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Abhijit Debnath
Subject Matter Specialist (Horticulture) KVK, Dhalai, Tripura, India

Rubin Debbarma
Subject Matter Specialist (Plant Protection) KVK, Dhalai, Tripura, India

Bapi Das
Scientist, ICAR NEH Region, Tripura Centre, Lembucherra, Debendrachandranagar, Tripura, India

Agniva Halder
PhD Scholar Department of Horticulture & PHT, Palli-Siksha Bhavana-Visva Bharati, Sriniketan, West Bengal, India

Pradipto Kumar Mukherjee
MSc (Horticulture), Department of Horticulture & PHT, Palli-Siksha Bhavana-Visva Bharati, Sriniketan, West Bengal, India

Corresponding Author:
Abhijit Debnath
Subject Matter Specialist (Horticulture) KVK, Dhalai, Tripura, India

Review on recent advances in integrated management of ginger soft rot disease

Abhijit Debnath, Rubin Debbarma, Bapi Das, Agniva Halder and Pradipto Kumar Mukherjee

Abstract
India is one of the world's top producers and exporters of ginger (*Zingiber officinale* Roscoe), making it a significant spice crop. The crop is badly affected by a number of diseases during cultivation, the most significant of which are soft rot, *Phyllosticta* leaf spot, bacterial wilt, storage rot, mosaic, yellows, and chlorotic fleck. Ginger rhizome rot is a seed (rhizome) and soil-borne disease, with soil having a significant impact on the occurrence and severity of the disease. The physical and chemical characteristics of the soil are a major factor in the severity of the ginger rhizome rot disease. These illnesses significantly lower the prospective profits. Integrated pest management (IPM) strategies that use appropriate microbial agents like *Streptomyces* spp., *Bacillus subtilis*, *Pseudomonas* spp., and *Trichoderma harzianum* to control soft rot are becoming more and more popular. These strategies aim to sustainably increase ginger production while also improving its medicinal and pharmaceutical properties. This study examines the geographic distribution, symptoms, losses, host resistance, disease cycle, causal organism, epidemiology, biological, chemical, and integrated control and management of the aforementioned diseases.

Keywords: *Zingiber officinale* Roscoe, soft rot, *Phyllosticta*, geographical distribution, resistance, IPM

Introduction

Ginger (*Zingiber officinale* Rosc.) is a herbaceous perennial whose rhizomes are used as a spice. India is one of the world's top producers of ginger. Several regions of the world have ginger farms. Odisha, Kerala, Karnataka, Arunachal Pradesh, West Bengal, Sikkim, and Madhya Pradesh are among the Indian states that grow ginger (Kumar *et al*. 2008) [17].

It can become rather dangerous and result in large losses when it's warm and muggy outside. Practically every region in the globe where ginger is grown has it. In the year 1907, the disease was initially noted in Gujarat, Surat, India (Butler, 1907) [4].

In India, different ginger-growing regions produce a variety of ginger cultivars, most of which bear the names of the regions in which they are raised. Maran, Kuruppampadi, Ernad, Wynad, Himachal, and Nadia are some of the well-known indigenous cultivars. Additionally, among growers, exotic cultivars like Rio-de-Janeiro have become very well-liked. In Kerala, Karnataka, and Tripura, ginger are often planted as an intercrop in coffee, orange, coconut, and areca nut crops. Tomato, potato, chili, brinjal, and peanut crop rotation should be avoided, though, as these plants are hosts for the pathogen that causes wilt, *Ralstonia solanacearum.*

Many diseases, including leaf spot (*Phyllosticta zingiberi*), soft rot (*Pythium* spp.), bacterial wilt (*Ralstonia solanacearum*), and fusarium yellow (*Fusarium* spp.), have been identified in Sikkim (Avasthe *et al*. 2014) [3]. The most harmful disease that affects ginger, known as soft rot, causes total loss of all infected clumps. *Pythium aphanidermatum*, a soil-borne pathogen, is responsible for the illness. Moreover, *P. vexans* and *P. myriotylum* have been linked to the illness.

Among these, soft rot is a serious illness that globally severely reduces the output of ginger crops. *Pythium aphanidermatum* is the species that mostly causes soft rot, however, numerous employees from other states also reported *Pythium deliense*, *Pythium myriotylum*, *Pythium pleroticum*, *Pythium vexans*, and *Pythium ultimum* as sources of the disease (Sarma, 1994) [23].

This pathogen can be spread by soil and seeds. The pathogen makes plants infected by it develop yellowing leaves and decaying rhizomes. To control the disease, various systemic medications including Carbendazim (0.1%), Ridomil MZ (0.2%), and Topsin M (0.2%) are employed. Both the ecology and the quality of the ginger are endangered by the expensive chemicals. Compared to contact fungicides like copper and sulphur compounds, it may cause the pathogen to acquire resistance. In light of these facts, the current study was conducted to investigate the effects of botanicals, biocontrol agents, and fungicides that are approved for use in organic farming on the soft rot pathogen *Pythium aphanidermatum* as well as the incidence of soft rot, germination percentage, and yield of ginger under field conditions.

Although ginger farming has enormous potential for both domestic and international markets, the difficulties experienced by ginger producers can differ depending on where farming is being done. The main issue with ginger is soil-borne pathogens like *Pythium* soft rot and worms. Because of the mountainous and uneven terrain, land holdings are relatively modest, and as a result, farmers harvest as many crops as necessary from a single plot of land, making it impossible to cultivate crops on a wide scale. Deforestation, soil erosion, and the loss of forest base resources are three primary drawbacks of shifting farming. Since the majority of farmers grow ginger via shifting cropping, this livelihood approach is not long-term. A jhum land is abandoned after two to three years in order to allow the soil to maintain its fertility, which takes five to ten years. The jhum cycle has significantly decreased recently, and as a result, soil quality has declined.

Soft rot disease is one of the major disease in ginger growing bets of Tripura which resulted low yield. The crop is hampered by the significant weed infestations, insect and disease outbreaks, and rhizome rot or leaf spot caused by the monsoon season's high rainfall. Price volatility and ginger consistency are the main issues affecting ginger marketing and production in the research area. The production and marketing of ginger are impacted by additional factors such as limited innovation in ginger farming, a lack of storage facilities, and a land tenure structure. For ginger farmers, marketing their products is the most crucial job. This is valid for the district's small, marginal farmers who produce modest surpluses for sale. One of the biggest issues facing the district's ginger farmers is price volatility. When there is an emergency or a financial crisis and the farmers are unable to wait for the market to normalize and the price of ginger to increase as planned, they harvest the ginger and sell it to neighbourhood traders or dealers for extremely low prices.

In certain cases, farmers lose money because there isn't enough storage space for their produced goods, which are then sold to brokers at extremely low prices—say, Rs. 12–15 per kilogramme at the weekly market—affecting the farmer's revenue. For the existing farmers, it is urgent that they have access to clear market information as well as basic necessities like suitable facilities for storing and sorting ginger, holding capacity to wait until the price of ginger improves, adequate and affordable transportation facilities for transporting ginger to the nearest market.

Methodology

Ginger is grown either as a mono-crop or in intercrop with mandarin orange and maize. Numerous illnesses exist, such as soft rot (*Pythium* spp.), leaf spot, bacterial wilt (*Ralstonia solanacearum*) Fusarium yellow (*Fusarium*) with *Phyllosticta zingiberi* spp.), as reported by Avasthe *et al*. (2014) [3].

The selection of healthy, disease-free seeds is a crucial step in reducing the likelihood of contamination by *Pythium* spp. (Dake 1995) [31]. There are a number of seed treatment strategies that can be used to produce seeds of the desired quality. These include seed protection (either biologically, physically, or in combination with other methods), seed disinfestations (which control spores on the seed surface), and seed disinfection (which gets rid of pathogens living inside the cells). Chemical infusion is one method of controlling pathogens without endangering embryos or the potential for seeds to germinate (Bennett *et al*. 1991) [32].

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In this paper different methodologies has been discussed and put forward for the researchers, and stakeholders to understand and update the recent advances for the control of ginger soft rot disease management.

According to Srivastava (1994) [27], Sikkim's badly maintained soil might result in a yield loss of 40–50% or even more. Effective pathogen suppression by cultural, biological, and chemical techniques is part of disease management (Dake and Edison 1988, Sarma 1994) [8, 23]. This disease is very sensitive to all commercial ginger germplasm now available. The condition is managed using a variety of systemic drugs, such as Topsin M (0.2%), Ridomil MZ (0.2%), and carbendazim (0.1%). In addition to being expensive, the chemicals are bad for the environment and the quality of the ginger (Tarafdar and Saha 2007) [28]. In contrast, to contact fungicides such as sulphur and copper compounds, it can cause the pathogen to become resistant.

Ginger farms frequently use cultural practises such seed selection, crop rotation, tillage, organic amendment, drainage, and quarantine to prevent soft rot and stop *Pythium* spp. from spreading to undamaged fields (Le *et al*., 2014) [18]. Important sources of perennation and disease dissemination are infected rhizomes. Using disease-free rhizomes when planting is the most effective way to treat the illness (Dohroo, 1993) [5].

A large number of seed cakes were used in the studies by Ghorpade and Ajri (1982) [9] and Kausal and Siddique (2003) [16] to combat a variety of soil-borne plant diseases, including *Pythium* spp. They found that seed cakes significantly decreased the occurrence of ginger rhizome rot and raised production. When it came to yield, every treatment with organic amendments out produced the control. The highest ginger yield (5.76 t/ha) was found to be considerably produced by basal application of mustard seed cake. Haque *et al*. [2015] [12] discovered that by lessening the severity of the ginger disease, the compost treatment improved plant development and healthy plants. Compost treatment resulted in a higher yield of ginger, increasing the total rhizome yield

over the control plot by approximately 1.66%.
According to Harvey and Lawrence (2008) [11], crop rotations have the ability to alter *Pythium* spp. populations. They proposed that specific *Pythium* spp. would be connected with each crop and that crop rotation might partially limit the amount of possible inoculum.
Rames *et al*. (2013) [21] also found that, compared to plots treated with fumigant or left as bare fodder, the species richness of bacterial and fungal soil populations was significantly higher in plots with a 4-year programme of summer and winter crop rotations or a continuous growth of pasture grass (*Digitaria eriantha* sub sp. pentzii), where all the green biomass was returned to the fields before the ginger was grown.
According to Dohroo (1993) [5], soil additives modify the soil reactivity and the spectrum of soil microflora, which in turn affects the pathogens contained in the soil. After adding soil amendments such as oil seed cakes, neem cakes, and other organic matter from different field plants, there was a documented decrease in the occurrence of soft rot (Sadanandan and Iyer, 1986; Thakore *et al*., 1987) [22, 29]. The degree of soft rot in ginger was reduced by up to 89% when neem seed powder and punarnava (*Boerhavia diffusa*) leaves were incorporated into the soil during land preparation, as opposed to poultry manure (Gupta *et al*., 2013) [10].
In these ginger fields, the addition of organic matter, such as sawdust and poultry manure (200 t/ha), enhanced the richness of soil microbial communities (Rames *et al*., 2013) [21]. In addition to supporting ginger growth and yield, these practices raised soil carbon levels and water infiltration rates, which inhibited soft rot on ginger. In pot culture trials testing organic and inorganic amendments to minimize rhizome rot, neem seed cake was shown to be the most beneficial, with the least average mortality of 20.3 percent, followed by poultry manure (22.7%) (Kadam *et al*., 2014) [33].
Ginger is cultivated from sea level to an altitude of 1500 m above sea level and does best in a warm, humid atmosphere. Both rain-fed and irrigated settings are suitable for growing ginger. A moderate amount of rain is required for the crop's successful cultivation from the time of sowing until the rhizomes sprout, as well as somewhat frequent, strong downpours during the crop's growing phase and a month or so of dry weather before to harvest. Sandy loam, clay loam, red loam, or lateritic loam are the best types of well-drained soil for ginger.
Ideal soil is a friable loam that is high in humus. Ginger should not be grown in the same soil year after year because it is an exhausting crop.
Healthy ginger rhizomes should be selected for disease free cultivation and healthy plants.
For planting, seed rhizomes must be collected from disease-free fields. Ginger should not be planted in the same field repeatedly every year. Avoid areas where potatoes or other solanaceous crops are grown. When the illness is discovered in the field, the infected clumps can be gently removed without causing soil to leak, and the affected region and nearby areas can be sprayed with 0.2% copper oxychloride. Care should be taken to burn or otherwise destroy the removed plants far from the farmed area.
The rhizomes known as seed rhizomes are used to propagate ginger. Small, 20–25 g, 2.5–5.0 cm long portions of carefully kept seed rhizomes with one or two healthy buds are taken from the rhizomes. Region by area and depending on the growing technique used, the seed rate varies. 1500 to 1800 kg/ha is the range of the seed rate in Kerala. The seed rate may vary between 2000 and 2500 kg/ha at higher altitudes.
Nearly all of the surveyed fields in all four districts of Sikkim showed signs of disease incidence; the highest incidence of rhizome rot was found in the South district (30.0% and 25.7%, respectively, in 2011–12 and 2012–13), while the lowest incidence was found in the North district (10.0 and 9.7%, respectively). The high incidence may be attributed to heavy rains, improper drainage, and the virulent nature of the pathogen, in addition to farmers using infected rhizomes for cultivation (Dohroo *et al*. 2015) [7].
In order to reduce the spread of *Pythium* spp., several cultural methods, such as seed storage, seed choice, sowing period, crop rotation, drainage, area selection, land preparation, weed control, fertiliser treatment, soil management, etc., are typically used in ginger fields. The technology developed by IISR, 2015. But Seed treatment with *T. harzanium* @ 3 g/lt is one of the promising methods to control the seed-borne soft rot disease in ginger.
It has been extensively shown that several plant extracts have fungicidal action against *Pythium* species in both vitro and *in vivo* settings (Parveen and Sharma 2014) [19]. By using the Poisoned Food Technique, plant extracts such as garlic (*Allium sativum*), onion (*A. cepa*), titepati (*Artemisia vulgaris*), chilouney (*Schima wallichii*), banmara (*Chromolaena odorata*), tulsi (*Ocimum sanctum*), marigold (*Tagetes erecta*), pudina (*Mentha arvensis*), and Lantama (*Lantana camara*) were tested in vitro against *Pythium aphanidermatum*.
Plants were spaced 20–25 cm apart along the rows and 20–25 cm between the rows after being shade dried for 3–4 hours. The seed rhizome bits are placed in hand-dug, shallow trenches, which are then covered with a thin layer of soil, well-rotted farmyard manure, and levelled. The hot water treatment @ 47 °C for 30 min + *T. harzianum* + three periodic drenching of COC @ 0.3% at 20 day interval was found effective with the lowest average per cent incidence of rhizome rot disease.
The symptoms of soft rot disease is The pseudostem's collar is where the infection first appears, and it spreads both upward and downward. Affected pseudostem becomes wet and begins to rot, which spreads to the rhizome and causes soft rot. Later on, root infection is also noted. Foliar symptoms begin as a slight yellowing of the lower leaf tips, which eventually extends to the leaf blades. Early on, the middle of the leaves are still green, but the edges start to turn yellow. From the lowest portion of the plant upward, all of the leaves begin to yellow. The pseudostems then droop, wither, and dry. It is transmitted through soil. The fungus is able to thrive in two different ways: (a) in diseased rhizomes retained for seed; and (b) through dormant structures like chlamydospores and oospores that spread to the soil from infected rhizomes. With the arrival of the southwest monsoon, the fungus grows as soil moisture levels rise.
The infection is particularly likely to affect younger sprouts. The disease of rhizome rot is made worse by nematode infection. The two key elements that predispose to the disease are a high temperature above 30 °C and a high soil moisture level. The disease becomes more severe as a result of the field becoming waterlogged from inadequate drainage.
Sprouting, and survival of rhizomes were 83.5 and 82.80 respectively in the rhizomes treated with *T. harzanium* which KVK South Tripura trialed. Disease infection is reduced to 1.10%.

Many researchers have reported *A. sativum's* antifungal activities (Singh *et al*. 1979, Singh and Singh 1980) [25, 24]. According to Kurucheve and Padmavathi (1997) [34], bulbs of *Allium sativum* (10%) had the lowest mycelial growth (176.0 mg). According to Sivaprakash *et al*. (2012) [26], of the plant species examined, the mycelial growth of *P. aphanidermatum* was completely inhibited by the bulbs of *A. sativum* (10%), *Allium cepa* var. *aggregatum* (20%), *Lawsonia inermis* leaves (20%), Piper betle leaves (20%), Eucalyptus globulus, and Vitex negundo (40%). According to Zagade *et al*. (2012) [35], the leaf extract of Zimmu (*Allium sativum* L. × *Allium cepa* L.) significantly inhibited *P. aphanidermatum's* mycelial growth.

Dohroo *et al*. (2015) [7], found that the most successful method of controlling the disease was to apply hot water rhizome therapy at 47oC for 30 min in combination with *T. harzianum*, followed by three mancozeb soaks. In addition, Amaresh *et al*. (2004) [1] showed that treating ginger rhizome rot caused by *P. aphanidermatum* with 2 tonnes of neem cake per hectare and treating seeds with 0.3% copper oxychloride both improved crop production.

T. harzianum also inhibited bacterial and fungal pathogen-induced mortality, rhizome rot, and root rot, according to Rajan *et al*. (2002) [20]. Turmeric rhizome rot can be effectively treated with Trichoderma isolates, according to Anup and Bhai's (2014) [2] findings. In our investigation, we found that the combined effect of COC, hot water treatment, and *T. harzianum* was greater than their independent effects.

Once introduced, *Pythium* spp. can persist in the soil for an extended amount of time (Hoppe, 1966) [13]. As a result, controlling soft rot becomes challenging. When applied as 30-minute dip treatments for rhizomes, chemicals such mancozeb, ziram, guazatine, propineb, and copper oxychloride effectively prevented soft rot (Dohroo and Sharma, 1986; Thakore *et al*., 1988) [6, 30].

Once the leaves turn yellow and begin to progressively dry out, the crop is ready for harvesting approximately eight months after it was first planted. The dried-out leaves, roots, and adhering soil are gently removed from the clumps by lifting them with a shovel or digging fork, revealing the rhizomes beneath. Ginger is harvested starting in the sixth month and used for cooking vegetables. After a thorough water wash, the rhizomes are dried in the sun for a day.

Dry ginger is prepared by soaking the produce (harvested after 8 months) in water for 6-7 hours. After that, the rhizomes are thoroughly scrubbed to remove the debris. Following cleaning, the rhizomes are taken out of the water, and the outer skin is peeled off using pointed bamboo splinters. Avoid deep scraping to protect the oil cells just below the epidermis. The peeled rhizomes are uniformly cleaned and dried for a week in the sun. Rub the dried rhizomes together to remove any remaining skin or dirt. Depending on the variety and region of the crop's cultivation, the production of dry ginger ranges from 19 to 25 percent of that of fresh ginger.

Conclusion

Soft rot is said to be the most damaging of the various ginger diseases and a major barrier to cultivation in ginger-growing regions. *Pythium* spp. are the primary cause of this illness. Worldwide, there are many distinct species of *Pythium* that can cause soft rot. Ginger losses as a result of soft rot ranged from 4 to 100% among various nations.

The disease can spread through seeds and soil, and it feeds on contaminated seed rhizomes to survive between crops. Numerous environmental and soil-related factors affect the severity of *Pythium*. Research indicates that a variety of approaches, including chemical, biological, and cultural techniques, have been successfully used to manage *Pythium* soft rot. However, a single strategy's efficacy was not attained in a useful manner.

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