Original Article

Plant Disease Management Approaches for Organic Crop Production in Indian Scenario: A Critical Review

Kishor Chand Kumhar* | **Bijender Singh Beniwal**| **Ram Dhan Jat**| **Bharat Patel** |**Anil Kumar**| **Hans Raj**| **Mukesh Kumar**| **Narender Kumar**| **Suresh Kumar**

Deendayal Upadhyay Centre of Excellence for Organic Farming, Chaudhary Charan Singh Haryana Agricultural University, Hisar–125504, India

Use yor device to scan and read the article online

Citation Kumhar KC, Beniwal BS, Jat RD, Patel B, Kumar A, Raj H, Kumar M, Kumar N, Kumar S., **Plant Disease Management Approaches for Organic Crop Production in Indian Scenario: A Critical Review**. *J. Plant Bioinform. Biotechnol.*, **2022**, *2*(1): 1-12.

https://doi.org/10.22034/jpbb.2022.327017.1018

Article info
Received: 2022-01-29
Accepted: 2022-04-20
Available Online:
Checked for Plagiarism: Yes
Peer Reviewers Approved by:
Dr. Sami Sajjadifar
Editor who Approved Publication:
Dr. BehzadGhareyazi

Keywords:
Organic Agriculture, Diseases, Biological Control Agents, Indigenous Formulation, Cereals, Vegetables, Fruits

ABSTRACT

In recent times, the agricultural scenario has been undergoing a drastic change in converting from an inorganic to an organic system. It has been gaining fabulous popularity amongst the farmers, consumers as well as researchers. The reason is the harmful effects of inorganic agrochemicals and fertilizers that had drawn the attention of people to a greater extent. The excess and non-judicious usage of inorganic inputs has deteriorated the health of soil, environment, and human being, besides creating an ecological imbalance. To tackle such concerns for sustainable and healthy food production, adoption, and promotion of the organic agriculture could be an appropriate approach which is the need of the hour. However, numerous biotic and abiotic factors limit the success of crop production in such agricultural systems. Among such biotic factors, the plant diseases which are caused by several phytopathogenic fungi, bacteria, viruses, and nematodes play a crucial role. Plant diseases could be managed through agronomic practices such as crop rotation, flooding, deep ploughing, soil solarization, manipulating planting time, irrigation, fertilization, composting, weeding, sanitation, tillage, etc. and use of biological control agents like species of *Trichoderma*, *Ampelomyces*, *Pseudomonas* and *Bacillus,* indigenous formulations/indigenous technology knowledge (ITKs), etc.

1. Introduction

The interest in organic crop production has been increasing day by day since the last decade because of the increased negative impact of conventional agriculture production systems. Production of crops has adopted the inorganic agricultural inputs primarily agrochemical which has been used starting from the seed treatment till harvesting of the crop either for providing a protective umbrella against various diseases caused by various bacteria, fungi, nematodes, and viruses. The frequent and injudicious application of inorganic agrochemical inputs has led to several environmental and health-related problems [1].

The demand for organic food commodities has increased tremendously and hence researchers, as well as growers have been focusing their attention towards the organic crop production in which the use of inorganic inputs such as chemical insecticides, weedicides, fungicides, nematicides etc. is completely avoided. However, successful crop

***Corresponding Author:** *Kishor Chand Kumhar (kishorkumarc786@gmail.com)*

production through this system faces various biotic and abiotic challenges, too [2,3].

The organic farming was primarily initiated by British botanist Sir Albert Howard in 1905. However, in India, it was initiated during the late 1990s. The government of India in 2001 implemented the national program for organic production to promote organic farming. Organic farming was started in several states. Sikkim has converted cent percent of the agriculture into an organic state in this country. At the present time, India has less than 2% net area under it [4] with a production of about 1.70 million MT certified organic products with voluminous export of different organic food items.

The occurrence of plant diseases is one of the prominent concerns in organic agriculture. Various fungi, bacteria, and viruses infect the crops which include genera *Pythium*, *Phytophthora*, *Fusarium*, *Macrophomina*, *Rhizoctonia*, *Sclerotinia*, *Ustilago*, *Puccinia*, *Curvularia*, *Colletotrichum*, *Alternaria*, *Erysiphe*, *Uncinulla*, *Phyllactinia*, *Sclerospora*, *Peronospora*, *Helminthosporium* etc. as notable/major phytopathogenic fungi causing huge crop losses [5]. *Xanthomonas*, *Pseudomonas*, *Erwinia*, *Ralstonia* etc. are important phytopathogenic bacterial genera. Likewise, several viruses incite different plant diseases. For the management of plant diseases, plant protection measures start as early as from seed treatment and would continue until crop harvesting in different crops [6,7].

This review paper is mainly focused on the major components of available non-chemical means of plant diseases management. The organic crop production excludes the use of synthetic/inorganic chemicals for the control of plant diseases. Natural and safer means to achieve the target are being considered in such a production system which includes various agronomic practices, farm implements, application of biological control agents, plant, and animal-based preparations that are found as useful integral components in the basket of plant protection measures.

2. Role of Agronomic Practices for Disease Management

The cultural practices such as crop rotation, flooding, deep ploughing, soil solarization, adjusting planting date, irrigation, fertilization, composting, weeding, sanitation, tillage, etc. help in minimizing plant disease infections. Pre- and post-sowing cultural operations such as field preparation, deep summer plowing, adequate plant nutrition, field sanitation/hygiene, removal of alternate host plants, green manuring, sowing time and methods, inter- and mixed cropping, crop rotation, water management, soil solarization, hot water treatment, resistant cultivars, clean and healthy seeds, the proper disposal of crop residues, etc. help in controlling several plant diseases [8,9].

The severity of soil-borne diseases in organic agriculture is reported to be comparatively less than conventional agriculture [10,11], because the addition of organic matter encourages the activities of antagonists and beneficial microorganisms in the soil [12,13,14]. Soil solarization helps in decreasing the inoculum load of some phytopathogenic fungi, bacteria, and nematodes [15]. Green manuring with Dhaincha (*Sesbania*sp.) and Sunhemp (*Crotalaria juncea*) minimizes the sheath blight of paddy caused by *R. solani* [16] and the red rot disease of sugarcane [17]. Ridge sowing had helped in the reduction of the late blight of potato [18] and the smut disease of wheat [19]. Tikka disease (*Cercospora* sp.) of the groundnut could be reduced when the crop is grown in a wider space [20]. Chickpea blight (*Ascochyta* sp.) can be reduced if it is sown deeply [15].

The inter-cropping and mixed cropping are beneficial in organic agriculture as far as disease management is concerned. Wheat/mustard+chickpea intercropping reduced the incidence of rust and blight disease [21,22]. The fine-tuning of crop sowing time can save or escape the crops from the attack of certain diseases. Root rot, blight, and wilt disease of chickpea can control the delayed sowing. The early sowing of mustard crop reduces the white rust disease. Lady's finger

(Okra) *Abelmoschus esculentus*, sown during February – March, reported less incidence of yellow vein mosaic virus (YVMV) disease [15]. Water is an essential input for the production of the agricultural crop; its optimum application helps in keeping diseases under control. The incidence of red rot disease of sugarcane declined when it was irrigated through drip method in comparison to a normal way of irrigation [23]. The common scab of potato could be minimized when moisture level at the time of tuberization was maintained near field capacity [15]. The removal and destruction of certain alternate host plants (Table 1) is a vital operation to manage plant diseases.

Table 1. Alternate host plants of crop diseases

Crop	Disease	Alternate host
Wheat	Rust	*Agropyron* sp.
Pearl millet	Ergot	*Cenchrus ciliaris*
Maize	Downy mildew	*Saccharum spontaneum*

3. Role of Tillage and Types of Irrigation

The disease suppression was improved by the long-term reduced and no-tillage management practices with and without crop rotation [24,25]. A diversified crop rotation improved spring wheat yield by up to 30% in no-tillage [26].

Conservation tillage enhanced both soil fertility and pest control, decreased water quality regulation and weed control, without affecting crop production and disease control [27]. Potatoes grown in rotation with barley and red clover under conservation tillage were less diseased than those in a shorter rotation with conventional tillage [25]. Soil agro-ecosystems can be modified through rotation and conservation tillage practices to improve disease suppression by enhancing the antibiosis abilities of endophytic and root zone bacteria [25].

In the organic systems, control of cereal fungal diseases is usually achieved by crop rotation and incorporation of residues into the soil [28]. Without the option of incorporating residues, the disease pressure in organic reduced tillage systems may be higher than conventional systems and ultimately lead to the yield reduction [29]. Biomass incorporation into the soil may also reduce some soil-borne pathogen load [30]. Ploughing under infected crop debris is also a good sanitation measure to control certain soil-borne plant pathogens as tillage can expose the infected plant materials to sunlight, directly kill phytopathogens. The removal of the diseased plants along with surrounding soil has reduced further spread of lettuce drop or white mold caused by *S. sclerotiorum* [31]. Disinfection and cleaning of farm implements through heat treatment and ultraviolet (UV) treatment as preventative measures to avoid pathogen contamination from one area to another while their movement [32].

Irrigation leads to the production of a dense crop influencing the micro-environment within the crop canopy. Irrigation, especially sprinkler, results in a reduction in canopy temperature while increasing the relative humidity and the period of leaf wetness. Irrigation influences disease development not only via an impact on conditions that favor host infection, but also in terms of pathogen sporulation and the subsequent spore dispersal [33].

The choice of the irrigation system affects plant development as well as disease occurrence, pathogen dispersal, and rates of disease progression. Furrow irrigation requires a large quantity of water and usually demands a higher dose of nitrogenous fertilizers which can predispose the plants to many diseases. Besides, soil-borne phytopathogens can easily be spread in the irrigation furrows along with water flow [34]. Drip irrigation avoids wetting of the aerial plant parts and hence reduces the incidence of foliar diseases [35].

Alternaria late blight of pistachios affects leaves and fruits, and deteriorates its quality and ultimately leads to profit loss to the growers. High humidity in the orchard increases the magnitude and severity of the blight infection. It was found that the buried drip system reduced orchard humidity, dew duration, and increased temperature and further significantly reduced leaf symptoms of the disease and fruit infection at harvesting [36].

The viability of the drip irrigation for the management of spinach downy mildew disease was demonstrated at the University of California Desert Research and Extension Center located in the low desert of California for two crop seasons. Various combinations of drip line spacing and installation depths were compared with sprinkler irrigation. The finding of the experiment revealed that the downy mildew incidence was lower in plots irrigated through drips [37].

A field experiment on the effect of drip and furrow irrigation on the development of grey mould disease of tomato, caused by *Botrytis cinerea*, conducted under greenhouse conditions in northern Algeria revealed that the attacks of fungal pathogen started earlier in furrow irrigation than drip irrigation. Disease infection and its severity were higher under furrow than the drip irrigation which caused higher plant mortality in the furrow irrigated greenhouses. Hence, it was concluded that the drip irrigation could be a useful tool of integrated protection approaches for minimizing a load of chemical pesticides on greenhouse tomato crop [38].

4. Role of Indigenous and other Preparations

There are certain indigenous formulations, prepared from cow urine, cow dung, garlic, milk, ash, buttermilk, etc. are capable of taking care of various plant diseases (Tables 2 & 3).

Table 2. Indigenous formulations for the control of plant diseases

Indigenous Formulation	Effective for the Control
Beejamrit	Seed borne diseases
Garlic extract (10%)	*R. bataticola* and *F. oxysporum* in chickpea
Raw milk	Downy mildew of pearl millet
Cow dung extract	Paddy blast
Bael leaf extract	Paddy diseases
Cow urine	Cucumber rot disease (*Sclerotinia sclerotiorum*)
Cow dung ash	Fungal diseases
Cow urine buttermilk	Rust diseases

Table 3. Botanicals for plant disease management in organic agriculture

Plant	Botanical name	Disease	Formulation
Marigold	*Tagetes* sp.	Root rot, rust, nematodes	Aqueous extract of leaves and roots
Mahua	*Madhuca longofolia*	Stem rot and root rots	2.5 – 3.0% oil emulsion
Onion	*Alium cepa*	Fungal diseases	Extract of crushed bulbs
Dhatura	*Datura stramonium*	Wheat rusts and other fungal diseases	Dry leaf powder
Chaulai	*Amaranthus* sp.	Wheat rusts	Aqueous extract of leaves
Turmeric	*Curcuma longa*	Root rot	Rhizome powder

[21]

5. Role of Biological Control Agents

The biological control agents are the ideal option to take care of phytopathogens. Biological control agents comprise of certain species of fungus, bacteria, and viruses. However, for the management of plant diseases, fungal, and bacterial candidates (Table 4) play a crucial role. Among various BCAs, *T. harzianum*, *T. viride,* and *P. fluorescence* had been occupied the prime position. Here the prime focus has been paid to genus *Trichoderma* because of its highly exploited biological control agent.

Table 4. Biological control agents for control of plant diseases as per the Central Insecticide Board of India

Sr. No.	Biological control agent	Microbial candidate	Target
1	Fungi	*T. harzianum*	Soil-borne fungal diseases
		T. viride	Soil-borne fungal diseases
		A. quisqualis	Powdery mildews
2	Bacteria	*P. fluorescens*	Seed, soil and airborne pathogens
		Bacillus sphaericus	Several phytopathogens
		B. subtillus	Several phytopathogens

Source: http://ppqs.gov.in/sites/default/files/list_of_registered_pesticides.pdf

5.1. Current status of Biopesticide formulations

There is a long list of about 970 registered manufacturers with the Central Insecticide Board & Registration Committee (CIB & RC) for the manufacturing and marketing of biopesticides in India which 558 *Trichoderma* spp. (Figure 1). It includes private companies, government organizations, and NGOs. Presently, wettable powder (WP) and liquid formulations are available for the use by end-users; however, WP formulation in different concentrations (0.5 to 6.0%) is dominant (Figure 2). The liquid formulations contribute less than 2% of total formulations (Figure 3).

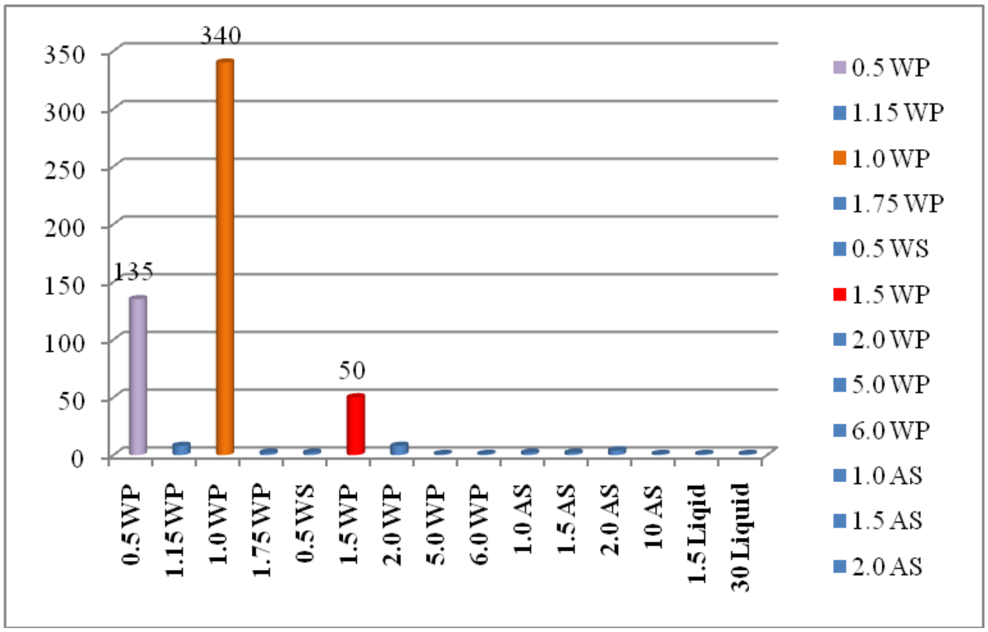

Figure 1. Number of manufacturers of different *Trichoderma* formulations concentration wise

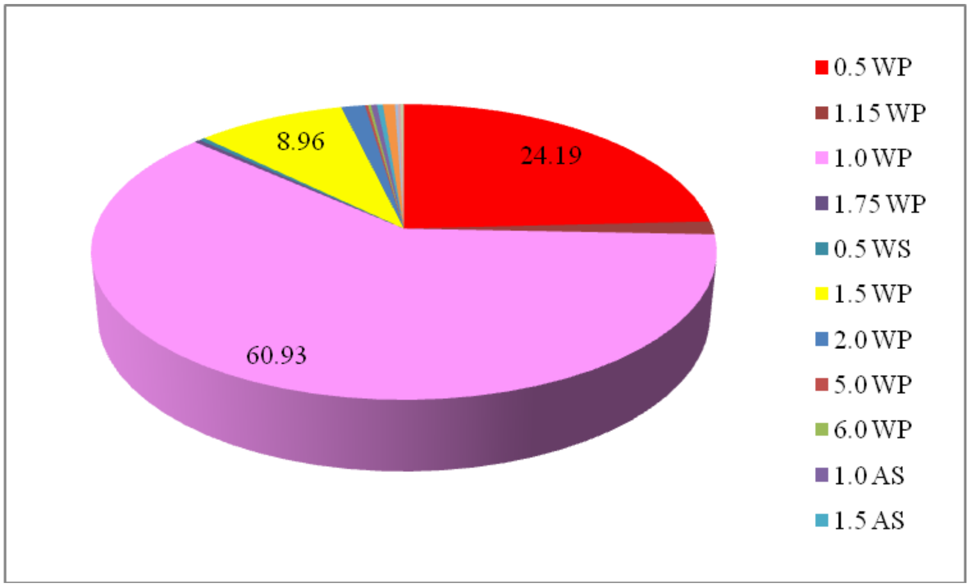

Figure 2. Per cent share of manufacturer of *Trichoderma* WP formulations

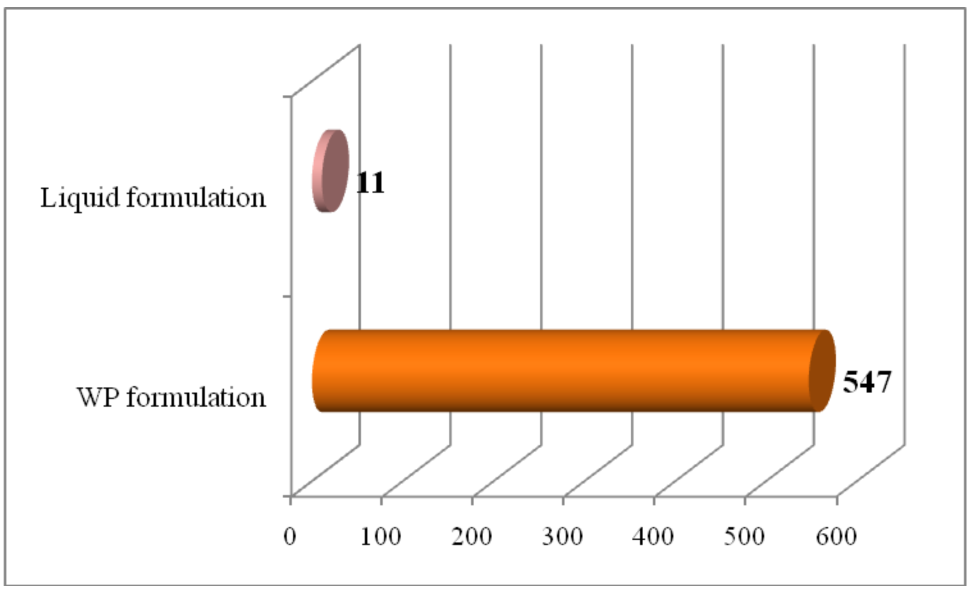

Figure 3. Status of *Trichoderma* WP and liquid formulation manufacturers

5.2. Management of plant diseases through seed treatment with biopesticides/botanicals

Seed treatment is an important and economical practice to manage the seed-borne phytopathogen at the initial stage with the minimum cost. For this purpose, a small quantity of desired input is required and this practice is highly feasible in handling. For seed treatment, formulation of *T. harzianum*, *T. viride*, *P. fluorescence,* Beejamrit, cow urine, Jeevamrit, etc. can be used. Seedlings of vegetable crops can be treated with *T. viride*, *T. harzianum,* and *P. fluorescence* just before transplanting into the main field (Table 5).

Table 5. Seed treatment with promising BCAs and other inputs for organic agriculture

Input	Crop	Adopted by
Cow urine	Okra, brinjal seed treatment	Tamilnadu*
Beejamrit	Chilli seed treatment	Tamilnadu*
Jeevamrit	Chilli seed treatment	Uttrakhand*
Trichoderma	Chilli seed treatment	Uttrakhand*
T. viride	Chickpea seed treatment	Madhya Pradesh#
T. harzianum	Tomato seedling treatment	Meghalaya#
T. viride	Maize seed treatment	Meghalaya#
T. viride	Broccoli seed treatment	Sikkim#
P. fluorescens	Broccoli seed treatment	Sikkim#
T. viride	Nursery soil treatment	Sikkim#
P. fluorescens	Coriander seed treatment	Sikkim#
T. viride	Tomato seed treatment	Sikkim#
T. viride	Capsicum seed treatment	Sikkim#
P. fluorescens	Capsicum seed treatment	Sikkim#
T. viride	Chilli seed treatment	Tamilnadu#
P. fluorescens	Chilli seed treatment	Tamilnadu#
T. harzianum	Wheat seed treatment	Uttar Pradesh#
P. fluorescence	Wheat seed treatment	Uttar Pradesh#
Trichoderma	Wheat seed treatment	Uttarakhand#
Pseudomonas	Wheat seed treatment	Uttarakhand#
Pseudomonas + *Trichoderma*	Pea seed treatment	Uttarakhand#
Pseudomonas + *Trichoderma*	Chickpea seed treatment	Uttarakhand#
Trichoderma *P. fluorescence*	Wheat seed treatment	Dharwad#
Trichoderma	Potato seed treatment	Dharwad#

*National Centre of Organic Farming
#Indian Institute of Farming Systems Research

5.3. Management of plant diseases through soil treatment with BCA

Soil residential phytopathogens such as *Pythium*, *Phytophthora*, *Fusarium*, *Rhizoctonia*, *Sclerotinia*, *Macrophomina,* etc. play an important role in the development of various soil-borne diseases such as root rot, wilt, and seedling rot of various crops. Management of such fungal phytopathogens can be achieved through the application of certain BCAs like *T. harzianum*, *T. viride*, *P. fluorescence,* etc. through soil drenching with water, BCA enriched farmyard manure and vermicompost. There are several species of *Trichoderma*, however *T. harzianum*, *H. lixii*, *T. atroviride*, *H. atroviridis*, *T. asperellum,* and *T. virens* are potential biocontrol agents against phytopathogens [39,40]. Application of *T. viride* enriched FYM (5 kg/plant) to two-year guava saplings at the basin near root zone resulted in decreased wilt incidence and better plant growth in terms of stem girth [41]. *T. harzianum* when applied (50 g/vine) in black pepper field, it had effectively managed the foot rot disease. For the management of pomegranate, wilt bio-formulation of *T. viride* (0.1 and 0.2%) was found significantly superior over the control. Soil application of *T. harzianum* plus *T. virens* is efficient in managing stem bleeding disease of coconut [42]. Five monthly applications of *T. harzianum* (50g/plant) in banana reduced 50% of vascular discoloration index of Fusarium wilt disease and increased the yield [43]. *T. asperellum* found inhibitory against *Pythium aphanidermatum*, *P. debaryanum*, *Sclerotium rolfsii,* and *S. rolfsii*, *F.oxysporum* f. sp. *lycopersici* and *Alternaria solani*. Application of

Trichoderma (@20 kg/ha) along with 2.0 tones castor cake/ha reduced nematode population and increased yield in pomegranate.

The soil application of silver nanoparticles synthesized from *T. asperellum* resulted in a complete control of *Fusarium* wilt in cv. Grand Nain [44]. *T. harzianum* talc formulation could control root rot disease of citrus up to 80%, and under field conditions [45].

Some strains of *Pseudomonas* spp. And *Trichoderma* spp. were found to be effective in controlling wilt of banana, caused by *F. oxysporum* f. sp. *cubense* (Foc) race 1 under field conditions [46]. Isolates of *Trichoderma* and *Aspergillus* when applied in the field for the control of guava wilt disease caused by *F. oxysporum* f. sp. *psidii* and *F. solani*, they could reduce disease incidence and promote the plant growth [41].

5.4. Management of plant diseases through foliar application of BCAs

Foliar application of BCAs is advisable for the management of airborne fungal and bacterial phytopathogens such as species of *Alternaria*, *Curvularia*, *Fusarium*, *Colletotrichum*, *Pestalotiopsis*, *Pyricularia*, *Puccinia*, powdery and downy mildew pathogens of cereal, vegetable and the other crops (Table 6). The potent microbial candidates include *T. viride*, *T. harzianum*, *P. fluorescence,* and *A. quisqualis*. Post-prune foliar application of *T. harzianum* and *T. viride* is a common practice in tea (*Camellia* sp.) crop production in Darjeeling and North East region of India [47,48]. When a combination of *T. harzianum* and *P. fluorescens* was sprayed before harvesting of mango fruits, it had suppressed post-harvest fruit rot in Dasheri mango [49]. Banana hands (cv. Grand Nain) when dipped in *T. asperellum* suspension and packed without ethylene absorbent extended its shelf life up to 75 days at 13.5 °C. There was no incidence of anthracnose and crown rot [44]. It was noted that *T. viride*, *T. harzianum,* and *T. asperellum* were potential antagonists for the management of *F. solani* and *Pestalotiopsis theae* causing dieback and grey leaf spot disease of tea [50,51]. Foliar spray of *T. asperellum* and *T. atroviride* could manage dieback disease of tea (*Camellia* sp.) and enhance the vegetative growth in terms of more number of pluckable shoots [52].

Table 6. Foliar spray of Biological control agents in organic agriculture

Input	Crop disease	Adopted by
Trichoderma sp.	Anthracnose of chilli	Uttrakhand*
P. fluorescence and *Trichoderma* spp.	Rust, powdery mildew and blight of pea	Uttarakhand#
P. fluorescence and *Trichoderma* spp.	Wilt and blight of chickpea	Uttarakhand#
T. harzianum + *P. fluorescence*	Black rust, brown rust, yellow rust and leaf blight of wheat	Jharkhand#
T. harzianum or *T. viride*	Loose smut of wheat	Jharkhand#

**National Centre of Organic Farming*
#Indian Institute of Farming Systems Research

5.5. Management of plant diseases through paste application of BCA

Application of *Trichoderma* paste (20% w/v) is generally done after severe pruning operations (rejuvenation prune and medium prune) in tea plantation to protect the plants from airborne pathogens. Such an application can be useful in horticultural crops in which pruning is done.

5.6. Important considerations for the desired success of BCAs

There are certain issues/concerns which should be taken into consideration for achieving desired benefits from the use of BCAs. The important concerns are: (1) reliable source of procurement, (2) assurance of fresh formulations, (3) avoidance of tank mixing with agrochemicals, (4) tank mixing with compatible bio formulations, (5) repeated application at the proper interval, (6) the use of neat and clean separate sprayers for such formulations, (7) seeking the technical advice from experts for their uses, (8) the application during early morning and late evening, (9) the procurement in a well-ventilated store under lock and the key to keep away from children reach, and (10) the assurance of product quality through Certification agency such as IMO, Ecocert, Lecon, or any other approved agency.

6. Conclusion

There are several promising approaches or techniques for the successful control of plant diseases under the organic agriculture system. The success of organic agriculture determined by the appropriate field operations such as crop rotation, flooding, deep ploughing, soil solarization, adjusting planting date, irrigation, fertilization, composting, weeding, sanitation, tillage, removal, and destruction of the alternate host plants of different phytopathogens and the others. Farm implements account for the disease severity of various crop plants. Biological control agents such as *T. harzianum, T. viride, A. quisqualis, P. fluorescens, B. sphaericus, B. subtillus*, and the other preparations made from cow urine, cow dung, milk, medicinal plants, etc. are efficient in controlling several plant diseases safely. Managing plant diseases through these approaches could be safer for the agroecosystem, overall environment, soil health, and human health, and also it would be the right step in sustaining crop production to meet out the demand of growing population.

Table 7. Foliar spray of botanical and other inputs organic agriculture

Input	Crop disease	Adopted by
Cow urine	*Phomopsis* blight of Brinjal	West Bengal*
Ash	Chilli Diseases	Uttrakhand*
Garlic plus khadi soap	Chilli Diseases	Uttrakhand*
Cow urine, garlic, yeast and salt	Powdery mildew of chilli	Uttrakhand*
Pestoneem	Bacterial blight of carrot	Meghalaya#
Derisom	Powdery mildew of carrot	Meghalaya#
Neem Seed Kernel Extract (NSKE)	Powdery mildew of coriander	Sikkim#
Milk	Powdery mildew of pea	Sikkim#
Tulsi and neem oil	Anthracnose of Capsicum	Sikkim#
Neem oil	Foliar diseases of maize	Tamilnadu#
Sour buttermilk	Rusts of wheat	Uttar Pradesh#
Mustard-milk extract	Karnal bunt of wheat	Uttar Pradesh#

**National Centre of Organic Farming*
#Indian Institute of Farming Systems Research

Abbreviations

NPOP- National Program for Organic Production, **BCA**-Biological Control Agent

Availability of data and material

Data and materials used in this article are available with corresponding author.

Ethics approval

No human or animals were used in the present research.

Consent to participate

All authors are agree to participate

Consent for publication

All the authors are agree to publish this article.

Acknowledgement

The authors are highly thankful to Professor R. K. Jhorar, Former Dean College of Agricultural Engineering and Technology, for inspiring to bring up this review article. Our sincere thanks are also due to Dr. Azariah Babu, Deputy

Director (Research), Tea Research Association, North Bengal Regional Research and Development Centre, Nagrakata, Jalpaiguri, West Bengal, India for sharing his inputs and improving quality of the manuscript.

Orcid

Kishor Chand Kumhar: https://orcid.org/0000-0003-1250-9464
Bharat Patel:
https://orcid.org/0000-0003-1678-9838

References

1. Elahi E, Weijun C, Zhang H, Nazeer M. (2019). Agricultural intensification and damages to human health in relation to agrochemicals: Application of artificial intelligence. *Land Use Policy*, 83: 461–474. [Crossref], [Google Scholar], [Publisher]
2. Gaur A, Kumar A, Kiran R, Kumari P. (2020). Importance of seed-borne diseases of agricultural crops: Economic losses and impact on society. In Seed-Borne Diseases of Agricultural Crops: Detection, Diagnosis & Management, 3–23. [Crossref], [Google Scholar], [Publisher]
3. Katsaruware-Chapoto R D, Mafongoya P L, Gubba A. (2017). Responses of Insect Pests and Plant Diseases to Changing and Variable Climate: A Review. *Journal of Agricultural Science*, 9(12): 160. [Crossref], [Google Scholar], [Publisher]
4. Manjula M, Devi, P I. (2021). Organic farming in India: Catalysts that can help in transition. In Ecology, *Economy and Society*, 4(1): 21–29. [Crossref], [Google Scholar], [Publisher]
5. Agrios G N. (2005). Plant Pathology.5th Edition. Elsevier Academic press. pp. 922. [Google Scholar], [Publisher]
6. Xue A G, Guo W, Chen Y, Siddiqui I, Marchand G, Liu J, Ren C. (2017). Effect of seed treatment with novel strains of *Trichoderma* spp. on establishment and yield of spring wheat. *Crop Protection*, 96: 97–102. [Crossref], [Google Scholar], [Publisher]
7. Sawant I S. (2014). *Trichoderma*- Foliar Pathogen Interactions. *The Open Mycology Journal*, 8(1): 58–70. [Crossref], [Google Scholar], [Publisher]
8. Shirazi, Z., Khakdan, F. (2021). In Silico Genome-Wide Identification and Characterization of Glutathione Peroxidase Gene Family in Wild Cherries (Prunus avium L). *Journal of Plant Bioinformatics and Biotechnology*, *1*(1), 60-72. [CrossRef], [Google Scholar], [Publisher]
9. R Salehi Sardoei, A., Rezaei, H., Ghasemi, H. (2021). In Silico Evaluation of Expansin-Gene Function in Softening and Fruit Ripening. *Journal of Plant Bioinformatics and Biotechnology*, *1*(2), 73-83. [CrossRef], [Google Scholar], [Publisher]
10. Lotter D W, Granett J, Omer A D. (1999). Differences in grape phylloxera-related grapevine root damage in organically and conventionally managed vineyards in California. *Hort science*, 34(6): 1108-1999. [Crossref], [Google Scholar], [Publisher]
11. Wang R, Xu H, Mridha M. (2000). Nitrogen metabolism affects resistance to Phytophthora. *J Crop Prod.,* 3(1): 77-84. [Google Scholar]
12. Mandelbaum R, Hadar Y. (1990). Effect of available carbon source on microbial activity and suppression of *Pythium aphanidermatum* in compost and peat container media. *Phytopathology,* 80(9): 794-804. [Google Scholar], [PDF]
13. Hu S, Van Bruggen A H C, Wakeman R J, Grunwald N J. (1997). Microbial suppression of in-vitro growth of *Pythium ultimum* and disease incidence in relation to soil C and N availability. *Plant and Soil,* 195(1): 43-52. [Crossref], [Google Scholar], [Publisher]
14 Hoitink H A J, Boehm M J. (1999). Biocontrol within the context of soil microbial communities: A substrate-dependent phenomenon. *Annual Review Phytopathology,* 37: 427-46. [Crossref], [Google Scholar], [Publisher]
15. Ismail, S. (2021). Cholinesterase and Aliesterase as a Natural Enzymatic Defense against Chlorpyrifos in Field Populations of Spodoptera Littoralis (Boisdüval, 1833) (Lepidoptera, Noctüidae). *Journal of Plant Bioinformatics and Biotechnology*, *1*(1), 41-50. [CrossRef], [Google Scholar], [Publisher]

16. Naddaf, M., Rabiei, G., Ganji Moghadam, E., Mohammadkhani, A. (2021). In vitro Production of PPV-free Sweet cherry (Prunus avium cv. Siahe-Mashhad) by Meristem culture and micro-grafting. *Journal of Plant Bioinformatics and Biotechnology*, *1*(1), 51-59. [CrossRef], [Google Scholar], [Publisher]
17. Sezhian N. (1999). Soya fights red rot in sugarcane. *Kisan World*, 4: 44-45. [Google Scholar]
18. Fazeli-Nasab, B., Rahmani, A., Khajeh, H. (2021). Effects of culture medium and plant hormones in organogenesis in olive (CV. Kroneiki). *Journal of Plant Bioinformatics and Biotechnology*, *1*(1), 1-13. [CrossRef], [Google Scholar], [Publisher]
19. Hassabnis S N, Kulkarni S, Patil BN. (1997). Role of nitrogen fertilization and host plant density in the management of leaf rust incidence in wheat. *J. Maharashtra Agric. Univ.,* 26(3): 254-56. [Google Scholar], [Publisher]
20. Ghewande M P. (1982). Diseases of groundnut and their management. Annual Report NRCG, Junagarh. Pp 34-42. [Google Scholar]
21. Chandra K, Greep S. (2005). Biocontrol agents and biopesticides (liquid formulations), Regional Centre of Organic Farming, Bangalore. [Google Scholar]
22. Gaur R B, Sharma R N. (2010). In: Proceeding of Validation of some traditional wisdom of farming communities of semi-arid region of Rajasthan, India-Regional review International Conference on Traditional Practices in Conservation Agriculture. Choudhary SL, Khandelwal SK and Nene YL (Eds).September 18-20, 2010. pp 142-51. [Google Scholar]
23. Khajeh, H., Fazeli, F., Mazarie, A. (2021). Effects of Culture Medium and Concentration of Different Growth Regulators on Organogenesis Damask rose (Rosa damascena Mill). *Journal of Plant Bioinformatics and Biotechnology*, *1*(1), 14-27. [CrossRef], [Google Scholar], [Publisher]
24. Rensing C, Zhang H L, Kellock M, Palojärvi A, Parikka P, Jauhiainen L, Alakukku L. (2020). Tillage System and Crop Sequence Affect Soil Disease Suppressiveness and Carbon Status in Boreal Climate. *Front. Microbiol.*, 11: 534786. [Crossref], [Google Scholar], [Publisher]
25. Peters R D, Sturz A V, Carter M R, Sanderson J B. (2003). Developing disease-suppressive soils through crop rotation and tillage management practices, *Soil and Tillage Research*, 72(2): 181–192. [Crossref], [Google Scholar], [Publisher]
26. Jalli M, Huusela E, Jalli H, Kauppi K, Niemi M, Himanen S, Jauhiainen L. (2021). Effects of Crop Rotation on Spring Wheat Yield and Pest Occurrence in Different Tillage Systems: A Multi-Year Experiment in Finnish Growing Conditions. *Frontiers in Sustainable Food Systems*, 5(July): 1–14. [Crossref], [Google Scholar], [PDF]
27. Tamburini G, De Simone S, Sigura M, Boscutti F, Marini L. (2016). Soil management shapes ecosystem service provision and trade-offs in agricultural landscapes. *Proceedings of the Royal Society B: Biological Sciences*, 283(1837): 20161369. [Crossref], [Google Scholar], [Publisher]
28. Naderi, D., Jami, R., Rehman, F. (2021). A Review of RNA Motifs, Identification Algorithms and their Function on Plants. *Journal of Plant Bioinformatics and Biotechnology*, *1*(1), 28-40. [CrossRef], [Google Scholar], [Publisher]
29. Cooper J, Baranski M, Stewart G, Nobel-de Lange M, Bàrberi P, Fließbach A, Peigné J, Berner A, Brock C, Casagrande M, Crowley O. (2016). Shallow non-inversion tillage in organic farming maintains crop yields and increases soil C stocks: a meta-analysis. *Agronomy for Sustainable Development*, 36(1): 1-20. [Crossref], [Google Scholar], [Publisher]
30. Liebman M, Davis A S. (2000). Integration of soil, crop and weed management in low-external-input farming systems. *Weed Research*, 40(1): 27–47. [Crossref], [Google Scholar], [Publisher]
31. Baysal-Gurel F, Gardener B M, Miller S A. (2012). Soilborne disease management in organic vegetable production. *Organic Agri.* [Google Scholar], [Publisher]
32. Panth M, Hassler S C, Baysal-Gurel F. (2020). Methods for Management of Soilborne

Diseases in Crop Production. *Agriculture*, 10: 16. [Crossref], [Google Scholar], [Publisher]
33. Rotem J Palti J. (1969). Irrigation and plant diseases. *Annu. Rev. Phytopathol*., 7: 267-288. [Crossref], [Google Scholar], [Publisher]
34. Lopes C, Marouelli W, Café Filho A. (2006). Association of irrigation with vegetable diseases.*Annual Review of Plant Pathology*, 14: 151-179. [Crossref]
35. Bhat R G, Subbarao V. (2001). Cultural control. In: Maloy, O.C., Murray T.D., editors. Encyclopedia of Plant Pathology 1. New York, NY, USA: John Wiley & Sons. pp. 274-279. [Crossref]
36. Goldhamer D A, Michailides T J, Morgan D P. (2002). Buried drip irrigation reduces fungal disease in pistachio orchards. *California Agriculture*, 56(4): 133-138. [Crossref], [Google Scholar], [Publisher]
37. Montazar A, Cahn M, Putman A. (2019). Research Advances in Adopting Drip Irrigation for California Organic Spinach: Preliminary Findings. *Agriculture,* 9: 177. [Crossref], [Google Scholar], [Publisher]
38. Aissat K, Nicot P, Guechi A, Bardin M, Chibane M. (2008). Grey mould development in greenhouse tomatoes under drip and furrow irrigation. *Agronomy for Sustainable Development*, 28(3): 403-409. [Crossref], [Google Scholar], [Publisher]
39. Jeger M J, Jeffries P, Elad Y, Xu X M. (2009). A generic theoretical model for biological control of foliar plant diseases. *J. Theor. Biol.*, 256: 201-214. [Crossref], [Google Scholar], [Publisher]
40. Hjeljord L, Tronsmo A. (1998). *Trichoderma* and *Gliocladium* in biological control: an overview. *Trichoderma* and *Gliocladium*, Enzymes, Biological Control and Commercial Applications, 2: 131-151. [Crossref], [Google Scholar], [Publisher]
41. Gupta V K, Misra A K. (2009). Bioefficacy of bioagents against Fusarium wilt of guava. *J. Mycol Pathol*, 39(1): 101-106. [Google Scholar], [PDF]
42. Anonymous. (2010). DARE/ ICAR Annual report 2009-10.Crop management. Pp. 48-63. [Crossref]
43. Anonymous. (2014). DARE/ ICAR Annual report 2013-14. Crop management. Pp. 56-67. [Crossref]
44. Anonymous. (2017). DARE/ ICAR Annual report 2016-17.Crop management.Pp. 216. [Crossref]
45. Anonymous. (2018). DARE/ ICAR Annual report 2017-18.Crop management. Pp. 189. [Crossref]
46. Bubici G, Kaushal M, Prigigallo M I, Gómez-Lama Cabanás C. Mercado-Blanco J. (2019). Biological Control Agents Against Fusarium Wilt of Banana. *Fron. Microbio.,* 10: 616. [Crossref], [Google Scholar], [Publisher]
47. Anonymous. (2005). The Planters' Handbook. Digitised and published by Tocklai Experimental Station, Tea Research Association, Jorhat – 785008, Assam. Pp. 131.[Crossref]
48. Barthakur B K, Dutta P. (2011). Disease management in tea. pp. 182-188. In: Tea field management. A compilation of lecture notes. Editor – B. K. Goswami. [Crossref]
49. Anonymous. (2009). DARE/ ICAR Annual report 2008-09.Crop management. Pp. 46-59. [Crossref]
50. Kumhar K C, Babu A, Bordoloi M, Banerjee P, Dey T. (2015). Biological and chemical control of *Fusarium solani*, causing dieback disease of tea *Camellia sinensis*(L): An in vitro study. *Int. J. Curr. Microbiol. App. Sci*, 4(8): 955-963. [Google Scholar], [PDF]
51. Kumhar K C, Babu A, Bordoloi M, Benarjee P, Rajbongshi H. (2016). Comparative bioefficacy of fungicides and *Trichoderma* spp. against *Pestalotiopsis theae*, causing grey blight in tea (*Camellia* sp.): An in vitro study. *Int. J. Curr. Res. Biosci. Plant Biol.*, 3(4): 20-27. [Crossref], [Google Scholar], [Publisher]
52. Kumhar K C, Babu A, Arulmarianathan J P, Deka B, Bordoloi M, Rajbongshi H J, Dey P. (2020). Role of beneficial fungi in managing diseases and insect pests of tea plantation. *Egyptian Journal of Biological Pest Control*., 30(78): 1-9. [Crossref], [Google Scholar], [Publisher]