The genus *Chrysosporium*, its physiology and biotechnological potential

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Summary The genus *Chrysosporium* is reviewed including its 11 species without intercalary conidia, 29 species with intercalary conidia, three species with uncertain position and four undescribed species with their report of isolation, physiology, antagonistic, keratinolytic and pathogenic potentials. Research revealed considerable biotechnological potential for recycling keratinous waste in soil and secretion of enzymes and antimicrobials. Its taxonomic relation with dermatophytes and their relatives is of immense importance. Germplasm collection of *Chrysosporium* and its teleomorphic connections is aplaused.

Key words *Chrysosporium,* Biotechnological Potential, Review

The genus *Chrysosporium* was introduced by Corda [1]. Saccordo [2] placed it in synonymy with *Sporotrichum*. Later this genus was reviewed [3-5]. Twenty two species of *Chrysosporium* were recognised [5]. Since then several species have been added to this genus. Large number of workers have isolated *Chrysosporium* species from many different habitats around the world. Until recently, interest was restricted only to reports of its occurrence but as research into this fungus has gained momentum it has been evaluated as a potential fungus. Recently the research carried out on *Chrysosporium* has increased markedly and information has begun to appear. While isolating *Chrysosporium* by hair baiting and other methods its potential to degrade keratin was particularly emphasized. In view of this, its activity in soil and water sediments of polluted and fresh water sites is also receiving attention. Perhaps some species of *Chrysosporium* may be utilized for recycling of keratinous waste in soil and as water pollution indicators which certainly pave the way towards a congenial environment. Secretion of some of their metabolites, particularly enzymes and antimicrobials, is gaining the attention of pharmaceutical industries. The resemblance of *Chrysosporium* to dermatophytes, and their pathogenic potential, is directly related to health of human beings and animals. In addition to the keratinous substrates, this genus is now being found associated with other non keratinous substrate too. This potential, and its similarities to *Myceliophthora*, *Emmonsia*, *Zymonema*, *Geomyces*, *Trichosporiella*, *Malbranchea*, *Ovadendron*, *Botryotrichum*, *Sepedonium*, *Mycogone*, *Sporotrichum* and others and associated teleomorphs, is of immense diagnostic importance. Long term studies [6-11] on the biology of *Chrysosporium*, and other scattered reports, revealed that its wide distribution is due to its antagonistic potential and ability to produce enzymes and other extracellular metabolites [12-14].

Looking into all the above potential of *Chrysosporium*, it was intended to review all possible available work on this genus, which has not been reviewed before, in spite of the fact that the amount of new information has grown enormously in recent times.

Forty - seven species of *Chrysosporium* are listed here along with their report of isolation including some salient features.

Species with intercalary conidia

White colony

1.*Chrysosporium* anamorph of *Rollandina vriesii* Apinis Trans. Brit. Mycol. Soc. 55:501, 1970.

25-30 mm on PYE in 14 days, terminal and lateral conidia smooth and thin walled, 1 celled, 3-6x2-3 µm, wide scar, 1-2 µm, keratinolytic.

2.*Chrysosporium* anamorph of *Arthroderma curreyi* Berk Outl. Bri. Fungol. 357, 1860.

30-50 mm on SGA in 14 days, terminal and lateral conidia mostly sessile, smooth or slightly echinulate, thin, 1 celled, rarely 2 celled, 3-6x2-3 µm, wide scar, 1-2 µm, keratinolytic [15-19].

3.*Chrysosporium* anamorph of *Arthroderma cuniculi* Dawson Sabouraudia 2:187, 1963.

35-60 mm on SGA in 14 days, terminal and lateral conidia sessile, smooth, thin walled, 1 celled or 2-3 celled, mostly 3-8x2-3 µm, scar 1-2 µm, keratinolytic [16,17,20].

4.*Chrysosporium* anamorph of *Pectinotrichum llanense* Varsavsky & Orr Mycopath. Mycol. Appl. 43:231, 1971.

5-15 mm on Czapeck agar in 14 days, terminal and lateral smooth and thin walled, 1 celled, 4-6.5x2-3 µm, scar 1-1.5 µm, keratinolytic [21].

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5.*C. synchronum* van Oorschot Stud. Mycol. 20:42, 1980.

80 mm on PYE in 7 days, terminal and lateral conidia thin walled, smooth or echinulate, 1 celled, 7.5-11x4-5.5 µm, scar 0.5-1 µm, not keratinolytic.

Other than white

6.*C. sulfureum* (Fiedl.) van Oorschot & Samson Stud. Mycol.20:28, 1980.

10-15 mm on PYE in 14 days, pale creamy yellow, terminal and lateral mostly sessile, 2–8 per conidiogenous, smooth and thin becoming thick walled, some times echinulate, 1 celled, 3-8x3-6 µm, wide scar, 1.4 µm, not keratinolytic, shows preference for fatty or calcium rich material [22-24].

7.*C. georgii* (Varsavsky & Ajello) van Oorschot Stud. Mycol.20:31, 1980.

10-30 mm on 2% malt agar in 14 days, white or pale buff or pink, terminal and lateral smooth and thin walled, 1 celled, rarely 2-3 celled, 3-8x2-3 µm, wide scar, 0.5-4.5 µm, keratinolytic [25,26].

8.*C. lucknowense* Garg Mycopath. Mycol. Appl. 30: 224, 1966.

55 mm on SGA in 14 days, cream, terminal and lateral 1-4 conidia on one hyphal cell in close proximity, thin, 1 celled, 2.5-11x1.5-6 µm, keratinolytic [22,23,26,27].

9.*C. filiforme* Sigler, Carmichael & Whitney Mycotaxon 14:261, 1982.

40 mm in 21 days on PYE, white to buff, terminal or lateral conidia 0-1 or rarely 2 septate, sessile or on short pedicell, smooth, filiform upto 40 µm long, not keratinolytic.

10. *C. mephiticum* Sigler Can. J. Bot. 64: 1212, 1986.

50-62 mm on PYE and CER in 25 days, creamy white, terminal and lateral smooth, mostly sessile, in close proximity, 2.5-3.5x2.5-3 µm, scar 1-1.5, keratinolytic, strong and pungent odour.

11.*C. gourii* Jain, Deshmukh & Agrawal Mycoses 36:77, 1993.

74 mm on SGA in 18 days, white to cream to yellowish brown, terminal and lateral, smooth or rough, thin walled, 1 celled, 2.5-6x2-4 µm, keratinolytic.

Species with intercalary conidia

White colony

12.*C. queenslandicum* Apinis & Rees Trans. Brit. Mycol. Soc. 67:524,1976.

55-65 mm on PYE in 14 days, white, intercalary conidia several, smooth and slightly thick, 1 celled, 3.5-9.5x3.6 µm, broad basal scar, keratinolytic [17,21-23,25-27].

13.*Chrysosporium* anamorph of *Gymnoascus demonbreunii* Ajello & Cheng Mycologia 59:692,1976.

25-33 mm in 14 days on hay infusion agar, white, intercalary conidia most abundant, smooth and thin, 5-11x4.5-6 µm, conidia always terminal, never lateral, smooth, thin walled, 1 celled, 6-9x5-6 µm wide basal scar, 1.5-2.5 µm, keratinolytic [21].

14.*C. carmichaelii* van Oorschot Stud. Mycol. 20:15,1980.

15-30 mm in 14 days, white, intercalary less abundant, smooth, thin, 3-6x1.5-3 µm, terminal and lateral smooth or rarely rough, 1 or rarely 2 celled, 3-6x3-3.5 µm, not keratinolytic [17,18,22,23,27,28].

15.*C. tropicum* Carmichael Can. J. Bot. 40: 1170, 1962.

50-60 mm in 40 days, white, intercalary not common, smooth and slightly thick, 3-4x6-10.5 µm, terminal and lateral smooth or slightly thick, 1 or rarely two celled, 3.5-7.5x3-4.5 µm, basal scar 1.5-2 µm, keratinolytic [16-18,21-23,25-33,36-53].

16.*C. xerophilum* Pitt Trans. Brit. Mycol. Soc. 49: 468, 1966.

85 mm on cherry deccoction agar in 7 days, white, intercalary conidia not always abundant, sometimes in chains of 2-6, smooth and thin or thick walled, 7.5-12x3-4.5 µm, terminal and lateral, smooth, thin or thick walled, 4-13x3-10 µm, wide basal scar, 1.5 µm, weak keratinolytic, osmophilic [21].

17.*C. pannicola* (Corda) van Oorschot and Stalpers Stud. Mycol. 20:43,1980.

20-38 mm on PYE in 14 days, white, intercalary less abundant, smooth or echinulate, thick walled, 4-8x2-3 µm, keratinolytic [15,17,18,20,22,23,26,27,34,54,55].

18.*C. indicum* (Randhawa & Sandhu) Garg Sabouraudia 4:262,1966.

40-50 mm on PYE in 14 days, white, intercalary conidia less abundant, smooth or slightly echinulate, thin walled, 6-12x2-3.5 µm, keratinolytic [15-23,25-32,40, 44,45,48,54, 56].

19.*C. sinense* Liang Acta Mycologica Sinica 10:50,1991.

30 mm in 20 days at 18°C on SDA, intercalary conidia abundant, 1.2-3.7x3.7-10 µm, terminal and lateral, 2.4-3.8x4.0-5.7 µm, development of synnemata, isolated from endosclerotium of *Cordyceps sinensis* [Berk.] Sacc.

20.*C. geophilum* Kushwaha & Shrivastava Curr. Sci. 58:970,1989.

60-70 mm on SGA, white, reverse pale creamy brown, intercalary conidia less, rough or smooth walled, 2-4 µm, lateral conidia sessile or on short protrusions, initially echinulate becoming smooth on transfers, thick, 1 or rarely 2 celled, 4-20x2-4 µm, keratinolytic.

21.*C. botryoides* Skou Mycotaxon 43:237,1992.

White colony, ramose on MGYA, conidia 1 celled, thick walled, occur so close together that they look like bunches of grapes, globose to pyriform, up to 10.2 µm, intercalary conidia sparsely present, rounded in agar, single or a few in chains, not keratinolytic, osmophilic.

22.*C. globiferum* Skou Mycotaxon 43:237,1992.

White, dense with slightly ramose margin on MGYA, conidia 1 celled, thick walled, globose to pyriform, upto 11.1 µm, intercalary conidia abundant, rounded in agar, not keratinolytic, osmophilic.

23.*C. hispanicum* Skou Mycotaxon 43:237,1992.

White, dense on MGYA, conidia 1 celled, thick walled, globose to pyriform, upto 13.4 µm, in agar only terminal conidia, intercalary conidia very sparcely in agar, not keratinolytic, osmophilic.

24.*C. holmii* Skou Mycotaxon 43:237,1992.

White, intercalary conidia turncate never in pronounced amount, not in agar, terminal globose conidia, pyriform up to 12.8 µm, not keratinolytic, osmophilic.

25.*C. medium* Skou Mycotaxon 43:237,1992.

White, flat on MGYA, conidia 1 celled, globose to pyriform, upto 9.8 µm, intercalary abundant in agar, not keratinolytic, osmophilic.

26.*C. minor* Skou Mycotaxon 43:237,1992.

White, flat, conidia 1 celled, globose to pyriform, up to 8.4 µm, intercalary conidia single and rounded in agar, not keratinolytic, osmophilic.

27.*C. pyriformis* Skou Mycotaxon 43:237,1992.

White, dense, flat on MGYA, conidia 1 celled, thick walled, globose to pyriform up to 11.0 µm, intercalary conidia in agar more or less rounded, not keratinolytic, osmophilic.

Other than white

28.*C. pseudomerdarium* van Oorschot Stud. Mycol. 20:14,1980.

7-20 mm on PYE in 14 days, white, locally pale yellow, intercalary conidia intially smooth and thin walled or becoming echinulate and / or thick walled, 3-6x3-6 µm, terminal and lateral in chains up to 4, initially smooth and thin becoming echinulate, 1 celled, 2-6.5x1.5-5 µm, weak keratinolytic [25,26].

29.*C. merdarium* (Link ex Grev.) Carmichael Can. J. Bot.40:1160,1962.

30-35 mm on PYE in 14 days, white becoming bright yellow, pink or green, intercalary conidia few, 5-12x3-6 µm, terminal and lateral 1 celled, 4-10x3-6 µm, not keratinolytic. *G. uncinatum* do not develop conidia on PYE while these are abundant on hay infusion agar [15,16,20-24,31,36].

30.*C. keratinophilum* D. Frey ex Carmichael Can. J. Bot. 40:1157,1962.

40-50 mm on PYE in 7 days, white to cream, sulphor yellow, intercalary conidia less abundant or rare, smooth or echinate, thick walled, 6-25x3.5-7 µm, terminal and lateral smooth or echinate, thick, 1 celled, 3.5-22x3.5-11 µm, keratinolytic [15,17,20-23,25,26,30,32,34-38, 40,41,43-45,47,54-66].

31.*C. inops* Carmichael Can. J. Bot. 40:1156,1962.

0.5-10 mm on PYE in 14 days, cream, conidia terminal or intercalary, smooth and thick walled, 1 celled, 6.5-12x5-9 µm, not keratinolytic.

32.*Chrysosporium* anamorph of *Renispora flavissima* Sigler et al Mycotaxon 10:133, 1979.

30-40 mm on PYE in 14 days, pale yellow, buff centre, intercalary conidia rare, initially smooth, thin or thick walled, verrucose, 1 celled, 6-8x5-8 µm, keratinolytic.

33.*C. lobatum* Scharapov Nov. Syst. niz. Rast. 15:144, 1978.

30-35 mm on PYE in 14 days, white becoming pale green or pale grey, intercalary conidia rare, smooth, thin walled becoming echinulate, thick walled, 1 celled, 3-4x2-3 µm, terminal and lateral, smooth and thin walled becoming reddish brown to dark brown, echinulate, thick walled 1 celled, 2-4x1.5-3.5 µm, scar 0.5-1.5 µm, keratinolytic.

34.*C. vespertilium* Guarro, Vidal & de Vroey Mycotaxon 59:189,1996.

34-45 mm on PYE in 14 days, yellow, intercalary conidia rare, smooth and thin walled, 1-3 celled, 5-20x2-5 µm, scar 2.5 µm, keratinolytic, coiled sterile hyphae.

35.*C. pilosum* Gene, Guarro & Ulfig Mycotaxon 50:107,1994.

Restricted, 0.4-0.7 mm on PYE, raised, yellowish white to mustared yellow or light brown, reverse brownish or dark brown, intercalary conidia smooth, thin becoming thick walled and verrucose, 1 celled, 3.5-5.5x3-4 µm, terminal and lateral smooth and thick walled, becoming coarsly verrucose, 1 celled, 4-6x3.5-5.5 µm, scar 1.5-2 µm, poor keratinolytic, broad, simple, thick walled, brownish sterile hyphae present.

36.*C. europae* Sigler, Guarro & Punsola Can. J. Bot. 64:1212,1986.

50-60 mm on PYE in 35 days, vinaceous buff or brown diffusing pigment, intercalary 4.5 µm, terminal and lateral 8.5x2.5-3.5 µm, keratinolytic.

37.*C. zonatum* Al - Musallam & Tan Persoonia 14:69,1989.

55 mm on PYE in 14 days, white to buff, intercalary conidia abundant, 5-12x2-4 µm, terminal and lateral thick walled and verrucose at maturity, 1-2 celled, 5-7x3-5 µm, scar 2-2.5 µm, keratinolytic and cellulolytic.

38.*C. vallenarense* van Oorschot & Piontelli Persoonia 12:487,1985.

Colonies restricted on YpSs at 25°C, white becoming sulphor yellow, conidia terminal, often developing sympodially, rarely intercalary, tuberculate, 3.5-5.5x5-7 µm. Isolated from keratinous substrates. Conidia resembling those of *Chrysosporium* anamorph of *Renispora flavissima*.

39.*C. siglerae* Cano & Guarro Mycotaxon 51:75,1994.

10-15 mm on PYE in 21 days at 28°C, pale yellow, conidia mostly lateral, 1 celled, smooth to slightly verrucose, 5-30x2-3.5 µm, 2 celled, 10-16x2-3 µm, intercalary in series of two or more, 10-15x2-2.5 µm, keratinolytic.

40.*C. farinicola* (Burnside) Skou Friesia 11:70.1975.

27-45 mm in 14 days on honey agar, initially white or becoming pale greenish yellow or pale brown, intercalary conidia abundant, smooth, thick walled, 3-12x5-12 µm, terminal and lateral smooth, thick walled, 1 celled, 6-15x4.5-9 µm, wide basal scar, 1.5-5 µm, not keratinolytic, osmophilic [22,23].

Species with uncertain position

41.*C. parvum* [or *Emmonsia*?]

42.*C. crescens* [or *Emmonsia*?]

Placed under *Emmonsia* Cif & Montemartini on the basis of blastic conidia and thick walled chlamydospore- like celles [5,67].

43.*C. racemosus* Sharma, Bhattacharjee & Bhadauria Indian Phytopath. 46:404,1993.

1-1.2 cms in 7 days at 28±1°C on PDA and Czapecks dox agar, initially white, later changes to cream, green, dark brown to blackish brown. Conidiophore branched with thick, numerous scars [hilum]. Acropleurogenous and pedicellate aleurospores aggregate to form clusters at intercalry position of hyphae. The described species without camera leucida drawings or photographs does not seems to be *Chrysosporium* because conidia do not have scars and are round. The cultures were not available.

Species in press

44.*C. undulatum* Vidal, Ulfig & Guarro
45.*C. fluviale* Vidal, Ulfig & Guarro
46.*C. submersum* Vidal, Ulfig & Guarro
47.*C. minutisporosum* Vidal, Ulfig & Guarro

Genus *Chrysosporium* have following teleomorphs also

Gymnoascus arxii, G. uncinatus, Nannizziopsis spp., *Amauroascopsis perforatus, Aphanoascus durus, Aph. clathratus, Aph. fulvescens, Aph. hispanicus, Aph. reticulisporus, Aph. saturnoideus, Aph. terreus, Aph. verrucosus, Arthroderma multifidum, Arth. tuberculatum, Arth. croccatum, Arth. silverae, Ctenomyces serratus, Ajellomyces dermatitidis, Aj. capsulatus, Apinisia graminicola, Api. queenslandica, Neoxenophila foetida, Renispora flavissima, Amauroascus albicans, Am. aureus, Am. volatilis-patellis, Orromyces spiralis, Phaneochaeta chrysosporoidea, Pseudarachmiotus orissi, Bettsia alvei, Bettsia* species, *Cordyceps* species.

Temperature

There are many reports of the ability of *Chrysosporium* to grow at sub zero and above 37°C. *C. keratinophilum, C. tropicum* and *C. queenslandicum* grows at 37°C. *C. asperatum, C. pannorum* and *C. indicum* grows in antarctic soil [68,69] and *C. evolceanui* in alpine soil [70]. Garg et al [71] found 21-50 and 25-30°C optimum for *C. pannicola* and *C. keratinophilum*. The growth of *C. tropicum* was rapid at 27°C and 37°C showed minimum rate of growth [72]. Maximum germination of conidia of *C. tropicum* took place at 32°C within 24 hours. Low temperature also supported conidial germination [72]. Slight growth of *C. pannorum* at -6°C [73] and good growth at -5°C and at 5°C was reported [74-75]. Rapid growth of this fungus occurred at 15°C [76], maximum growth was at 25°C [74,75] and its rate of growth reduced at 30-37°C [75,77,78].

pH requirements

A. uncinatum and *A. curreyi* are acidophilic and *C. tropicum, C. keratinophilum,* and *A. quadrifidum* were found to be alkalophilic [79]. *C. pannorum* grew well at sea water salinity [77] but 20% sodium chloride inhibited its growth when used in Czapecks medium [80]. *A. curreyi* survives in mud and sand dunes of coastal soils [81] and *C. tropicum* and *C. indicum* in marine soils [82]. For *C. tropicum* 7 pH was optimum but it grows at 3 and 7 pH also [72]. Garg *et al.* [71] gave a range of soil pH in relation to the distribution of *A. fulvescens, C. keratinophilum, C. pannorum, C. tropicum, C. asperatum, C. evolceanui* and *C. serratus*.

Moisture contents

Occurrence of *A. curreyi* was reported in nests with 11.81% and 19.81% water content while *C. keratinophilum* was isolated from nests with higher moisture content showing a hygrophilic nature [83]. The hygrophilic nature of *A. fulvescens* and *C. keratinophilum* was also confirmed [84]. *C. pannorum* survived in habitats of little or no biotic influence [68]. A high percentage of spore germination in *A. uncinatum* and *Ctenomyces serratus* at 90-100 RH was recorded [85]. Minimum aW for growth at 25°C on NaCl of *C. pannorum, C. xerophilum* and *C. fastidium* was 0.92, 0.71 and 0.69 respectively. The growth rate of *C. fastidium* in medium containing glycerol was lower than with glucose and fructose. Pugh and Evans [85] reported higher percentages of spore germination in *A. uncinatum* and *C. serratus* at 90-100 % RH.

Humus

Distribution of *Chrysosporium* was not affected by humus [86] and this fungus along with *C. indicum* and *C. tropicum* occurred in soil made up of disintegrated lava with low organic matter [74]. Nigam and Kushwaha [23] also reported *C. carmichaelii, C. evolceanui, C. indicum, C. keratinophilum, C. merdarium, C. pannicola, C. queenslandicum* and *C. tropicum* in house dust, which is very low in organic matter. Katiyar and Kushwaha [88] reported *C. keratinophilum, C. tropicum* and *Chrysosporium* spp. with 100 % hair perforation ability from sand of Mediterranean sea which was very poor in organic matter.

Mycelial growth of *C. tropicum*

Growth of *C. tropicum* was measured on 12 agar media as follows: oat meal> YpSs> glucose asparagine> potato dextrose> Czapecks dox> SAA> malt extract> tryptone agar> Czapecks dox +yeast extract> peptone dextrose> Sabouraud dextrose> Sabouraud dextrose+ yeast extract. Maximum sporulation was recorded on Sabouraud dextrose agar supplemented with yeast extract followed by tryptone agar [89]. This fungus grows in varying concentrations of glucose while 6% glucose favoured maximum growth. A study of carbon metabolism in *C. tropicum* was made at 5-15 days of incubation. The rate of assimilation of glucose, sucrose, mannose, maltose and lactose by *C. tropicum* was studied chromatographically [90]. Growth and sporulation of 15 species of *Chrysosporium* including 6 strains of *C. tropicum* were different on 7 media. Six strains could be categorised in 3 groups based on their growth characteristics [91].

Glucose supported maximum mycelial growth of *C. tropicum* and fructose was assimilated more slowly than mannose among the monosaccharides. Utilization of sucrose, maltose and polysaccharide was average. Mannose and starch showed an increase in growth rate up to 10 days of incubation and then gradually decreased. Mannose and maltose were utilized very rapidly by this fungus and exhausted within 5 days. Glucose, fructose, sucrose, lactose and starch were not completely utilized [90]. *C. tropicum* synthesized galactose, glucose and fructose [90]. *C. tropicum* exhibited carbon heterotrophy, as was reported in other soil saprophytes, and meets its requirements from various sources.

Nitrogen nutrition and metabolism

Analysis of filtrates of *C. tropicum* at 4 days revealed arginine, asparagine, aspartic acid, hydroxyl proline and threonine, while at 12 days cystine, proline and serine were also detected. Mycelial extract revealed the presence of arginine, Y amino butyric acid, asparagine, cystine, histidine, hydroxy proline and serine.The asparagine utilization by *C. tropicum* was rapid. Suitability of ammonium nitrate and some other nitrogen sources for the growth of *C. tropicum* was studied by replacing asparagine. The rate of utilization of asparagine and synthesis of cell bound and cell free aminoacids was studied [92].

C. tropicum grew fairly well in nitrogen provided in the form of nitrate but nitrate from ammonium source supported completely less mycelial growth. Cystine supported maximum mycelial yield. Peptone was found to be the best source for the fungus while tyrosine seems to be poor in this respect. Alanine, arginine, aspartic acid, cystine, glycine, glutamic acid, histidine, leucine, methionine, phenyl alanine, proline, serine, tyrosine, aspartic acid+glutamic acid+arginine and alanine+ asparagine+ histidine+ phenyl alanine+ proline+ cystine and sodium nitrate, ammonium sulphate and peptone were also all tested for the growth of *C. tropicum*.

Vitamin requirements

A mixture of biotin, cyanocobalmin, pyridoxin, riboflabin was used with the omission of one vitamin each time and the mycelial weight of *C. tropicum* was determined. It grew in the medium provided with all the five vitamins whereas it showed a sudden decrease when biotin

and cyanocobalmine were omitted individually from the combination, pointing towards their deficiency [93].

Spore germination

Germ tubes of conidia of *C. tropicum* attained an average length in plain agar in 24 hours while in SDA mycelial clumps were developed in 24 hours. One percent glucose and 0.01% peptone induced 100% germination [94]. Maximum germination of conidia of *C. tropicum* took place at 32 ºC within 24 hours. A low temperature of 12 ºC also supported conidial germination [94]. The keratinized and non-keratinized propagules of *C. tropicum* and *C. keratinophilum* showed differences when germinated on different substrates, but were similar in their ability to tolerate temperature exposure by two methods [95]. Glucose was found to be a good carbon source for germination. Fructose, mannose, sucrose, maltose, lactose and starch did not favour germination [94]. It was shown that in *C. tropicum* with an increase up to 0.2% in the concentration of nitrogen content of sodium nitrate, the percentage of spore germination was also increased upto 60% within 24 hours. Twelve per cent germination was recorded when 0.01% nitrogen from nitrate source was added to the medium. Nitrogen given in the form of ammonium sulphate exhibited an opposite effect. In this case the maximum germination was recorded at 0.01% nitrogen. In organic nitrogen, asparagine could induce germination up to 52%. An equimolar mixture of asparagine, aspartic acid and glutamic acid supported 58% spore germination of *C. tropicum* [94].

Antibiotic response to growth and spore germination

Dermostatin showed the highest inhibition of *C. tropicum* at its lowest concentration of 200 µg/ml while aureofungin showed maximum inhibition at 1000 µg/ml when supplemented with SDA. MICs of aureofungin and dermostatin was 600 and 200 µg/ml. Maximum inhibition was caused by griseofulvin at 1000 µg/ml [96]. Complete inhibition of spore germination of *C. tropicum* was caused by aureofungin at a concentration of 500 µg/ml. Aureofungin was found to be effective even at its lower dose as it also inhibits the length of the germ tube. Dermostatin induced the swelling of the spores before the emergence of the germ tube [96]. The culture filtrates of *M. fulvum*, *M. gypseum* and *T. mentagrophytes* inhibited conidial germination of *C. tropicum* [72]. Biomass of *C. tropicum* was reduced by prednisolone at its lowest concentration [97].

Sensitivity to plant extracts, volatile substances, soaps, detergents, oils and biocides

Plant extracts of garlic, ginger, neem, ocimum, onion, yellow oliander and a mixture of all these inhibited growth of *C. tropicum* [72]. Mycostatic fumes of some volatile substances such as formic acid, acetic acid, ethyl, methyl, isopropile and butyl alcohols, diethyl ether and chloroform were able to reduce the growth of *C. tropicum* in liquid culture to more than half [72]. Biomass loss was noticed of some keratinophilic fungi including *C. tropicum* by ethyl alcohol, isopropyle alcohol, chloroform, carbon tetra chloride, carbon disulphide, acetone and benzene [98].

Opportunistic fungal strains have been found to be implicated in mycotic diseases of man and animals. Influence of some homeopathic drugs was studied to inhibit the hair invasion activity of *A. terreus*, *C. keratinophilum* and *C. tropicum* mechanically and ezymatically. Mezerium, petroleum, ustilago and sepia caused 100% inhibition of hair perforation and no protein could be released in the culture filtrates at their higher doses [99]. Similarily some hair dyes: black diamond, black rose, mehndi and amla were used to inhibit hair perforation. Complete inhibition of hair perforation was at 100 µg/ml for black diamond and black rose, and the other two were comletely inhibitory at 1000 µg/ml for these fungi. Five Indian soaps: kesh nikhar, godrej shikakai, swastik shikakai, vipro shikakai were inhibitory for hair perforation at 1000 µg/ml; shampoos: Optima, Organics, Pantene, Sunsilk, detergents; Areil, Rin, Surf Excel, Wheel; and agrochemicals: bavistin, thiram, neem, ocimum, urea, rock phosphate, NPK and zinc sulphate were also completely inhibitory for hair perforation and protein release by the above three fungi at their higher doses [100].

Six plant extracts of *Lawsonia inermis*, *Eclipta alba*, *Nyctanthus arbortristis*, *Datura stramonium* and a mixture of all the extracts were used for testing antifungal activity of *C. tropicum* [101]. Essential oils of *Mentha arvensis*, *Trachyspermum ammi*, *Cymbopogan nardus* and *Eucalyptus citriodora* also caused more than 77% inhibition of *C. tropicum* [102]. *Chrysosporium* species were inhibited by himax and tree burb [103]. Mycostatic effect of tea, coffee, proteinex, coconut oil, linseed oil and vegetable oil was studied on *C. tropicum*. Coffee and tea extracts were inhibitory for growth when these were used with Sabouraud dextrose agar while proteinex showed negligible inhibition, mustard and linseed oil were found to be the most inhibitory [104]. *C. pannorum* was reported to be resistant for higher concentration of organic mercurial preparation [105]. This fungus was also used in the removal of phosphate from sewage [106]. *C. keratinophilum* was resistant to cadmium concentrations as high as 560 ppm [107].

Keratinolytic potential, enzymes and secondary metabolites

C. pannicola, *C. keratinophilum* and *C. tropicum* took as little as 5 days to colonize human hair [108]. *C. carmichaelii*, *C. evolceanui* and *C. indicum* were found to be late colonizers of hair. A perforating group of *C. keratinophilum*, *C. pannicola*, *C. queenslandicum* and *C. tropicum* and a non - perforating group of *C. carmichaelii*, *C. evolceanui* and *C. indicum* were recognised. *C. indicum*, *C. keratinophilum* and 2 *Chrysosporium* spp. isolated from sand of a Mediterranean beach were able to perforate human hair in 18 days and completely digested it [88]. Five strains of *C. tropicum* caused 100 % hair perforation and 12 strains decolourised the hair, out of 12 *C. indicum* 5 caused 100% perforation and all 11 decolourised hair, of 10 *C. queenslandicum* 6 perforated hair and all decolourised hair, of 5 *C. keratinophilum* 3 perforated hair and all decolourised hair, of 3 *C. pannicola* all perforated hair and decolourised hair. All these strains when grown on dermatophyte test medium develop zones ranging from 3-17 mm [109].

Fifteen strains of *C. tropicum* took 7-40 days for colonization and perforation of human hair in soil [110]. In an another study *C. carmichaelii*, *C. evolceanui*, *C. farinicola*, *C. indicum*, *C. keratinophilum*, *C. lucknowense*, *C. pannicola*, *C. queenslandicum* and *C. tropicum*

colonized human hair *in vitro* in 3-9 days [111]. Among the eight species of *Chrysosporium*, *C. keratinophilum* was able to perforate and degrade buffalo, cow, dog, goat, horse and human hairs rapidly. Infected hair showed undulation, lifting and disruption of cuticle, narrow and broad perforating organs, projection of medulla and decolouration of hair as induced by this fungus [111]. English [112] observed cuticle lifting, erosion of cortex and perforating organs in hair penetrated by *C. keratinophilum*. Seven types of perforators developed by *A. terreus*, *C. keratinophilum* and *C. tropicum* were also observed [88,113-116]. The manner in which *Chrysosporium* species attacked hair was intermediate between dermatophytes and keratinophilic fungi [117].

C. keratinophilum, *C. tropicum*, *C. indicum* and *A. fulvescens* were reported as keratin colonizers [118-132]. Most active keratinolysis was shown by *A. terrreus*, *A. fulvescens*, *C. pannicola*, *C. queenslandicum*, *C. xerophilum*, *C. tropicum*, *C. keratinophilum*, *Chrysosporium* anamorph of *A. cuniculi* and *Chrysosporium* anamorph of *A. curreyi* [133]. The penetration of hair *in vitro* by *C. tropicum* was similar to dermatophytes showing the ability to infect [134]. The ability of *A. fulvescens* and *A. verrucosus* to penetrate hair, was found to be different from *A. keratinophilus* [135]. Determination of this, and keratinolytic ability was demonstrated by a new method by inoculating the fungus directly on hair tied in a tube [136].

A. terreus, *C. serratus*, *C. tropicum* and *C. keratinophilum* isolated from museum soil were found to deteriorate feathers and produce 98, 44, 96 and 76 ku/ml keratinase and release 680, 789, 830 and 650 µg/ml net protein [137]. *C. crassitunicatum* and *C. tropicum* released 690 and 788 µg/ml protein and produced 88 and 33 ku/ml keratinase from hen feathers [138]. *C. crassitunicatum*, *C. tropicum* and *C. indicum* produced 130.2, 77.2 and 75 ku/ml keratinase when pig hairs were used [139] and role of *C. carmichaelii*, *C. evolceanui*, *C. indicum* and *C. tropicum* in keratin degradation [140] and characterization of extracellular proteolytic enzyme of *C. tropicum* and its role in keratin degradation was also monitored [141]. *C. tropicum* degraded buffalo horn, woman hair and wool [142]. Amylase production by *C. tropicum* was reported [143]. *C. merdarium*, *C. keratinophilum*, *C. indicum*, *C. crassitunicatum*, *Chrysosporium* anamorph of *Pectinotrichum llanense* and *Chrysosporium* anamorph of *A. cunicuili* were found to degrade chicken feathers [144].

Liquification of gelatin is a criterion for identification of the filamentous phase of *Chrysosporium*, *Blastomyces* and *Histoplasma* [145]. *C. indicum* is able to digest gelatin [146]. *C. carmichaelii*, *C. evolceanui*, *C. indicum*, *C. keratinophilum* and *C. merdarium*, two strains of *C. queenslandicum*, four strains of *C. tropicum* also liquified gelatin [147]. *C. tropicum*, *C. zonatum* and *Chrysosporium* anamorph of *A. curreyi* utilizes standard lipids and fatty acids [cholesterol, palmitic and linolytic acids] and evidence is available for the uptake and degradation of cholesterol by *C. keratinophilum*.

Nineteen enzymes were produced by 390 strains of *Chrysosporium* [148]. *C. tropicum*- amylase, urease, pectinase, keratinase, esterase lipase, leucine aryl amidase, cystine arylamidase, alpha galactosidase, alpha glucosidase, beta glucosidase, N acetyl glucosaminidase, alpha mannosidase. *C. merdarium*- amylase, keratinase, urease, esterase lipase, leucine arylamidase, alpha galactosidase, beta galactosidase, alpha glucosidase, N acetyl glucosaminidase. *C. indicum*- amylase, cellulase, pectinase, keratinase, leucine arylamidase, cystine arylamidase, alpha galactosidase, beta glucosidase, N acetyl-glucosaminidase, alpha mannosidase, *C. keratinophilum*- amylase, cellulase, urease, pectinase, keratinase, esterase, esterase lipase, lipase, leucine arylamidase, chymotrypsin, alpha galactosidase, beta glucuronidase, alpha glucosidase, beta glucosidase, N acetyl glucosaminidase, alpha fucosidase. *C. queenslandicum*- amylase, urease, pectinase, keratinase, esterase, lipase, leucine arylamidase, cystine aryla midase, alpha galactosidase, alpha glucosidase, N acetyl glucosaminidase. *Chrysosporium* anamorph of *A. curreyi*- amylase, keratinase, esterase lipase, lipase, leucine arylamidase, cystine arylamidase, trypsin, chymotrypsin, alpha galactosidase, beta glucuronidase, alpha glucosidase, N acetyl glucosaminidase. *C. carmichaelii*- amylase, urease, keratinase, esterase lipase, lipase, leucine arylamidase, cystine arylamidase, alpha galactosidase, alpha glucosidase, beta glucosidase, N acetyl glucosaminidase. *C. georgii*- amylase, urease, pectinase, keratinase, esterase lipase, lipase, leucine arylamidase, cystine arylamidase, alpha galactosidase, beta glucosidase, N acetyl glucosaminidase.

Production of anthroquinines [questin and questinol] and asteric acid by *C. merdarium* was reported [149]. Secondary metabolites produced by keratinophilic fungi were discussed [140]. Elastase was produced by *C. evolceanui* and *C. indicum* [150]. Phospholipids and acetone soluble lipids were detected in cold mycelial extracts of *C. tropicum* [151]. *C. indicum* produces L-Arginyl- D - allothreonil- L-phenylalanine wich is antifungal [152]. *C. pannorum* produces cryscandin, antibacterial and anticandida and pinnorin-3-hydroxy-3-methylglutaryl co enzyme, a reductase inhibitor [153,154].

Antagonistic potential

In vitro studies revealed that *C. tropicum* was inhibited by staling substances of *C. evolceanui*, *C. indicum*, *C. lucknowense*, *Aspergillus flavus*, *A. niger*, *Chaetomium globosum*, *Cladospora* species, three species of *Penicillium*, *T. vanbreuseghemii* and *M. gypseum*. The ability of *C. tropicum* to interact with 12 keratinophilic and saprophytic fungi was evaluated in dual cultures. It was overgrown by *A. niger* and *C. globosum* but other fungi showed inhibition when in opposition to it. Eight fungi were able to cause hyphal inhibition of *C. tropicum* at a distance. Frequent curling, penetration, granulation, lysis and chlamydospore formation in *C. tropicum* were observed during hyphal interference. *C. tropicum* penetrated the mycelium of *A. niger* [12]. Antagonistic potential of *C. tropicum* against *C. indicum*, one *Penicillium* species and *M. gypseum* is indicative of production of some inhibitory substances [12].

The growth of *C. indicum* was promoted by nine keratinophilic fungi [155]. With *C. tropicum* it exhibited maximum positive antagonistic potentiality while with *A. benhamiae* - strain it showed least promotion in growth. With both of these fungi *C. indicum* produced intermingling colonies, the score being 1 and no zone of inhibition. *C. queenslandicum* inhibited this to the maximum extent thus exhibiting a maximum negative antagonistic nature. The inhibiting species developed a zone of inhibition exceeding 2 mm. This intermingled freely with 10 fungal partners while with 3 isolates it produced a zone of inhibition less than 2 mm, the score being 2 as described for soil fungi [156]. *C. queenslandicum* showed the greatest capacity to interact with as many as 14 fungi, which it exhibited a promoting nature. Maximum antagonistic potential of *C. queenslandicum* to promote was observed against *Chrysosporium* species with mutual inhibition and it was assigned a score of 2. This was more inhibited when grown against *Chrysosporium*, an ana-

morph of *R. vriesii*, with the score being 3, *Malbranchea* species could intermingle freely with it. Its higher index of dominance showed its high cometitive nature.

The study of dual culture interaction showed that out of 17 isolates interacted, two *C. queenslandicum* showed a similar antagonistic potential exhibiting a maximum antagonistic nature against other fungi. The overall sequence of antagonistic potential can be summarized as *C. queenslandicum* 264 and 265> *Malbranchea* sp.> *Chrysosporium* sp. 234, *Chrysosporium* anamorph of *R. vriesii* 208> *Chrysosporium* sp. 215, *C. indicum*, *C. indicum* 201, 221, *C. tropicum* 263, 449> *C. indicum* 238> *Chrysosporium* sp. 442> *Chrysosporium* sp. 267> *A. benhamiae* +> *A. benhamiae* -> A. *ciferrii* [155].

The antifungal potential of *C. carmichaelii*, *C. queenslandicum* and six strains of *C. tropicum* was studied against *Acrophialophora fusispora*, *Alternaria alternata*, *A. tenvissima*, *Aspergillus flavus*, *A. niger*, *Aureobasidium* sp., *Botrytis* sp., *Cladosporium* sp., *Cunninghamella* sp., *Fusarium* sp., *Harposporium* sp., *Mucor* sp., *Penicillium citrinum*, *Rhizopus nigricans*, *Torula* sp., white sterile mycelium and three unidentified fungi. One strain of *C. tropicum* allowed minimum number of fungi to grow. Staling substances of other *Chrysosporium* spp. also caused inhibition of soil fungi. Metabolites secreted by *C. evolceanui*, *C. pannicola*, *C. queenslandicum* and one strain of *C. tropicum* showed strong antifungal activity against *A. niger* [157].

Thirty *Chrysosporium* spp. caused inhibition of the radial extension of *M. gypseum*, ranging from 20-100%. Twenty one showed more than 50% inhibition of *M. gypseum*, 15 caused more than 50% inhibition of *A. niger*, three strains completely inhibited *A. niger*, six caused more than 50 % inhibition of *P. citrinum* while four completely inhibited this fungus. Neither of the *C. evolceanui* were inhibitory. Out of eight strains of *C. indicum* three inhibited *M. gypseum*. *C. keratinophilum* was less than 50% inhibitory. *C. lobatum* inhibited *M. gypseum*. One strain of *C. tropicum* was 100% inhibitory for *M. gypseum* and another for *P. citrinum* while other showed less than 50% inhibition of these fungi [155]. Interaction experiments on *Chrysosporium* anamorph of *Arthroderma* were also carried out [158].

The volatiles emnated from three strains of *C. tropicum* were inhibitory for *T. mentagrophytes*. Inhibition of *T. rubrum* was caused by volatiles of *C. indicum*, *C. lobatum*, and two strains of *C. tropicum*. The effect of fungal staling substances of eight *Chrysosporium* spp. on soil mycoflora was studied [157] and it was found that among four strains of *C. tropicum* one allowed a minimum number of fungi to grow. Staling substances of other *Chrysosporium* spp. also caused inhibition of soil fungi. Metabolites secreted by *C. evolceanui*, *C. pannicola*, *C. queenslandicum* showed strong antifungal activity against *A. niger* [157]. The effect of staling products of keratinophilic and non-keratinophilic fungi on the growth and spore germination of *C. tropicum* was studied [159]. The inhibition /promotion in dual cultures depends on many factors such as staling products of interacting colonies, pH change, nutrient media depletion or alteration of nutritional ingredients besides hyphal interference. Colony interaction in a number of cases is represented by mutual inhibition in growth of both fungal partners. The relative difference reveals the measure of susceptibility and antagonistic ability of the fungus. The development and subsequent formation of chlamydospores, lysis, coiling, deformation, granulation and swelling in dual cultures in most cases are evidence of their successful competition [14].

Combined effect of *Chrysosporium* with other keratinophilic fungi on hair and feather decomposition

Combination of *C. keratinophilum* with *C. queenslandicum*, *C. tropicum* and *M. gypseum* enhanced feather decomposition. The synergistic action of *C. keratinophilum* and *M. gypseum* was most effective as it caused highest protein release in the course of feather decomposition *in vitro*. The course of wool degradation by *C. keratinophilum* acting singly and in combination with *C. carmichaelii*, *C. tropicum* and *M. gypseum* was studied by measuring protein released in the culture medium and weight loss of wool up to four weeks. The combined effect of these fungi on the continual breakdown of wool by *C. keratinophilum* and the effect of the addition of *C. keratinophilum* on the continual degradation of wool by *C. carmichaelii*, *C. tropicum* and *M. gypseum* were also studied. The synergistic action of *C. keratinophilum* and *M. gypseum* on wool was found to be more effective. The biodegrading potential of *C. keratinophilum* can be made more effective by *M. gypseum* and *C. carmichaelii*, if the latter fungi join halfway through keratinolysis. *C. keratinophilum* did not act as a follower fungus in wool degradation [167]. A series of experiments were performed to see if keratinolytic *C. carmichaelii* and *C. tropicum* could be effective on the amount of wool decomposed by *C. keratinophilum*. It would be expected to occur because some of these might be utilising protein released as it breaks down. In doing so, it should relieve competitive inhibition of keratinase action and also relieve repression of keratinase synthesis [167].

C. indicum, *C. keratinophilum*, *C. pannicola*, *C. queenslandicum* and *C. tropicum* were also used for their capacity to degrade horn, hair and wool [142]. *C. europae* decomposed feather and released 457.33 µg/ml protein along with another 47 *Chrysosporium* strains tested. NaCl, KCl and Ca Cl_2 inhibited protein release from feathers when *C. keratinophilum* was used. This fungus was also used for feather decomposition during solid state fermentation [169].

Fungal colonization of hair in contact with soil

C. tropicum appeared in 6 days on fresh feathers in peptone and water amended soil while it took more time in the presence of glucose to colonize defatted and sterilized feathers. In the presence of water 16-20 days were taken to colonize 100% fresh and defatted feathers. More than 25 days were required for achieving 100% colonization in the presence of glucose. Sterilized human hair was not completely colonized in peptone and glucose amended soil up to 25 days. Cow, goat and horse hairs were colonized completely in 20 days while fresh horse hair required more than 25 days in glucose amended soil [111].

Five strains of *A. keratinophilus* perforated hair in soil and caused 48-54% hair perforation in 30 days [100]. *A. terreus* perforated 63-100% hair. *C. articulatum* and *C. carmichaelii* colonized hair in 12 and 18 days but could not perforate them. Six *C. indicum* colonized hair in 4-15 days and 5 strains perforated hair. Five strains each of *C. keratinophilum*, *C. pannicola* and *C. tropicum* colonized 100% hair in 3-5 days. *C. queenslandicum*, *C. zonatum* and *C. xerophilum* also colonized hair through soil but later did not perforate hair.

Decomposition of hair and feather in soil

The hair from humans and animals and feather from birds which come to the soil either as dropped off or dead are affected by microbial decomposition. In the past few decades some studies on the decomposition of keratin in submerged cultures appeared. Biodegradation of keratin by using *Chrysosporium* and other related fungi in submerged culture is reviewed [160] and scattered reports are available in literature [137,138,142,161-168,170-172]. The process of keratin decomposition has also been found to be very fast in soil and it plays a very important role in energy transformation and nutrient cycling in soil. Decomposition of keratin in soil has received very little attention [167,174,175]. Several species of *Chrysosporium* were found to degrade hair through soil by a new method [166]. Combinations of *C. indicum* and *C. keratinophilum*, *C. pannicola* and *C. keratinophilum*, *C. queenslandicum* and *C. keratinophilum*, *C. tropicum* and *C. keratinophilum*, *M. gypseum* and *C. keratinophilum* were employed for finding out weight loss of hair and feather in soil

The midway addition of the *C. keratinophilum* in *C. queenslandicum* experimental set showed 100% weight loss of feathers in 3 weeks. It is evident from overall observations made during experiments that, in general, the fungi acting in combination are found to be more effective in keratin decomposition than the individual action of various fungi. The midway addition of *C. keratinophilum* was the most effective in *C. tropicum* amended soil while midway additon of *C. queenslandicum* was more successful when initially inoculated with *C. keratinophilum*.

Feather and wool degradation by *C. keratinophilum* was studied in natural garden and sterilized garden soil, where it was presumed that *C. keratinophilum* utilises keratin without any competition from microorganisms for up to 3 weeks, and later a slight decline was noted. This showed that *C. keratinophilum* can efficiently cause keratin breakdown while competing with other fungi in soil [167]. The effect of *C. tropicum* on soil which had received decomposed wool products was studied during seed germination and seedling growth of *Brassica campestris* Linn, *Zea mays* Linn and *Phaseolus* Roxb. and it was concluded that this fungus could be used for the slow release of nitrogen fertilizer in soil [176].

Pathogenicity

Chrysosporium sp. was cultured from a tissue biopsy of the nasal mucosa which was found in brain, lungs and left kidney as well as nasal and sinus regions [177]. *Chrysosporium* sp. was isolated from 2 biopsy specimens of a 24 - year - old man [178] and three other male patients [179].

Pathogenecity of *Chrysosporium* spp. and *C. parvum* var *crescens* was also confirmed [180-182]. *Chrysosporium* infection in a bone marrow transplant recipient was noted as *Chrysosporium* which caused an invasive infection in an 18 - year - old woman where infection began as a facial swelling and which extended into the central nervous system [183]. Studies were carried out on the epidemiological, immunological, biochemical and physiological properties of *Chrysosporium* sp. and *C. keratinophilum* along with some dermatophytes [184].

The pathogenic role of *C. keratinophilum*, *C. asperatum*, *C. georgii*, *C. tropicum*, *C. pannorum*, *Chrysosporium* state of *A. curreyi*, *Chrysosporium* state of *A. multifidum*, *Chrysosporium* state of *A. tuberculatum* is uncertain but their ability to remain viable for several weeks in skin and peritonial tissue indicates that they could become pathogenic in certain circumstances [181,182]. Antigenic activity within the genus *Chrysosporium* was demonstrated [185]. *A. keratinophilus*, *A. fulvescens*, *A. reticulisporus* and *A. verrucosus* produced nodular lesions when inoculated intraperitonially [186]. The isolation of *C. merdarium* from nail, *C. pseudomerdarium* from lung of rodent, *C. carmichaelii* from human skin and sputum, *C. queenslandicum* from snake, *Chrysosporium* anamorph of *Gymnoascus demonbreunii* from human, *Chrysosporium* anamorph *of Pectinotrichum llanense* and *C. inops* from human skin, *C. sulfureum* from bones, *Chrysosporium* anamorph of *Rollandina vriesii* from skin and lung of lizard, *C. lobatum* from scrappings of human and skin crest and *C. pannicola* from dog [5] are all also indicative of their potential for pathogenecity.

Future Prospects

It is felt that there has been no attempt to determine the geographical distribution of *Chrysosporium*. Large areas of the world have yet to be sampled for its teleomorphic connections and germplasm collection. Molecular characterization of *Chrysosporium* species, its teleomorphs and related genera may be able to provide help in solving diagnostic problems but this criterion should be cosidered as the second step because visualization of characteristics has always had the upper hand. More information on the pathogenic and saprophytic survival, spread and nature of the life cycle of *Chrysosporium* is needed. An approach in using combinations of wild as well as genetically engineered strains of a single species or different species of *Chrysosporium* for enhancing biodegrading potential merits study. Detailed ecological and physiological studies followed by suitable selection and development of specific strains may lead to a commercially viable use of fast - growing non - pathogenic strains of this fungus.

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