Leaf spot disease of groundnut: A review of existing research on management strategies

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Abstract: The early and late leaf spot disease (ELS and LLS) caused by the Cercospora arachidicola and Cercosporidium personatum is one of the most important economic diseases in groundnut production. The effect of the disease can lead to up to 70% yield loss under severe conditions. Even though there are an array of management approaches in curbing the menace of the disease, these seem not to be enough to completely control the disease. It is therefore important to develop additional and more improved strategies via the implementation of sustainable approaches. Around the globe, several researches have been conducted on this topic, with most of them leading to prosperous and dynamic outcomes that could lead to a lasting solution to the disease, and hence improving farmers’ income. It is therefore important to know what work has been done in order to identify gaps that needs to be filled. The objective of this review is to discuss recent research findings on the management of the leaf spot disease on groundnut. This will include cultural control, chemical control, the use of antagonistic organisms, and host plant resistance. These areas unabatedly continue to be an active research area, and current information on their efficacy will continuously be available. In this review, we have discussed some of the mechanisms involved and also suggested some ways to maximize the outcomes for further interventions.

Subjects: Agriculture & Environmental Sciences; Botany; Entomology; Microbiology; Entomology; Epidemiology

Keywords: Cercospora arachidicola; Cercosporidium personatum; chemical control; resistance; yield loss

1. Introduction

The leaf spot disease caused by the Cercospora arachidicola and Cercosporidium personatum is one of the most detrimental foliar diseases of groundnut. This disease, due to its drastic reduction of photosynthetic tissues in plant foliar parts, leads to about 70% yield loss in susceptible cultivars (Mohammed et al., 2018). Due to the economic importance of this disease, most scientists have developed an undying zest in coming out with approaches to mitigate the menace of the disease (Denwar et al., 2021b; Nana et al., 2022; Tengey, 2018; Zongo et al., 2019). These approaches are chemical, biological, cultural management, and breeding for resistant varieties (Mugisa et al., 2016). Although chemical methods have frequently been employed in the management of leaf spot disease, they also pose an ever-ending threat to society. Chemicals with ingredients such as methyl bromide and strobilurin used in controlling the leaf spot disease have lethal effects on non-target organisms and both underground and surface water bodies (Bula-yhsinghala & Shaw, 2014; Cullen et al., 2019; Feng et al., 2020). Due to this, a number of chemicals, especially those containing strobilurin and methyl bromide fungicides, have always been of concern to society.
(Bulayhsinghala & Shaw, 2014; Feng et al., 2020). It is important to note that groundnuts, just as any other plants, have various ways of defending themselves against many diseases. These include root exudates, hypersensitive response, alteration of their rhizosphere through signalling compounds, among others (Bell et al., 2019). The use of leaf spot-resistant cultivars has also been used by many scientists and farmers as an effective way of managing the disease (Mohammed et al., 2018). However, not many leaf spot-resistant varieties are commercially available to farmers. Also, there is a tendency of resistance breakage when new C. arachidica and C. personatum biotypes emerge (Mohammed et al., 2018). Cultural practices such as weed control, proper planting distance, and crop rotation have also gained some relevant importance in the management of the disease. In recent times, scientists have done several studies into developing new strategies for groundnut leaf spot management. The use of other living organisms such as bacteria and fungi, and natural bioactive substances are some of the approaches that have been studied for their efficacy in managing the disease.

2. Biological control
Biological control is an intentional and purposeful introduction of antagonistic living organisms, other than the resistant host plant, to control the populations and activities of specific or a range of phytopathogens (Morin, 2020; Tariq et al., 2020). Per this explanation, biological control methods may include the use of various strains of rhizobacteria to manage many diseases in plants, including leaf spot of groundnut. For example, literature has documented the use of Agrobacterium radiobacter UHFBA-218 strains and Allorhizobium vitis strain ARK-1 in the control of crown gall, and Rhizoctonia, the causative agent for seedling blights (Kawaguchi & Noutoshi, 2022). With regards to leaf spot disease, many studies, for example Nana et al. (2022), have revealed recently that the application of Lecanicillium lecanii was effective in the management of the leaf spot disease. Furthermore, some reports have documented the use of Dicyca pulvinata (Berk. & Curt.) v. Ar x (= Hansfor dia pulvinata (Berk. & Curt.) Hughes) and Verticillium lecanii (Zimmerm.) Viegas (Lecanicillium sp.) which are antagonistic as effective in the management of the early and late leaf spots of the peanut. In India, it has been revealed that the use of V. lecanii that parasitized the uredospires of Puccinia arachidis (Speg) has drastically reduced the extent of rust and late leaf spot on peanut leaves (Subrahmanyam et al., 1990). As effective as biocontrol agents can be, it can be traced back to many decades through the practices of traditional crop rotation practices that primarily suppresses the activities and population of plant pathogens to a level below economic injury levels (Acharya et al., 2021). This could mean that the sole implementation of biological control measures could possibly not achieve maximum results or otherwise must be supplemented with other control measures. Nevertheless, this approach still stands as one of the most effective sole components of leaf spot disease management in most developed and developing countries (Nana et al., 2022). In other aspects of this approach, enriching the soil by the application of compost and manure increases the activities of antagonistic microflora, thereby accelerating the process of controlling the activities of soil inocula of leaf spot-causing organisms (C. arachidica and C. personatum; Acharya et al., 2021).

3. Cultural control
In cultural control, various farm operations and practices are employed as a system of controlling pests and diseases. Practices such as mulching, plant density, cultivation techniques, planting date, time of harvest, strip farming, crop rotation, selection of clean and healthy planting materials, fertilizer application, soil solarization, and soil water management have been used over the years (Branch et al., 2021; Mugisa et al., 2016). Depending on the objective and the situation at hand, these practices are implemented solely or in combination with others to control the incidence and severity of various kinds of crop diseases and pests. However, the implementation of one or more of the above cultural practices is the only economically viable method of controlling disease in some category of crops (Branch et al., 2021; Richard et al., 2022). For example, the sole implementation of crop rotation is one of the best systems to control the incidence and severity of plant diseases (Richard et al., 2022). However, one must be knowledgeable in the types of crops that are added in the crop rotation
scheme as this could increase or decrease the efficiency of the scheme (Jalli et al., 2021). In addition, it could also pose a risk of higher disease incidence and severity in groundnut farms if not selected carefully. To avoid this, it is important to select rotational crops that are non-hosts or not susceptible to the leaf spot disease of groundnut pathogens. For example, non-host plants such as millet, sorghum, and maize can successfully be used in a crop rotation scheme for 2–3 years (Branch et al., 2021; Richard et al., 2022; Woo et al., 2022). Cultural control methods such as crop rotation and ploughing, pruning and roguing, apart from promoting healthy growth of crops, also serve as a measure of reducing inoculum load of pathogens in an area as well as promoting the biological activities of other antagonistic organisms in the soil (Woo et al., 2022). According to Lucas et al. (1992), crop rotation, coupled with rouging and removal of other infected plant debris as well as crop rotation, has been proved to be one of the very efficient ways of managing the disease. For example, an appreciable control of the ELS was achieved by crop rotation with bahiagrass (Brenneman et al., 1995). Also, sporulation of the leaf spot-causing organism has been significantly reduced by deep ploughing of crop residues (Brenneman & Culbreath, 2005).

4. Chemical control
Most farmers in both developed and developing countries resort to chemical control method in managing the leaf spot disease (Atri et al., 2022; Bairwa et al., 2022; Gupta et al., 2022). Fungicide application over the years has been a very important component in the management of plant diseases across the globe. Before the 1970s, systemic fungicides gradually began to replace most indigenous and non-systemic fungicides which were more effective and with higher specificity in disease management (Das & Pattanayak, 2020). Undoubtedly, the application of fungicides over the years has proven to have contributed to the achievement of higher yield among many crops. According to the reports of Atri et al. (2022), grain yields in groundnut increased significantly when fungicides were applied. In other studies, Anco et al. (2020) also revealed that the application of prothioconazole with fluxapyroxad and pyralostrobin was effective in an integrated disease management of groundnut leaf spot disease. The application of thiophanate methyl (Topsin-M) reduced the severity of most foliar fungal diseases (including the leaf spot disease) of groundnut (Kamber et al., 2020; Nutsugah et al., 2007). Due to this, higher pod and biomass yields were observed. Also, the application of carbendazim at a rate of 1.5–2.0 mL/L has been recommended by Plantwise (2017). Fungicide application in high-value crops has contributed immensely to the great harvest of higher quality produce and with uniform appearance (Anco et al., 2020; Kamber et al., 2020). Studies has revealed that non-application of fungicides has led to the outbreak of serious phytopathogenic challenges among most vegetable crop farms (Awurum et al., 2016). However, as relevant as the application of fungicides in groundnut production, higher intensities and/or inappropriate application of these chemicals in most agriculture fields undoubtedly have become an issue of great concern over the past decades (Cullen et al., 2019; Feng et al., 2020). Furthermore, the application of synthetic fungicides in disease control programs has been associated with resistance in many pathogens, pathogen resurgence, impacts on non-target organisms, as well as other ecological and human health-related concerns (Hu & Chen, 2021). Also, other findings revealed that more than 145 fungal species have developed some chronic levels of resistance to most existing synthetic fungicides (Massi et al., 2021). Other studies reveal that new races and biotypes of pathogens usually occur between 5 and 10 years after an introduction of an effective synthetic chemical control agent (Avalos et al., 2022). This finding also revealed a higher level of residues of synthetic pesticides and fungicides in food materials and environments that has been treated previously. These residues in most cases maintain their toxicity for almost throughout the food chain and also impair metabolic processes of non-target species that consume it (Cullen et al., 2019; Feng et al., 2020).

5. Host plant resistance
Any plant that is able to oppose the development and activities of a particular pathogen is considered to be resistant to the pathogen (Saraswathi & Advances, 2020). In most developing countries, host plant resistance serves as a very important approach to controlling most diseases.
6. Conclusion and future perspective
Considering the economic importance of the leaf spot disease and the environmental concerns on the use of chemicals in managing the disease, it is therefore important to develop an environmentally friendly strategy. It is also important to unabatedly improve existing green methods with the aim of upgrading their efficiency levels. For example, issues about the optimum rate, frequency, timing, and method of application of antagonistic organisms and other biocontrol agents under field conditions must be addressed. Also, industries and scientific research should focus on taking advantage of already developed strategies. This will pave the way for easy adoption by farmers on different scales. For decades now, the use of biocontrol agents has been relevant in the management of the ELS and the LLS disease. However, since new species of the disease-causing organisms are identified and classified, it is important that much attention is given to it with several evaluations for better results. To date, sole implementation of any management approach has been unsuccessful in the management of the leaf spot disease. It is therefore important to integrate the implementation of biocontrol method, and others such as cultural control method, and host resistance. In recent studies, culture practices such as crop rotation in combination with biocontrol methods have been evaluated in managing the disease. However, recent advances in technology and knowledge have made more room for further studies on how these new approaches can be synergistically implemented. For example, studies on the scheme and sequence of crop rotation may influence the inoculum load of rhizosphere.
In conclusion, researchers should focus on environmentally benign approaches which will be based on multidisciplinary approaches to fill the gap of most single-edge management approaches. This will also reduce a possible complexity and resistance of different fungicidal components, hence making resistance highly improbable. No matter the strategies that would be devised in the future, their attempts should be focused on the stability, environmental conditions such as non-targeted organisms, and association of individual plants with fungi antagonists of various interest.

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References
Acharya, L. K., Balodi, R., Raghavendra, K. V., Sehgal, M., & Singh, S. K. (2021). Diseases of groundnut and their eco-friendly management. Biotic Research Today, 3(9), 806–809.
Anco, D. J., Thomas, J. S., Jordan, D. L., Shew, B. B., Manfort, W. S., Mehl, H. L., Small, I. M., Wright, D. L., Tillman, B. L., Dufault, N. S., Hagan, A. K., & Campbell, H. L. (2020). Peanut yield loss in the presence of defoliation caused by late or early leaf spot. Plant Disease, 104(5), 1390–1399. https://doi.org/10.1094/PDIS-11-19-2286-RE
Atti, A., Bonyal, D. K., Bhwardew, N. R., & Roy, A. K. (2022). Exploring the integrated use of fungicides, bio-control agent and biopesticide for management of foliar diseases (anzacrocne, grey leaf spot and zonate leaf spot) of sorghum. International Journal of Pest Management, 1–12. https://doi.org/10.1080/09670874.2022.2039799
Avalos, M., Garbevo, P., Vater, L., van Wezel, G. P., Dickerschat, J. S., & Ulanova, D. (2022). Biosynthesis, evolution and ecology of microbial terpenoids. Natural Product Reports, 39(2), 249–272. https://doi.org/10.1039/d1np00047k
Awurum, A., Enyiukuwa, D., & Okojemam, V. (2016). Influence of plant gained compounds on the initiation and development of fungal diseases of onion. Journal of Biology, Agriculture and Healthcare, 6(9), 2224–3208.
Bairwa, N. K., Jambhulkar, P. P., Sushmitha, V., Arya, M., Manjunatha, N., Bajpai, R., Singh, D., Mani, C., Kumar, S., Chaturvedi, S. K., & Laksman, D. (2022). Evaluation of fungicides and bacterial antagonists for management of Corynespora leaf spot on mungbean (Vigna radiata L. Willczek). Archives of Phytopathology and Plant Protection, 55(4), 433–453.
Bell, C. A., Lilley, C. J., McCarthy, J., Atkinson, H. J., & Urwin, P. E. (2019). Plant-parasitic nematodes respond to root exudate signals with host-specific gene expression patterns. PLoS Pathogens, 15(2). https://doi.org/10.1371/JOURNAL.PAT.1007503
Bhat, R. S., Venkatesh, JadHAV, M. P., Patil, P. V., & Shirasawa, K. (2002). Genomics-assisted breeding for resistance to leaf spots and rust diseases in peanut. Accelerated Plant Breeding, 4, 239–278. https://doi.org/10.1007/978-3-030-81107-5_8
Branch, W. D., Brown, I. N., & Culbreath, A. K. (2021). Planting date effect upon leaf spot disease and pod yield across years and peanut genotypes. Peanut Science, 48(1), 49–53. https://doi.org/10.3146/PS20-24.1
Brenneman, T. B., & Culbreath, A. K. (2005). The integrated pest management system. http://nespol.cpes.peach.net.edu/pa
Brenneman, T. B., Sumner, D. R., Baird, R. E., Burton, G. W., & Minton, N. A. (1995). Suppression of foliar and soilborne peanut diseases in bahiagrass rotations. Phytopathology, 85(9), 948–952. https://doi.org/10.1094/Phyto-85-948
Bulayshingha, A. T., & Shaw, I. C. (2016). The toxic chemistry of methyl bromide. Human & Experimental Toxicology, 33(1), 81–91. https://doi.org/10.1177/0960327113493299
Codjia, E. D., Olasanni, B., Agre, P. A., Uwugaren, R., Ige, A. D., Rabbi, I. Y., Olasanni EMAIL, B., & Coutinho, T. (2022). Selection for resistance to cassava mosaic disease in African cassava germplasm using single nucleotide polymorphism markers. South African Journal Of Science, 2, 118. https://doi.org/10.17159/sajs.2022/11607
Cullen, M. G., Thompson, L. J., Carolon, J. C., Stout, J. C., & Stanley, D. A. (2019). Fungicides, herbicides and bees: A systematic review of existing research and methods. PLoS ONE, 14(12), 1–17. https://doi.org/10.1371/journal.pone.0225743
Das, S., & Pattanayak, S. (2020). Integrated disease management on grapes—a pioneer of a reformed movement towards sustainability. International Journal of Current Microbiology and Applied Sciences, 9(5), 993–1005. https://doi.org/10.20546/ijcmas.2020.905.109
Deowar, N. N., Simpson, C. E., Starr, J. L., Wheeler, T. A., & Burrow, M. D. (2021). Evaluation and selection of interspecific lines of groundnut (Arachis hypogaea L) for resistance to leaf spot disease and for yield improvement. Plants, 10(5), 873. https://doi.org/10.3390/plants10050873
Deowar, N. N., Simpson, C. E., Starr, J. L., Wheeler, T. A., & Burrow, M. D. (2021). Evaluation and selection of interspecific lines of groundnut (Arachis hypogaea L) for resistance to leaf spot disease and for yield improvement. Mdi.Com. https://doi.org/10.3390/plants10050873
Dermoe, H., & Sones, K. (2017). Groundnut cropping guide. Mytropah. African Soil Health Consortium. http://afri casoilhealth.cabi.org/wpcontent/uploads/2017/07/562-ASHC-English-Groundnut-A4-bw-lowres.pdf Accessed November 2019
Feng, Y., Huang, Y., Zhan, H., Bhatt, P., & Chen, S. (2020). An overview of strobilurin fungicide degradation: Current status and future perspective. *Frontiers in Microbiology*, 11, 1–11. https://doi.org/10.3389/fmicb.2020.00389

Gupta, P. K., Kaur, J., Tak, P. S., Sandhu, S. K., & Pannu, P. P. S. (2022). Current status of Cercosporidium fungi in India, effective management strategies and future directions. *Indian Phytopathology*, 75(3), 1–12. https://doi.org/10.1007/s42360-022-00052-w

Hu, M., & Chen, S. (2020). Non-target site mechanisms of fungicide resistance in crop pathogens: A review. *Microorganisms*, 9(3), 1–19. https://doi.org/10.3390/microorganisms9030502

Jali, M., Huuseela, E., Jalli, H., Kauppi, K., Niemi, M., Himanen, S., & Jauhiainen, L. (2021). Effects of crop rotation on spring wheat yield and pest occurrence in different tillage systems: A multi-year experiment in finnish growing conditions. *Frontiers in Sustainable Food Systems*, 5. https://doi.org/10.3389/fsufs.2021.647335/PDF

Kamber, U., Javed, N., Junaid, M., Abbas, H., & Ehtesham, M. (2020). Research article evaluation of advanced mung bean germplasm against leafspot disease. *Pakistan Journal of Agricultural Research*, 33(4), 872–877.

Kankam, F., Kojo, K. Y., & Addai, I. K. (2020). Evaluation of groundnut (Arachis hypogea L.) Mutant genotypes for resistance against major diseases of groundnut. *Pakistan Journal of Phytopathology*, 32(1), 61–69.

Kawaguchi, A., & Noutoshi, Y. (2022). Insight into inducing disease resistance with Allorhizobium viti strain ARK-1, a biological control agent against grapevine crown gall disease. *European Journal of Plant Pathology*, 162(4), 981–987. https://doi.org/10.1007/s10658-021-02440-3

Lucas, G. B., Campbell, C. L., & Lucas, L. T. (1992). *Introduction to plant diseases: Identification and management*. Chapman and Hall.

Massi, F., Torriani, S. F. F., Borghi, L., & Toffolatti, S. L. (2021). Fungicide resistance evolution and detection in plant pathogens: Plasmopara viticola as a case study. *Microorganisms*, 9(1), 1–18. https://doi.org/10.3390/microorganisms9010119

Mohammed, K. E., Afutu, E., Odong, T. L., Okello, D. K., Nuwamanya, E., Grignon, O., Rubaihayo, P. R., & Okori, P. (2018). Assessment of groundnut (Arachis hypogea L.) genotypes for yield and resistance to late leaf spot and rosette diseases. *Journal of Experimental Agriculture International*, 21(5), 1–13.

Morin, L. (2020). Progress in biological control of weeds with plant pathogens. *Annual Review of Phytopathology*, 58(1), 201–223. https://doi.org/10.1146/annurev-phyto-010820-012823

Mugia, T. O., Karungi, J., Akello, B., Ochwo-Ssemakula, M. K. N., Biruma, M., Okello, D. K., & Otim, G. (2016). Determinants of groundnut rosette virus disease occurrence in Uganda. *Crop Protection*, 79, 117–123. https://doi.org/10.1016/j.cropro.2015.10.019

Nana, T. A., Zonga, A., Neya, B. F., & Sankara, P. (2022). Assessing the effects of Leccanulicium lecanii in the biological control of early and late leaf spot of peanut in vitro (Burkina Faso, West Africa). *African Journal of Agricultural Research*, 18(1), 1–7.

Nutsugah, S., Oti-Boateng, M., Brandenburg, R. L., & Jordan, D. L. (2007). Management of leaf spot diseases of peanut with fungicides and local detergents in Ghana. *Plant Pathology Journal*, 6(3), 248–283. https://doi.org/10.3923/ppj.2007.248.253

Plantwise. (2017). Pest management decision guide: Green and yellow list. https://www.plantwise.org/ KnowledgeBank/pmdg/20177800655

Rani, A. R., Singh, P., & Kumar, G. (2017). Pros and cons of fungicides: An overview in *International Journal of Engineering Sciences and Research Technology*, 6, 112–117.

Richard, B., Qi, A., & Fitt, B. D. L. (2022). Control of crop diseases through Integrated Crop Management to deliver climate-smart farming systems for low- and high-input crop production. *Plant Pathology*, 71(1), 187–206. https://doi.org/10.1111/PPA.13493

Saraswathi, J., & Advanes, N. M. (2020). Host plant resistance in castor accessions against defoliators. In *Advances in Agriculture entomology* (p. 81). https://www.researchgate.net/profile/Challa-Yashaswini/publication/348565819_Botanical_insecticides/links/600561ce0e6ddccdb8610b4k/Botanical-insecticides.pdf?page=85

Subrahmanyak, P., Reddy, P. M., & McDonald, D. (1990). Parasitism of rust, early and late leafspot pathogens of peanut by *Ventricillium Lecanii*. *Peanut Science*, 17(1), 1–4.

Tariq, M., Khan, A., Asif, M., Khan, F., Ansari, T., Shariq, M., & Siddiqui, M. A. (2020). Biological control: A sustainable and practical approach for plant disease management. *Acta Agriculturae Scandinavica Section B: Soil and Plant Science*, 507–524. https://doi.org/10.1080/09067410.2020.1784262

Tengey, T. (2018). Genetic mapping of leafspot resistant QTLs, and introgression into West African adapted and US-high oleic peanuts. https://ttu-ir.tdl.org/handle/2346/74528

Woo, S. L., Filipis, F., De, Zotti, M., Vandenberg, A., Huci, P., & Bonanomi, G. (2022). Pea-rotation effects on soil microbiota diversity, community structure, and soilborne pathogens. *Microorganisms*, 10(370), 1–12.

Zongo, A., Konate, A. K., Koita, K., Sawadogo, M., Sankara, P., Ntare, B. R., & Desmae, H. (2019). Diallel analysis of early leaf spot (*Cercospora arachidicola*) disease resistance in groundnut. *Agronomy*, 9(1), 1–12. https://doi.org/10.3390/agronomy9010015
