The Pathogenicity and the Biological Control Potentials of *Cladosporium cladosporioides* and *Epicoccum nigrum* in Crops: A Review

Aigbe[*], S. O

[*]*Department of Crop Science, Ambrose Alli University, Ekpoma, Nigeria*

Abstract- **Cladosporium species are cosmopolitan fungi in nature and exhibit diverse lifestyles including saprophytes, plant pathogens, fungicolous, human pathogens and endophytes. Similarly, Epicoccum nigrum is a fungus species that is both plant pathogenic and and endophyte. It is a widespread fungus which produces coloured pigments that can be used as antifungal agents against other pathogenic fungi. Cladosporium cladosporioides and Epicoccum nigrum have both been severally reported as pathogens of economically important crops plants. They have also both been reported as biological contro agents of some pathogens of important certain crops. This is a review of the pathogenicity and the biological control activities of these fungi on econimically important crops.**

Keywords- **Cladosporium cladosporioides, Epicoccum nigrum, pathogenicity, biological control**

I. INTRODUCTION

Cladosporium is one of the most common genera of fungi occurring on various substrates and includes species antagonism to pathogenic fungal species has been described for the genus (Singh and Singh, 1994). *Cladosporium* with diverse lifestyles. Besides saprophytic behavior, *cladosporioides* has also been previously reported on two-spotted spider mite (*Tetranychus urticae*) and on alfalfa weevil larvae (Narmani *et al*., 2016). *Cladosporium cladosporioides* colony on Potato Dextrose Agar (PDA) was observed to have a velvet-like appearance, and their color ranged between olivaceous-brown and smoky-grey to olive and almost black. The intercalary conidia of the isolates were elliptical to limoniform. The secondary ramoconidia of these isolates were 0- or 1-septate. (Nam *et al*., 2015). Colony, after 18 days of incubation at 25°C on PDA was observed to appear gray in color, with salient points, short dense fluffiness, clear water exudates on top, and yellow pigment released into the media. The backside of colony appeared dark brown. Conidia were round to fusiform, growing singly or in clusters. Septa were observed in some conidia (Sun *et al*., 2017).

Epicoccum nigrum is a fungus species in the phylum Ascomycota. It is a plant pathogen and endophyte. It is a widespread fungus which produces coloured pigments that can be used as antifungal agents against other pathogenic fungi (MoldHelp, 2004). *Epicoccum nigrum* has yellow colony on PDA, which appear reddish toward center at back side of plate (Adelaide, 2016). *Epicoccum nigrum* produce pigment in PDA which is dark orange to green-yellow color; the fungus produce no spore at times (Adelaide, 2016). *Epicoccum nigrum* has no known teleomorph form (Anderson *et al.*, 1981), as it is only known to reproduce asexually. The fungus was reported to grow felty colonies in bright shades of yellow, orange, and red, often with brown or black throughout (Pfaller, *et al.*,2009; Mims and Richardson, 2005) . Colonies were observed to grow quickly, reaching about 6 cm in diameter in 2 days at room temperature. Mycelia contain both chitin and cellulose. *Epicoccum nigrum* forms blastoconidia that are darkly coloured, warted and spherical, reaching 15 to 25 µm in diameter (Pfaller, *et al.*, 2009). Conidia grow on a sporodochium, formed by warty and fibrous hyphae(Pfaller, *et al.*, 2009; Mims and Richardson, 2005). Sporulation is induced under Wood's light, or sometimes upon exposure to cold temperatures with a subsequent return to room temperature (Pfaller, *et al.*, 2009). Pigment production is also sensitive to light and temperature changes (Gribanovski-Sassu and Foppen, 1968). *Epicoccum nigrum* produces a variety of biomedically and industrially useful metabolites, including important antifungal agents and pigments, including: flavipin, epicorazines A and B, epirodin, epicocconone, and a variety of carotenoid pigments (Bamford, 1961; Brown *et al*., 1987). Most of *Epicoccum nigrum* metabolites showed cytotoxic, anticancer, antimicrobial and anti-diabetic activities (Fatima *et al*., 2016). This work therefore review the pathogenicity and biological control activities of *C. cladosporioides* and *E. nigrum* in economically important crops.

A. Pathogencity of Cladosporium cladosporioides and Epicoccum nigrum

Cladosporium cladosporioides has been reported to be pathogenic to plants. For instance, *C. cladosporioides* was reported to cause papaya scab in Iran (Baharvandi, H. A.; Zafari, D. 2015), leaf spot on *Dendrobium officinale* in China (Sun *et al*., 2017), leaf spot of pecan and *Alstroemeria aurea* plants in Brazil (Walker *et al*., 2018; Meneses *et al*., 2018), blossom blight in strawberries in Korea (Nam *et al*., 2015) and fruit blotch of zapote mante (*Pouteria campechiana*) in Mexico (Nabor-Romero, 2018). *Cladosporium cladosporioides* has also been reported as is one of the promising entomopathogenic fungi acting as insect pathogenic microorganism that can also be used as a source of toxins against insect pests. Entomopathogenic fungi were among the first organisms used for microbial control of insect pests. A number of fungal species has been recognized for this purpose (Gottel *et al*., 1990; Ferron *et al*., 1991). Many species of *Cladosporium* were used in the microbial control of plantinsect pests like aphids and whiteflies which showed resistance to chemical insecticides. *C. cladosporioide* was recorded as natural pathogen of cowpea *Aphis crassivora* (Ibrahim, 2012) and cabbage aphid, Brevicoryne brassicae L. (Ibrahim, 2017) revealing high virulence against aphid populations. Many bioactive compounds were isolated from *C. cladosporiodes*. Kobayashi *et al*. (1989) isolated the calphostin family of natural products from fermented broths of *C. cladosporioides*. Also, Sakagami et al. (1995) isolated Cladosporol from the culture filtrate of *C. cladosporioide*, which showed antitumor activity in mice. Some pentacyclic composts of cytokines and tyrosine kinase inhibitory properties, were isolated from *C. cladosporioides* (Wrigley *et al*., 2001). In addition, Wang *et al*. (2013) studied the extracts of *C. cladosporioides* (Fresen.) and isolated four compounds including cladosporin; isocladosporin; 5′ hydroxyasperentin; and cladosporin-8-methyl ether. Some of these metabolites exhibit bioactive or insecticidal properties which enable us to use them for insect pest control. Cotton aphid, *Aphis gossypii* is a serious pest damaging cultivated crops either directly by sucking plant sap or indirectly by transmission of many plant viruses leading to great loss of crop yield. It effectively transmits polyviruses, such as cucumber mosaic virus, watermelon mosaic virus 2 and zucchini yellow mosaic virus (Capinera, 2005). Controlling this pest with insecticides led to many problems in environment, human health and non-target organisms. So, the bioinsecticides which depend on microorganisms or their toxins can be used as more secure alternatives of the traditional insecticides (Shaker *et al*., 2019)

In an experiment in Poland, to identify the pathogens present in the pea seeds of different cultivars, *Epicoccum nigrum* was one of the fungus isolated along with other fungal pathogens such as *Alternaria* and *Fusarium* species Wilman *et al*. (2014). Pathogecity of *E. nigrum* were similarly reported in *Cucumis melo* by Bruton *et al*. (1993) and in *Lablab purpureus* and loquat by Mahadevakumar *et al*. (2014) and Wu *et al*. (2017) respectively. In the later study, isolates having 98% identity with *E. nigrum* (KC568289 and KY303832) caused leaf spot in *Lablab purpureus* and brown leaf spot in loquat, respectively. Recently and also for the first time, Colavolpe *el al*. (2018) reported leaf spot in *L. corniculatus* caused by *E. nigrum* in Argentina.

B. Biological Control Potential of Cladosporium cladosporioides and Epicoccum nigrum

Some of the most common examples of the antagonism in *Cladosporium* come from the relationship between *Cladosporium* spp. and rust pathogens (Pusz, 2015; Wilman *et al*., 2014), such as *C. cladosporioides* parasitizing *Venturia inequalis* and *Puccinia striiformis* f.sp. tritici (Stupar *et al*., 2014). *Cladosporium cladosporioides* was observed to significantly promotes host seed germination of coastal plant *Suaeda salsa* and other plant growth. *Cladosporium cladosporioides* was also present in the phyllosphere, rhizosphere and root endosphere of *S. salsa*, supported the evidence of its primary soil-borne origin and both epiphytic and endophytic infection of host tissues (Qin., *et al*., 2016).

Despites the pathogenicity report of *E. nigrum*, most isolates have been reported to control many impotant plant pathogens. It is commonly found growing on cereals and seeds, as well as other crops including corn, beans, potatoes, peas and peaches (Anderson *et al*., 1981; Flannigan *et al*., 2011). It produces a variety of pigmented and non-pigmented antifungal and antibacterial compounds (Brown *et al*., 1987; Gribanovski-Sassu and Foppen, 1967). These antimicrobial compounds are effective against other fungi and bacteria present in soil (Brown *et al*., 1987). In Brazil, *E. nigrum* is used to support root growth and control sugarcane pathogens (Fávaro *et al*., 2012). Hashem and Ali in 2004 observed that *E. nigrum* could be used successfully as an environmentally safe and economic biological control agent to protect cotton (cv. Giza 83) from damping-off and root-rot diseases caused by *P. debaryanum*. Effective disease suppression by *E. nigrum* has similarly been demonstrated against a diverse range of pathogens including: *Monilinia laxa* (Larena *et al*. 2005; De Cal *et al*. 2009; Larena and Melgarejo 2009), Sclerotinia sclerotiorum (Hoyte *et al*. 2007; Huang and Erickson 2008), Diplodia corticola (Campanile *et al*. 2007), *Botrytis cinerea* (Elmer and Reglinski 2006; Walter *et al*. 2006; Card *et al*. 2009), *Fusarium oxysporum* f. sp. *conglutinans* (Park *et al*. 2002), *Magnaporthe grisea* (Kawamata *et al*. 2004), *Phytophthora* spp. and *Pythium* spp. (Brown *et al*. 1987; Hashem and Ali, 2004), *Macrophomina phaseolina* (Hashem, 2002) and *Rhizoctonia solani* (Lahlali and Hijri 2010; Hashem, 2002). Recent study by Alcock *et al*. (2015) showed flavipin and epirodin produced by saprophytic isolates of *E. nigrum* had antimicrobial properties. Preliminary studies by Alcock *et al*. (2015) on 280 New Zealand isolates of *E. nigrum* confirmed that all but two produced a yellow, intensely pigmented substance in sufficient amounts to inhibit the germination of *Botrytis cinerea* conidia. Prior to this in 2015, F avaro *et al*. also observed that an *E. nigrum* strain, isolated from sugarcane leaves, showed *in vitro* antagonistic activity against the sugarcane phytopathogens *Fusarium verticillioides*, *Colletotrichum falcatum*, *Ceratocystis paradoxa*, and *Xanthomonas albilineans*.

C. Biological Control as Alternative to Synthetic Fungicides

Increasing restrictions on pre- and postharvest pesticide treatments (Jacometti *et al*. 2009; Hillocks 2012) combined with an ever greater demand for organic food (Karabulut *et al*. 2010) have stimulated interest in biological control of plant pathogens as an alternative to the use of synthetic fungicides. In some countries, entire regions have converted their pest and disease control strategies to biologically based methods (Maxwell, 2008). Many microorganisms, including the filamentous fungus, *Epicoccum nigrum* (Link) (syn. *E. purpurascens* Ehrenb. Ex Schlecht), have previously been evaluated as potential biological control agents against a wide range of economically important plant diseases (Elmer and Reglinski 2006). Researchers in biological control have been attracted to *E. nigrum* for a variety of reasons including the following: antimicrobial metabolite production (Brown *et al*. 1987), ease of culturing on simple substrates (Larena *et al*. 2004), tolerance to environmental extremes (Hannusch and Boland 1996), persistence on host tissues (Boyd-Wilson *et al*. 1998) and good efficacy in field experiments (Elmer and Reglinski 2006).

Recently, Hulikere *et al*. (2016) identified *Cladosporium cladosporioides,* isolated from seaweed (*Sargassum wightii*), as an endophytic fungus containing ethyl acetate extract with significant antioxidant and angiosuppressive activity. This extract confer on the fungus an antiangiogenic, wound healing and antioxidant property. Also, in an apple field trials carried out by Köhl *et al*. (2015), the overall results of the field trials consistently showed—for the first time—that stand alone applications of the antagonist *C. cladosporiides* H39 can reduce apple scab in leaves and fruit. Results from a study carried out by Torres *et al*. (2017) on chrysanthemum white rust, indicate that *Cladosporium* species had potential as biological control agents.

D. Conclusion

According to Fernando (2009), integrated pest management (IPM) involves the use of resistant varieties and healthy seeds, crop rotation, frequent crop monitoring, early detection and identification of the pest or disease etc. Therefore chemical use for pest and disease control can be drastically reduced if integrated disease management that is based on the use of biological control agents is practised. The widespread use of the chemical fungicides has become a subject of the research concern due to their harmful effect on non-target organisms as well as their possible carcinogenicity. The use of fungal biocontrol agents is becoming an increasingly important alternative to chemicals in crop protection against many diseases (Tyler *et al*., 2001). Further studies is hereby recommended to elucide both the pathogenicity and the biological control potential of *C. cladosporiides* and *E. nigrum* in economic crops of other national agro ecologies where they have not been yet studied.

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