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A REVIEW: SOFT ROT OF GINGER (*ZINGIBER OFFICINALE*) CAUSED BY *PYTHIUM* AND ITS CONTROL & MANAGEMENT STRATEGIES

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ABSTRACT
Ginger (*Zingiber officinale*) is an important spice crop in India. It has great importance as commercial crop. India is one of the leading producer and exporter of ginger in the world. During cultivation, harvesting and storage the crop is infected by various diseases. The economically important disease associated with ginger is soft rot of ginger rhizomes. The disease reduces the potential yields of ginger drastically. In the present review paper the causal organism, disease cycle, epidemiology, losses, symptoms, host resistance, cultural, chemical, integrated management and the biological control measures of soft rot disease of ginger have been discussed.

KEYWORDS: causal organism, disease cycle, epidemiology, losses.

Ginger general introduction

Ginger is a tropical plant cultivated all over the world due to its culinary and medicinal properties. It is one of the most important spices commonly used in food, which increases its commercial value. It is a globally known food and flavoring ingredient which is also reputed for its wide range of medicinal properties. Ginger is considered as one of the most important members of the Zingiberaceae family, which possesses enormous medicinal, nutritional, and ethnomedicinal properties and hence, it has been extensively used as a spice, flavoring agent, and herbal remedy all over the world. The rhizomes of ginger consists of a unique homologous series of compounds ie. gingerols, shagols which are the major phenolic plant secondary metabolites responsible for its unique flavor and health benefits. The rhizome of ginger commonly contains carbohydrates, proteins, fats, fiber, water, and essential oils. Therefore, it is effectively used for the treatment of common cold, headache, nausea, and stomach ache (Gupta and Sharma 2014). In addition to its nutritional and flavoring applications, ginger has potential uses in traditional medicine for multiple health benefits (Le et al. 2014). As far as the medicinal properties are concerned, ginger possess antimicrobial, anti-inflammatory, antipyretic, antioxidative, hypoglycemic, hepatoprotective, diuretic, and anticancerous properties (Karuppiah and Rajaram 2012). Ginger also has a great potential health benefits including its chemopreventive, blood pressure-lowering, cholesterol-lowering and antiplatelet aggregation properties (Kumara et al. 2017).

The world trade in ginger is estimated at about US$190 million per year. The total production of ginger in the world is about 60–70%. Out of this, almost 30% is converted to dry ginger, 50% is used as green ginger, and the rest of the 20% is utilized as seed materials (Parveen and Sharma 2014).

Considering the huge importance of ginger, the total area under its cultivation has been increased time to time for the enhanced production, but unfortunately, it is declined over time due to various disease associated with it. During cultivation, harvesting, storage and marketing the crop is severely affected by soft rot and reduce its potential yields drastically.

International Status

Global consumption of ginger is increasing every day, as World Ginger market is growing at a speed of 10% annually in terms of quantity. It is also reported that the price of Ginger is also growing at 12% per annum. India, Nigeria, Ethiopia and Peru are some countries those have gained the market in terms of quantity though they all have loosened in terms of price. The world trade trends of 2012 showed that there is a growth of 11% on the value of ginger and 8% growth in the quantity during the five year trade. The global ginger market grew at a CAGR (Compound annual growth rate) of 4.8% between 2016 and 2020. The global ginger processing market is expected to grow at a CAGR of 13.40% during 2021-2026. On the basis of the packaging, the market has been bifurcated into the food industry, pharmaceutical industry, cosmetic industry and others. Among these, the food industry holds the majority of the total market share.USA is the first choice as a demanding market for ginger producing counties to export the Ginger. Germany, Japan, Netherland, United Kingdom, Lithuania are other attractive markets. The demand and need of ginger and its products are increasing with the time.

If we consider the amount of the value received by the exporting country, India is the largest Exporter in the world. In year 2012 India has exported ginger of worth $ 42.91 Million. Ethiopia and Nepal are listed thereafter. But if we consider quantity Nepalese ginger export is placed in first position with 46.53 thousand tons in the year 2012. India is second with 32.82 thousand tons and Ethiopia, Nigeria, Chinese Taipei, Malaysia are then after.

Although the area under production in India is large as comparison to other countries but yield and quality is low. Decrease in production and quality is mainly associated with the diseases infection by various fungal, bacterial and viral pathogens.

National Status

Ginger (*Zingiber officinale* Roscoe) is an important spice crop in India. India is the leading producer and exporter of ginger in the world. The productivity of ginger in India is 40,903MT with annual income of Rs. 44.04 crores in the year 2010-2011 (Dohroo *et al*., 2012). The important ginger-producing states of India include Meghalaya, Arunachal Pradesh, Karnataka, Orissa, Assam, Gujarat, and Kerala, which altogether contributes about 65% to the country's total ginger production (M.Roy et al. 2018).

India is inferior in comparison to other ginger producing countries like China, Nigeria and Ethiopia. This is because of low productivity and infection with rot causing fungi *Pythium* and other fungal, bacterial and viral diseases. But India has advantage because the Middle East, USA, UK are the principle buyers and they purchase ginger from India (www.indiaagronet.com).

Among these, India is one of the largest producers of ginger with the crop occupying maximum area and production(Gupta and Kaushal 2017). According to the newspaper, The Hindu Business Line, dated April 20, 2017, India is the top producer of ginger in 2015– 2016 with an estimated production of 799,860 tons from 153,450 ha of lands. However, in terms of area under cultivation, Nigeria and China are at the top. China and India contributed almost 50% of world's ginger production (https://www.pressreader.com/india/the-hindu-business-line/20170420/282144996223449).

The most common forms of ginger production in India are raw, powder, bleached, oil, oleoresins, fresh in brine, pickled, candied, garbled and as a syrup (www.indiaagronet.com). But inferior quality due to various ginger diseases decreases the commercial value of Indian ginger.

Rajasthan is the single largest producer of many spices like Chilli, turmeric, ginger, fennel, dill seeds and garlic (agricommodityprices.com/2010). Ginger has dual importance as spice and medicine. In Rajasthan ginger is grown in Udaipur, Chittor, Dungarpur and Banswara. Among total area under ginger production, approximately 90% ginger produced in Jhadol block (a tribal-dominated block) of Udaipur district.

However, during the last 10 years both the area under cultivation and average productivity of ginger have shown a declining trend due to severe rot attack caused by *Pythium* species. Traditionally, a large number of farmers cultivated ginger in this region, but many gave up its cultivation owing to the frequent ginger rot disease that destroyed the crops (Access 2008).

Hence there is an urgent need to let the farmers know about how to handle with the ginger farms and how to protect the crop. So they may again join their traditional crop farming. This review will be beneficial for the researchers as well as for the agricultural employees and for farmers as they may get guidance for ginger farming from their local kisan seva Kendra, Kisan Mitra etc.

Soft Rot disease of ginger

In high temparature and humid conditions, this disease is considered serious problem and cause significant yield losses. It is prevalent in almost all ginger growing areas of the world. Soft rot of ginger rhizome was first recorded during the year 1907 from Surat, Gujrat, India (Butler, 1907). In Southern Rajsthan the climatic conditions are very favorable for ginger rot disease. Southern Rajsthan has a warm climate and good temperature for the growth of *Pythium* spp.

Symptoms

Ginger crop is affected by this disease not only throughout the growing period but after harvesting, during marketing and storage also. Almost all parts of the plant including sprouts, roots, developing rhizome and collar region of the pseudostem are susceptible to infection. Symptoms of soft rot first appear on above ground parts at the collar region in the form of soft watery, brown lesions. These lesions then slowly enlarge and coalesce, causing the stem to rot and collapse (Dohroo, 2005). On the leaves, the primary symptoms caused by the basal infection which appear as yellowing of the tips of older leaves first with the chlorosis gradually moving towards down along their margins involving the rest of the leaf blade and eventually the leaf sheath. As the older leaves progress the younger once start to develop similar symptoms progression unless the entire plant dies (ISPS, 2005).Once it happens, infected stems are easily dislodged because of change in the structural integrity. Rhizomes from diseased plants appear brown, water soaked, soft and rotten, and it get decayed gradually (Dohroo, 2005).

Causal Organism

Several species of *Pythium* (*Pythium aphanidermatum* (Edson) Fitz, *P. myriotylum* Drechsler, *P. spinosum* Sawada, *P. splendens* Braun, *P. ultimum* Trow, *P. deliense* Meurs, *P. graminicola* Subram etc.) have been reported to cause soft rot disease in ginger in different parts of the world. *Pythium* spp. are fungal-like microorganisms belonging to the family *Pythiaceae* of the order *Peronosporales* of the phylum *Oomycota*. It is a member of the kingdom Stramenopila (Webster and Weber, 2007). *Pythium aphanidermatum* is one of the most notorious and virulent member of the family. The mycelium of *P. aphanidermatum* are colourless, sometimes lustrous and occasionally slightly yellowish due to abundant oospores or hyphal swellings or they maybe grayish lilac (Dohroo *et al*., 2012). The main hyphae are up to 10 µm wide. Sporangia consisting of terminal complexes of swollen hyphal branches of varying length and up to 20 µm wide. Oogonia terminal, globose, smooth, 20-25 µm in diameter. Anthredia are mostly intercalary in position, sometimes, broadly sac shaped, 10-14 µm wide Oogonium, monoclinous or diclinous, oospores aplerotic (18-22 µm) in diameter, wall 1-2 µm thick. Sporangia are never detached from the hypha. The oospores are smooth walled, plerotic (oospore wall fused with oogonial wall) and they are spherical in shape measuring 12.0-20.0 µm in diameter (Dohroo, 1982). Zoospores are flagellated and are released either by a pore developed at the tip of sporangium or by bursting of vesicle.

Disease cycle and epidemiology

There are mainly two ways by which the disease is carried over and propagated firstly by diseased rhizomes as oospores in scales (Thomas, 1938) and secondly through oospores present in the soil. *Pythium* species are capable of saprophytic survive very well in plant debris. The infected plant debris present/remaining in the field are the important source of primary inoculum. Such plant parts may contain large number of perennating oospores. The disease is both seed and soil borne. The wet soil conditions, high soil moisture and soil temperature are the most important factors influencing the development of rot of rhizome disease. Severity of disease is more in areas where rainfall is high or rhizomes are planted in heavy clay soil and if soil has less porosity and poor drainage. The optimum temperature for germination of *P. aphanidermatum* and *P. myriotylum* is about 34^{o}C (maximum is 40^{o}C). A warm and humid climate predisposes the plant to infection at sprouting stage, because of its tender and succulent tissues (Dake, 1995).

Control Measure & Management

Soft rot is considered a complex disease problem. To control this notorious pathogen, various available methods should be combined to obtain significant results against this devastating disease.

Cultural practices

Cultural practices including seed selection, organic amendment, crop rotation, tillage, drainage and quarantine are commonly employed in ginger fields to control the soft rot and to limit the spread of this notorious *Pythium* spp. in fields that are unaffected (Le *et al*., 2014). Infected rhizomes are basic source of spread of disease. The best method to manage the disease is the use of disease free rhizomes during planting (Dohroo, 1993). Harvey and Lawrence (2008) suggested that the crop rotations could change *Pythium* spp. populations and potential inoculum could be reduced to some extent by the process of crop rotation. Rames *et al.* (2013) were also had the conclusion that crop rotation is good to decrease the disease severity in ginger pots. Soil amendments alter the soil reaction, change the spectrum of soil microflora and thus affect the pathogens existing in soil (Dohroo, 1993; Dohroo and Pathania, 1997). Smith and Abbas (2011) suggested that good water drainage is very important in soft rot control and management because of zoospores production by *Pythium* spp. Zoospores are motile and able to swim and spread in free water.

Organic Amendments

Organic matters are important for plants and help to overcome the plants against pathogen attack. Organic matter influences physical characters of soil such as pore size, aeration, temperature, water retention capacity etc. which help in better solubilization of minerals. They also provide nutrients on decomposition. Chen *et al.* (1988a,b) reported that organic matter suppress the growth of *Pythium.* Reduction in soft rot incidence was observed after the addition of soil amendments like oil seed cakes, neem cake and other organic matter in field condition (Sadanandan and Iyer, 1986; Thakore *et al.*, 1987). Integration of neem seed powder and punarnava (*Boerhavia diffusa*) leaves, instead of poultry manure, into soil at the time of land preparation also reduced soft rot intensity in ginger by up to 89% in comparison to the untreated control (Gupta *et al.*, 2013).

Amendment of organic matter, including poultry manure and sawdust (200 t/ha) enriched diversity of soil microbial communities in the ginger fields (Rames *et.al.*, 2013). These practices also increased soil carbon levels and water infiltration rates which supported growth and yield of ginger and helped to suppress soft rot on ginger (Smith *et al*., 2011; Stirling *et al.*, 2012). Neem seed cake was found most effective with least average mortality of 20.3 per cent followed by poultry manure (22.7%) while evaluating organic and inorganic amendments to manage rhizome rot in pot culture studies (Kadam *et al*., 2014). Kumar *et al*. (2012) also found that *Schima wallichii* and *Datura* spp. were the best mulches with regard to suppressing soft rot caused by *P. aphanidermatum* with the level of disease incidence at 12 and 14%, respectively, compared to 48% in a non-mulched treatment. Suppression of *Pythium* spp. by organic amendment is also reported by Inbar *et al.*, 1991;

Craft and Nelson, reported the antifungal activity of vermicompost against *Pythium.* Noble and Coventry, (2005) reported that soil amended with vegetable composts provided 20-60 per cent reduction in *Pythium.* Raoudha *et al.*(2009) reported the effect of bacterial isolates from compost amended with solid olive mill wastes against *P. aphanidermatum.* Poudyal (2011) concluded that soil amended with organic manure, reduces disease severity and plays vital role in soft rot control in ginger and may provide an economically acceptable approach for management of the disease in various crops. It is likely, however, that specific components of the compost microflora contribute disproportionately to disease suppression, through the production of antifungal metabolites or by other mechanisms.

Addition of organic matter improves crop yield mainly by enhancing soil fertility. Considerable improvements in soil structure, water retention capacity and aeration in different types of soils have been observed following the addition of green manures, farm yard manures and other organic matter. Another additional advantage of using organic matter is the activation of many beneficial microbes antagonistic to soil borne pathogens, leading to disease suppression (Vidyasekaran, 1988).

Sadanandan and Iyer (1986), reported neem oilcake @ 2mt/ha gave reduction of rhizome rot disease of ginger and increased yield by 1.78mt/ha. Thakore, (1987) also reported that,neem oil cake as well as other oil cakes has also been shown to reduce ginger rhizome rot caused by *P. aphanidermatum*. Rajan and Singh, (1973) also reported that soil amendments with castor, groundnut, sesamum, margosa, coconut oil cakes and sawdust with and without incorporation of urea were significant against *Pythium* in ginger soft rot. Dataram, (1988) also reported that soil amendment with wood sawdust also reduced the *Pythium* incidence in ginger. The bioorganics were found effective against ginger rot up to 85 to 90% and increase the plant yield by suppressing the pathogen and increasing the metabolic activity of plants.

Cow dung compost is also reported to be significant against *P. aphanidermatum* (Muhammad and Amusa 2003). Larbi, (2006) observed the presence of *Pseudomonas aeruginosa* and *Rhizobium radiobacter* in cow dung manure, both bacterial isolates were found significant against *P. ultimum* and *P. aphanidermatum*. Maha panchgavya, a concoction made from five cow products was tested against *P. aphanidermatum* causing damping-off and reported 48.2 per cent control of disease in *in vivo* condition (Kumar *et al.,* 2010).

Chemical management

Pythium spp. can survive in the soil for a long period once introduced (Hoppe, 1966). Therefore, the management of soft rot becomes difficult. Chemicals such as mancozeb, ziram, guazatine, propineb and copper oxychloride effectively controlled soft rot when used as 30 minutes dip treatments for rhizomes (Dohroo and Sharma, 1986; Thakore *et al.*, 1988). An experiment conducted on a naturally infested field with *P. aphanidermatum* in Raigarh, India, showed that seed dipping applications with Ridomil MZ at a rate of 1.25 g/L could increase survival of rhizomes by about 30 percent in comparison to hot water treatment at 51oC for 30 min (Singh, 2011). Seed coating with Fytolan (copper oxychloride) 0.2 percent + Ridomil 500 ppm + Bavistin (carbendazim) 0.2 percent+ Thimet could keep ginger rhizomes free from soft rot in a pot trial (Rajan *et al*., 2002). Similarly, Smith and Abbas (2011) found that fungicides such as metalaxyl, Ridomil, Maxam XL (fludioxonil) and Proplant (propyl carbamate hydrochloride) applied as a seed treatment could give significantly better control of soft rot caused by *P. myriotylum* than sole carbendazim seed treatment in a pot trial.

Different chemicals have also been tested by various workers as soil drench against soft rot of ginger. Soft rot was reduced by zineb, captafol, methyl bromide, mercuric chloride, thiram, phenyl mercury acetate, copper oxide and mancozeb (Doshi and Mathur, 1987). Dohroo *et al.* (1984) found metalaxyl application quite effective for the control of rhizome rot. Dipping of seed one day before planting and soil drenching with a mixture of metalaxyl plus captafol 3 months after planting controlled soft rot of ginger (Rathaia,1987). Fosetyl-Al, metalaxyl, oxadixyl, propamocarb and ethazole (epidiazole) were also evaluated against *P.aphanidermatum.* Metalaxyl formulations (Ridomil 5G and Apron 35 WS) gave best control of the disease when used as soil and seed treatments (Ramachandran *et al*., 1989). Srivastava (1994) managed soft rot (*P. aphanidermatum*) in Sikkim effectively by drenching the soil with zineb or mancozeb following rhizome treatment with carbendazim and incorporating Thiodan dust into the soil to control insect invasion. Nath (1993) suggested planting of ginger under shade after treating with 1 per cent formaldehyde. Treated rhizomes grown under shade had 19.4 per cent incidence of soft rot (*P. myriotylum*) as compared to 41.3 per cent incidence in treated rhizomes grown without shade.

Biological management

Trichoderma spp. are the most widely used biocontrol agents for control of soft rot of ginger. Non-volatile and volatile compounds produced by *T. viride* could inhibit the growth of *P. myriotylum* recovered from infected ginger by 70 and 100%, respectively when assessed *in vitro* (Rathore *et al*., 1992). In addition, *T. harzianum* and *T. saturnisporum* also showed strong antagonism against *P. splendens in vitro* (Shanmugam *et al*., 2013a). Along with *Trichoderma* spp., several rhizobacteria were also antagonistic and showed significant inhibition of *P.myriotylum* growth in dual culture assays (Bhai *et al*., 2005).

Dohroo *et al*. (2012) found that growth of *P.aphanidermatum* on PDA amended with onion and garlic extracts at 5% and 7.5% (v/v), respectively, was completely inhibited by poisoned food technique. Fresh and stored cow urine also strongly inhibited the growth of *P.aphanidermatum* at a concentration of 20% (v/v) by using the similar technique (Rakesh *et al.*, 2013). Use of *Jeevatu*, particularly *Jeevatu* based organic liquid manure, was found to play a vital role in soft rot control and no further spread of the disease was observed after the application of *Jeevatu* based organic liquid manure in the field in Lalitpur district of Nepal (Poudyal, 2012).

Ram *et al*. (2000) found that the percent of soft rot on *Trichoderma.* spp. coated ginger was 2-3 times less than that of the untreated control. Suppression of soft rot was even better, reducing soft rot incidence up to four times, once seed ginger was first surface disinfested with 1% HOCl for 5 min and soaked in a suspension of *Trichoderma* spp. talc-based formulation (6 x 107 CFU/L) and followed by three applications of talc-based formulation (3 x 106 CFU/ g) to the soil at 15 day intervals from the time of planting (Shanmugam *et al.*, 2013b). An application of *T. harzianum* + *Glomus mosseae* + fluorescent Pseudomonad strain G4 limited infection of *P. splendens* to 10% compared with 30, 43, and 50% infection in treatments with *T. harzianum*, *G. mosseae*, and G4 as single treatments, respectively (Gupta *et al.*, 2010). Moreover, antagonists also play a role as plant growth promoters. Growth and yield of ginger growing in soil with antagonistic agents were better compared to soil without biocontrol agents application (Bhai *et al.*, 2005; Gupta *et al.*, 2010; Shanmugam *et al*., 2013a). A mixture of *Burkholderia cepacia* + *T. harzianum* recorded a maximum rhizome production efficiency of 84% with reduction of soft rot incidence of 79.7% under polyhouse conditions. Such reduction of soft rot incidence was attributed to the increase in products of defense gene chitinase and which might be involved in disease suppression.

In field experiments, the same mixture reduced the rhizome rot up to 49.3% and an increased rhizome yield with an average increase of 60.0% over the untreated control (Shanmugam *et al*., 2013b). Praveen and Sharma (2014) screened crude extracts of 20 plant species against *P. aphanidermatum in vitro* and found that *Jacaranda mimosifolia*, *Moringa olifera* gave the best inhibitory activity of 27.7%. Lumsden *et al.* (1983), Hadar and Mandelbaum, (1986); Mandelbaum *et al.* (1988); Mandelbaum and Hadar, (1990) reported that organic materials like poultry waste showed antifungal activity against *Pythium*. Teodore and Toribio, (1995) reported that sugarcane residues, poultry slurry and municipal bio-solids also showed disease suppressing activity against ginger rot caused by *Pythium.* Many researchers reported antifungal activity of plant extracts against many fungal species.

Host resistance

Developing a *Pythium* resistant variety would be ideal for effective soft rot disease management. Indrasenan and Paily (1974) reported that Maran cultivar was resistant against soft rot caused by *P. aphanidermatum.* Setty *et al.* (1995a) evaluated eighteen ginger cultivars against soft rot (*Pythium* sp.) under field conditions and none was found resistant, however, cultivars Supraba and Himachal Pradesh demonstrated less than 3 per cent disease incidence. Senapati and Sugata (2005) screened 134 ginger varieties available in Koraput, Orissa, India and found one resistant cultivar and eight others with moderate resistance. Kavita and Thomas (2008) found that the accessions of *Zingiber zerumbet* were the most suitable candidates for donating soft rot resistance to cultivated ginger. Bhai *et al.* (2013) screened 650 ginger accessions and showed that only 7 percent of the accessions were having the relative resistance to the pathogen.

The disease is important because it causes economic losses to growers resulting in decreased prices of products to the consumers. It is very important to identify the factors affecting disease severity and to develop control measures for rhizome rot. Control measures such as seed treatment, soil treatment, soil amendment, sanitation, drainage, intercropping etc. have some effect in controlling the disease.

Management of *Pythium* spp by Nanotechnology

Nanotechnology offers an ecofriendly alternative for plant disease management and has many advantages over conventional chemical methods, which are associated with ecotoxicity. Nanomaterials in agriculture aims to decrease the quantity of chemicals by smart delivery of active ingredients (Gogos et al. 2012). Nanoparticles can sustainably increases the ways in agriculture yield and mitigate the present implications (Fraceto et al. 2016). Different types of nanoparticles are used in agriculture, which depends upon the mode of action. The widely used nanoparticles include silver, gold, copper, titanium, zinc, silica, aluminum, chitosan, and sulfur. (Sabir et al. 2014). The use of nanoparticles suppress the growth of pathogens as well as promote the vegetative growth of that plant (El-Argawy et al. 2017). Ponmurugan et al. (2016) Nanoparticles possess strong antifungal activity against various plant pathogens and also help to maintain the soil nutrients status of NPK. Nanoparticles can also inhibit the growth of pathogenic fungi (Khan and Rizavi 2014). Nowadays, nanotechnology-based new products are launched in market due to their immense benefits. The controlled release of active ingredients can be achieved through nanoparticles as a carrier for chemicals these formulations may decrease the amount of fungicide input and environmental hazards (Manjuntha et al. 2016).

Integrated management

Management of soft rot is difficult by following a single approach because it does not work effectively to suppress the pathogens under field conditions. Therefore, an integrated approach was suggested by Smith and Abbas (2011) which was mainly based on cultural practices and a strict quarantine procedure to manage the disease, while Mathur *et al.* (2002) found that soil solarization and application of fungicides could effectively minimize the incidence of soft rot caused by *P. myriotylum*.

Rhizome treatments with Ridomil MZ (metalaxyl +mancozeb) at 6.25 g/L in addition to soil drench with Thimet (Phorate) and Ridomil MZ at 10 L/3x1 m plot at 60 days after sowing gave the best control of *P. myriotylum* on an experimental ginger field in southern Rajasthan, India. The treatments performed even better in solarized plots achieved by sealing thick transparent polythene film over the soil surface for 20 days. Lokesh *et al.* (2012) suggested that seed ginger could be solarized at 47^{o}C under 200 mm polyethylene sheet for 30 min for *Pythium* spp. disinfestations. However, longer periods (up to 4 weeks) of soil solarization caused significant reduction in the populations of *Pythium* spp. and a lower disease incidence in solarized plots (Deadman *et al*., 2006). Dohroo and Gupta (2014) reported combined applications of bioagents more effective in reducing the disease than the individual treatments. *T. harzianum+ P.fluorescens + B. subtilis* gave minimum disease incidence on rhizomes (8.64 %) as well as on tillers (12.50 %). Copper oxychloride rhizome treatment effectively suppressed the disease development (5.16%) at 150 days after planting in the field followed by neem extract rhizome treatment (Lalfakawma *et al*., 2014). A two years field study indicated that rhizome treatment in hot water at 47°C for 30 min and soil application of *T. harzianum* @ 2.5 kg/ 50 kg FYM/ha, followed by three drenching of mancozeb @ 0.25% were most effective in limiting the incidence of soft rot on ginger besides having their significant response in improving the growth and yield (Dohroo *et al*., 2015). However, soft rot (rhizome rot) is a common disease of ginger caused by *Pythium* spp. It is the most destructive disease of ginger, which can reduce the production by 50 to 90%. Application of chemical fungicides is considered as an effective method to control soft rot of ginger but extensive use of fungicides pose serious risk to environmental and human health. Therefore, the development of ecofriendly and economically viable alternative approaches for effective management of soft rot of ginger such diseases is essentially required. An acceptable approach that is being actively investigated involves nanotechnology, which can potentially be used to control *Pythium* spp. specially *P. aphanidermatum.* The present review is aimed to discuss the various methods available for the management of *Pythium* spp. the important causal agent for soft rot of ginger.

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