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A Review on: common botanicals in Nepal on management of crop diseases

Abstract

The crop production is turn down by many pathogens, weeds, insects comprising 36.5% of annual loss under field and 14% during storage conditions. Among many practices adopted to manage plant diseases, use of synthetic chemicals is more convinced and are adopting as a last resort of the disease management worldwide. Despite of its efficacy, use of chemicals is threatening the environments, health of human and animals because of its residual toxicity, non- specificity, resurgence and costly nature. Emerging agriculture is now being replacing the hazardous chemicals through the use of biological and botanicals. The botanicals growing naturally possess numerous antimicrobial metabolites that act against various pathogens reducing the disease severity with out having adversities on animal health and environment. Neem, Melia, Datura, garlic, ginger, turmeric, eucalyptus, onion, basil, tobacco, nettle, black pepper, chilli etc. have antimicrobial metabolites such as phenols, phenolic acids, quinones, flavones, flavonoids, flavanols, tannins, coumarins etc. These constituents can be potential pesticides. From *in-vivo* and *in-vitro* studies on their effectiveness it has been proved that they can be the best substitutes for synthetic chemicals in agriculture. Among the plant species in world, only 10% of the plant species have been reported to have pesticidal activities. Identification of such plant species and production of plant-based formulation is most essence for economic and eco-friendly management of plant diseases. Therefore, having a better understanding of these alternative pesticides could be beneficial for engaging in sustainable agriculture, especially given that they are less dangerous, practical from an economic standpoint, simple to use and capable of managing pests and pathogens in both fields and stores (postharvest). The review is subjected to study the efficacy of botanical extracts for the management of crop diseases as a better alternative to the chemicals and it summarizes the findings from previous researches.

Keywords: botanical extracts, disease management, IDM, crop diseases

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Introduction

About thirty six percent of production of crop is annually lost due to diseases, pests and weeds under field condition and post-harvest loss during storage is about 14%. The decline in crop production due to various diseases have been managed using various practices from the antiquity. Plant diseases can be managed by various techniques including the use of resistant varieties, cultural practices, physical measures and chemical, biological control and biointensive approaches. Cultural and physical methods are not among the much-adopted crop management measures.[1] Disease management using fungicides, the last resort for plant protection, is still continuing as the predominant plant protection tool.[2] The indiscriminate use of synthetic pesticides for the management of the plant diseases created huge environmental risks and toxic health hazards on human. The increasing public concerns over the levels of pesticides residues in foods also encouraged the use of biological or botanical pesticides as a best alternative to the chemical pesticides. Although use of chemicals has effective control over plant diseases and has been considered to be the cheap and most efficient way to prevent diseases. Since use of chemicals are hazardous to soil and users, use of biological control agents is the best alternative to the toxic chemicals.[3] The uses of chemicals need to be restricted in agriculture because they cause development of resistant pathogen population, accumulate in soil, water and plants and are not biodegradable and ultimately, they affect environment and living organisms. According to Dubey et al.,[4] and Kumar et al.,[5] because of carcinogenicity, teratogenicity, high and acute residual toxicity, hormonal imbalance, long degradation period, environmental pollution and their adverse effects on food the use of synthetic chemicals to control postharvest biodeterioration has been restricted. Since early 1970s, agriculture worldwide has struggled with the evolution of pathogen resistance to disease control agents due repeated use of chemical pesticides which brings a desire to public for safer pesticides with less environmental impact.[6]

Plants have tremendous ability to produce secondary metabolites which are antimicrobial in nature. These metabolites comprise phenols, phenolic acids, quinones, flavones, flavonoids, flavanols, tannins, coumarins etc.[7,8] The antifungal activity of plant extracts may be more effective than some commercial synthetic fungicides. Plant extracts with phenolic structures, like carvacrol, eugenol, and thymol are highly active against the pathogen and these groups of compounds show antimicrobial effect and serves as plant defense mechanisms against pathogenic microorganisms.[7] The extracts used to kill the plant pathogens are called botanical pesticides or botanicals. These extracts are toxic to the pathogens and in addition with this they are ecofriendly, target specific, economic and biodegradable in nature. The antifungal compounds presence in plants have been found to develop resistance ability in plants against pathogens.[9] The secondary metabolites comprise of induced inhibitory compounds these include phytoalexins, PR proteins, active oxygen species, plant lectins, etc.[10] These induced inhibitory compounds induce defense mechanism in plants against various pathogens. Worldwide only 10% of plant population has been recorded to have pesticidal activities.[11] There are many herbs, shrubs and trees which are useful as sources of botanical pesticides. Garlic, neem, onion, ginger extracts inhibit *Pythium aphanidermatum,*[12] *Cymbopogon citratus* possessed antifungal effect against *Rhizoctonia solani* affecting rice,[13] Garlic, eucalyptus, lemon grass, Tulsi significantly inhibited the mycelia and sclerotia of *R. solani,*[14] Negi and Kumar[15] reported that 20% extracts of neem

and garlic in vitro inhibited *Xanthomonas axonopodis* pv. *citrii*, the citrus canker pathogen. Many weeds in agriculture field Lantana, Parthenium, Datura, *Artemisia, Ageratum* etc. have antifungal activity against various pathogens. The ultimate aim of the review paper in this area has been the development of alternative control strategies to reduce dependency on synthetic fungicides.

Materials and methods

This paper was drafted after collecting essential information from the various literatures available on internet regarding the efficacy of different botanical pesticides, biological pesticides, plant extracts on crop disease management Table 1.

Table 1 Some of the commonly used botanicals for plant disease management in agriculture field

Plant Extracts	Essential oils
Neem (*Azadirachta indica*, A. Juss), Garlic (*Allium sativum*, Linn., Eucalyptus (*Eucalyptus globulus*, Labill., Turmeric (*Curcuma Longa*, Linn., Tobacco (*Nicotiana tabacum*, Linn., Ginger (*Zingiber officinale*, Rosc.) Chinaberry (*Melia azedarach*) Thorn Apple (*Datura stramonium* Linn.) Black pepper *(Piper nigrum* Linn.) etc.	Nettle oil (*Urtica* spp.), Thyme oil (*Thymus vulgaris*, Linn.), Eucalyptus oil *Eucalyptus globulus*, Labill. Rue oil (*Ruta graveolens*, Linn.), Lemon grass oil (*Cymbopogon flexuosus* (Steud.) Wats. and Tea tree oil (*Melaleuca alternifolia*). Spearmint (*Mentha spicata* Linn.) *Ocimum gratissimum* fennel, peppermint, caraway, geranium etc.

Neem (*Azadirachta indica*, A. Juss)

Among several plant species investigated, the neem (*Azadirachta indica A. Juss*) is one of the most effective plant species possessing pesticidal properties against various pests of agriculture.[16] Neem is highly recognized as "Life giving tree", "Village pharmacy", "Divine tree", "sacred offering of nature" with having several valuable properties.[17,18] According to Debashri &Tamal,[19] the leaves of *A. indica* contains carbohydrates (48-58%), protein (14-18 %), crude fibre (11-24%), ash (7.7- 8.5%), crude fat (2.3-6.9%), calcium (0.8-2.4%) and phosphorus (0.13-0.24%), numerous of amino acids, as well as carotenoids and other constituents. Neem oil contains over 100 biologically active compounds.[20] Triterpenes also known as limonoids and azadirachtin are found to cause 90% of their effect on most pests.[21] Other components present include meliantriol, nimbin, nimbidin, nimbin, nimbolide, fatty acids (oleic, stearic, and palmitic) and salannin. The seeds of the neem is the main source of these compounds although other parts of the neem tree contain less amount of azadirachtin. Schmuttere[22] reported that the neem oil cake is rich in high amount of Sulphur and oil is rich in fatty acid.

Wide spectrum of agricultural pests including even a louse in human to major insects (*Locusta*, armyworm), nematodes (root knot), fungus (rhizoctonia) and virus (Rice stunt virus) are being controlled by neem.[23] Acharya et al.,[24] reported that the neem and its products have antifungal, antibacterial, antiviral, antidiabetic, anthelmintic, anti-carcinogenic, anti-inflamatory properties and are used as contraceptive and sedative. Neem oil, leaf extracts, root extracts and bark extracts are neem products with pesticidal properties.

Neem oil

Neem oil is extracted from the seeds of the neem tree and has pesticidal and medicinal properties due to which it has been used in pest control in agriculture. Neem oil is a better pesticide due to its repellent, insecticidal, nematicidal, bactericidal, and fungicidal activities.[25] The oil contains around 300 biologically active compounds, most notably azadiractin - a triterpene.[26,27] Neem oil is a potent and preventative fungicide used to treat and prevent a number of diseases, including anthracnose, Alternaria blight, downy and powdery mildews, rust, scab and blossom blight, and leaf spot.[28] Meera et al.,[29] reported that neem extracts have inhibitory effect against mycelial growth and sporulation of the *Colletotrichum capsici*. According to Aboellil[30] trilogy, a naturally occurring substance from *A. indica,* dramatically slowed the growth of cucumber powdery mildew and induce resistance in cucumber plants. According to Sanjeet et al.[31] *A. alternata*-caused faba bean leaf spot was effectively controlled by *A. indica* extracts in both lab and outdoor settings. Babu et al.,[32] mentioned that spraying with 3 % of neem oil in tomato pot cultures resulted in 53 % reduction in disease incidence over the control. Neem oil is effective to control leaf spot of groundnut and chilli diseases. The seeds of rice coated with urea and neem control the seed infection of rice blast.

Leaf extracts

Alkaloids, glycosides, tannins, flavinoids, reducing sugars, carbohydrates, and steroids are among the biologically active substances found in neem leaves.[33] Neem leaves can be utilized in a variety of ways, including being ground into a powder or being combined with aqueous methanolic or ethanolic extracts.[34] According to Singh et al.,[35] treatment of infected banana fruit with an aqueous leaf extract of *A. indica* gave good control of the progression of Fusarium wilt of banana caused by *Fusarium oxysporum* with the least amount of fruit weight loss. Aqueous leaf extracts of neem inhibited the mycelial growth and spore production of *Helminthosporium* and *Pyricularia* causing brown leaf spot and blast of rice respectively.[35] Plant extracts of neem have played significant role in the inhibition of seed-borne pathogen *F. oxysporum* and also improve the quality of seed and emergence of plant seeds.[36] In addition, with this leaf extracts of neem also reduce the incidence of early blight (*Alternaria solani*) and increase the yield in tomato plants.[37] According to Kishore et al.,[38] *Phaeoisariopsis personate*, the culprit for late leaf spot of ground nut, was severely inhibited by an ethanol leaf extract of *A. indica.* Bankol and Adebanjo[39] showed that neem leaf extract inhibited the growth of four pathogenic fungi (*Macrophomina phaseolina, F. moniliforme*, *F. solani*, and *Botryodiplodia theobromae*) in vitro. According to Dwivedi and Shukla,[40] the rate of mycelial growth inhibition increased with plant extract concentration. Moreover, 100% aqueous neem (*A. indica*) leaf extract completely prevented Spore germination of *Fusarium* spp. Concentration of 20% neem extracts have good control over *Alternaria solani* and *Fusarium oxysporum* in tomato with increased growth parameters of tomato plants.[41]

Garlic (Allium sativum, Linn)

According to numerous scientific research, garlic is well recognized for its ability to stimulate plant development and to protect plants because of its bactericidal and fungicidal activities (depending on Allicin and Alliin).[42] Garlic extracts has good antioxidant properties showing a positive correlation between increased antioxidative

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components and different stress tolerance.[43] It is allicin that gives garlic its characteristic odour. Allicin has several potential targets within the cell and it is difficult for organisms to mutate to resistance. Curtis et al.,[44] and Portz et al.,[45] reported that allicin is active against a broad-spectrum of taxonomically diverse organisms. The volatile antimicrobial substance allicin (diallyl thio sulphinate) is synthesized in garlic when the tissues are damaged and the substrate alliin (S-allyl-L-cysteine Sulphoxide) mixes with the enzyme alliin-lyase.[46] Several studies have shown that garlic has in vitro antibacterial, antifungal, and anti-oomycete activity.[44] Slusarenko et al.,[47] showed that garlic juice was able to reduce disease severity in several test pathosystems such *Magnaporthe oryzae* in rice, *Hyaloperonospora parasitica* in Arabidopsis, and *Phytophthora infestans* (ibid) in potato. Gujar et al.,[46] reported that allicin effectively controlled seed-borne *Alternaria* spp. in carrot, Phytophthora leaf blight of tomato and tuber blight of potato. Ethanol extract of bulb and leaves of garlic has been reported to reduce the incidence and severity of *Curvularia lunata.*[47] According to Reddy et al.,[48] crude extract of garlic significantly reduces the *Aspergillus flavus* incidence.

Mode of action of garlic extracts against fungal pathogens:[49]

I. Delay and inhibit spore germination

II. Inhibits protein and DNA synthesis

III. Inhibits production of mycotoxins

IV. Disrupts cellular components and their activities

V. Hyphal and mycelial modification

Chinaberry (Melia azedarach L.)

Like *Azadirachta indica,* a member of the Meliaceae family, *Melia azedarach* L. (Meliaceae) is one of the most beneficial medicinal herbs. Every section of *M. azedarach* possesses certain medical qualities similar to *A. indica* and can therefore be used commercially.[50] From various studies *Melia* contains number of organic molecules viz. terpenoids, flavonoids, steroids, acids, anthraquinones, alkaloids, saponins, tannins.[51,52]

Eucalyptus (Eucalyptus globulus, Labill.)

Eucalyptus is an evergreen, tall tree, or shrub, belonging to Myrtaceae family. About 700 species of Eucalyptus, more than 300 volatile oils are found in their leaves. The leaves of the Eucalyptus possess essential oil consisted mainly of oxygenated monoterpenes, monoterpenes and oxygenated sesquiterpenes.[58] Essential oils are concentrated liquids with hydrophobic properties that are derived from plants and contain volatile aromatic chemicals.[59] Biological activity such as antifungal,[60] antibacterial, insecticidal, and nematicidal effects were previously reported to exist in them.[61] Katooli et al.,[62] showed complete inhibition of mycelial growth in *Pythium ultimum* and *Rhizoctonia solani* on all concentration of essential oil after 30 days of inoculation. *P. ultimum* and *R. solani*, the two most significant soilborne fungi, had 100% complete inhibition of mycelial growth as results obtained from Huv et al.,[63] showing that *Eucalyptus unigera* oil inhibited the growth of three phytopathogenic fungi, including *C. gloeosporioides, R. solani*, and *Pythium* spp.

Turmeric (Curcuma Longa, Linn.)

On the Indian subcontinent, turmeric (*Curcuma longa*) is widely farmed and consumed as a spice. Traditional medicine has employed the turmeric plant as a treatment for a variety of illnesses, such as diabetes, liver ailments, and cough.[64] The bio efficacy of the extracts, EOs, and chemical components of the genus Curcuma have been documented, and it has been claimed that it is effective in battling plant pathogens and insect pests that harm food. However, this information is dispersed across numerous research papers. The active component of turmeric, curcumin, belongs to the terpenoids family and has antifungal, antibacterial, and antiprotozoal properties. The mode of action of phytochemical terpenoids is membrane disruption.[8] The crude extracts of rhizome of turmeric have antifungals activity against some of the important diseases caused by *Phytophthora infestans, Fusarium solani, Pyricularia oryzae.*[65] Additionally, it has been discovered that 10% dosages of turmeric extract can prevent the growth of the causative agent of cassava spot disease, *Xanthomonas axonopodis* pv. *Manihotis*.[66] Many Curcuma species also show potential antifungal action in addition to their antibacterial activities. For instance, at each of the investigated concentrations*, C. longa* EO shown potential fungitoxicity against *Alternaria dianthi* and *Fusarium oxysporum* f.sp. *dianthi,* which attack carnations, and *Curvularia trifolii* f.sp. gladioli and *F. oxysporum* f.sp. *gladioli*, which attack gladioli.[67] Additionally, *Sclerotium rolfsii*, which causes sclerotial rot, was suppressed by EOs from *C. longa*,[68] and curcuminoids produced from *C. longa* rhizome were successful in treating Colletotrichum species. According to Chen et al.,[69] the leaf extract of *C. longa* showed antifungal efficacy against the fungi *Alternaria alternata*, *Cladosporium cladosporioides, Colletotrichum higginsianum*, six species of *Fusarium*, *Sclerotinia sclerotiorum*, and *Rhizopus oryzae*.

Thorn apple (Datura stramonium Linn.)

According to Awulachew,[70] the thorn apple is widely used as botanical pesticides worldwide. Some Datura species viz. *D. discolor*, *D. metel* and *D. stromonium* are found effective and have antifungal activities against various fungal diseases. The leaves, stem and fruits extracts have been used to control various fungal diseases of plants. From the various researches Datura has been investigated to have phenolic compounds, alkaloids, lectins, withanolides, terpenes etc.[70] Moreover, antifungal activity; Datura species have antibacterial, cytotoxic, antioxidants, herbicidal, acaricidal and insecticidal properties. The methanolic extracts of seeds, roots, leaves and stem of Datura inoxia was used to inhibit the growth of *Alternaria solani*, *Fusarium solani*, *Aspergillus flavus*, *A. niger* and *Helianthus sporium*[71] The extracts of various parts of *D. metel* in various solvents viz. hexane, chloroform, acetone and methanol have antifungal activity against *A. niger*, *A. fumigatus* and *A. flavus.*[72] The secondary metabolites such as atropine (alkaloid) produced in Datura due to biotic and abiotic stress are investigated to have antipathogenic effects against various phytopathogens.

Bojho (Acorus calamus)

Acorus calamus is most widely used as medicinal herbs under family Acoraceae. According to Mukherjee et al.,[73] it is one of the perennials, semiaquatic herbs having creeping rhizomes. It is known from various names viz. Sweet flag (English), Shi chang Pu (Chinese), Kalamus (Germany), Bajai (India) and Bojho (Nepali). *Acorus calamus* rhizomes, leaves, and essential oil are high in a variety of chemical components. Tewari et al.[74] observed the ethanol extracts from the rhizome of *Acorus* contains glycosides, terpenoids and sterols. The antifungal chemical found in *A. calamus* is β-asarone, which is thought to be the most physiologically active compound in *A. calamus* rhizomes.

The ethanol extracts of *A. calamus* inhibits *Alternaria brassicae*, *Alternaria* spp., *Fusarium* spp., *Rhizoctonia* spp., and *Sclerotium* spp. at various concentration ranging from 0.10% to 10% .[75]

Mungkornasawakul et al.,[76] reported, *Alternaria, Botrytis, Fusarium* and Septoria are found sensitive to *A. calamus* extracts. Mongkolsawat[77] found that A. calamus was most effective in inhibiting the growth of *Collectotrichum* spp. The extracts from the root of the Acorus is found effective to control leaf blight of tomato caused by *Alternaria solani*.[78]

Lemon grass (Cymbopogan citratus)

Lemon grass (*Cymbopogan citratus*) is a *Poaceae* family native sweet-smelling tall sedge. It grows throughout tropical and subtropical South East Asia and Africa. It contains 1 to 2% essential oil on a dry basis, with chemical composition varying greatly depending on genetic diversity, habitat, and agronomic treatment of the culture.[79] Appendini & Hotchkiss[80] reported that the essential oil of lemongrass contains high amount of citral and has antimicrobial properties against human and plant pathogens. The concentration of 500 ppm lemongrass enriched in PDA media was fungicidal for *Colletotrichum coccodes, Cladosporium herbarum, Rhizopus stolonifer* and *Aspergillus niger.*[81] As per the study of Mishra & Dubey,[82] the growth of *Fusarium verticillioides* decreased by 90 and 100% at 500 and 1000 ppm lemongrass oil in PDA. Plotto et al.,[83] studied that *Geotrichum candidum* was more responsive to lemongrass oil vapours compared to thyme or oregano oils. Abd-El-Khair and Wafaa[84] reported that the leaf extract of lemongrass is effective for the management of early and late blight of potato caused by *Alternaria* spp. and *Phytophthora* spp. respectively. Moreover, this can be used against bacterial soft rot of cabbage and Alternaria blight of mustard reported by Acedo et al.,[85] and Patni et al.,[86] respectively.

Table 2 Antipathogenic properties of *Melia azedarach* L

Extracts of *Melia*	Target organism/Pathogens	References
Fruits, leaf, seeds	*Macrophomina phaseolina, Ascochyta rabiei, Aspergillus flavus, Fusarium monitiform, Microsporum cans, Diaporthe phseolorum, Sclerotina sclerotiorum, Fusarium verticillioides*	53, 54, 55, 56, 57
Methanolic leaf extract	*Sclerotium rolfsii*	50
Ethanolic leaf extract	*Alternaria solani, Fusarium oxysporum*	41

Basil/Tulsi (Ocimum sanctum, Ocinum bacilicum)

The Tulsi leaf extract contains a small amount of volatile oil, which is a source of phytochemicals like aldehyde, terpenes (sesquiterpenes, monoterpenes), and phenols. It also contains a small amount of saponins, tannins, glycosides, quinone, phlobatanin, flavonoids (orientin & vicenin), steroids, coumarin, and alkaloids.[87] Aqueous and Acetone extract of Tulsi (*O. sanctum*) has been found to be antifungal activity against many fungi such as *Curvularia penniseli*, *Alternaria tenuis* and *Helminthosporium* spp.[88,89] and Rao & Nigam[90] concluded in their research that the Tulsi leaves extract & essential oil were effective against pathogenic fungi such as *Candida guillermondii*, *Colletotricum capsici*, *Alterneria solani*, *Fusarium solani*, *Curvularia* spp. and *Helminthosporium oryzae*, which is responsible for spoilage of fresh produce. Pramanick and Phookan[91] reported that leaf extracts of *O. sanctum* effective against sheath rot of rice. Moreover, Charcoal rot and wilt of cowpea can be controlled by leaf extracts of *Ocimum.*[92] From the study of Abd-El-Khair and Wafaa,[84] the leaf extracts of *Ocimum bacilicucm* can be used for the management of early and late blight of potato. Similarly, it can be effective against rubber spot disease Table 3.[93]

Table 3 Other botanicals for plant disease management

SN	Botanicals	Parts used and forms	Plant diseases	Pathogens	References
1.	Onion (*Allium cepa*)	Seed extracts	Early blight of potato Late blight of potato Maydis leaf blight of maize	*Alternaria solani* *Phytophthora infestans* *B. maydis*	84 94
2.	Chilli (*Capsicum frutescens*)	Fruit extracts	Early blight of potato Late blight of potato Fusarium wilt of muskmelon	*Alternaria solani* *Phytophthora infestans* *Fusarium* spp.	84 95
3.	Mentha arvensis	Oil	Post harvest rot of citrus		96
4.	Mustard (*Brassica* spp.)	Leaf extracts	Fusarium wilt of muskmelon	*Fusarium* spp.	95
5.	*Dioscorea bulbifera*	Leaf extracts	Late blight of potato	*Phytophthora infestans*	97
6.	Ginger (Zingiber officinale)	Oil	Post harvest rot of citrus		96
7.	Guava (*Psidium gaujava*)	Leaf extracts	Bacterial soft rot of cabbage	Bacteria	85
8.	Marigold	Leaf extracts	Wilt complex of lentil		98
9.	Ashoka (*Ashoka* spp.)	Leaf extracts	Alternaria leaf spot of mango	*Alternaria* spp	99
10.	Milkweed (Aank) *Calotropis* spp	Leaf manure Extracts	Sheath blight of rice Root knot of chickpea	*Rhizoctonia solani* *Meloidogyne spp.*	100 101

Source of table: Kumar and Singh.[102]

Conclusion

Management of plant diseases is not solely an approach to eradicate or exclude the pathogens from the crops and protecting crops but is a complex and integrated approaches which requires an understanding of host-pathogen-environment interaction and way of farming. So there is no single specific means to protect crops from the pests. Farmers have been convinced to use fungicides against the various diseases from the antiquity. Being hazardous in nature, fungicides are not being so popular among the growers. Despite of their effectiveness, fungicides are now being replaced by biological and botanical pesticides through the concept of integrated plant disease management (IDM). The large numbers of constituents of plants being antimicrobial in nature are found suppressing the plant diseases. The active ingredients present in plants may either act on the pathogen directly, or induce systemic resistance in host plants. The growing agriculture system exploits the

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botanicals for the replacement of hazardous chemicals for inclusion in integrated disease management programs. Being economic, target specific, eco-friendly and biodegradable nature of botanicals, they are safer to use and can be degraded into harmless compounds with time. The antimicrobial nature of botanicals because of secondary metabolites production such as phenols, phenolic acids, quinones, flavones, flavonoids, flavanols, tannins, coumarins etc. make them potential pesticides against plant diseases. The documentation of plants with potential antimicrobial compounds should be done and their biocontrol efficacy against the pathogens should be further studied *in vitro* and *in-vivo*. Numerous field trails should be conducted for the assessment of practical applicability of botanicals in field conditions and should be integrated along with other management strategies for the plant diseases. Studies should be targeted to ascertain the toxicity of those botanicals and their secondary metabolites to crops, animals, people and environment aiming biosafety.

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Conflict of interest

Authors declare that there is no conflict of interest.

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