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A review on *Chaetomium globosum* is versatile weapons for various plant pathogens

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Abstract
Chaetomium globosum is a potential bio control agent against various seed and soil borne pathogens. Plant pathogens are the main threat for profitable agricultural productivity. Currently, Chemical fungicides are highly effective and convenient to use but they are a potential threat for the environment. Therefore the use of biocontrol agents for the management of plant pathogens is considered as a safer and sustainable strategy for safe and profitable agricultural productivity. Many experiments and studies revealed by various researchers *C. globosum* used as plant growth promoter and resulted into high yield of crops in field conditions. *C. globosum* produces pectinolytic enzymes polygalacturonate trans-eliminase (PGTE), pectin trans-eliminase (PTE), viz., polygalacturonase (PG), pectin methyl esterase (PME), protopectinase (PP), xylanase and cellulolytic (C and C) 1 xenzymes and various biologically active substances, such as chaetoglobosin A, Chaetomium B, C, D, Q, R, T, chaetomin, chaetocin, chaetochalasin A, chaetoviridins A and C. The present aim of this article we have discussed the various aspects of biocontrol potential of *Chaetomium globosum.*

Keywords: Biological control, *Chaetomium globosum*, plant pathogens

Introduction
Chaetomium globosum is so far commonest and most cosmopolitan fungi especially on plant remains, seeds, compost paper and other cellulosic substrates. (Domsch *et al*. 2007) [7]. It is a common colonizer of soil and cellulose producer with ability to degrade cellulosic and other organic materials, it is one of the commonest species growing saprophytically in the rhizosphere and phyllosphere. It has been reported to be a potential bio-control agent suppresses the growth of bacteria and fungi through competition, mycoparasitism, antibiosis, or their various combinations (Zhang & Yang 2007). There are many studies with promising results on using endophyte *Chaetomium* spp. as a biocontrol agent. Endophytes are capable to reduce in the host the effect of fungi diseases, through secondary metabolites production as alkaloids. (Poulina Moya *et al*. 2016) [14]. Antagonistic mechanisms of this fungus include competition for space and nutrients (Vannaci & Harman 1987) [23], mycoparasitism (Mandal *et al*., 1999) and metabolite production (antibiosis) such as chaetomin, chaetoglobosin, cochliodinol, chaetosin and prenisatin (Brewer *et al*., 1970; Brewer *et al*., 1972; Brewer & Taylor, 1978.

Moreover, the hazardous use of heavy chemical fungicide caused environmental pollution and build up of chemical residues in the air, soil, water and agricultural products. Recently, the biological control of plant pathogens has been taking place and it has served as a new strategy for disease control (Soytong, 1995) [18]. This successful use of biological control measure particularly reduce the chemical usage and improved agro ecosystem for sustainable agriculture and has maintained ecological balance. It was found that using the specific strain of *C. globosum* Kunze could control many plant pathogens, for example *C. globosum* was shown to be antagonistic to *Fusarium* spp. and *Helminthosporium* spp. (Tveit and Moore, 1954) [19] and was antagonistic to *Alternaria brassicicola* (Vannacci and Harman, 1987) [23], and reduced the inoculum of *Botrytis cinerea* (Kohl *et al*., 1995). In many years of research work strain of *C. globosum* have been screened and found to control other economically important plant pathogens like *Phytopthora palmivora*, *Phytopthora parasitica*, and *Colletotrichum gloeosporioides* (Soytong, 1991).

Morphology of *Chaetomium globosum*
Chaetomium is a genus of the class Pyrenomycetes (Ascomycotina), Order Sordariales and family Chaetomiaceae. It is a dematiaceous (dark-walled) mold normally found in soil, air, and plant debris. There are about 95 species in the widespread genus (Kirk *et al*. 2008) [11]. Members of this genus typically have superficial, ostiolar perithecia, covered in hairs.

Asci are often clavate and evan evanescent, bearing eight spores. *Chaetomium* colonies grow rapidly, they have a cottony appearance and are initially white in colour, the mature colonies becoming grey to olive, and later sometimes tan to red or brown to black.

Microscopic observation of *Chaetomium globosum* can produce an Acremonium-like state (imperfect stage) on culture media and it is characterized by superficial flask-shaped perithecia, which are surrounded by dark and stiff hair. Asci are often clavate and evanescent, bearing eight spores. Ascospores are usually lemon-shaped, commonly coloured olive-brown. Perithecia showed densely haired surfaces and the shape of perithecia varied from globose to subglobose. The ascospores released inside the perithecium were seen oozing out from ostiole. The results were much similar to those reported by Ahammed *et al.* (2005), Prokhorov *et al.* (2011), Maheswari *et al*. (2013).

Growth and sporulation of *Chaetomium globosum* in synthetic and non synthetic media

Chatterji (1966) studied that *Chaetomium globosum*, grown at 30 ^{0}C on media in which the source of nitrogen is ammonium tartrate, produces no mature perithecia, although perithecial initials appear freely. Maturation of initials occurs at 26 ^{0}C, or in the presence of certain other fungi. Organic phosphates, biotin and other substances also affect the development of perithecia. Domsch *et al*. (2007) [7] revealed that good sporulation of most *Chaetomium* globosum was obtained on substrates with a high C/N ratio. Therefore the microscopic characters were recorded mainly for colonies on cornmeal agar. In case of Neeta Sharma *et al*. (2011) revealed that growth and sporulation of *Chaetomium globosum* was excellent on Malt yeast extract agar medium(64.96mm) followed by Nutreint yeast agar medium (27.53mm) while poor growth was recorded Czapeks dox agar medium (11.56mm) and Richard medium (7.8mm) Kiran *et al*. (2015) studied the growth and sporulation of *Chaetomium globosum* was excellent on sabouraud medium(90 mm) because glucose or maltose and peptone were the most suitable carbon and nitrogen source for *Chaetomium* growth followed by PDA (63 mm), while minimum growth was observed on Czapeks dox agar medium. Sharma *et al*. (2010) who studied colony diameters of *C. globosum* over 4 weeks on different agar media *viz*., potato dextrose agar (PDA), oatmeal agar (OA), cornmeal agar (CMA) and malt extract agar (MEA) and found that oatmeal agar exhibited comparatively higher mycelial growth and sporulation. Poulina Moya *et al*. (2016) [14] In oatmeal agar the isolates showed olivaceous-yellow colonies according to the color of Isolate C5 showed globose or oval ostiolar ascomata with straight or undulate hairs unlike isolate 2, which showed irregular hairs with no undulations. Both isolates showed terminal hairs all unbranched and displayed one-celled, lemon-shaped ascospores, In PDA isolate C5 was slightly yellower than C2 and showed margins wavy or irregular, while C2 developed full edges. The growth on the several media did not evidence major differences. It was slightly higher on OA followed by MEA. At 7th day on the three media, C2 grew faster than C5. Andrez fojutowski *et al*. (2015) [2] Growth of *Chaetomium globosum fungus in laboratory conditions on* salt-agar medium quiet fast and growth rate of 5, 7, day is 29mm, 43mm respectively.

Effect of different temperature on the growth of *Chaetomium globosum*

Basu *et al*. (1948) reported that vegetative growth of *Chaetomium globosum* was more rapid at 30 ^{0}C than at 22 ^{0}C. Incase of Matthew *et al.* (2008) [12] studied the growth and mycotoxin production by *Chaetomium globosum* which was favored in a neutral P^H. In this study, the influence of ambient pH on the growth of *C. globosum* was examined on an artificial medium. Whereas Asgari *et al.* (2011) [3] revealed that growth-temperature relationships of the *Chaetomium* sp. growing well at 20 ^{0}C–30 ^{0}C and maximum at 35 ^{0}C–40 ^{0}C. The results were conformity with the Neeta Sharma *et al*. (2011) who revealed that optimum temperature radial growth of *C. globosum* appeared in between 25 to 35 ^{0}C. Excellent growth on 30^{0}C and good growth recorded on growth 25 ^{0}C, while almost nil growth on 15 ^{0}C and 10 ^{0}C. Similar results obtained by Kiran *et al*. (2015) in temperature study it was observed that *Chaetomium* can nicely grow between 20 to 35 ^{0}C temperature range but it can flourish nicely at 35 ^{0}C temperature while temperature below 15 ^{0}C and above 45 ^{0}C were almost nil growth of *Chaetomium*. Similar reports of Ahammed (2005) who studied optimum temperature for growth of *C. globosum* by growing the fungus in medium along with best nitrogen, carbon, vitamin, having optimum pH, incubated at different temperatures *viz*., 18 ^{0}C, 25 ^{0}C, 28 ^{0}C, 35 ^{0}C and 40 ^{0}C, this investigations also showed that thermophilism of *C. globosum*, as it could grow best at temperature of 35 ^{0}C. Most of the species grow best between 25 to 35 ^{0}C and require a cellulose-rich medium for sporulation. *Chaetomium globosum* is a saprobic organism and their ability to suppress plant pathogens resulted to induced growth, and high yield of the plant (Sibounnayong *et al.* 2005).

***Chaetomium globosum* as a biocontrol agent**

Miedtke *et al.* (1990) reported that *Chaetomium globosum* as antagonists of the perfect stage of the apple scab pathogen (*Venturia inaequalis*) under field condition. In autumn, *Chaetomium globosum* were applied to detached apple leaves naturally infected by *V. inaequalis.* Treated leaves were overwintered on the orchard floor in boxes covered with coarse plastic mesh. Guang *et al*. (1991) [8] tested the study of endophytic fungi *Chaetomium* ND35 antagonism to plant pathogens *viz., Macrophoma kuwatsukai*, *Rhizoctonia solani* and *Sclerotium rolfsii* (*Corticium rolfsii*) were evaluated *in vitro* and *in vivo*. In case of wheat Biswas *et al*. (2000) [5] studied antagonism of *Chaetomium globosum* to *Drechslera sorokiniana,* the spot blotch pathogen. Interaction between *Chaetomium globosum* and *Drechslera sorokiniana* produced inhibition zone, indicating biocontrol mechanism of *C. globosum* through antibiosis. (Soytong *et al*., 2001) [16] the biocontrol potential of Chaetomium spp. was reported against *Fusarium, Helminthosporium, Pythium ultimum, Alternaria raphani*, *A. brassicicola and Phytophthora* pathogens. Singh *et al*. (2002) studied the management of Pigeonpea wilt by *Chaetomium globosum* was used as bioagent against *Fusarium udum in vitro*. Aggarwal *et al*. (2004) [1] reported the role of antibiosis in the biological control of spot blotch (*Cochliobolus sativus*) of wheat by *Chaetomium globosum.* Production of antifungal compounds by *Chaetomium globosum* (Cg) and their role in suppression of spot blotch of wheat caused by this fungus under *in vitro.* Istifadah *et al*. (2006) revealed that isolates of endophytic *Chaetomium* spp. inhibit the fungal pathogen *Pyrenophora tritici-repentis in vitro*. Tomilova *et al*. (2006) [20] studied the effect of a preparation from *Chaetomium* fungi on the growth of phytopathogenic fungi. They studied the fungicidal activity of a biological preparation from the fungi of the genus *Chaetomium* against soil phytopathogenic fungi *Rhizoctonia* *solani* and *Fusarium oxysporum*. Emmanuel *et al*. (2013) evaluated the inhibitory activity of *Chaetomium globosum* extract against Philippine strain of *Pyricularia oryzae*. *Pv. oryzae* were isolated from blast infected leaves of rice in Pangasinan, Philippines. They were cultured and their identities were validated morphologically. Results implied the growth of *P. oryzae* could be inhibited with 500 to 1000 ppm of ethanol extract of *C. globosum in vitro*. Kumar *et al*. (2013) identified antifungal principle in the solvent extract of an endophytic fungus *Chaetomium globosum* from *Withania somnifera*. Extracts of *Chaetomium globosum* EF18, was found effective against *Sclerotinia sclerotiorum*. V. Shanthiyaa *et al*. (2013) [22] reported that among eight C. globosum isolate Cg-6 showed greater inhibition to mycelial growth of *P. infestans in vitro*. *C. globosum* Cg-6 was formulated as a liquid and applied as a tuber, soil and foliar treatment either individually or in combination against *Phytophthora* infection in potato plants. Among different treatments, combined application of *C. globosum* as a tuber treatment @ 1 ml/kg of tubers, as a soil application @ 1 ml/kg of Farm Yard Manure (FYM) and foliar spray @ 0.7% resulted in significantly less late blight infection (72%) compared to untreated control (100%) under field conditions. The application of *C. globosum* resulted in greater tuber yield by reducing late blight infection in two field trials when compared to untreated controls. The study clearly demonstrated the potential use of *C. globosum* as a biocontrol agent in the management of late blight disease in potato plants. Poulina Moya *et al*. (2016) [14] The results confirm the identity of the pathogens and the isolates of *Chaetomium globosum* species group. Inhibition of *B. sorokiniana* and *D. teres* by C2 and C5 accounted for 30% and 31.2%, and 40% and 36% respectively, compared with the control. The mechanisms of action against *B. sorokiniana* and *D. teres* were antibiosis and competition and mycoparasitism, respectively. Moreover, it was also reported that *C. globosum* could produce certain antibiotics and release these to suppress the damping-off of sugar-beet caused by *Pythium ultimum* (Di Pietro *et al*. 1991)

Conclusion

In recent years, biological control of soil-borne pathogens has received increasing attention as a promising supplement or alternative to chemical control. To improve efficacy of *Chaetomium globosum* bioagent mechanism of action, nutrition, and ecology of understanding is needed.

Several methods have been established to quantify fungi in soils, including counting the number of fungal spores physically or by plating on selective medium. These techniques have limited success, since they neither ensure adequate sensitivity and accuracy, nor differentiate the desired species isolate from the native organisms. Compared to the above methods, the use of molecular markers provides much promise for the rapid identification and quantification of specific bio control agents in soil and plant. The genome of a microorganism offers several possibilities for monitoring. Genetic interaction of *Chaetomium globosum* other (fungi and plants) an in depth understanding of mechanisms is lacking. The absence of high throughput studies in these organisms has been due to the lack of whole genome sequences. The genome of *Chaetomium* spp. has been extensively investigated has proven to contain many useful genes, along with the ability to produce a great variety of expression patterns, which allows these fungi to adapt to many different environments (soil, water, dead tissues, inside the plant, etc.). Finally, understanding the mechanism of interaction *Chaetomium* spp. between and the plant has provided for the first time the opportunity to genetically increase the ability of a Chaetomium spp. strain for the management plant diseases.

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