvularia muehlenbeckiae* (Olivas-Peraza *et al*., 2021). The fungus has also been reported to cause leaf spots on guar (*Cyamopsis* *tetragonoloba*) in Sinaloa (Tovar *et al*., 2022). Soybean is the only economically important host in which the fungus *C. muehlenbeckiae* causes leaf spots in Sinaloa; it has also been recorded that it causes leaf lesions in pecan trees (*Carya illinoinensis*) in China (Lv *et al*., 2023) and firs (*Cunninghamia lanceolata*) (Cui, 2020), also in Chin. In Sinaloa, the fungus has been found to be associated to leaf spot on coyote tobacco (*Nicotiana trigonophylla*) (Guerra-Meza, 2021). Although soybean leaf blight is caused by *C. muehlenbeckiae* in Sinaloa, whether Johnson grass, guar and coyote tobacco can act as potential sources of inoculum for the development of the disease is unknown. Hence the importance of cross-inoculating with isolates of the fungus from different plant species, which will contribute to the understanding of the ecology, epidemiology and management of the disease in economically important crops.

Leaf blight (*Alternaria* sp.) in castor bean (*Ricinus comunis*). The wild castor bean is considered an exotic invasive species that behaves as perennial when growing as ruderal in Sinaloa. Its leaves display irregular, light to dark brown spots measuring between 0.5 and 1.0 cm (Figure 3E); when the spots coalesce, they can cover up to 25% of the surface of the leaf, leading to defoliation, mainly in the leaves of the bottom third of the plants. Preliminary studies have proven that the leaf spot in the wild castor bean is caused by *Alternaria ricini*, and in artificial inoculations, also caused the disease in the commercial castor bean (Olivas-Peraza, 2018), which coincides with earlier reports of the disease implicating *A. ricini* as the causal agent of the disease in commercial castor bean in Mexico (López-Guillén *et al*., 2015) and in other parts of the world (Masirevic *et al*., 1993; Nagaraja and Krishnappa, 2016a; 2016b). In Sinaloa, symptoms of leaf blight in wild castor bean are found during the autumn-winter, when the periods of relative humidity ≥ 90% from 12 to 16 h a day and temperatures fluctuate between 8 and 28 °C, which coincides with the cycle of the castor bean. Pathogenicity tests indicate that the wild castor bean plant is a potential source of inoculum for the development of leaf blight caused by *A. riccini* in cultivated castor bean.

Mildew (*Pseudoperonospora cubensis*) in wild melon (*Cucumis melo* var. Dudaim). Cantaloupe grows as a weed, but also as a ruderal in northern Sinaloa. It occurs in high populations in vacant agricultural fields during the summer and the early autumn in Sinaloa. In the past six years, this plant has displayed symptoms and signs of mildew. The disease is polycyclic and the plants display pale green to yellow, non-delimited spots on the upper side (Figure 3F), and on the lower side, the signs consist of sporangiophores and sporangia with a hairy, brown or purple growth. The incidence of mildew in cantaloupe is 100% and it destroys up to 50% of the plant foliage. The first symptoms of the disease in wild cantaloupe appear in the last week in September and the first one in October, when the commercial cucurbits are still not transplanted in the region. The pathogenicity of *P. cubensis* from wild melon in cucurbits planted in Sinaloa has yet to be proven. However, studies in the United States indicate that *P. cubensis* survives the winter as an obligate biotroph in wild or cultivated cucurbits in Florida, whereas he pathogen does not survive the winter in the northeastern states of that country due to low temperatures in the winter. Thus, through wind dispersal and the presence of susceptible hosts in the dissemination path, the oomycete is spread from Florida to the northeastern states of the United States when the disease occurs during the spring and summer (Ojiambo and Holmes, 2011). In Sinaloa, greenhouse plantations for the production of cucurbit seedlings begin on the first week in October. The sporulation of *P. cubensis* in wild cantaloupe is abundant and the levels of humidity and the temperatures favor the development of the disease, both in wild cantaloupe and cultivated cucurbits. However, the survival mechanism of the pathogen during the summer, when temperatures reach up to 40 °C, is unknown.

Weeds and ruderals as potential sources of inoculum in vegetable diseases in vegetable gardens in Sinaloa. This study addresses viral and fungal diseases that have been found in weeds and ruderals, and which have the potential to appear on vegetable crops. The importance of weeds and ruderals, as well as the abundance and motility of insect vectors of viral diseases in tomatoes for processing was proven in Sinaloa. Through studies on the presence of potential sources of inoculum and populations of potential insect vector species, a viral disease management species a viral disease management system was designed for tomatoes for processing (Nelson *et al*., 1994).

FUTURE LINES OF RESEARCH

Studies on the role played by weeds and ruderals as potential sources of inoculant as potential sources of inoculum for the development of cultivated plants are incipient in Mexico (Nelson *et al*., 1994). This study shows the current status on the subject in Sinaloa. As a result of this work, new lines of research are proposed, concerning studies on the distribution in space and time of annual and perennial wild plants with the potential to be sources of inoculant for the development of viral diseases and fungal leaf diseases in cultivated plants.

In order to identify fungi associated to foliar diseases in wild plants, we resorted to morphometric studies, the use of RT-PCR and multigene phylogenetic studies, as well as pathogenicity tests, in some cases. In the case of viruses, mainly serological tests were used. Undoubtedly, although validation tests are required, the advent of molecular tools such as High-Throughput Sequencing (HTS) enables preliminary diagnostics in the early stages of the diagnosis for the presumptive identification of virus sequences in which RT-PCR or ELISA can be used to confirm the viral agent (Massart *et al*., 2017). HTS helps find all viruses, including new variants, as well as viroids (Al Rwahnih *et al*., 2015; Rott *et al*., 2017). This study marks only the beginning of future studies on potential sources of inoculum for the development of diseases in agricultural crops, where HTS would be a useful tool, as it would help find viruses in cultivated and wild plants, even in asymptomatic plants (Jacques-Davy and Gubba, 2020). However, the use of tools such as HTS and bioinformatics in the study of phytopathogenic viruses in Sinaloa and the rest of the country will require the development of projects that imply large investments. Nevertheless, this is the pathway towards the implementation of sustainable strategies for the management of diseases in agricultural crops. Alongside this, in addition to these innovative detection tools, botanists should be included to study the ecology of ruderals and weeds, as well as virologists, entomologists and epidemiologists. Besides identifying viruses and fungi associated with diseases in weeds, it is also important to show their pathogenicity in cultivated plants and vice versa. A similar approach should be taken for viruses, although the transmissions of viruses from wild plants must be carried out through potential vector insects, as well as understanding the forms of transmission.

In the management of viral diseases in northern Sinaloa, the implementation of risk assessment levels for the incidence of such diseases in tomatoes for processing in the municipalities of El Fuerte, Ahome and Guasave in the 1990s stands out. This model helped evade high-risk areas for the plantation of tomato for processing. Sanitation measures were also taken, along with the evasion of large populations of vector insects in the management of diseases caused by different types of viruses (Nelson *et al*., 1994). This is a success story of the management of this type of diseases, although it is advisable to design, evaluate and implement risk levels, not only in tomato for processing, but also for the group of vegetables grown in Sinaloa. Consideration should also be given to the different produce-growing areas of the state, since there is variation in wild vegetables and their populations, as well as the levels of incidence of diseases, as it is assumed that, as the levels of incidence increase, so do probabilities of transmission. The types of vegetables and planting dates can also vary in Sinaloa, as well as the populations of weed and ruderal plants found in the region. In addition, new viral diseases have emerged in recent years, such as the *Tomato apex necrosis virus* (Turina *et al*., 2007), the *Tomato marchitez virus* (Camacho-Beltrán, 2015) and the *Tomato brown rugose fruit virus* (García-Estrada *et al*., 2022), for which greater knowledge is required regarding their respective host ranges. Another important aspect of the pathogen-wild plant interaction is the range of hosts of the pathogen. In this regard, attention to the host range of the pathogen has always been directed towards cultivated plants, but not on wild plants where pathogens with a broad host range in which a wide range of hosts between species, genera and even families can be included (Dinoor and Eshed, 1984), which has a direct impact on the ecology, epidemiology and the management of viral diseases.

To date, the origin of viruses in wild and cultivated plants in Sinaloa is unknown. Most of them are perhaps exotic and were introduced into the country via a seed or other means. Once these viruses became established in agricultural crops, they spread to weeds and ruderals through vector insects. Hence the importance of establishing efficient means to detect viruses on seeds and propagational material introduced into the country; in this way, the risk of emerging diseases in the country can be reduced. High-Throughput Sequencing (HTS) stands out as a detection method, since it is redirected to a wide range of viruses (Rubio *et al*., 2020). Perhaps this technique can also be applied to the detection of viruses in potential vector insects in the future.

For established viral diseases affecting both wild and cultivated plants in Sinaloa, it is important to consider resorting to: a) predatory arthropods and parasitoids (Dáder *et al*., 2012), as well as entomopathogenic fungi, nematodes and bacteria as biological control agents (Kalha *et al*., 2014); b) protease inhibitors, neurotoxins or gene silencing through RNA targeting the primary metabolism of the vector insect (Fereres and Raccah, 2015; Nandety *et al*., 2015; Vogel *et al*., 2019); c) agronomic practices such as targeted planting dates to avoid large populations of vector insects and d) interference in the transmission process by applying mineral oil, synthetic peptides or modified proteins that compete with proteins codified by the viruses, which can interact with receptors of the vector insect (Lecoq and Desbiez, 2012; Blanc *et al*., 2014) .

In diseases in weeds and ruderals, there is a wide space for the identification of fungi associated with them. Their pathogenicity must also be determined in agriculturally important plants and vice versa, mainly when in both there is a coincidence of species of the same genus and/or species. Studies are also required on the ecology of fungi associated to wild plants, since it is common to find them in weeds and ruderals during the autumn-winter and the symptoms do not appear in the summer, when temperatures reach 39-40 °C in northern Sinaloa.

Conclusions

In Sinaloa, a wide range of vegetables is planted. The incidence of viral and fungal diseases is frequent in solanaceae and cucurbitceae planted during the autumn-winter season in the area. At the same time, several species of ruderal weeds belonging to these and other botanical families display symptoms of viral and fungal diseases in the environment in which the produce is grown. The relationship between these pathogens with wild plants implies a risk of transmission towards the cultivated plants. To date there are no studies on the spatial and temporary distribution of weeds and ruderals in the valleys of Sinaloa, as well as the populational fluctuations of the vector insects of the viral diseases of this type of plants to cultivated plants and vice versa. There are also no modern systems to detect phytopathogens in plants or in potential vectors. Future research lines should address these topics, with the collaboration of botanists, entomologists, plant pathologists, and bioinformaticians; this will allow a sustainable management of diseases in vegetable gardens and other important crops in Sinaloa.

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