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Management of Diseases in Legumes through Organic Approaches: A Review

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Abstract:
Legumes are group of leguminous crops and are mainly known as the nitrogen fixers and these are one of the important components for sustainable agriculture in many parts of the world. These crops are grown for their tremendous benefits to the human beings especially legumes are nutrient rich grains. Pulses/legumes are important source of protein for the poor as well as the vegetarian population of the world and these are consumed on a regular basis because of their highly nutritional values. In countries like India, amino acids of pulses protein complement that of cereals as they are generally eaten together for a complete balanced diet. Pulses are important not only in India but also in many other poor countries where these crops are seen as an easy source of nutrition. Also, 2016 was declared as international year of Pulses by United Nations Organization. Chickpea, lentil, pea, pigeonpea, mungbean, urdbean, lentil, pea and rajma are important grain legumes. Besides there are many arid legumes crops like mothbean, cowpea, horsegram etc. grown in arid areas of the world. Diseases of pulses are one of the most important biotic constraints to their production. Their management strategies need to be percolated to the growers so as the losses caused by the diseases is contained and the growers are benefitted economically. Pulses encounter a wide range of diseases caused by a variety of pathogens that are mostly fungal and viral. However, there are many diseases caused by bacteria and nematodes too. Organic methods are cost effective, easy to use, maintain quality of the crops and moreover helps in boosting up the fertility of soils.

Keywords: Legumes, organic, neem oil, diseases, rust, pathogen.

Introduction:

Leguminous crops play a vital role in the realm of agriculture due to their significant contributions both economically and nutritionally. These versatile plants belong to the Fabaceae family and encompass a variety of species such as beans, lentils, chickpeas, peas, and soybeans. The growth of these legumes is substantially hindered by both environmental elements and microorganisms that prey on them, affecting various parts of the plants such as stems, leaves, shoots, and roots, among others (Nair *et al*. 2019; Boufleur *et al*. 2021). Legumes have been under cultivation across the globe for centuries, ingraining them as an indispensable component of diverse agricultural systems. These crops hold substantial economic significance for farmers, communities, and the global market at large. Renowned for their strong market demand and economic advantages, they contribute significantly to both domestic and international trade.

Pulses are cultivated on approximately 12-15% of the world's arable land, addressing around 30% of the global human dietary protein nitrogen requirements (Graham and Vance 2003). Legumes face a range of harmful diseases, including powdery mildew, downy mildew, root rots, anthracnose rusts, wilts, bacterial blights, mosaic diseases, and more. Alongside this, pod borers, nematodes, parasitic weeds, and sap-sucking insects also exert substantial damage on legume crops, leading to diminished yields and reduced produce quality. In the context of India, insects, diseases, and other factors account for losses of 29%, 22%, and 12%, respectively (Yaduraju, 2006). On a global scale, the corresponding figures for losses caused by insects, diseases, and other pests stand at 30%, 20%, and 5%, respectively (Katiyar and Singh, 2015). Employing organic amendment practices proves to be more effective in safeguarding farmers' finances and ensuring higher produce quality compared to chemical controls.

Importance of disease management in legumes:

Diseases can have a severe impact on legume crops, resulting in lower yields and financial losses for farmers. Taking control of these diseases allows farmers to safeguard their crops and ensure a robust harvest. Legumes hold a crucial role in sustainable agriculture, possessing the ability to naturally capture atmospheric nitrogen, thus reducing the necessity for synthetic fertilizers and enhancing soil health. Diseases can weaken legume plants, compromising their nitrogen-fixing capabilities and detrimentally affecting soil fertility. By managing diseases, farmers can secure the sustainability of legume-centered cropping systems and advance environmental stewardship. Disease outbreaks have the potential to curtail the availability and accessibility of legume crops, consequently impacting both food security and nutrition. Through effective disease management, the production and availability of legumes stand protected, making a valuable contribution to a more dependable and diversified food supply. In India, Acharya (1985) has underscored the critical oversight of plant protection in pulse cultivation, noting that only 5 to 6% of growers employ protective measures on a mere 1.5% of the total area dedicated to these legume/pulse crops.

Diagnosis of Diseases Caused by Different Types of Pathogens:

Diseases can strike at any juncture throughout the plant's growth cycle. Swift and precise identification of the disease's origin, coupled with the immediate application of an effective remedy, stands as a pivotal requirement to shield the crop from harm. Particularly, infectious diseases instigated by living microorganisms, invisible to the naked eye, possess the alarming capability to swiftly devastate an entire crop. Below, a roster of diverse disease types is presented:

Fungi:

Fungi are multicellular microscopic organisms that can grow to their food, usually in the form of filamentous strands. Their growth pattern is radial, so on surfaces such as plant leaves, the effects of their growth may be seen as circular spots. However, fungal infections of other plant parts, such as roots, may produce no visible structures. Some symptoms can indicate these infections. For example, browning of the water-conducting tissues of the stem, in combination with wilt, can indicate infection by the Fusarium wilt fungus. Other disease symptoms, such as blight (a general death of tissue), which can have a variety of causes. Most fungi that infect leaves require free moisture to initiate infection, with the exception of powdery mildew fungi, which need only high humidity to initiate infection. Fusarium wilt is one of the major diseases of chickpea and at national level the yield losses encountered was reported to the tune of 60 per cent (Singh *et al.,* 2007). It causes complete loss in grain yield if the disease occurs in the vegetative and reproductive stages of the crop (Haware *et al.,* 1990; Navas *et al.,* 2000). *F. oxysporum* f. sp. *ciceris* infects chickpea at seedling as well as at flowering and pod forming stage (Grewal, 1969); with more incidence at flowering and podding stage if the crop is subjected to sudden temperature rise and water stress (Chaudhry *et al.,* 2007). Fusarium wilt causes economic loss in pigeon pea of about 97000 tonnes per year in India (Joshi *et al.,* 2001).

Fungi, as multicellular microscopic organisms, thrive by feeding on their nourishing substrate, typically in the form of filamentous strands. They exhibit a radial growth pattern, so when they colonize surfaces like plant leaves, their expansion manifests as circular patches. However, fungal infestations in other plant components, such as roots, might not result in discernible structures. Certain symptoms can serve as indicators of these infections. For instance, the browning of water-conducting tissues in the stem, coupled with wilting, can signal an invasion by the Fusarium wilt fungus. Other disease manifestations, like blight (a general death of tissue), which have various causes. The majority of leaf-infecting fungi rely on available moisture to kickstart infection, though powdery mildew fungi deviate from this norm by initiating infection solely through elevated humidity. Among the primary afflictions of chickpeas, Fusarium wilt stands as a prominent threat, leading to national-level yield losses reaching up to 60% (Singh *et al*., 2007). Complete grain yield failure is a consequence when the disease strikes during the vegetative and reproductive stages of the crop (Haware *et al*., 1990; Navas *et al.,* 2000). F. *oxysporum* f. sp. *ciceris* targets chickpeas during both seedling and flowering/pod formation phases, with higher incidence during flowering and podding when sudden temperature spikes and water stress are experienced (Chaudhry *et al*., 2007). The economic toll of Fusarium wilt is exemplified by pigeon pea, causing annual losses of around 97,000 tonnes in India (Joshi *et al*., 2001).

Bacteria:

Bacteria, minute single-celled microorganisms, persist through a state of dormancy. In cases where bacteria target leaves, they might provoke the emergence of circular blemishes; however, more typical for bacterial infections are irregular lesions that remain confined within the leaf's veins. Bacteria also hold the capacity to induce soft decay in plant parts, often accompanied by an unpleasant odor. The occurrence of bacterial leaf spot was initially documented in China (Fang *et al*., 1964). Within India, Patel and Jindal (1972) brought forth two novel afflictions affecting mung beans: Bacterial leaf spot and Halo blight, during the years 1968 and 1969, respectively. The discerning characteristics of this ailment encompass brown, circular to uneven, dry, elevated patches on both leaves and stems. *Xanthomonas campestris* pv. *vignaeradiate* [(Sabet, Ishaq, and Khalil) Dye] is the inciting agent of bacterial leaf blight. This bacterium, gram-negative in nature, takes the form of rod-shaped cells bearing a single polar flagellum. Notably, the pathogen can also infiltrate *Phaseolus vulgaris*, P. *hontus*, P. *braclantus*, *Dolichos lablab*, and *Lens culineris*.

Viruses:

Viruses represent submicroscopic entities that exclusively duplicate within living plant cells. To proliferate within plants, they rely on vectors like insects. The emblematic virus symptom often manifests as a mosaic pattern on leaves, although viruses might incite a range of other indications, such as necrotic lesions and stunted growth, which can stem from different causes. Among the insect vectors known to transmit viruses are aphids, leafhoppers, whiteflies, and thrips. Sterility mosaic disease (SMD) significantly impairs pigeon pea cultivation across the Indian subcontinent and other Asian nations (Ghaneker *et al*., 1992). The threat posed by SMD to pigeon pea cultivation in the Indian subcontinent has escalated (Singh *et al*., 1999), leading to an annual loss of approximately 300,000 metric tons of grains, accounting for over $150 million solely in India (Kumar, 2000). Notably, control measures for SMD remain elusive except for the employment of resistant cultivars. Leaf crinkle, attributable to urdbean leaf crinkle virus, stands as a formidable constraint on the prosperous cultivation of mungbean (*Vigna radiata* (L.) Wilczek) in India. Urdbean leaf crinkle virus (ULCV) infections in mungbean have been documented in India by Singh *et al*. in 1979. The transmission of the crinkle disease is facilitated through sap, grafting, insect vectors, and seeds. Beniwal *et al*. (1980) reported seed transmission rates as high as 15% in mungbean. Numerous studies have noted its transmission by various insects, including aphids such as *Aphis craccivora* and A. *gossypii* (Bhardwaj and Dubey, 1986; Dhingra, 1975), beetles like *Henosepilachna dodecastigma* (Beniwal *et al*., 1980), and the whitefly *Bemisia tabaci* (Narayanasami and Jaganathan, 1974). The virus can also be transmitted through sap.

Nematodes:

Nematodes, minute roundworms on a microscopic scale, subsist by consuming plant roots. The root knot nematode, for instance, engenders root galls and malformed roots across a wide spectrum of crops. In cases of severe infestation, plants may wither and perish. Nematodes are also capable of provoking traits such as stubbiness, necrosis, and root stunting. All nematodes that parasitize plants have developed a specialized instrument known as a stylet—a hollow, extendable mouthpart. This stylet serves to inject secretions into host tissues and puncture plant cell walls for nutrient withdrawal (Hussey and Grundler, 1998). Certain phytonematode species adopt a migratory parasitic approach, rapidly decimating plant cells, while others in later life stages adopt a sedentary lifestyle, modifying plant cells to sustain a localized nutrient source that fosters parasitic success. Although a few nematode genera, such as Ditylenchus and Aphelenchoides, afflict the aerial tissues of cultivated legumes like alfalfa (*Medicago sativa*), the majority of phytonematode species target the roots of plants (Hussey and Grundler, 1998).

Major diseases in legumes:

1. French bean:

French beans (*Phaseolus vulgaris* L.) have a soft velvety pod with fleshy seeds and are smaller than common green beans. During cultivation, this crop is affected by several diseases of fungal, bacterial and viral nature which not only reduce the quality but also quantity of the crop.

1.1. Root Rot and Web Blight: Root rot and web blight stand as profoundly critical diseases afflicting this crop worldwide, particularly under warm and damp conditions. Within India, the impact of this ailment is substantial, with recorded yield losses of green pods ranging from 8.4% to 64.6% at different stages of plant growth. Incidences of root rot have been observed up to 15% in fields around Bangalore (Sharma and Sohi, 1980; Sharma and Sohi, 1981). This disease not only affects roots but also infests the stem, leaves, pods, and seeds (Mathew and Gupta, 1996). Furthermore, research by Sanchez and Cardenaz (1988) revealed that root rot's impact spans from the emergence of plants to the initial 30 days of crop growth. The causative agent behind this disease is *Rhizoctonia solani* Kuhn.

1.2. Angular Leaf Spot: This disease holds significant implications for French beans, especially in mid-hill conditions, where the interplay of moderate temperatures and high humidity creates an ideal environment for its proliferation. Within India, the extent of damage inflicted by this disease is noteworthy; encompassing both compromised and unsellable pods, the losses are estimated to range from 40% to 70% (Singh and Saini, 1980). Notably, Ponappa *et al*. (1976) documented a staggering 80% yield reduction, accompanied by the premature demise of plants in the Bangalore region of Karnataka. The pathogen's host range is extremely narrow, confined exclusively to the leguminous family. It targets all verdant parts of the plants – leaves, petioles, stems, pods, and seeds – manifesting an array of distinct symptoms.

1.3. Anthracnose: This ailment holds significant importance among common bean crops globally, with its impact being particularly pronounced in tropical and subtropical areas (Pastor-Corrales *et al*., 1994). While this affliction is prevalent worldwide, including in tropical and subtropical regions, its toll on yield is greater in temperate zones compared to its effects in the tropics. Under conditions conducive to disease development, the losses stemming from this malady can escalate to as much as 100 percent, especially when heavily contaminated seeds are sown. In the state of Himachal Pradesh, India, reports indicate a range in disease incidence from 5.0 to 65.0 percent across various locales, resulting in substantial yield reductions during certain years (Sharma et al., 1994; Padder and Sharma, 2010).

2. Mung bean:

Mungbean (*Vigna radiata* (L.) Wilczek) commonly known as green gram or golden gram or sona or mung is an important pulse crop being a crop of tropical and subtropical region mungbean crop has ability to tolerate warm temperature as high as 40°C.

2.1. Powdery Mildew: Powdery mildew poses a significant challenge to the cultivation of mungbeans, emerging as a recent limiting factor in the *Rabi*-sown mungbean crops of Odisha, Andhra Pradesh, Karnataka, and Tamil Nadu. This disease leads to yield losses ranging from 9% to 50% in the fields of farmers (AVRDC, 1982). Manifesting across all aerial parts of the plant, the disease initially presents as white powdery patches on leaves and other verdant sections, later transitioning to a more subdued hue. These patches gradually expand, taking on a circular form that extends to cover the lower surfaces as well. The powdery mildew, brought about by the obligate parasite *Erysiphae polygoni*, takes an ectophytic nature, spreading atop the leaf's surface and sending haustoria into the epidermal cells to extract nutrients.

2.2. Cercospora Leaf Spot: The first documented instance of Cercospora leaf spot was recorded in Delhi, India (Munjal *et al*., 1960). This ailment, which can lead to yield losses ranging from 50% to 70%, has been observed and documented by Lal *et al*. (2001) and Chand *et al*. (2012). In India, this disease is prevalent in numerous mungbean-growing states, notably Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, Rajasthan, Himachal Pradesh, Odisha, Assam, and Maharashtra. It initiates by manifesting as water-soaked spots on the lower leaves of infected plants and subsequently extends its reach across the entire plant. The discernible symptoms manifest as small, numerous leaf spots with a pale brown center and a reddish-brown margin. These characteristic spots can also emerge on branches, petioles, and pods. Mungbeans are susceptible to infection by five species of Cercospora, each exhibiting slight variations in their symptoms. Notably, C. *cruenta* infects mungbeans and produces distinct spots, particularly around the flowering stage.

2.3. Dry Root Rot: Dry root rot, a significant affliction of mungbean induced by *Macrophomina phaseolina* (Tassi) Goid, poses a grave challenge and is a substantial hindrance to mungbean production across all cultivation regions. This disease was initially reported in Jabalpur (M.P.), India. The pathogenic impact extends to various plant components, including roots, stems, branches, petioles, leaves, pods, and seeds. During the pre-emergence stage, the fungus is responsible for seed rot and the mortality of germinating seedlings. In the post-emergence phase, seedlings undergo blight due to infections originating from the soil or seeds themselves. *Macrophomina phaseolina* (Tassi) Goid, also known as *Rhizoctonia bataticola* (Taub) Butler, is the causative agent behind this ailment. The pathogen infiltrates mungbean plants at both intercellular and intracellular levels, rapidly spreading to encompass extensive portions of host tissues, ultimately leading to their demise.

3. Lentil:

It is botanically known as *Lens culinaris* Medikus ssp. *culinaris* is one of the oldest legumes known to mankind. It is grown and consumed in many countries of the world. In Hindi it is known as *Masur* or *Masoor*.

3.1. Wilt disease: Among the array of diseases that impact lentils, the most widespread is the wilt brought about by *Fusarium oxysporum* f.sp. *lentis*. In India, this disease is extensively prevalent in all lentil cultivation regions, presenting a significant biotic threat that particularly jeopardizes lentil production, especially within central India. It is generally accepted that the degree of yield loss corresponds to the percentage of plant mortality. For instance, a 50 percent plant mortality due to wilt is anticipated to result in a 50 percent yield reduction. The wilt disease manifests both before and after emergence stages. In the case of post-emergence infection, seedlings encounter affliction during the early stages of development (Vasudeva and Srinivasan, 1952; Khare, 1979). Although the seeds germinate, the emerging seedlings falter to rise above the soil surface, succumbing to death during or shortly after germination. Nevertheless, post-emergence wilting is more pronounced during two plant growth phases: the seedling stage and the mature stage (flowering and podding). Seedlings are notably affected at an exceedingly early stage, often within 4-5 days post germination. Affected seedlings display browning of the radicle along with a decreased count of secondary (smaller) roots.

4. Pea:

The pea is most commonly the small spherical seed or the seed-pod of the flowering plant species *Pisum sativum*. Each pod contains several peas, which can be green or yellow. In India, the crop is cultivated in northern and central parts of the country. It is an important *Rabi* pulse crop grown in about 0.97 m ha with annual production of 0.89 m tonnes. The major field pea growing states are Uttar Pradesh, Madhya Pradesh, Jharkhand, Bihar, Assam and Maharashtra. Most common diseases of pea are given below.

4.1. Pythium seed and seedling rot: The causal organisms include *Pythium ultimum*, P. *aphanidermatum*, P. *irregulare*, P. *debaryanum*, and others. Diseases induced by *Pythium* spp. are commonly known as seed rot, damping-off, or root rot. Infected seeds undergo a softening process, with the fungal hyphae heavily infiltrating the soil surrounding the seed. In cases where radicles or plumules emerge, an attack by *Pythium* spp. can render them soft, watery, and translucent, sometimes accompanied by cotyledon rot. Typically, the pathogen targets developing tissues like root tips. *Pythium* spp. are present in soil in the form of sporangia or oospores. The severity of damage escalates when soil moisture levels are high and the soil temperature ranges between 10 to 15 °C.

4.2. Fusarium root rot: The causal organism is *Fusarium solani* f.sp. *pisi*. In the early stages, symptoms on seedling roots manifest as streaks ranging from reddish brown to blackish brown, located near the soil line. These streaks extend both upward and downward from the soil line into the root zone. While there might be a reddish discoloration in the vascular system of the roots, this discoloration typically doesn't progress beyond the soil line. Visible symptoms above ground encompass stunted growth and the yellowing of the lower foliage. Conditions unfavorable for root growth, such as soil compaction, soil temperatures exceeding 30°C, high soil moisture, and poor soil fertility, contribute to the exacerbation of root rot.

4.3. Rust: Rust stands as one of the most economically significant afflictions in field peas. The root cause of this ailment is *Uromyces fabae*. Particularly in North India, this disease poses a serious threat (Mishra *et al*., 2009). As a consequence of the disease, the plant's stem becomes distorted, often leading to the demise of the affected plant. The initial signs manifest as yellow spots that host aecia in either round or elongated clusters. Subsequently, powdery and light brown uredopustules develop. The optimal conditions for the disease's progression involve high humidity, cloudy weather, and temperatures within the range of 20-22°C. The plants adopt a distinct dark brown or blackish appearance, noticeable as patches within the field.

5. Cowpea:

Cowpea (*Vigna unguiculata*) is mainly grown in tropical and sub-tropical regions in the world for vegetable and grains and to lesser extent as a fodder crop. It is a most versatile pulse crop because of its smothering nature, drought tolerant characters, soil restoring properties and multi-purpose uses (Oyewale and Bamaiyi, 2013). It is found to be suitable for both normal and late sown condition during rainy seasons.

5.1. Anthracnose: Anthracnose disease continues to pose a severe health threat to cowpea crops, acting as a significant barrier to its economically viable cultivation. Infected seeds serve as the primary source of infection. Damp, warm, and highly humid conditions play a critical role as major contributing factors for cowpea susceptibility. The disease spreads through various agents such as air currents, water, and contact**.**

5.2. Charcoal Rot (Damping Off): Charcoal rot, induced by *Macrophomina phaseolina* (Tassi) Gold, is widespread within all cowpea cultivation regions of Haryana and Rajasthan. Initial signs of the disease become apparent around the collar region of the plant, manifesting as dark brown to black lesions that partially or completely encircle the stem. Over time, these lesions expand both upwards and downwards, eventually encompassing the entire plant. Affected tissues take on a charcoal-like appearance. The charcoal coloration on stems or branches may or may not be continuous.

Organic ways of controlling diseases in legumes:

The natural compounds found in plants have played a significant role in discovering new germicides, nematicides, and to some extent, viricides. These compounds are used either by directly applying them to diseases or by exploiting their properties to strengthen plants against various challenges. Biopesticides, which are natural plant-derived products, fall under the category of secondary metabolites. These include alkaloids, terpenoids, phenolics, and other minor chemicals. Plants are abundant sources of these bioactive organic chemicals. It's estimated that there could be as many as 400,000 secondary metabolites in plants (Mamun, 2011). Around 2,121 plant species are reported to have pest control properties. Plants like neem, ghora-neem, mahogany, karanja, adathoda, sweet flag, tobacco, derris, annona, smart weed, bar weed, datura, calotropis, bidens, lantana, chrysanthemum, artemisia, marigold, clerodendrum, wild sunflower, and many others can be cultivated by growers with minimal expenses and extracted using traditional methods. Various organic control measures are described below**.**

Bio control agents:

Numerous attempts have been undertaken to control various diseases affecting pulse crops by introducing bioagents that inhabit natural substrates in the soil. Among these beneficial microorganisms, *Trichoderma* species, known for their antagonistic properties, have been extensively investigated within the pulse crop ecosystem. They have demonstrated successful outcomes in mitigating diseases such as wilts, root rots, collar rot, and stem rot caused by different pathogens including *Fusarium* spp., *Rhizoctonia solani*, R. *bataticola*, *Sclerotium rolfsii*, *Sclerotinia sclerotiorum*, *Ascochyta, Cercospora*, *Alternaria* spp., *Phytophthora* spp*., and Pythium* spp. across various pulse crops and field plants. For instance, in chickpeas, treating seeds with a formulation containing *Trichoderma harzianum* derived from tea leaves at a rate of 10gm per kg of seeds proved effective in managing chickpea wilt. Furthermore, the application of a formulation based on wheat bran sawdust also showed promise (Singh *et al*., 2007). Similarly, diseases like damping-off, root, and/or stem rot, caused by diverse organisms, can be efficiently controlled by incorporating T. *viride* (isolate TVM2). Additionally, distinct strains of *Trichoderma* have been shown to effectively combat root rot disease in field peas caused by F. *solani* f. sp. *pisi* (Kapoor *et al*., 2006).

Organic Amendment of Soil:

The decomposition of organic substrates such as farmyard manure, compost, oil cakes, decomposed leaves, and animal litter compost is a biological and microbial process that yields multifaceted effects. This process enhances soil health and structure while also boosting microbial populations, which can have both direct and indirect impacts. Some microbes serve as direct antagonists to plant pathogens, while others indirectly affect the biological balance through their metabolic byproducts. For instance, compost is particularly effective in fostering a diverse soil environment, hosting numerous soil organisms. This compost acts as nourishment and refuge for antagonistic microorganisms that compete against plant pathogens, those that prey upon and parasitize pathogens, and even those that produce antibiotics. In cases like root rots caused by *Pythium* and *Phytophthora*, the compost's rich population and diversity of beneficial microbes tend to suppress these diseases. These antagonists impede spore germination and the infection of plants growing in the treated soil (Harrison *et al*., 1999). However, for more consistent and reliable outcomes, it's essential for the compost itself to maintain stability and a uniform level of quality.

Plant extracts:

Plant extracts used for the control of phytopathogens have primarily been derived from tree species such as eucalyptus and neem (constituting 24% of the studies involving extracts), as well as from herbaceous species like garlic, citronella, mint, rue, yarrow, ginger, basil, camphor, turmeric, and ocimum (making up 54%). Additionally, there are numerous other plant species whose antimicrobial potential has been explored by researchers. In terms of pathogen groups, a significant portion of the research (30% of the studies with extracts) has focused on those causing diseases in the plant canopy. Genera like *Alternaria*, *Bipolaris*, *Crinipellis*, *Corynespora*, and *Colletotrichum* account for 15% of the research. Soil-borne pathogens constitute 20% of the investigations, with a notable emphasis on pathogens like *Rhizoctonia*, *Sclerotium*, *Sclerotinia*, *Fusarium*, and *Phytophthora*. Post-harvest pathogens such as *Penicillium*, *Aspergillus*, and *Rhizopus* are featured in 9% of the studies, while the Meloidogyne nematode is considered in 9.5%. In terms of host plants, 30% of the research has centered around crops like beans, soybeans, coffee, wheat, cotton, and cassava. Vegetables, including cucumber and tomato, account for 20%, with tomatoes alone representing 15% of all research involving extracts. Fruits, like papaya, strawberry, and cocoa, make up 10% of the research (Stangarlin *et al*., 2011).

Table 1: Management of fungal diseases of pulses/legumes by plant products:

Name of fungal diseases	Causal Agent	Botanical control	References
Wilt of lentil	*Fusarium oxysporum* f. sp. *lentis*	Extract of ginger, garlic and neem	Garkoti *et al.* (2013)
Root rot of French bean	*Rhizoctonia solani*	Extracts of *Artemisia vulgaris*, *coix lacryma jobi*, *Lanatana camera*	Mangang and Chhetry (2012)
Wilt of chickpea	*Fusarium oxysporum* f.sp. *ciceri*	Aqueous leaf extracts *Azadirachta indica* and *Lantana camara*	Kamdi *et al.* (2012)
Root rot of mung bean	Macrophomina Phaseolina	Oil of palmarosa, lemongrass, citronella, mentha and tulsi	Kumari *et al.* (2012)
Wilt of pigeon pea	Fusarium *oxysporum* f. sp. *udam*	Leaf extract of *Azadirachta indica*, *Datura festilosa*, *Tagetes erecta*, *Eucalyptus citridora*, *Agele marmelos* and *Mimusops elengi*	Singh *et al.*(2010)

Table 2: Use of botanicals in viral disease management of pulses/legumes:

Name of viral diseases	Name of virus	Botanical control	References
Yellow mosaic disease of mumgbean and urdbean	Mungbean yellow mosaic virus	Root extract of *Boerhaavia diffusa* and leaf extract of *Azadirachta indica*	Singh and Awasthi (2009)
		Leaf extract of *Clerodendrum aculeatum*	Verma and singh (1994)

<table>
<tr><td rowspan="2">Urdbean leaf crinkle disease</td><td>Urdbean leaf crinkle</td><td rowspan="2">Leaf extract of Datura metal
Neem oil and mustard oil</td><td rowspan="2">Chaudhury and Saha (1985)
Trivedi et al. (2014)</td></tr>
<tr><td>Yellow mosaic disease</td></tr>
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Table 3: Some plant products and their efficacy:

S. no.	Plant products	Virus	Vectors
1.	Neem oil (5 percent spray)	RTV	N. Virecens
2.	Neem cake	“	“
3.	Custard apple oil	“	“
4.	Custard + neem oil	“	“
5.	Achras sapota	Ragimosaic	“
6.	Basella	Nubra	“
7.	*Mirabilis jalapa*	“	“

Neem products:

While neem has been utilized by humans for various purposes since ancient times, its scientific recognition for its insecticidal, fungicidal, nematicidal, and antiviral properties has emerged more recently. A neem oil formulation known as "Trilogy" has received approval from the EPA for application on food crops. Additionally, products like "Rose Defence" and "Triact" have been developed for ornamental plants, specifically targeting common diseases such as Powdery mildew, rust, black spot, *Botrytis*, and Downy mildew.

Table 4: Effect of Various Neem Products on different Pathogens:

S.No.	Neem product	Effective against pathogen
1	Neem oil cake	*Sclerospora sacchari*
2	Fruit pulp	*Rhizoctonia solani*
3	Extract oil	Inhibition of germ tube growth of *Ersyiphe polygoni* (Singh and Singh, 1981)
4	Extract	Mycelial growth and spore germination of *Curvularia lunata*, *Aletrnaria alterneta*.
5	Neem oil	*Fusarium monoliforme*, M. *phaseolina*, D. *rostratum*, powdery mildew, Black spots.

Conclusion:

Pesticidal compounds derived from plants are notably more effective and tend to have minimal to no adverse effects on humans. However, substantial work remains to be accomplished before botanical pesticides can be extensively employed on a larger scale. The utilization of biocontrol agents contributes to environmental safety. Among these agents, *Trichoderma* stands out as a well-established biocontrol agent, showcasing effectiveness against diverse pathogens. *Trichoderma* harbors numerous biocontrol genes that aid plants in developing resistance against pathogens. Formulations based on *Trichoderma* are cost-effective, safe, and environmentally friendly. Once a potentially valuable plant species is identified, focused breeding and selection efforts are essential to enable economically viable production of antagonistic compounds from such plants. The safety and targeted action of these botanicals must be thoroughly tested. This trend has prompted various experts to supplement synthetic chemicals with economically viable natural alternatives for all types of farmers in the future. The ongoing global emphasis on botanical pesticides is likely to yield novel insights and prototype models that will steer forthcoming research initiatives in the field of plant protection.

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