WEEDS AS RESERVOIRS OF CROP PATHOGENS AND PESTS: IMPLICATIONS FOR INTEGRATED MANAGEMENT

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Abstract

Weeds pose a significant challenge in agriculture by competing with crops for essential resources such as water, nutrients, sunlight, and root space, leading to substantial reductions in yield and quality. In addition to their direct competition, weeds serve as alternate and alternative hosts for various pests, including pathogens, insects, mites, nematodes, and rodents, thereby sustaining pest populations and contributing to disease cycles. The relationship between weeds and phytopathogens is complex, with weeds acting as reservoirs and dispersal agents for numerous bacterial, fungal, and viral pathogens. Asymptomatic infection of weeds by pathogens further complicates disease management, making them persistent threats to global food security. Moreover, weeds support a diverse range of insect pests, from monophagous to polyphagous species, which utilize them as food sources, overwintering sites, or breeding grounds. While weeds can exacerbate pest outbreaks, they also play a role in supporting beneficial organisms that contribute to biological control. Given their dual role in agroecosystems, effective weed management is crucial in integrated pest and disease control strategies. Understanding the ecological interactions between weeds, pests, and pathogens is essential for minimizing crop losses while maintaining biodiversity and ecological balance in agricultural landscapes.

Introduction

Weeds have long been considered a persistent challenge to successful crop production, primarily due to their competition with crop plants for essential growth-limiting resources such as water, nutrients, sunlight, and root space (Anwar et al. 2009; Ramachandra Prasad and Sanjay 2016). This competition leads to significant reductions in crop growth, yield, and quality, with crop losses due to weeds (33%) surpassing those caused by pathogens (26%), insect pests (20%), storage pests (7%), and rodents (6%) in India (Yaduraju et al. 2015; Yaduraju and Mishra 2018). Beyond direct competition, weeds play a crucial role in agricultural ecosystems by serving as alternate and alternative hosts for various pest organisms, including pathogens, insects, mites, nematodes, and rodents (Thomas et al. 2005; Saeed et al. 2015; Mishra 2018).Weeds can act as alternate hosts when they belong to a different plant family than the primary crop host, allowing pest organisms to complete their life cycles. A classic example is the black or stem rust pathogen (Pucciniagraminis var. tritici), which infects wheat (Triticum spp., Poaceae family) and requires barberry (Berberis vulgaris, Berberidaceae family) as an alternate host to complete its reproductive cycle (White 1970). Similarly, many fungi, bacteria, and viruses rely on alternate weed hosts to sustain infection chains between cropping seasons (Singh et al. 2010; Webb et al. 2012).Alternatively, weeds serve as alternative (collateral) hosts when they belong to the same plant family as the primary crop host, providing a refuge for pests during non-cropping seasons. These hosts facilitate the survival and reproduction of pest organisms such as Pyriculariagrisea (Magnaporthegrisea), the causal agent of blast disease in rice (Poaceae), which persists on grassy weeds like Brachiariamutica, Digitariamarginata, and Echinochloa crus-galli Such alternative hosts ensure pest populations remain viable until susceptible crops are reintroduced, thereby contributing to pest outbreaks and disease epidemics.

The ecological implications of weed hosts extend beyond agricultural losses. Invasive weeds have been shown to disrupt native biodiversity, support populations of non-native organisms, and hybridize with native species, thereby altering gene pools (Yandoc-Ables et al. 2006). Furthermore, their unchecked proliferation in non-crop areas, such as field margins, roadsides, and irrigation channels, creates reservoirs for pest organisms that may later infest crop fields (Bhowmick 2002; Anwar et al. 2009; Ntidi 2018). Notably, the invasive weed Partheniumhysterophorus has become a major menace in India, colonizing vacant lands and serving as a host for numerous crop pests (Sushilkumar 2009, 2014; Sushilkumar and Varshney 2010; Mondal and Duary 2014).Given the significant role of weeds in maintaining pest populations, their management is essential for integrated pest and disease control. Strategies such as field sanitation, which involves the removal of weed hosts and volunteer plants, help break infection cycles and prevent pest carryover between seasons (Schroeder et al. 2005; Levins and Miranda 2007; Singh et al. 2009). For instance, the eradication of common weed hosts like Abutilon indicum and Solanumnigrum has been shown to reduce whitefly infestations in cotton fields (GoI 2014). Conversely, in some agroecosystems, maintaining low levels of weed hosts can support beneficial natural enemies, contributing to biological pest control (Levins and Miranda 2007; Naveed et al. 2007; Saeed et al. 2015).Understanding the dual role of weeds as alternate and alternative hosts is crucial for developing sustainable pest management strategies. While they provide refuge for pests, they also serve as important ecological components that can either exacerbate or mitigate pest pressures, depending on their management. Recognizing this dynamic is essential for minimizing crop losses while maintaining ecological balance within agricultural landscapes.

1. Interactions Between Weeds, Hosts, and Pathogens

A plant disease generally develops from the interaction of three components: the host, the pathogen, and the environment. Plant pathogens, including bacteria, mollicutes, viruses, viroids, and fungi, form intimate relationships with their host plants through pathogenesis, which involves infection, colonization, reproduction, and spread. As a result, these pathogens prevent plants from performing to their maximum potential and can have devastating ecological, economic, and social consequences globally (Velásquez et al. 2018). The nature of the host, pathogen, and environmental conditions determines whether a disease remains endemic or sporadic or develops into an epidemic or epiphytotic form. The abundance of susceptible hosts in a given area significantly contributes to pathogen survival and spread, leading to disease outbreaks under favorable environmental conditions.Many plant pathogens are hardy and can survive for extended periods under unfavorable conditions. They also evolve continuously, developing novel and more virulent strains through mutation, enabling host range expansion and increased resistance to environmental stresses. Plant diseases remain a persistent threat to global food security, contributing to poverty, hunger, and malnutrition (Records et al. 2020). Historical examples include the Irish potato famine caused by Phytophthorainfestans (Nelson and Ristaino 2011) and the Bengal famine due to Cochliobolusmiyabeanus (formerly Helminthosporiumoryzae), which resulted in 50–90% yield losses in rice production (Padmanabhan 1973).

2. Role of Weeds in Pathogen Survival and Spread

In tropical regions where crops such as rice (Oryza sativa), cassava (Manihotesculenta), sweet potato (Ipomoea batatas), and yams (Dioscorea spp.) are cultivated year-round, the continuous presence of host plants allows pathogens to persist by continuously infecting new hosts. In temperate regions, self-sown (volunteer) crop plants often grow along roadsides, fence lines, and irrigation channels, serving as weeds in paddocks during non-cropping periods. These volunteer plants enable pathogens to survive during intercropping periods and act as inoculum sources when the main crop is replanted. For instance, Xanthomonascampestrispv. campestris, the causal agent of black rot in Brassicaceae plants, is known to survive on related weed species such as wild radish (Raphanusraphanistrum).

Most phytopathogens are not strictly host-specific; many have broad host ranges that extend across different plant families (Linde et al. 2016). Weeds often belong to the same family as cultivated crops and share similar botanical characteristics, making them susceptible to the same pathogens. While weeds tend to be genetically diverse and may exhibit lower susceptibility to diseases, they often function as reservoirs or obligate hosts for crop-associated pathogens (Wisler and Norris 2005, Singh et al. 2010). Because weeds can survive throughout the year, they frequently serve as over-summering or overwintering hosts for various phytopathogens and their arthropod vectors (Webb et al. 2012). This ability increases the risk of disease outbreaks in crops and complicates disease management strategies.

3. Asymptomatic Weed Hosts and Disease Management

In many cases, phytopathogens infecting weeds may not produce visible symptoms, making their role in disease transmission less apparent. This asymptomatic infection can lead to challenges in crop disease management (Shrestha et al. 2016). For example, common dicotyledonous weeds in soybean (Glycine max) fields can serve as asymptomatic hosts for Fusariumoxysporum, a blight pathogen that retains pathogenicity for soybean (Helbig and Carroll 1984). Moreover, pathogen populations originating from genetically diverse weed hosts may evolve higher virulence compared to those from monoculture crops. Weedy or wild relatives of crops may play a major role in pathogen evolution, necessitating their inclusion in disease management strategies (Linde et al. 2016).

4. **Weeds as Pathogen Dispersal Agents**

Weeds also contribute to the long-distance spread of plant pathogens. Many weed species are prolific seed producers, and their seeds can act as passive carriers of pathogens. This mode of dispersal allows pathogens to travel vast distances and facilitates disease emergence in new regions (Darrasse et al. 2010). Effective disease management strategies must therefore integrate weed control measures to limit their role as pathogen reservoirs. This includes removing volunteer plants, controlling weed populations in and around crop fields, and implementing proper field sanitation practices to minimize pathogen survival and transmission.

In conclusion, the relationship between weeds and plant pathogens is complex and dynamic, with weeds serving as crucial reservoirs and dispersal agents for numerous phytopathogens. Managing weed populations is an essential component of integrated disease management to reduce the spread of crop diseases and improve overall agricultural productivity.

Weed-Pathogen Dynamics: A Scientific Viewpoint

1. **Phytopathogenic Bacteria and Weed Association**

A diverse range of bacteria are associated with numerous wild hosts and weeds, increasing the risk of infecting cultivated crops (Kyrkou et al. 2018). For example, Xanthomonascampestrispv. musacearum, responsible for banana wilt, severely affects banana (Musa spp.) production. Studies have shown that weeds and crops associated with banana can influence the disease dynamics by facilitating the pathogen's spread, survival, and perpetuation (Ocimati et al. 2018). Similarly, Xylellafastidiosa causes Pierce’s disease (PD) in grapevines, with Bermuda grass (Cynodondactylon) reported as a favored host of key PD vectors (Hopkins and Purcell 2002).

Another critical bacterial pathogen, Pseudomonas solanacearum, causes bacterial wilt in a variety of crops. It has been isolated from multiple weed species in the Solanaceae and Asteraceae families, often displaying visible symptoms and serving as reservoirs of the pathogen.

2. **Phytopathogenic Fungi and Weed Association**

Several grasses act as collateral hosts for phytopathogenic fungi such as Sclerosporasacchari and S. philippinensis (downy mildews), Pyriculariaoryzae (rice blast), and Ustilagoscitaminea (sugarcane smut), which produce abundant inoculum leading to epidemics. The introduction of eastern white pine (Pinusstrobus) into Europe and the USA contributed to an outbreak of heteroecious blister rust of pine caused by Cronartiumribicola.Verticilliumdahliae, a fungus associated with dicotyledonous weeds, was reported to have spread from weeds to cultivated crops such as cotton Rhynchosporium commune, the causal agent of leaf blotch in cultivated barley, is frequently found on weedy barley grass (Hordeum spp.) with high genetic diversity

(King et al. 2013).Soybean rust, caused by Phakopsorapachyrhizi, poses a global threat to soybean production, causing up to 80% yield loss in susceptible cultivars (Chander et al. 2019). Kudzu (Puerariamontana var. lobata) in the southern USA acts as an overwintering host for the pathogen, enabling its survival under unfavorable conditions (Ward et al. 2012). Similarly, Bipolarisoryzae, responsible for brown spot disease in rice, persists on Leersiahexandra (southern cutgrass), making it a significant reservoir for disease recurrence.Another example is Phytophthoracapsici, a notorious pathogen affecting vegetable crops. It survives on weeds, complicating control efforts and allowing the pathogen to persist in the absence of a host crop. Rust pathogens like Pucciniagraminis, responsible for wheat rust, complete part of their lifecycle on wild ber (Zizyphusrotundifolia) during non-crop periods (Bhowmick et al. 2016).

3. Phytopathogenic Viruses and Weed Association

Weeds often serve as alternate hosts for plant pathogenic viruses, providing a bridge for their transmission and persistence in agroecosystems (Aguiar et al. 2018; Wisler and Norris 2005). Many plant viruses require insect vectors for transmission. Weeds act as intermediate hosts for both the viruses and their vectors, thereby complicating disease management (Shrestha et al. 2016).For instance, Beet necrotic yellow vein virus (BNYVV) and Beet soil-borne virus (BSBV) persist in weeds and are transmitted by the plasmodiophoridPolymyxabetae (Mouhanna et al. 2008). Similarly, Squash vein yellowing virus (SqVYV), transmitted by the whitefly Middle East–Asia Minor 1 (MEAM1) [formerly Bemisiatabaci biotype B], devastates Citrulluslanatus (Florida watermelon) (Webb et al. 2012). Common cucurbit weeds such as Cucumismelo var. dudaim (smell melon) and Momordicacharantia (wild bitter melon) serve as natural hosts (Adkins et al. 2008; Shrestha et al. 2016).In wheat, Wheat streak mosaic virus (WSMV) and its vector, the wheat curl mite (Aceriatosichella), find refuge in grassy weeds and wild grasses (Ito et al. 2012). In India, chili mosaic disease results from various viral infections, each with different host ranges, complicating management strategies (Dasgupta 1988). Rice Yellow Mottle Virus (RYMV) in Africa relies on wild and weedy rice species as reservoirs, facilitating its transmission to cultivated rice fields (Johnson et al. 1999; Rodenburg and Johnson 2009).

4. Implications for Disease Management

Weeds, as alternative hosts for phytopathogens, significantly impact disease epidemiology by allowing pathogens to persist and spread. Their role is particularly crucial in cases where the pathogen has a broad host range and crop rotation is a key control measure. For instance, Xanthomonascampestrispv. campestris, the black rot pathogen of crucifers, survives on related weeds such as horseradish (Armoraciarusticana) (Vicente and Holub 2013). Similarly, barberry (Berberis spp.) eradication in temperate regions has been instrumental in controlling Pucciniagraminis, the causal agent of wheat stem rust (Bhowmick et al. 2012).A comprehensive understanding of weed host-pathogen relationships is essential to develop integrated disease and weed management strategies. Removing overwintering hosts, implementing proper crop rotations, and controlling weedy reservoirs can help break pathogen life cycles and reduce disease incidence. Given the ability of weeds to persist through prolific seed production, underground rhizomes, and vegetative propagation, targeted management strategies must account for their role as pathogen reservoirs. Future research should focus on understanding weed-pathogen interactions at the molecular level to refine control strategies and minimize disease risks in agroecosystems.

5. Weed Host–Insect Pest Relationship

The interactions between insects and their host plants range from highly specialized to generalized feeding behaviors. Phytophagous insects locate their host plants within mixed vegetation, facing threats from various abiotic and biotic factors, which often limit the damage they cause in natural ecosystems (Capinera, 2005). In contrast, in agro-ecosystems, natural regulatory factors play a limited role, leading to frequent insect pest outbreaks (Sharma et al., 2017). Insects exhibit a spectrum of feeding behaviors, from monophagous species that feed on a single plant species to polyphagous species that consume a wide range of plants across multiple families. Weeds, in particular, harbor many insect pests during both crop and off-seasons (Bernays& Chapman, 1994).

a. Monophagous Insects

Monophagous insects feed exclusively on one plant species or on plants within a single genus. For example, the spotted alfalfa aphid (Therioaphismaculata) feeds only on alfalfa (Medicago sativa), and the brown planthopper (Nilaparvatalugens) feeds on rice throughout South and Southeast Asia. The Klamath weed beetle (Chrysolinaquadrigemina) is a monophagous herbivore used for the biological control of Klamath weed (Hypericumperforatum) in California. The European spruce sawfly (Diprionhercyniae) feeds exclusively on spruce trees in north-temperate regions of Europe and America (Bernays& Chapman, 1994). Such insects may enter diapause when their host plants are unavailable.

b. Oligophagous Insects

Oligophagous insects feed on several plants, usually in different genera within a plant family (Capinera, 2005). The Colorado potato beetle (Leptinotarsadecemlineata) primarily feeds on about 14 plants in the genus Solanum under the Solanaceae family. The reddish potato beetle (Leptinotarsarubiginosa) is more restricted, feeding on solanaceous plants, including two species of Physalis and two of Solanum. Many grasshoppers, like the migratory locust (Locustamigratoria), feed on various grasses with common features (Bernays& Chapman, 1994). Weeds and wild plants from the same genera or family can act as alternative hosts for these insects in the absence of their preferred host plants.

c. Polyphagous Insects

Polyphagous insects feed on a relatively large number of plants from different families. They often have a well-defined preferential hierarchy, turning to alternative hosts only when preferred

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hosts are unavailable (Capinera, 2005). Several aphid species, including the green peach aphid (Myzuspersicae) and the potato aphid (Myzuseuphorbiae), colonize potato plants. These aphids are typically polyphagous, feeding on hundreds of host plants across multiple families, including cultivated and wild weed hosts (Singh & Singh, 2016). The cotton leafhopper (Amrascadevastans) is a major insect pest of cotton and a well-known polyphagous herbivore. The tropical armyworm (Spodopteralitura) is a serious polyphagous pest that prefers to consume the leaves of weed hosts like Alternantheraphiloxeroides, Euphorbia hirta, Eichhorniacrassipes, Trianthemaportulacastrum, Partheniumhysterophorus, Cichoriumintybus, Rumexobtusifolius, and Ipomoea fistulosa (Sushilkumar& Ray, 2007).

In agricultural systems, weeds directly serve as important food sources or provide other ecosystem resources for herbivorous arthropods and indirectly support carnivorous arthropods by providing food and shelter to their prey (Capinera, 2005; Norris &Kogan, 2005). For example, black-jack (Bidenspilosa) is an alternative host to common bean insect pests during the off-season (Laizer et al., 2019). Wild and weedy rice are alternative hosts of the African rice gall midge in rice (Johnson et al., 1999; Rodenburg& Johnson, 2009). Weeds that are closely related to crops are particularly important in harboring insects that attack those crops. Some weeds may distract beneficial insects such as pollinators, while others attract them (Laizer et al., 2019). Napier grass (Pennisetumpurpureum) can defend itself against pest attacks by secreting a sticky substance that physically traps the pest (Capinera, 2005).

Weeds not only harbor insect pests that damage crop plants but also play a role in harboring insect vectors responsible for transmitting crop diseases. The American palm cixiid (Mynduscrudus) is a vector of lethal yellowing disease in coconut palms (Eziashi et al., 2013). In India, carrot weed (Partheniumhysterophorus) is an alternate host of striped mealybug (Ferrisiavirgata) in Punjab and Haryana and cerembycid borer (Nupserha sp.) in Madhya Pradesh (Sushilkumar, 2009). Additionally, P. hysterophorus is the most preferred host for the leaf-feeding Mexican beetle (Zygogrammabicolorata), which is used for the biological control of this invasive weed (Sushilkumar&Bhan, 1998).

The Role of Mites in Weed-Host Interactions

a. Host Specificity of Phytophagous Mites

Phytophagous mites from families such as Tetranychidae, Tuckerellidae, Tenuipalpidae, Nalepellidae, Eriophyidae, Rhyncaphytoptidae, and Tarsonemidae exhibit varying degrees of host specificity. Eriophyoid mites, in particular, are highly host-specific (Gupta, 1985; Vásquez et al., 2015), whereas mites from Tetranychidae, Tenuipalpidae, and Tarsonemidae demonstrate broader host ranges (Gupta, 1985). Some polyphagous mites infest a diverse array of plant species (Gupta, 1985).

b. Agricultural Impact of Mites

Mites from the Eriophyidae and Tetranychidae families significantly impact crops such as beans, brinjal, cotton, cucurbits, okra, apple, ber, citrus, and mango in Northern India (Rathee&Dalal, 2018). Eriophyoid mites, also known as gall mites, form an intimate relationship with their host plants and exhibit limited reproductive host ranges (Vásquez et al., 2015). Some tetranychid mites also display host specificity (Gupta, 1985).

c. Alternative Hosts and Mite Persistence

Oligonychusindicus primarily infests Dicanthiumannulatum but also utilizes sugarcane and sorghum as alternative hosts, persisting even through the rainy season (Khan & Murthy, 1956).

The date palm mite (Oligonychusafrasiaticus) has alternative hosts within the Arecaceae and Poaceae families, including Hyphaenethebaica, Phoenix canariensis, Cenchrusciliaris, Dichanthiumannulatum, and Pennisetum species in Saudi Arabia (Alatawi, 2020). This mite coexists with other phytophagous mites and predatory mites such as Spinibdellacronini (Bdellidae) and Cydnoseiusnegevi (Phytoseiidae) on grasses under date palms (Alatawi, 2020).

The tomato russet mite (Aculopslycopersici) disperses from perennial hosts to tomato plants after transplanting and overwinters in alternative hosts when primary hosts perish (FAO, 2017).

Removing alternate weed hosts like shaggy button weed (Borreriahispida), goat weed (Scopariadulcis), chocolate weed (Melochiacorchorifolia), and Fussialasuffruticosa effectively controls the red spider mite (Oligonychuscoffeae) infestation in tea plantations (TBI, 2019).

d. Mite Outbreaks in Agricultural Fields and Predatory Mites and Their Roles

In Midsouth cotton fields, spider mite infestations, mainly from Tetranychusurticae, T. desertorum, T. turkestani, and T. cinnabarinus, correlate with population levels on alternate weed hosts such as Amaranthuspalmeri (Palmer amaranth) and Ipomoea lacunosa (pitted morning-glory) in Arkansas (Steinkraus et al., 2003). These mites spread via wind, human activity, or animal movements.The coconut eriophyid mite (Aceriaguerreronis) is an invasive pest with a restricted host range, affecting Cocosnucifera (coconut) and Borassusflabellifer (palmyra palm) in India (Nair et al., 2005).In Turkey, Aceriasolstitialis persists on yellow star thistle (Centaureasolstitialis), Centaureacyanus, Centaureadiffusa, Carthamustinctorius, and Cynarascolymus (Vásquez et al., 2015).Predatory mites from families such as Cheyletidae, Stigmaeidae, Tydeidae, Bdellidae, Cunaxidae, Erythraeidae, Ameroseiidae, Ascidae, and Phytoseiidae generally lack host specificity. However, some species exhibit plant preferences, while others have broader host ranges (Gupta, 1985). Phytoseiid mites, potential predators of citrus rust mites and broad mites, utilize host plants for colonization, pollen food sources, and domatia for protection (Kreiter&Tixier, 2002). These mites prefer leaf undersurfaces with raised veins, dense hairs, or sheltered structures in vein axils.

Conclusion

Weeds are integral components of agricultural ecosystems, with both detrimental and beneficial roles in pest and disease dynamics. Their ability to act as alternate and alternative hosts for pests and pathogens makes them significant contributors to crop losses. The persistence of weeds in and around farmlands provides a continuous bridge for pathogen and pest survival, increasing the risk of disease outbreaks and insect infestations. However, certain weed species also support natural enemies that aid in pest control, highlighting the need for strategic weed management rather than complete eradication. Effective disease and pest management strategies should incorporate an integrated approach, including field sanitation, crop rotation, targeted weed removal, and biological control measures. Future research should focus on molecular-level interactions between weeds and pathogens to refine management strategies and develop sustainable solutions for reducing agricultural losses. By balancing weed control with ecological conservation, agricultural productivity can be enhanced while maintaining environmental sustainability.

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