<u>Review Article</u>

Cercospora Leaf Spot Disease ofCastor in Ericulutre: A Review on Existing Management Strategies

Abstract:

The deadly illness known as "Cercospora leaf spot of castor" affects castor (Ricinus communis L.) plants, which serve as the main food supply for the eri silkworm (Samia ricini Donovan). It is brought on by the fungal infection Cercospora ricinella. The growth and development of eri silkworms as well as the production of silk may be negatively impacted by this disease, which can result in large losses in leaf output, quantity, and quality. This article covers a range of environmentally friendly methods for controlling Cercospora leaf spot in castor plants. It also looks at the effects of chemical fungicides on silkworms and the possibilities of integrated approaches to disease control.By adopting eco-friendly and sustainable methods, the ericulture industry can effectively combat this disease while ensuring the safety and well-being of the eri silkworms and the environment.

Keywords: Frog-eye disease, shot hole symptom, eri silkworm, phytoextracts, biocontrol agents, *Trichoderma viride*, integrated disease management

Introduction

Samia ricini Donovan, the eri silkworm, mostly consumes the leaves of castor (Ricinus communis L.), so this plant is vital to the ericulture sector. A tamed insect, the eri silkworm can feed on a variety of host plants and reproduces several times a year. It is the source of eri silk, also referred to as Ahimsa silk or the poor man's silk (Sarmah et al., 2023). One of the main things preventing castor cultivation from yielding large quantities of high-quality leaves is disease. From the time of planting, a number of fungal pathogens can cause diseases that impact the castor leaves, roots, or stems. The most important of them are foliar pathogens, or diseases of the leaves. According to Sujatha et al. (2011), they can severely destroy 20–25% of the leaf area and reduce leaf production by 15%–25%, which results in a loss of both number and quality of leaves. Silkworms that are fed damaged leaves grow poorly as larvae and become more vulnerable to bacterial, viral, and fungal infections (Saad et al., 2019). The quality of the castor leaves affects the robust and healthy growth of silkworms, which in turn affects the amount and quality of cocoons produced (Ramanamma, 2009).

Castor (*Ricinus communis* L.) is highly susceptible to *Phytopthoraparasitica* (causing seedling blight), *Alternaria ricini* (Alternaria blight), *Cercosporaricinella*(Cercospora leaf spot), *Leveillulataurica* (powdery mildew) and *Fusarium oxysporum* (wilt)(Sharma and Rana, 2019). Cercospora leaf spot is one of the major fungal infections that affect the crop; in castor plantations developed for ericulture (the production of eri silk), it frequently results in the loss of foliage. In India, cercospora leaf spot is a serious problem that seriously damages the leaves that are used to feed eri silkworms (Singh et al., 2023). Cercospora ricinella Sacc. & Berl. is the fungal pathogen responsible for the disease. It is a seed-borne disease that, once established in fields, can live in the soil for up to two years and is spread by wind or rain splash (Chattopadhyay, 2000).

Temperatures between 27 and 32°C during the day, temperatures over 16°C at night, and relative humidity above 60% for at least 15 to 18 hours every day are all favourable to the growth of Cercospora leaf spot (Kethobile, 2018). Both leaf surfaces display these dots. As the spots grow, the core becomes pale brown and eventually grayish-white, encircled by a brown ring that can be wide and diffused or narrow and pointed, resulting in defoliation with the infected tissues frequently falling off, exhibiting symptoms similar to shot holes (Das et al., 2023). When the spots are close together, the intervening leaf tissue withers, and large brown patches of dried leaf occur (Lobar, 1999). The fungus fructifications appear as tiny black dots in the white center. The diseased spots often occur in great numbers scattered over the leaf and are roundish when young but may become irregularly angular when mature.The disease severity completely depends on its first appearance and continuous progress throughout the growing season when weather conditions are favourable.

Conventional Disease Management

According to research, the most efficient and cost-effective way to control Cercospora leaf spot disease is to apply effective fungicides as soon as symptoms appear. Subsequent applications should be made based on the condition of the environment and the presence of leaf spots (Ali et al., 2011). Applying a copper-based fungicide such as Bordeaux combination could aid in the management of the illness. It has been demonstrated that two treatments of carbendazim (1g/liter) or mancozeb (2.5g/liter) spaced 10–15 days apart can lower the incidence of illness. Spraying might not be ideal, though, if eri silkworm cultures are kept on castor plants. Disease management can also be aided by treating seeds with Thiram or Captan (3g/kg seed). Using resistant cultivars is seen to be the most efficient way to fight the illness(Altieri*et al.*, 2018).

Dey *et al.* (2017) found that spraying a 0.2% solution of bavistin (Carbendazim 50% WP) or 0.2% Karathane on mulberry leaves can help control Cercospora leaf spot, and the leaves can be used for silkworm rearing 7-10 days after the final spray. Pethybridge et al. (2020) reported that copper oxychloride + copper hydroxide and propiconazole significantly improved Cercospora leaf spot control in table beet if initiated prior to infection. Copper oxychloride is used for the control of fungal and bacterial diseases in fruit, vegetable crops, citrus, stone fruit, pome fruit, and ornamentals.In field trials conducted in Nigeria in 1981 and 1982, four systemic fungicide formulations (tridemorph, tridemorph plus maneb, carbendazim, and benomyl) and three non-systemic fungicides (captafol, mancozeb, and copper oxychloride) were evaluated for the control of early leaf spot (*Cercosporaarachidicola* Hori), late leaf spot (*Cercosporapersonatum* Berk. & Curt.), and rust (*Puccinia arachidis*Speg.) of groundnut (*Arachis hypogaea* L.). Plots receiving mancozeb and tridemorph plus maneb exhibited the best overall disease control and higher yields, followed by copper oxychloride (Salako, 1985).Bagwan (2010) reported that Thiram

(0.2%), Copper oxychloride (0.2%), and Mancozeb (0.2%) are compatible with *Trichodermaharzianum* and *Trichodermaviride*. In the experiment, *Trichoderma* was found to be insensitive to blue copper and captaf but highly sensitive to dithane, bavistin, and ridomil.

Spraying copper fungicides may help control the disease, but spraying is not desirable where eri silkworm cultures are maintained on castor plants.Due to the limitations of chemical pesticides for managing seed/soil-borne pathogens, biological management has become a widely accepted alternative for mitigating these problems. Biological management is also a key component of Integrated Disease Management (IDM). It is regarded as an alternative, eco-friendly, and sustainable control measure for plant diseases.The successful application of antagonistic microorganisms for controlling seedling blight in castor caused by *Phytopthoraparasitica* has been reported by several workers. Seed dressing with the antagonistic fungus *Trichodermaviride* at 4 g/kg seed has been reported to reduce disease incidence. Nowadays, several commercial formulations have been developed by different agencies, such as Bioveer, Biozium, Ecofit, Funginil, Trichoguard, Bioguard, Biocon, Defense-SF, Bioderma, Ecoderma, Bioshield, Biotole, Kalisena-30, etc. *Trichoderma*-based formulation products account for about 60% of the biofungicide market.Despite using *Trichoderma*-based biofungicides as an alternative and additive to chemical fungicides, their applications are limited because their efficacy is lower than that of chemical fungicides. Unfortunately, many potent fungal antagonists are sensitive to agrochemicals.

Plant extracts have been found effective against many plant pathogens and are increasingly used for controlling plant diseases in agricultural and sericultural crops. The use of biodegradable materials like fresh plant extracts has been prioritized during the last three decades for plant disease control, considering the high cost of chemical pesticides and their hazardous nature (Mitra*et al*., 1984).

Chemical control of diseases in castor involves the risk of residual toxicity to silkworms when the sprayed leaves are fed to them. Therefore, there is a need to find biodegradable, natural products or their non-toxic consortia for managing Cercospora leaf spot of castor caused by *Cercosporaricinella*.*Ocimum sanctum* Linn, also known as Tulsi or Holy basil, is an aromatic plant belonging to the Lamiaceae family. It is widely used in Ayurveda and Siddha systems of medicine to treat various ailments. Tulsi is known to possess antiseptic, analgesic, anti-inflammatory, antimicrobial, anti-stress, immune-modulatory, hypertensive, antioxidant, and hypoglycaemic properties (Hosdurga*et al.*, 2015).

Effect of chemical fungicides on silkworm

Researchers found that applying fungicides to mulberry plants, the sole food source for silkworms, increased caterpillar mortality up to threefold and significantly reduced the size of cocoons spun by surviving caterpillars, causing losses in silk production (Nicodemo, 2018). In the tests, mulberry leaves were offered to silkworm caterpillars 30 days after fungicide application. The researchers evaluated in vitro and in vivo mitochondrial bioenergetics of mitochondria from the caterpillars' heads and intestines, as well as their feed intake, mortality rate, and the weight of fresh cocoons and cocoon shells. At doses of 50 micromolar (in vitro) and 200 grams per hectare (in vivo), pyraclostrobin inhibited oxygen consumption, dissipated membrane potential, and inhibited ATP synthesis in the silkworms' mitochondria. Pyraclostrobin acted as a respiratory chain inhibitor, affecting mitochondrial bioenergetics, producing the expected effect on fungi in silkworm caterpillars. While the fungicide did not interfere with the silkworms' food consumption, it negatively affected mortality rate and cocoon weight at a dose of 100 grams per hectare.

The potential of a chemical to directly affect a species' ability to survive as a result of exposure and dosage is mostly dependent on its lethality. Non-lethality does not, however, imply that the material is safe; harm can still result. In this study, the lethality of caterpillars exposed to mulberry leaves contaminated with pyraclostrobin was found to be quite low. However, there were impairments in the head and intestine's mitochondrial bioenergetics, which had an adverse effect on the generation of cocoons and energy.In a study evaluating the toxicity of fungicides on cocoon and silk quality criteria as well as silkworms (Bombyx mori L.), it was shown that wettable sulphur 80% WP at 0.1% concentration and carbendazim 50% WP had no toxic effects, with no larval mortality three days after treatment.

Larval weight and length were higher in these treatments compared to others. Cocoon characters like cocoon weight, pupal weight, shell weight, shell ratio, and cocoon yield were also higher with carbendazim 50% WP and wettable sulfur 80% WP at 0.1%. Additionally, silk quality traits like filament length, filament weight, and denier were higher in these treatments (Manjunatha, 2017).Another study analyzed the effect of fungicides on silkworm larvae, finding that daily feeding on 1 and 2g/liter of carbendazim, a systemic fungicide, did not significantly affect larval and pupal mortality. However, the weight of treated larvae showed a considerable decrease of up to 37%. While economic traits of male and female adults treated with the fungicide decreased, the decrease was not significant for cocoon shell weight and hatching percentage (Etebari and Bizhannia, 2005).

Sustainable Disease Management Approaches

The significance of integrated disease management (IDM) solutions for fungal diseases, such as Cercospora leaf spot in castor caused by Cercospora ricinella, is emphasised by both Gupta (2022) and Anuradha (2023). These IDM tactics usually include biological, chemical, and cultural control techniques. Systemic and protectant fungicides are especially mentioned by Gupta, whilst Anuradha et al. (2023) emphasise the potential of biotechnological methods for producing resistant castor cultivars. Furthermore, Awad (2012) advocates for the management of fungal infections, including Cercospora leaf spot, by the use of biological control agents and chemicals that induce resistance. It is suggested that when developing strategies for managing Cercospora ricinella in castor, long-term sustainability should be taken into account.

Phytoextracts

Numerous bioactive substances, including phenols, phenolic acids, quinones, flavones, flavonoids, flavonols, tannins, and coumarins, are produced by plants. According to Das et al.

(2010), these substances have antibacterial qualities and act as defence mechanisms for plants against harmful microbes. The effectiveness of antagonists and herbal extracts against Fusarium oxysporum f. sp. ricini, the pathogen that causes wilt disease in castor plants, was assessed by Vahunia et al. (2017). Turmeric (Curcuma longa L.) and marigold (Tegetes erecta) plant extracts have shown efficacy against this fungus. Reddy et al. (2009) examined the effectiveness of plant extracts and essential oils from specific medicinal plants against the mulberry (Morus alba L.) leaf spot disease-causing agent, Cercospora moricola Cooke.

Eucalyptus globulus extract exhibited the highest mycelial growth inhibition (72.59%) at a 10% concentration. Other effective plant extracts included *Oscimum sanctum* (49.08%), *Phyllanthus emblica* (46.75%), *Aloe barbedensis* (45.75%), *Allium sativum* L. (41.08%), and *Azadirachta indica* (35.25%). Plant oils such as *Madhuca indica* oil (75.73% inhibition), *Cymbopogon citratus* oil (73.22%), and neem oil (24.44%) also inhibited the fungal mycelial growth compared to the control.

Effect of Phytoextracts on silkworm

Tulsi (*Ocimum sanctum* L.), known as the "Queen of Herbs," is a highly valued medicinal herb used in Ayurveda, Siddha, Unani, Greek, and Roman medicine for preventing and curing various illnesses. V^{th} instar *Bombyx mori* L. larvae were fed mulberry leaves enriched with different concentrations (1%, 2%, and 3%) of Tulsi leaf extract, and its effect on larval weight, cocoon weight, pupal weight, shell weight, shell ratio, and silk characteristics was studied. Among the different concentrations, 2% Tulsi extract was found to be the most effective compared to the control. Tulsi extract has a growth-promoting effect on silkworms, which helps enhance the commercial qualities of silk and can be used in sericulture for yield improvement (Padma Sree and Ramani Bai, 2015).

Sujatha et al. (2015) reported that when silkworms were fed mulberry leaves fortified with aqueous Tulsi leaf extract at the second instar, a positive response was observed in larval and economic parameters. The highest larval weight in three instars (third, fourth, and fifth) was noted at a 3% concentration. Post-cocoon characters also increased with increasing concentrations. At 3% leaf extract concentration, the maximum Effective Rate of Rearing (ERR %), total weight of 100 cocoons, average cocoon weight, average shell weight, average silk ratio, and average filament length were observed. The overall performance of *B. mori* in response to the treatment showed an improvement in commercial parameters.Saritha Kumari et al. (2010) studied that feeding mulberry leaves treated with aqueous leaf extracts of*Adhotodavasica*, *Phyllanthus niruri*, and *Terminalia arjuna* to first instar larvae of PM × CSR2 resulted in a positive response regarding rearing parameters. The highest larval weight in all instars was recorded with *P. niruri*.Pachiappan (2009) evaluated the antibacterial efficiency of certain plant extracts, including turmeric rhizome, amla fruit, asparagus, bael, boerhavia, garlic bulb, and basil. Among these, asparagus and basil showed effective growth inhibition against *Staphylococcus* sp. at various concentrations.

Manjunath *et al*. (2020) revealed significant results regarding the inhibition zone of *Bacillus* sp. by botanicals in vitro. For 1:1 and 1:3 proportions, *Adathodavasica* had a considerable zone of inhibition. *Agelemarmelos*, *Ocimum sanctum*, *Phyllanthus niruri*, *Solanum nigrum*, and *T. indica* were also found to be significant compared to the control.Gahukar (2014) reported that silkworms reared on mulberry leaves smeared with *Terminalia chebula*, *Coleus aromaticus*, and *Ocimum sanctum* exhibited increased larval weight, ERR, shell weight, silk productivity, and reduced fifth instar larval duration and mortality. Positive effects were observed compared to the control, suggesting that these botanicals at higher concentrations could enhance the economic and rearing parameters of silk.

Trichodermaviride

Trichoderma viride was found to be the most effective treatment for managing leaf spot (Cercospora arachidicola) on groundnut (Arachis hypogaea L.) in a study on the effectiveness of bioagents and botanicals against the disease. The yield from T. viride-treated plots was comparable to that of chemical-treated plots, and T. viride treatment was statistically the most cost-effective way after chemical treatment based on the cost-benefit ratio. Because T. viride is more environmentally friendly than chemicals, which can have negative effects on both the environment and human health, it is regarded as a superior option (Ramesh and Zacharia, 2017).

Using biopesticides comprising bioagents such as Trichoderma viride/harzianum and Pseudomonas fluorescens as seed/seedling/planting material, nursery treatment, and soil application against Cercospora leaf spot is advised by the AESA-based IPM package for castor.Essential oils, bioagents, and their mixtures were tested in an experiment to control Alternaria solani-caused early tomato blight and enhance growth metrics and yield. The most successful combination of all treatments for lowering early blight infection and raising growth metrics was neem oil + T. viride (2.5% + 2.5%), which was followed by neem oil (5%) and T. viride (5%) alone (Madhuri et al., 2021). Essential oils and T. viride shown to be a more cost-effective and efficient combination than each treatment alone.CZTV-1, a strain of Trichoderma viride, was tested against fifteen fungal plant diseases that were identified from castor, cumin, and groundnut. As per Singh and Jadon's 2019 study, T. viride (CZTV-1) exhibited a significant reduction in the mycelial growth of pathogenic fungi in dual culture assays. Specifically, it showed the least inhibition (29.0%) against Fusarium sp. (CZC-3) and the maximum inhibition (82.2%) against Aspergillus niger (CZGN-12), which was statistically comparable to Fusarium solani CZGN-9 (80.7%).

Effect of *Trichoderma*onsilkworm

A study assessed the detrimental effects of bacterial and fungal bioagents used to cure mulberry powdery mildew on silkworms over an extended period of time. The results showed that Trichoderma harzianum caused the larvae to grow to a weight of 21.46g and a length of 5.18cm, respectively. In comparison, the pupal and shell weights of 14.99g, 11.86g, and 3.17g, respectively, the shell ratio of 21.17%, and the cocoon production of 524.66g/dfl were all higher than those of the other treatments. The feeding of mulberry leaves treated with T. harzianum to silkworms resulted in superior filament weight (0.16g), denier (1.80% fineness), and length (769.05m). When leaves were fed three days after treatment with the bioagents' culture filtrate, the investigation showed that bioagents effective against mulberry powdery mildew, such as T. harzianum, T. viride at 15% concentration, Bacillus subtilis, and Pseudomonas fluorescens at 10-15% concentration, were safe for silkworms (Manjunatha et al., 2017).

A commercial chitinolytic enzyme mixture derived from Trichoderma viride was biochemically characterised by Berini et al. (2015), who also examined the mixture's effects on the peritrophic matrix (PM) of the silkworm Bombyx mori L. both in vitro and in vivo. Involved in both protection and digesting, the PM forms a physical barrier lining the midgut of the insect. The structure and permeability of the PM were significantly impacted by the enzymes in vitro. These findings were corroborated by a bioassay, which demonstrated that oral administration of the mixture altered PM levels, which had a negative impact on larval development, growth, and pupal weight in addition to increasing mortality. The antagonistic capability of four Trichoderma isolates against Beauveria bassiana, the causative agent of white muscardine illness in silkworms (Bombyx mori L.), was investigated by Ahmad & Ahmad (2020).

Examined were the effects of biocontrol agents' culture filtrate on pathogen sporulation and spore germination, as well as in vitro mycelial interaction. The isolates A and M of T. viride and isolates L and C of T. harzianum exhibited the largest inhibitory zones, respectively. All of the Trichoderma isolates grew larger than the pathogen in dual culture, coiled around its hyphae, and eventually dissolved it. The culture filtrate of T. harzianum isolate L exhibited a 55.35% inhibition of mycelial growth. Spore generation and germination were reduced by 63.65% and 83.70%, respectively, by T. viride isolate A. Antibiosis and hyperparasitism were the antagonistic processes. The results of the study showed that all of the biocontrol drugs that were evaluated had antagonistic qualities against B. bassiana in vitro and may be applied to the management of white muscle illness.

Challenges and Future Prospects

There are a number of obstacles and opportunities in the management of Cercospora leaf spot disease in castor plants, which is brought on by Cercospora ricinella. Creating efficient and long-lasting plans that reduce the usage of chemical pesticides and encourage environmentally friendly practices is a major challenge. In order to do this, strong biocontrol agents and plant extracts with broad-spectrum antifungal action against the pathogen must be identified and characterised. Additionally, as castor leaves are the main food source for eri silkworms, it is imperative to assess the compatibility and aftereffects of different management strategies on the health of these silkworms and their ability to produce silk. A promising approach is to incorporate cultural practices, botanicals, and biological control agents into an integrated disease management (IDM) programme that is comprehensive in nature.

Continuous research and monitoring are necessary to understand the evolving diversity within the Cercospora genus and its implications for the management of Cercospora leaf spot disease in castor cultivation. Breeding and developing castor cultivars with enhanced resistance or tolerance to Cercospora leaf spot is another area of focus.

Conclusion:

Much less research has been done on understanding the disease's underlying ecology or epidemiology, with the majority of studies on the topic focusing on the technical aspects of fungicide development. This makes it more difficult for us to use them effectively for host plant disease management. To incorporate biocontrol agents, such as botanicals or chemicals, into integrated disease management (IDM), one must possess a fundamental understanding of their ecology. Without a doubt, efforts to control this disease have been made employing a variety of chemical fungicides. But since we are working with the delicate and sensitive silkworms and we will be feeding these castor leaves to them, it becomes very important for us to improve our understanding of the compatibility and residual effect of the management approaches for the utilization of the control measure in a more efficient way.

Alternative environmentally friendly methods should be the focus of new research initiatives, since it appears that agents used in management practices and control measures typically have various effects on plant development, soil microbiota, and silkworm health in addition to managing the target organism. Feeding the larvae with high-quality, plentiful, and disease-free castor leaves is crucial to the success of growing eri silkworms. Therefore, good seed production and ericulture both depend on the clever and effective management of this disease. When eri silkworms are in good health, they produce more and better-quality cocoons, which in turn produces silk of a high calibre and eventually boosts the nation's economy by bringing in foreign exchange.

References:

[1]. Ali, M. Z., Khan, M. A. A., Rahaman, A. K. M. M., Ahmed, M. and Ahmed, F. (2011). Effect of fungicides on Cercospora leaf spot and seed quality of mungbean. *J. Expt. Biosci*, *2*, 21-26.

[2]. Ahmad, H. R. and Ahmad, G. (2020). *In vitro* Evaluation of *Trichoderma* Species for the Biological Control of *Beauveria bassiana* (Balls) Vuill. causing White Muscardine Disease of Silkworm, *Bombyx mori* L. under Temperate Conditions. *Int. J. Curr. Microbiol. App. Sci*, *9*(4), 945-951.

[3]. Altieri, M.A., Farrell, J.G., Hecht, S.B., Liebman, M., Magdoff, F., Murphy, B., Norgaard, R.B. and Sikor, T.O. (2018). Plant disease ecology and management. In *Agroecology* (pp. 307-319). CRC Press.

[4]. Anuradha, Sharma, A., Sood, S., Badiyal, A. and Sood, T. (2023). Fruit rot of Capsicum spp.: implications and management strategies. *The Journal of Horticultural Science and Biotechnology*, *98*(6), 715-731.

[5]. Awad, M. E. M., Abo-Elyousr, K. A., & Abdel-Monaim, M. F. (2012). Management of cucumber powdery mildew by certain biological control agents (BCAs) and resistance inducing chemicals (RICs). *Archives of phytopathology and plant protection*, *45*(6), 652-659.

[6]. Babu, A.M., Tomy, Philip and Vinod, Kumar (2007). Development of leaf spot fungus, *Cercosporaricinella*, on Castor leaf-an SEM Account. *J. Phytopathol*., *155*: 426-430.

[7]. Bagwan, N.B. (2010). Evaluation of Trichoderma compatibility with fungicides, pesticides, organic cakes and botanicals for integerated management of soil borne diseases of soybean [*Glycine max* (L.) Merril]. *Int. J. Plant Prot*., *3*: 206-209.

[8]. Berini, F., Caccia, S., Franzetti, E., Congiu, T., Marinelli, F., Casartelli, M. and Tettamanti, G. (2016). Effects of *Trichoderma viride* chitinases on the peritrophic matrix of Lepidoptera. *Pest Management Science*, *72*(5), 980-989.

[9]. Braun, U. and Crous, P.W. (2007). The diversity of cercosporoid hyphomycetes - new species, combinations, names and morphological clarifications. *Fungal Diversity*, *26*, 55-72.

[10]. Carlos, B.N., Silveira, E.B.D., Mello, S.C.M.D. and Fontes, E.M.G. (1998). Scanning electron microscopy of the infection process of *Cercosporacaricis* on purple nutsedge. *FitopatoBrasil*, *23*: 169-172.

[11]. Chattopadhyay, C. (2000). Seed borne nature of *Fusarium oxysporum* f. sp. *ricini* andrelationship of castor wilt incidence with seed yield. *J. Mycol. PL Pathol*., *30*: 265.

[12]. Conway, K.E. (1976). *Cercospora rodmanii*, a new pathogen of water hyacinth with biological control potential. *Botany*, *54*, 1079-1083.

[13]. Dange, S.R.S., Desai, A.G. and Patel, D.P. (1997). Management of wilt of castor in Gujarat state of India. *In: Proc. of International Conference on IntegratedPlant Disease Management for Sustainable Agriculture*, New Delhi, pp. 10-15.

[14]. Dange, S.R.S., Desai, A.G. and Patel, S.I. (2005). Diseases of castor, diseases of oil seedcrops, *Indus. Publishing Company*, Fs-5, Tagore Garden, New Delhi -110027, pp. 211-235.

[15]. Das, K., Tiwari, R. K. S. and Shrivastava, D. K. (2010). Techniques for evaluation of medicinal plant products as antimicrobial agent: Current methods and future trends. *Journal of medicinal plants research*, *4*(2), 104-111.

[16]. Dey, S., Haque, A. H. M. M., Hasan, R., Biswas, A. and Sarker, S. (2017). Efficacy of botanicals and chemicals to control Cercospora leaf spot disease of country bean in field condition. *Journal of Applied Life Sciences International*, *11*(3), 1-7.

[17]. Etebari, K., & Bizhannia, A. R. (2005). Bio-Economic Changes Due to Long Time Treatment of Carbendazim on Mulberry Silkworm (*Bombyx mori* L.). *Caspian Journal of Environmental Sciences*, *3*(1), 23-27.

[18]. Gahukar, R. T. (2014). Impact of major biotic factors on tropical silkworm rearing in India and monitoring of unfavourable elements: a review. *Sericologia*, *54*, 150-170.

[19]. Gfiliata, L.K. (2005). Evaluation of fungicides for the control of Altemaria blight of Castor. *J. Mycol. Pl. Pathol*., *35*(1): 88.

[20]. Gupta, P. K. (2022). Current status of Cercosporoid fungi in India, effective management strategies and future directions. *Indian Phytopathology*, *75*(2), 303-314.

[21]. Gupta, V.P., Tewari, S.K., Govindaiah, Bajpai, A.K. and Datta, R.K. (1995). Observations on the surface ultrastructure of conidial stage of *Cercosporamoricola* and its infection process in mulberry. *Sericologia*, *35*: 123-128.

[22]. Hesami, S., Khodaparast, S.A. and Zare, R. (2011). New reports on Cercospora and Cercospora-like fungi from Guilan province, Iran. *Iranian Journal of Plant Pathology*, 47, 131-132.
[23]. Hosadurga, R. R., Rao, S. N., Edavanputhalath, R., Jose, J., Rompicharla, N. C., Shakil, M. and Raju, S. (2015). Evaluation of the efficacy of 2% Ocimum sanctum gel in the treatment of experimental periodontitis. *International Journal of Pharmaceutical Investigation*, *5*(1), 35.
[24]. Lobar (1999). Some physiological studies on *Alternaria ricini* (Cook.) causing leaf spot of castor (*Ricinus communis* L.), AGRS Plant Disease.
[25]. Madhuri, I., Reddy, S. M. and Tiwari, S. (2021). Effect of different botanicals, *Trichoderma viride* and their combinations against *Alternaria solani* causing early blight of tomato. *International Journal of Current Microbiology and Applied Sciences*, *10*(01), 1011–1018. https://doi.org/10.20546/ijcmas.2021.1001.122.
[26]. Manjunath, G. C., Doreswamy, C. and Bhaskar, R. N. (2020). Evaluation of certain medicinal plant extracts for the management of late larval Flacherie disease of silkworm, *Bombyx mori* L. *Journal of Entomology and Zoology Studies*, *8*(4), 260-264.
[27]. Manjunatha, S.E., Kumar, V.P.S. and Kumar, N.K. (2017). Toxicological studies of mulberry powdery mildew effective fungicide residues on growth and development of silkworm (*Bombyx mori* L.), cocoon and silk qualityparameters. *Int. J. Curr. Microbiol. App. Sci*., *6*(11): 708-716.
[28]. Mitra, S.R., Choudhury, A. and Adityachoudhury, N. 1984. Production of antifungal compounds by higher plants – A review of recent researches, Journal of Physiology and Biochemistry, 11: 53 -90.
[29]. Nicodemo, D., Mingatto, F. E., Carvalho, A. D., Bizerra, P. F. V., Tavares, M. A., Balieira, K. V. B. and Bellini, W. C. (2018). Pyraclostrobin impairs energetic mitochondrial metabolism and productive performance of silkworm (Lepidoptera: Bombycidae) caterpillars. *Journal of economic entomology*, *111*(3), 1369-1375.
[30]. Pachiappan, P., Aruchamy, M. C., & Ramanna, S. K. (2009). Evaluation of Antibacterial Efficacy of Certain Botanicals Against Bacterial Pathogen *Bacillus* sp. of Silkworm, *Bombyx mori* L. *International Journal of Industrial Entomology*, *18*(1), 49-52.
[31]. Padma Sree, V. D. P., & Ramani Bai, M. (2015). Effect of *Ocimum sanctum* L. plant extract on the economic parameters of silkworm, *Bombyx mori* L. *Journal of Entomology and Zoology Studies*, *3*(2), 62-64.
[32]. Ramesh, M.A. and Zacharia, A. (2017). Efficacy of bio-agents and botanicals against leaf spot (*Cercosporaarachidicola* Hori.) of groundnut (*Arachis hypogaea*L.). J. *Pharmacog. Phytochem*., *6*(5): 504-506.
[33]. Reddy, C., Ramanamma, C. and Nirmala, R. (2009). Efficacy of phytoextracts and oils of certain medicinal plants against *Cercospora moricola* Cooke., incitant of mulberry (*Morus alba* L.) leaf spot. *J. Biopesticides*, 2(1): 77-83.
[34]. Salako, E. A. (1985). Fungicidal control of groundnut leaf spot and rust in Nigeria. *Crop Protection*, *4*(1), 33-37.

[35]. Sikdar, A. K. and Krishnaswamy, S. 1980. Assessment of leaf yield loss of two mulberry varieties due to leaf spot disease, Indian Journal of Sericulture, 19: 9-12.
[36]. Singh, S.K. and Jadon, K.S. (2019). Biocontrol efficacy of Trichoderma viride against fungal pathogens of cumin, groundnut and castor. Indian Phytopathology, 72: 537-543.
[37]. Sujatha, K., Sathish, J. and Anitha, J. (2015). Effect of medicinal botanical (*Ocimum sanctum*), family, Labiateae on commercial parameters of the silkworm, *Bombyx mori*, *L. Int. J. Multidisciplinary and Current Research*. Available at: http://ijmcr.com.
[38]. Uma Maheshwari, P., Krishnamurthy, S.K. and Yellamandareddy, T. (2008). Effect of organic and inorganic nutrient sources of yield of castor. *Crop Res*., *36*(1&3): 108-110.
[39]. Vahunia, B., Singh, P., Patel, N. and Rathava, A. (2017). Management of Fusarium wilt of castor (*Ricinus communis* L.) caused by *Fusarium oxysporum* f. sp. *ricini* with antagonist, botanical extract and pot experiment. *Int. J. Curr. Microbiol. App. Sci*., 6(9): 390-395.
[40]. Sarmah, P., Basumatary, P. and Debnath, P. (2023). Livelihood security of rural youth through traditional and scientific method of eri silk worm rearing in Kokrajhar district of Assam.
[41]. Sujatha, M., Devi, P. V., & Reddy, T. P. (2011). Insect pests of castor (Ricinus communis L) and their management strategies. BS publications, CRC press.
[42]. Saad, M. S., Elyamani, E. M., & Helaly, W. M. (2019). Controlling of bacterial and fungal diseases that contaminating mulberry silkworm, Bombyx mori by using some plant extracts. *Bulletin of the National Research Centre*, *43*, 1-9.
[43]. Sharma, D. K., & Rana, S. H. A. F. K. A. T. (2017). Seed-borne and post-harvest diseases of castor bean (Ricinus communis Linn.) and their management: A review. *J. Phytol. Res*, *30*, 31-45.
[44]. Singh, S., Jigyasu, D. K., Patidar, O. P., Kumar, A., & Shabnam, A. A. (2023). Eri Silk Insect (Samia ricini, Donovan). In *Commercial Insects* (pp. 103-125). CRC Press.
[45]. Kethobile, R. (2018). Effects of humidity, temperature and inoculum density under controlled environment and fungicide application under field conditions on the development of Cercospora leaf spot of Swiss chard.
[46]. Das, A., Verma, R., & Narzary, P. R. Diseases of Castor (Ricinus communis L.) and Their Integrated Management. In *Diseases of Oil Crops and Their Integrated Management* (pp. 188-204). CRC Press.

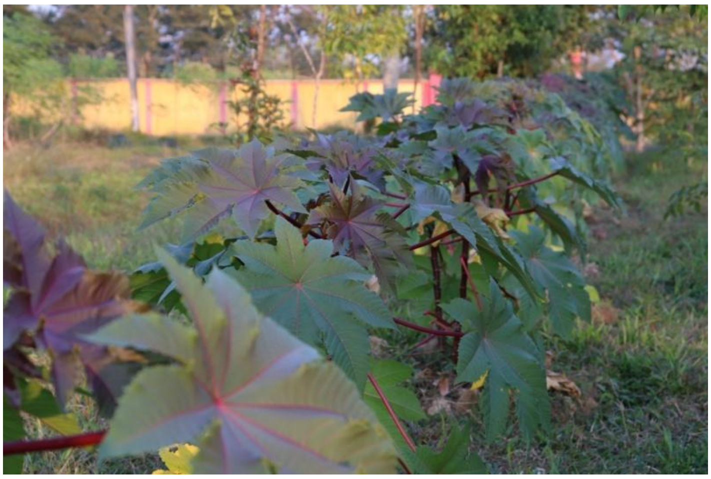

Figure 1. Castor cultivation at Germplasm Conservation Centre, Chenijan, Central Muga Eri Research and Training Institute (CMER&TI), Lahdoigarh

Figure 2 Cercospora leaf spot on castor leaf

Figure 3 Infected castor fields

Figure 4. Eri silkworm (Samia ricini Donovan) feeding on castor leaves