Cochliobolus, Bipolaris, and Curvularia Species

Subjects: Mycology

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Cochliobolus, *Bipolaris*, and *Curvularia* genera contain various devastating plant pathogens that cause severe crop losses worldwide. The species belonging to these genera also perform a variety of diverse functions, including the remediation of environmental contaminations, beneficial phytohormone production, and maintaining their lifestyle as epiphytes, endophytes, and saprophytes. Research has revealed that despite their pathogenic nature, these fungi also play an intriguing role in agriculture. They act as phosphate solubilizers and produce phytohormones, such as indole acetic acid (IAA) and gibberellic acid (GAs), to accelerate the growth of various plants. Some species have also been reported to play a significant role in plant growth promotion during abiotic stresses, such as salinity stress, drought stress, heat stress, and heavy metal stress, as well as act as a biocontrol agent and a potential mycoherbicide. Similarly, these species have been reported in numerous industrial applications to produce different types of secondary metabolites and biotechnological products and possess a variety of biological properties, such as antibacterial, antileishmanial, cytotoxic, phytotoxic, and antioxidant activities.

Keywords: Curvularia ; Bipolaris ; fungi ; phytohormones

1. Diversity, Habitation, and Ecology of *Cochliobolus*, *Curvularia*, and *Bipolaris*

The *Cochliobolus*, *Bipolaris*, and *Curvularia* species are found all over the world as pathogens and saprobes in plants, humans, and animals [1][2]. *Curvularia* species have also been found in the air [3], in aqueous habitats and in soil [2][4]. These species were reported primarily based on Poaceae members and are major pathogens of grass and staple crops, such as rice, maize, wheat, and sorghum [5]. *Caricaceae*, *Actinidiaceae*, *Convolvulaceae*, *Aizoaceae*, *Iridaceae*, *Polygonaceae*, *Lamiaceae*, *Oleaceae*, *Lythraceae*, *Fabaceae,* and *Rubiaceae* are among the other genera that serve as hosts [1][6]. Most *Curvularia* species, on the other hand, are found as facultative plant pathogens in tropical and subtropical environments, as well as endophytes on several Sudanese plants [7][8]. *Curvularia* also includes new human opportunistic pathogens, such as *C. chlamydospora* and *C. lunata,* which cause infections of the respiratory tract, cutaneous, brain, and ocular surfaces, primarily in immunocompromised people [9]. Other species, such as *C. hawaiiensis*, *C. australiensis*, *C. spicifera*, and *C. lunata*, have also been isolated from human specimens and are thought to be the cause of animal and human disorders [10]. Two more species, *C. hominis* and *C. tuberculata*, have recently been identified as causes of keratitis [11] and a human disseminated phaeohyphomycosis [12]. *Curvularia* spp. has replaced several species previously classified as *Pseudocochliobolus*. As a result, *Pseudocochliobolus* is not further considered a distinct genus, as the type has been synonymized with *Curvularia* [2].

Cochliobolus species are heterothallic fungi that thrive in soil and organic matter and as endophytes, producing secondary metabolites with important biological functions [13][14]. *Curvularia* [15] is a hyphomycete fungus that is both cosmopolitan and widespread. *Curvularia* is distinguished by the development of brown distoseptate conidia, which have paler terminal cells and inordinately larger intermediate cells, contributing to the curvature of the organism. It is worth noting that fungal endophytes are responsible for more than half of all bioactive substances discovered [16]. Many medicinal chemicals are derived from endophytic fungi, including those with anticancer, antifungal, antiviral, antibacterial, antitumor, and anti-inflammatory properties. *Cochliobolus* is a fast-growing fungus that may reach a diameter of 5.5 cm in just five days when plated on malt extract and Czapek's Agar media [17][18]. These species are weed pathogens, and because weeds and pathogens have evolved together over time, they can be used as weed herbicides [5].

2. The Pleomorphic Genus *Cochliobolus*

Pleomorphic fungi are allowed to have two names under the International Code of Botanical Nomenclature. Nonetheless, a worldwide goal is to give all fungi a single name [19]. Many *Cochliobolus* species have asexual stages in either *Bipolaris* or *Curvularia* and thus are synonyms. *Cochliobolus heterostrophus* and *B. maydis* (Y. Nisik. & C. Miyake) Shoemaker, for example, are biologically the same species, and *Cochliobolus geniculatus* R. R. Nelson and *Curvularia geniculata* (Tracy & Earle) Boedijn are biologically the same species. *C. bouteloua e, C. miakei*, *C. palmivora*, *C. sasae*, and *C. sitharamii* are the only species not connected to any anamorph state [20]. A *Cochliobolus* teleomorph was reported in *B. micropus* (Drechsler) Shoemaker, but it was never named or characterized, and its current name is *C. micropus* in the Index Fungorum database. According to an updated list in the Index Fungorum database there are 140 *Bipolaris* names, 54 *Cochliobolus* names, and 233 *Curvularia* names. Only 43 *Cochliobolus* teleomorphs are connected to the asexual states of *Bipolaris* (11 names) and *Curvularia* (18 names) [21]. The authors of [22] investigated nine *Curvularia* and *Bipolaris* species with unknown sexual states and discovered that they all share an ancestor with the sexual *Cochliobolus* species. Molecular analysis of *Bipolaris* and *Curvularia* species revealed that none of them were monophyletic [22]. When picking a unique name for a fungus species, there are several points of view based on which the name should be used, such as the oldest name, the teleomorphic name, or the most important name [23]. The name *Curvularia* [15] is older than *Bipolaris* [24] and *Cochliobolus* [25]; it may be necessary to use *Curvularia* for all species of these genera after the Botanical Code is updated in 2013 and Article 59 is no longer in effect.

3. Morphology of *Curvularia* and *Bipolaris*

Cochliobolus ascomata have a globose body and are dark brown to black in color. On the ascomata, hyaline-to-brown sterile hyphae and conidiophores are common [1]. Characteristics include bitunicate asci, 2–8-spored, cylindrical-to-obclavate or obclavate cylindrical. The ascus contains filiform ascospores that are more or less coiled in a helix. Most *Cochliobolus* species produce sterile protothecia (sclerotia) that lack ascogenous hyphae [24]**.** It is a saprophyte that lives mostly in the form of thick-walled conidia. It can also survive as a mycelium in soil or crop debris. In the disease cycle, the sexual stage is less important. Mycelium from infected seeds, conidia in the soil, and conidia on the kernel surface are all examples of the primary inoculum [21]. Conidia of diverse forms were found in *Cochliobolus* species, such as straight conidia, curved conidia, smooth conidia wall, curved conidia with 3-distoseptate, a tuberculate conidia wall, conidia with 5-distoseptate, and conidia with 6- to 10-distoseptate. The wall is made up of cells with the same or less body density. Asci are two to eight-spored, bitunicate, tubular to obclavate, or obclavate tubular [1]. In the ascus, ascospores are filamentous and spiral in a helix [1]. When the generic reports of *Bipolaris* and *Curvularia* are compared, the two taxa are morphologically very similar and cannot be distinguished using any taxonomic approach [1]. Furthermore, there are physical differences between these two taxa, such as septal structure; *Curvularia* species have euseptate conidia, whilst *Bipolaris* species have distoseptate conidia [26].

4. *Cochliobolus*, *Curvularia* and *Bipolaris* Lifestyle

4.1. Cochliobolus, Curvularia and Bipolari as Epiphytes

Epiphytic microorganisms live on the surfaces of aerial plant components, and many of them can affect pathogen growth [27]. Epiphyte–endophyte interactions have crucial implications for fungal biodiversity and plant health [28]. *Curvularia* and *Bipolaris* species have only been found as epiphytes in plants in a few cases. For example, *Lasiodiplodia theobromae*, a common fungal disease, is antagonized in vitro by *C. pallescens*, which was isolated as an epiphytic from the surface of banana fruit [29].

4.2. Cochliobolus, Curvularia, and Bipolari as Endophytes

Numerous *Cochliobolus* species have been found to be endophytes of diverse plant species, and their percentage frequency as compared to that of other species is often modest [30][31]. In wheat glumes, *B. sorokiniana* (sexual state: *C. sativus*) was found in high numbers [32]. Endophytes are commonly seen in the asexual stages of *Bipolaris* and *Curvularia*; however, there are rare reports of the teleomorph phase as endophytes. Recently, *C. lunata* strain AR11 was identified as an endophyte that was employed to improve rice plant growth and reduce salt and drought stress [33]. Furthermore, *C. iranica* a new endophytic species, was also isolated in Iran from ornamental trees [34]. Several *Curvularia* endophytes are latent pathogens in plants under stress, and they cause severe illness in Musa spp. [35]. The transformation of the life mode from endophyte to pathogen might be triggered by changes in host plant sensitivity, high humidity, or a lack of nutrients [36]. *C. protuberata* was also reported as an endophyte of *Dichantelium lanuginosum*, a form of a three-way symbiotic interaction with host plants, allowing them to live under harsh soil conditions [37]. Asexual stages of *Bipolaris* are common in marine sponges and can also be seen in combination with sea grasses [38]. The coastal sponge *Gelliodes carnosa* was found to be connected with a *Bipolaris* species that had close affinity with the widely-known plant pathogen *B. sorokiniana* [39].

4.3. Cochliobolus, Curvularia, and Bipolaris as Saprobes

Cochliobolus species and their asexual forms have also been isolated as saprobes [40][41]. *Cochliobolus* anamorphic states have been identified in conjunction with a variety of Poaceae species, including bamboo and other host plants. Various researchers have reported about 19 *Cochliobolus* species and their asexual forms from different plant dead materials. *C. lunata*, for example, is often seen as a bamboo clump saprobe [42]. Various *Cochliobolus* species and their asexual forms have been isolated from several dead wood plants [42][43].

5. Application of *Cochliobolus*, *Curvularia,* and *Bipolaris* in Agriculture and Functional Roles

5.1. As a Plant Growth Promotor

Several species of the *Cochliobolus* genus have been shown to promote plant growth. Compounds synthesized by *C. setariae* IF0 6635 promoted rice seedling elongation. The active compound designated as cis-sativenediol was isolated from both fungal mycelia and culture filtrates with several related metabolites, including its trans isomer. It is interesting that pathogenic fungi containing growth-inhibitory substances for host plants can also produce a plant growth-promoting substance. A fungal elicitor extract was used to test the growth-promoting effects of *C. lunatus* and *C. pallescens* recovered from the *Artemisia annua* L. plant [44]. Some chemical compounds produced by or found in endophytic fungus may be responsible for the growth-promoting effects of the fungal elicitor extract [45]. *Arabidopsis thaliana* (L.) Heynh. seedlings grew better when given a cell wall extract from an endophytic fungus [46]. As reported in other fungal species, there is a high concentration of chitin and chitosan in the cell walls of *Cochliobolus* fungi [47]. Artemisinin production in *A. annua* plants was activated by chitosan applied topically (foliar application) [48]. *Abelmoschus esculentus* (L.) Moench, grew taller, had more leaves, and produced more fruit due to this treatment [49]. Fungal elicitor extract, in addition, has the potential to induce stress responses in plants, making them more resistant to infections and other environmental challenges.

5.2. Phytohormone Production

Phytohormones are chemical messengers that influence the development of plants. At low concentrations, these compounds can control the metabolic activity of plants and have a wide variety of uses in agriculture [50]. One of the most important phytohormones, indole acetic acid (IAA), controls cell growth and division [51]. The plant-derived IAA is also produced by soil and endophytic microorganisms and has been shown to enhance plant development [52][53]. Endophytic fungi, such as *Curvularia* species, have recently been found to produce IAA in the tissues of aerial plant parts [54]. These fungi produce IAA, which has been demonstrated to increase plant biomass and root growth. The ability of *C. geniculate* to produce IAA was discovered in several experiments by enhancing plant growth [33][55][56][57]. When exposed to salt and drought stress, the *C. lunata* AR11 strain has the capacity to spontaneously synthesize the GAs (GA_1, GA_3, GA_4, and GA_7) and organic acids needed to increase nutrient absorption [33][58]. Similarly, *Bipolaris* sp. CSL-1 was reported to promote plant growth by producing IAA and GAs [59].

5.3. Phosphate-Solubilizing Agent

All plant parts contain endophytic fungi, and the solubilization of soil nutrients and the synthesis of phytohormones are numerous ways these fungi help plants grow [60]. Under harsh environmental circumstances, these fungi promote plant growth and health [56]. The hydrolytic enzymes produced by these fungi in the breakdown of organic matter have been studied in a few studies, but there are no studies on their involvement in the solubilization of insoluble nutrients in the soil and the availability of those nutrients to plants [61]. An essential macronutrient for plant development and growth is phosphorus (P). Tropical soils, on the other hand, have low P availability [62]. These complexes are insoluble because the negatively charged inorganic phosphate anion rapidly interacts with cations, such as iron, calcium, and aluminum. As a result, in alkaline soils, phosphate is often found as the tricalcium phosphate [$Ca_3(PO_4)_2$], whereas in acidic soils, it is found as $FePO_4$ and $AlPO_4$ [63]. Plants cannot readily access certain types of phosphate. As a result, synthetic P fertilizers are required to maximize crop productivity on soils like these. It is also worth noting that synthetic fertilizers have several negative impacts on ecosystems. In order to limit the usage of synthetic fertilizers, one alternate technique is to use soil microorganisms, particularly those capable of solubilizing insoluble nutrients. Research has shown that fungi are more effective than other soil microorganisms in breaking down nutrient bonds [64]. Researchers found that fungal isolates solubilized $Ca_3(PO_4)_2$ and rock phosphate more effectively than bacteria [65]. Phosphate rock may be more easily dissolved by the dark septate endophyte fungus [66]. Phosphate solubilization by *Curvularia* and *Bipolaris* strains has been found to promote plant growth [33][67]. Mixing non-antagonistic *Bipolaris* species in a bio-fertilizer formulation might be essential in improving $Al–PO_4$-H_2O solubilization and boosting soil fertility. The fungus showed promising characteristics for use as biofertilizers in agricultural acreage sustainability management. The root endophytic fungus *C. geniculata* from *Parthenium* Hysterophorus roots enhanced plant development via phosphate solubilization and solubilized $FePO_4$ and $AlPO_4$ more effectively than the easily solubilized $Ca_3(PO_4)_2$ phosphates [68].

6. *Bipolaris* and *Curvularia* Secondary Metabolite Production

Cochliobolus and its anamorph generate a wide range of secondary metabolites. Toxins and metabolites produced by taxa cannot be used to distinguish between both the species *Bipolaris* and *Curvularia* [1]. Curvulin, for example, is derived from *B. papendorfii* and *Curvularia* sp., among other sources [1]. Phytotoxic, cytotoxic, leishmanicidal, antioxidant, fungicidal, and antibacterial properties were found in many crude extracts of *Bipolaris* and *Curvularia*. It is possible that crude extracts of *Bipolaris* and *Curvularia* spp. might be used to treat various chronic disorders and might be beneficial for agriculture and pharmaceuticals. These secondary metabolites (SMs) come from various chemical families, including peptides, terpenes, quinones, alkaloids, polyketides, and anthraquinones. *Cochliobolus carbonum* produces EXG1p novel Exo-1,3-glucanase, a cell wall-degrading enzyme [69]. A Gamma pyrone [70] plant growth inhibitor and 6-Chlorodehydrocurvularin are produced by *Cochliobolus spicifer* [71]. These fungi synthesize IAA, which has been demonstrated to increase root growth and plant biomass [58]. The ability of *C. geniculate* to produce IAA was discovered in several experiments by enhancing plant growth [68]. When exposed to salt and drought stress, the *C. lunata* AR11 strain has the capacity to spontaneously synthesize the GAs (GA_7, GA_4, GA_3, and GA_1) and organic acids needed to increase nutrient absorption [33]. Cochlioquinones A and B, novel metabolites having a p-quinonoid origin, are generated by *Cochliobolus miyabeanus* [72]. The 9-hydroxyprehelminthosporol chemical generated by *Cochliobolus sativus* is an antiviral. Additionally, *Cochliobolus* exhibits other actions that may be beneficial to plants, including being a widespread disease of grasses (Poaceae) and essential food crops, such as rice, wheat, and maize [21]. *Cochliobolus*, for example, may be utilized as a biochemical modulator to relieve okra plant salinity stress [73][74]. Buffelgrass is poisonous to chloromonilinic acids C and D from *Cochliobolus australiensis*, which delay germination and drastically inhibit radicle development [75].

7. Biological Activities of the Genera *Curvularia* and *Bipolaris*

Cochliobolus species have also shown promise in a variety of biological functions. The metabolite extract or secondary metabolites, e.g., natural products from the genera *Curvularia* and *Bipolaris*, have powerful biological activity, such as antimicrobial (antibacterial and antifungal), antioxidant, leishmanicidal, cytotoxic, and phytotoxic effects. *Cochliobolus* metabolites were found to have antileishmanial properties against *Leishmania* and *Trypanosoma*. *Leishmania amazonensis* amastigote-like forms were killed by the crude extract of *Cochliobolus* sp. at 20 g/m concentration, and this action might be linked to the metabolites cochlioquinone A and isocochlioquinone A [73][76]. *Cochliobolus* metabolites were shown to have anticancer effects as well. Radicinin extracted from *Cochliobolus geniculatus* WR12 has an IC50 of 25.01 ppm against T47D cells [77]. Dendryphiellin I, which was isolated from the marine *C. lunatus* SCSIO41401, was discovered to be cytotoxic to three renal cancer cell lines (ACHN, 786-O, and OS-RC-2), a human liver cancer cell line (HepG-2), and a human gastric cancer cell line (SGC7901).

8. Role of *Cochliobolus*, *Curvularia,* and *Bipolaris* Species in Abiotic Stress Tolerance

8.1. Salinity Stress Tolerance

Cochliobolus exhibits different activities that can be useful for plants. For example, *Cochliobolus* can be used as a biochemical modulator to alleviate salinity stress in okra plants [73][74]. In many parts of the world, salinity is one of the major abiotic stressors that restricts plant growth, development, and improvement and causes an excessive decline in plant productivity [78]. Moreover, a quarter of the world's irrigated land suffers from salinity stress, making it one of the most critical environmental issues. Three different physiological stressors are applied to plants grown in salty environments. The earliest harmful effects of the sodium and chloride ions, which are present in salty soils, interfere with the structure of enzymes and other macromolecules, impede respiration and photosynthesis, damage cell organelles, cause iron deficiency, and inhibit protein synthesis [79]. Plants in salty soils are more susceptible to physiological dehydration because they must limit water transfer from roots to soil to maintain a lower internal osmotic potentials [80]. Finally, salty soil inhibits nutrient absorption in plants, resulting in an imbalance in plant nutrition. This kind of stress causes cellular death-causing reactive oxygen species (ROS) in plants. At such times, free electrons from electron transport chains in chloroplasts and mitochondria are provided by reactive oxygen species (superoxide, singlet oxygen, and hydrogen peroxide) and hydroxyl radical [81]. *C. lunatus* boosted okra plant growth and biomass while reducing lipid peroxidation in NaCl-treated plants. *C. lunatus* enhanced the amounts of flavonoids, phenolics, phytohormones, total chlorophyll, and proline in okra plants treated with NaCl [73][74].

8.2. Enhance Heat and Drought Stress Tolerance

As a result of the global warming caused by greenhouse gas emissions, which are expected to rise by 1.5 to 8.8 degrees Celsius by the year 2100 [82], there is a serious threat to food and nutritional security worldwide. Plants in their ecological niches must either evolve natural mechanisms or be genetically engineered with heat shock genes and cognates or specific non-protein-coding short RNAs to withstand heat stress and drought. When plants are exposed to both positive and negative stimuli, their genomes can sense them and regulate adaptability to selection forces with great care to ensure survival in a changing biota [83]. Soil temperature resistance may be improved by fungal symbiosis, by *C. cryptic* [84]. Tolerant of constant temperatures of 50 degrees Celsius and periodic soil temperatures of 65 degrees Celsius, *Dichanthelium lanuginosum* from geothermal soils in US national parks can survive for ten days due to a mutualistic relationship with *C. protuberata* [84]. When looking into geothermal habitats, scientists identified *C. crepinii* and *C. protuberrata*, both of which are attracted to the plant *Hedyotis diffusa*, and successfully boosted the thermostability [85]. Similarly, under controlled laboratory conditions, all *C. crepinii* and *C. protuberrata* isolates grew at 50 °C and gave 5 days of thermotolerance to *Oryza sativa* [85]. In spite of [84] showing a complicated link between *Curvularia* thermal tolerance virus (CThTV) and *C. protuberrata–D. lanuginosum* thermotolerance [84][85] various degrees of thermotolerance to their different hosts were found in *Curvularia* species in their biological habitat. Melanin of most *Bipolaris* and *Curvularia* species is expected to play a significant role in distributing heat along hyphae and sequestering oxygen radicals produced during heat stress [21][86][87]. Osmoprotectants, such trehalose, glycine betaine, and taurine production, have been related to virus-induced heat tolerance in *Curvularia* [37]. Fungi that produce melanin are also tolerant to abiotic stresses, such as high temperature, chemicals, radioactive pollution, solar radiation, and drought [88]. Recent research found that co-culturing pre-germinated rice seedlings with a thermotolerant endophyte improved root and shoot development under high-temperature stress [66]. Pre-germinated rice seedlings were infected with an endophytic thermotolerant fungus, which increased root length throughout the seedling phase [89]. *C. lunata* AR11 strain was recently identified as a plant growth-promoting fungus by producing phytohormones and alleviating drought and salinity stress in plants [33].

9. *Curvularia* and *Bipolaris* Biotechnological Applications

9.1. As a Biocontrol Agent

The relevance of an endophytic fungus as a plant biocontrol agent has been proven in several studies. Fungi as biological control agents are a rapidly growing area with implications for food security, human health, and animal and plant productivity [90]. Weeds are a cost-cutting measure in agricultural production [91]. Plant pathogens are now widely accepted as a viable, safe, and ecologically beneficial weed-management technique for agroecosystems. Mycoherbicides are important in the transition to organic farming and in reducing the usage of chemical herbicides. Infections may have developed biochemical methods to destroy the weed host, and *Bipolaris* sp. was tested in Australia as a potential herbicide against serrated tussock [92]. *Cochliobolus* strains have been found to contain curvularides, cochlioquinones, anthroquinones, and several new proteins associated with cyclic peptide control and cell wall disintegration. These chemicals could have significant pharmacological qualities, such as antifungal capabilities, and hence could be applied in medical research [93]. Invasive weed control is a serious difficulty in a mono-cropping system, since it reduces crop production and quality, causes allergic reactions after pollination, and causes aesthetic discomfort [94][95].

With the increased use of endophytic fungi proficiently producing phytotoxic poisons and thus gradually replacing synthetic herbicides, a paradigm shift has been noticed [13]. *Curvularia* species are an essential source of mycoherbicides because they produce a wide range of bioactive compounds [96]. *C. eragrostidis*, for example, produces phytotoxic chemicals, such as dehydrocurvularin, helminthosporin, and curvularin, which are used to suppress a variety of weeds [97]. While *C. eragrostidis* triggers plant diseases [98], it was discovered that dehydrocurvularin inhibits reoxidation of the photosynthetic chain's primary electron acceptor (QA) [99]. Helminthosporin, on the other hand, attacks the chloroplast function of the common weed *Digitaria sanguinalis* [99].

9.2. Cochliobolus, Curvularia, and Bipolaris Species in Enzyme Production and Biotransformation

A filamentous fungus mostly produces commercial and industrial enzymes. In 2018, industrial enzymes were expected to be valued at USD $5.6 billion [66]. In 2017, industrial enzymes had a 26 percent (USD $1.4 billion) impact on food and drinks, 18 percent (USD $969.3 million) in biofuels, and 14 percent (USD $754.4 million) in detergents. The demand for additional industrial enzymes is predicted to reach USD $7.7 billion by 2024 as a consequence of changing lifestyles and rising waste generation throughout the globe [66]. In contrast to other fungi, *Bipolaris* and *Curvularia* species synthesize extracellular enzymes radially, making them optimal for enzyme synthesis [100]. When compared to proteins in protein databases, almost 25.64 percent of *Cochliobolus lunatus* proteins have no putative activities, according to a secretomics analysis [66]. According to quantitative evidence, *C. lunatus* produces laccase and manganese (Mn) peroxidase at the same time [101]. According to a genome-wide study, single-copy gene loss in certain *Pleosporales* species allows them to produce manganese (Mn) peroxidase, which is generally conserved in *Basidomycetes* [102]. In *Pleosporale* order species (*Pyrenophora tritici-repentis*, *Stagonospora Nodorum*, and *C. heterostrophus*), only a single copy of the CCC1 gene, a Mn^{2+} and Fe^{2+} vacuolar transporter, was discovered [102]. However, it has been proposed that measuring laccase production might be as simple as combining suitable *Bipolaris* species or strains in the same microenvironment. *Curvularia* and *Bipolaris* species have been shown to generate bioactive antimicrobial chemicals that are used in enzyme manufacturing and biotransformation.

10. In Bioremediation and Waste Biomass Valorization

In both rich and emerging economies, poor industrialization, agricultural, and environmental policies have resulted in massive discharges of toxic waste, such as fluorinated and chlorinated aromatic hydrocarbons. Furthermore, laccase-producing organisms, such as genetically modified plants that overexpress laccase and free-living *Curvularia* and *Bipolaris* species, are used instead of costly physical and chemical detoxification methods [103][104]. Bringing these “nature bioengineering” fungus species on board and maximizing their capabilities could have ramifications in medicine, agriculture, and the chemical sector, ensuring the bio economy’s long-term maintenance and viability.

It is important to fully comprehend the economic benefits of the cryptic *Cochliobolus* complex at the organismal level, such as their role in the production of industrial enzymes [104], medications [105], and bioremediation [103], biodiesel [106]. Bioremediation is the capacity of microorganisms to break down (detoxify) harmful chemicals and undesirable organic compounds into non-toxic molecules [107]. In the agro-industry, palm oil extraction creates much bio waste, such as empty fruit bunches and palm oil mill effluent (POME). Palm trash is often disposed of by burning, which pollutes the environment. A mixture of ligninolytic enzymes (manganese peroxidase, lignin peroxidase, and laccase) and glycosylhydrolytic enzymes (xylanase and cellulase) is produced during POME–*Curvularia clavata* interactions [108]. In the instance of bioremediation, *C. lunatus* was found to biodegrade crude oil, resulting in a 1.5 percent weight loss (of the crude) in one week, 2.1 percent weight loss in two weeks, and 4.7 percent weight loss in three weeks [66][109]. Similarly, the fungus *C. lunatus* strain CHR4D was isolated from crude oil-polluted shorelines in India, and it was determined that chrysene ($C_{18}H_{12}$), a four-ringed high molecular weight polycyclic aromatic hydrocarbon, was degraded swiftly and effectively [110]. Surprisingly, after only four days, 93.10 percent of the chrysene was eliminated [110]. Unlike the use of *C. lunatus* to break down plastic [103], co-substrate, such as glucose and tartrate, were used to promote the production of extracellular lignin-modifying enzymes (LMEs) during chrysene metabolism, enhancing the fungus’ efficiency [110]. LMEs that may co-metabolize ringed high molecular weight polycyclic aromatic hydrocarbons to speed up decomposition include peroxidases, manganese peroxidases, and laccases [111].

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