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Dr. Sharanabasav Huded
Teaching Associate, Department of Plant Pathology, College of Agriculture, Professor Jayashankar Telangana Agricultural University, Hyderabad, Telangana, India

Sudhakar S
Scientist, Plant Protection, ICAR-KVK, Idukki, Kerala, India

Dr. Ramachandra Naik M
Assistant Professor and Head, Department of Botany, BLDEA`s, S.B Arts and K.C.P Science College, BLDE New Campus, Vijayapur, Karnataka, India

Dr. Rashmi Nigam
Department of Plant Pathology, J.V. College, Baraut, Baghpat, Uttar Pradesh, India

Ambika Bhandari
Assistant Professor, Department of Agricultural Science, K. R. Mangalam University, Sohna, Gurugram, Haryana, India

Madhu J
Ph.D. Scholar, Division of Plant Pathology, ICAR-Indian Agricultural Research Institute, New Delhi, India

Dr. Gayatri Sinha
Ph.D. Horticulture, Senior Technical Officer, ICAR-Central Rice Research Institute, Cuttack, Odisha, India

Corresponding Author:
Sudhakar S
Scientist, Plant Protection, ICAR-KVK, Idukki, Kerala, India

Field evaluation of the ICAR-IIHR Arka microbial consortium for managing Phytophthora and rhizome rot in small cardamom production

Sharanabasav Huded, Sudhakar S, Ramachandra Naik M, Rashmi Nigam, Ambika Bhandari, Madhu J and Gayatri Sinha

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Abstract
For five years, from 2016 to 2021, farmer's fields in Santhanpara, Udumbanchola, Vandanmedu, Nedumkandam, Kattapana, Rajakadu, and Rajakumari village of Idukki District in Kerala were used for field trials on the management of Phytophthora and rhizome rot diseases in small cardamom using various treatments of chemicals, biological agents, and biofertilizer. The treatments included spraying of 1% Bordeaux mixture (T_1), spraying with Bordeaux mixture and drenching of Fosetyl Al 80% WP (T_2), soil application of Trichoderma along with FYM (T_3), spraying of Potassium Phosphonate 3ml/l and drenching of Arka Microbial Consortium(AMC) 10 g per lit (T_4) and untreated control (T_5). For each treatment, 400 small cardamom plants were taken. AMC was drenched four times, during May-June, August-September, November-December and January-February months. The observations on percent capsule rot, rhizome rot and root rot (%) were recorded. The percent was calculated at five areas (1.0 square meter) randomly selected in the area of small cardamom. The least capsule rot (4.23%), rhizome rot (5.14%), leaf infection (3.15%) was observed in the treatment involving spraying of Potassium Phosphonate and drenching of Arka Microbial Consortium. The highest capsule rot (65.1%), rhizome rot (51.8%), leaf infection (42.3%) of Phytophthora and Rhizome rot was observed in untreated check which was followed by the treatments T_1, T_2, T_3.

Keywords: Disease management, Arka microbial consortium, cardamom, Phytophthora and rhizome rot

Introduction
Food is essential for human life and consists of edible plant material such as fruits, nuts, corms and leaves and animal tissues that may be eaten raw or cooked depending on cultural traditions (Sharma *et al*., 2002) [4]. Whether consumed raw or prepared as a dish, food provides the energy and nutrients needed for bodily maintenance, tissue repair and growth. Preferences for particular foods are shaped by cultural values as well as sensory qualities like taste, texture, appearance and mouthfeel. In food-service settings, seasonings, flavorings and enhancers are added to improve the taste of natural ingredients. Spices are non-leafy plant parts (buds, fruits, seeds, bark, rhizomes, bulbs, etc.) used primarily for flavor, though many also have medicinal uses. The term “herb” refers to leafy or soft flowering parts that serve similar purposes; some plants, such as coriander or dill, can be used as both herbs (fresh leaves) and spices (dried seeds or other parts). “Seasoning” is a broad term for aromatic ingredients that enhance food flavor (Park *et al*., 1998) [5], while “condiments” are prepared mixtures of spices or spice extracts added at the point of consumption. True or green cardamom (small cardamom) is derived from the seeds of *Elettaria cardamomum* (Zingiberaceae). It is native to India’s coastal regions but is now cultivated in Guatemala, Tanzania, Sri Lanka, El Salvador, Vietnam, Laos and Cambodia. India remains the leading exporter of dried cardamom, and the crop is produced throughout the tropics. Guatemala is the world’s largest producer, followed by India, with global output estimated at about 35 000 t yr^{-1}. Despite its economic importance, cardamom production is constrained by numerous pests and diseases. Small cardamom is particularly vulnerable to a range of pathogenic microbes; for example, Colletotrichum blight and leaf-spot diseases have become common in fields where crop management is inadequate (Fina *et al*., 2013) [6].

The Arka Microbial Consortium is a carrier-based product that combines nitrogen-fixing, phosphorus- and zinc-solubilizing, and plant-growth-promoting microorganisms in a single formulation. It contains three distinct bacterial strains *viz., Bacillus aryabhattai, Pseudomonas taiwanensis* and *Azotobacter tropicalis*. This technology eliminates the need for separate inoculants for nitrogen fixation, phosphorus solubilization and growth promotion, allowing farmers to apply the consortium via seed, soil, water or nursery media such as coco-peat. Major constraints in small cardamom cultivation

Small-cardamom (*Elettaria cardamomum*) yields are limited by a range of constraints, with plant diseases being a major factor. Historically, pathogens such as *Phytophthora meadii, Pythium vexans* and *Rhizoctonia solani* have caused extensive damage in plantations. Disease development depends on the availability of susceptible host tissue, a compatible pathogen and favorable micro-climatic conditions. During the monsoon, rot diseases specifically "azhukal" or capsule rot caused by *P. meadii* and clump rot caused by *P. vexans* can become severe, leading to substantial crop loss. These pathogens also affect nursery seedlings, causing damping-off and seedling rot. Capsule and clump rot have been reported as serious problems in cardamom fields for the past decade, with yield reductions of up to 50 %. Infected leaves initially show water-soaked lesions that later rot and shred along the veins, while capsules turn a dull green-brown, decay, emit a foul odor and eventually drop. Repeated fungicide applications aimed at soil-borne problems have added environmental concerns and raised production costs.

Azhukal/Capsule rot/Phytophthora fruit rot disease

Cardamom is primarily threatened by "azhukal" disease, also known as capsule or fruit rot, which is caused by *Phytophthora parasitica* var. *nicotianae* and *Phytophthora palmivora*. The symptoms can develop on both young and mature foliage. Initially, large, irregular, water-soaked spots that turn black appear on the leaves, and the exposed portions of unopened leaves may decay. At the base of the leaf sheath, gray patches with brown margins form, leading to rotting of the basal tissue and breakage of the pseudostem at the collar. The pathogen can spread to the underground parts, causing rhizome rot. Small, light-brown lesions develop on green, immature fruits; these fruits drop within three to six days, leaving only the fruit stalk. The tip of the inflorescence may also become rotted.

Soft rot or rhizome rot disease

Cardamom is also severely affected by soft-rot or rhizome rot, which is caused by *Pythium vexans, P. aphanidermatum* and *P. myriotylum*. The pathogen typically enters through the collar of the pseudostem, then spreads both upward and downward. Initially, the collar tissue becomes water-soaked and begins to decay, eventually reaching the rhizome and producing a soft rot. Later, root infection may also occur. Above-ground symptoms start as a light yellowing at the tips of the lower leaves, which gradually extends across the leaf blades. In the early phase the central part of each leaf stays green while the margins turn yellow. As the disease advances, the yellowing spreads upward through the foliage, followed by drooping, wilting and eventual desiccation of the pseudostem.

Management of Azhukal and Rhizome rot disease

Chemical control measures

With respect to the management of azhukal disease, removal and burning of infected plants, avoid moving of rhizomes from diseased areas to healthy area for planting. Provide proper drainage. Three sprays with Bordeaux mixture @ 1% in May, June and July. Soil drench with Bordeaux mixture @ 1 % (or) Copper oxychloride (COC) 0.25%. Management of soft rot or rhizome rot includes treatment of seed rhizomes with mancozeb 0.3% for 30 minutes before storage and once again before planting reduces the incidence of the disease. Cultural practices such as selection of well drained soils for planting is important for managing the disease, since stagnation of water predisposes the plant to infection. Seed rhizomes are to be selected from disease free gardens, since the disease is also seed borne. Once the disease is located in the field, removal of affected clumps and drenching the affected and surrounding beds with mancozeb @ 0.3% checks the spread of the disease.

Role of phosphonate fungicides in the management of soil borne diseases

The common chemical name for Aliette® is fosetyl-aluminum (fosetyl-Al). The discovery of the unique downward systemic transport properties of these phosphonate fungicides was of great significance for the control of soil-borne diseases caused by Phytophthora. Fosetyl-Al is the only commercially available fungicide known to be systemically transported in a downward direction in plants. This property permits the fungicide to be applied to foliage or tree trunks in order to control root diseases caused by Phytophthora (Mark Fenn and Michael D. Coffey, 1987) [2].

Biological control measures

Biological control of capsule rot and rhizome rot relies on bio-agents that offer an environmentally safe alternative to costly, hazardous fungicides. Field trials have shown that Trichoderma viridae and Trichoderma harzianum effectively suppress capsule rot, and a straightforward carrier-based multiplication medium for these fungi has been developed for on-farm use (Vijayan A. K., 2018) [7].

The Arka Microbial Consortium (AMC), a new product from ICAR-IIHR Bengaluru, is designed to improve plant nutrition and health in horticultural crops. It combines three distinct bacterial strains—Bacillus, Pseudomonas and Azotobacter—and can be delivered through soil drenching or drip bio-fertigation. The synergistic action of these microbes supports sustainable, low-cost production.

ICAR-KVK Santhanpara introduced AMC in Idukki district, Kerala, to help small-scale cardamom growers combat azhukal disease and rhizome rot. The technology quickly gained traction, with more than 5,327 farmers adopting it across approximately 12,452 ha. Its uptake has been reinforced through farmer-level demonstrations and other extension activities.

Materials and Methods

Field experiments on the control of capsule rot, rhizome rot and root rot in small cardamom were conducted in farmers' fields across seven villages of Idukki district—Santhanpara, Udumbanchola, Vandanmedu, Nedumkandam, Kattapana, Rajakadu and Rajakumari—over five seasons from 2016 to 2021.

Five treatments were compared, each applied to 400 cardamom plants:

1. Foliar spray of 1 % Bordeaux mixture (T_1).
2. Foliar spray of Bordeaux mixture followed by a soil drench of fosetyl-Al 80 % WP (T_2).
3. Soil incorporation of Trichoderma mixed with farmyard manure (T_3).
4. Foliar application of potassium phosphonate (3 ml l^{-1}) together with a drench of Arka Microbial Consortium (AMC) at 10 g l^{-1} (T_4).
5. Untreated control (T_5).

AMC was drenched four times a year during May-June, August-September, November-December and January-February. Disease incidence was measured as the percentage of capsule rot, rhizome rot and root rot in five randomly selected 1 m^2 quadrats per plot.

The formulas used are given below

Percent capsule rot infection = (No. of plants infected X 100/Total no. of plants)

Percent rhizome rot infection = No. of plants infected X 100/Total no. of plants)

Percent leaf infection = No. of leaves infected per plant X 100/Total no. of plants)

Results and Discussion

The findings are summarized in Table 1. The combination of a potassium-phosphonate spray followed by a drench of Arka Microbial Consortium (AMC) gave the lowest disease levels: 4.23 % capsule rot, 5.14 % rhizome rot and 3.15 % leaf infection. In contrast, the untreated control showed the highest incidence of Phytophthora and Pythium-related symptoms, with 65.1 % capsule rot, 51.8 % rhizome rot and 42.3 % leaf infection; the next best results were recorded in treatments T_1, T_2 and T_3.

Yield responded similarly: the AMC-treated plots produced the greatest dry-cardamom harvest (1.73 q ha^{-1}), followed by T_3 (1.68 q ha^{-1}), T_2 (1.65 q ha^{-1}) and T_1 (1.42 q ha^{-1}). The untreated check yielded only 0.90 q ha^{-1}.

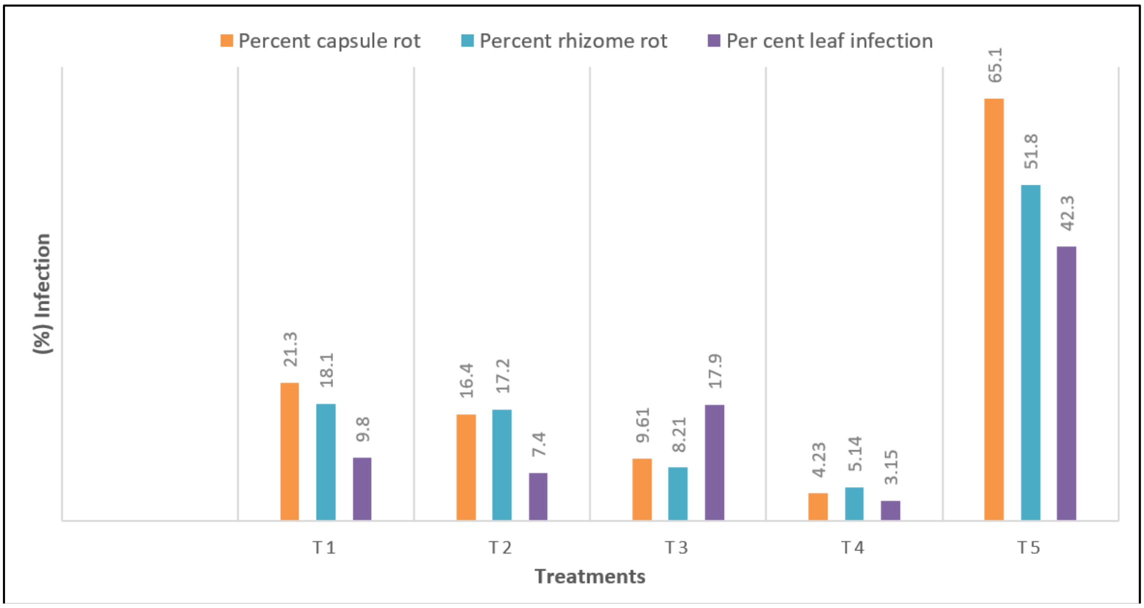
Economic analysis showed the highest benefit-cost ratio (3.10) for the AMC treatment, while the untreated control had the lowest (1.40). The ratios for the other treatments were 3.00 (T_3), 2.89 (T_2) and 2.65 (T_1).

A previous study (George & Kumar, 2018) compared several alternatives to the microbial consortium and found that the potassium-phosphonate spray plus AMC drench resulted in the smallest percentages of yellowing (7.99 %), leaf infection (2.24 %), collar infection (4.11 %) and wilted vines (0 %). The yield increase observed with AMC may stem from improved nutrient availability and a more balanced C:N ratio, which enhances carbohydrate synthesis and, consequently, productivity. Bio-fertilizer application can stimulate indigenous soil microbes, reactivating biogeochemical cycles and raising organic-matter content, which boosts bacterial populations (Watts *et al*., 2010; Krishnakumar *et al*., 2005) [9, 8].

Phosphonates are fully systemic fungicides that move both upward and downward in the plant via xylem and phloem (Guest & Grant, 1991) [10]. Their mode of action is multifaceted: they can directly inhibit pathogen growth and sporulation, and they also trigger host-defense mechanisms (Dalio *et al*., 2014; Kasuga *et al*., 2021) [11, 12].

Table 1: Assessment of phytophthora and rhizome rot diseases in small cardamom

Treatments	Details	Percent capsule rot	Percent rhizome rot	Percent leaf infection	Dry cardamom yield (q/ha)	B:C
T_1	Spraying of 1% Bordeaux mixture	21.30	18.10	9.80	1.42	2.65
T_2	Sprayingwith Bordeaux mixture and drenching of Fosetyl Al 80% WP	16.40	17.20	7.40	1.65	2.89
T_3	Soil application of Trichoderma along with FYM	9.61	8.21	17.90	1.68	3.00
T_4	Spraying of Potassium Phosphonate 3ml/l and drenching of Arka Microbial Consortium (AMC)	4.23	5.14	3.15	1.73	3.10
T_5	Untreated check	65.10	51.80	42.30	0.90	1.40



Conclusion

The technology gained popularity with the farmers and it is being followed by more than 5000 farmers of the district covering an area of 12,000 ha and further popularized through FLDs and other extension activities. After adoption of this technology, it saves the cost of chemicals application Rs. 4,500 per ha. The cost of application of AMC is Rs. 4,400/ha as compared to regular chemical application where it costs Rs. 21,000/ha. So, the reduction in cost of cultivation per ha is Rs. 65,000. The total net return gained per ha is Rs. 2, 79,000 due to introduction of AMC technology. The total economic benefits accrued since its release (2017) is estimated at Rs. 27.84 crore during the period 2017 to 2021.

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