INTRODUCTION

Fungi are widespread in the environment. Some seen in the normal commensal of animals and humans. During infection, they alter the host immune system turn as pathogenic, opportunistic and life-threatening [1]. It is estimated that nearly 300 million people are affected worldwide with serious fungal infections and 25 million are at high risk of dying or losing their sight. The severity of fungal infection in susceptible population ranges from acute, severe to chronic [2-7]. Azoles are the most widely used drugs to treat fungal infections due to their bioavailability and safety profile. Even though it shows a positive response to patients, due to its fungicidal effect rather than fungicidal effect frequent relapses occur [8]. Continuous and prolonged treatment with these drugs to an immunocompromised person resulted in the development of multidrug resistant fungal strains [9]. Moreover, prolonged antifungal therapy in heavily immunocompromised people can lead infection-related toxicities, nephrotoxicity, hepatotoxicity, recurrent drug infections, organ dysfunction, cutaneous reactions and malignancies [10and11]. For example, oral itraconazole causes nausea, hypertension, hypokalemia, edema in old age people. Therefore it is restricted to patients with heart failure [12]. Voriconazole treatment in ambulatory patients cause phototoxic reactions and this can lead to the development of squamous cell carcinoma and melanoma [13and14]. Increase in the multidrug resistant fungal strains, lack of drugs with new antifungal targets and the adverse effects of antifungal drugs for a long term use urge the need for the new antifungal agents which have new target site or mechanism to fight against multidrug-resistant (MDR) fungal strains as well as to overcome the disadvantage of commercially used antifungal drugs.

Cyanotis axillaris is an herbal weed belongs to the family of Commelinaceae. Traditionally C. axillaris is used to treat tymanitis, ascites, abscesses, fever, worms and ear drum infection [15]. There is no data for its antifungal activity in traditional use. Moreover, there is no scientific evidence for its antifungal activity. Since Products from plants are safe, easily available, less expensive, efficient over the synthetic drugs used in the market and having less side effect, we chose C. axillaris to examine its antifungal activity to explore new antifungal bioactive principle to overcome the existing old antifungal drugs to treat opportunistic fungal diseases. This study is the first to report the in vitro antifungal efficacy of C. axillaris.

MATERIALS AND METHODS

Collection and processing

Fresh whole plants of C. axillaris were harvested from the banana field in Pongumoodu, Thrissuranchapuram, Kerala, in the month of May and authenticated by the taxonomist Dr. D. Narasimhan, Centre for Floristic Research, Department of Plant Biology and Biotechnology, Madras Christian College, Chennai. The herbarium specimen has been deposited in Loyola College, Chennai, India, with the voucher number LCH 403. Plants were washed thoroughly and dried completely at room temperature under shade. Dried plants were ground into coarse powder using an electric blender and filtered through sieves. The powdered drug was stored in airtight container at ambient temperature for further use.

Chemicals and reagents

All solvents used for the extraction purpose were purchased from Merck, Germany. Chemicals and standard discs (fluconazole and clotrimazole) were procured from Himedia, Mumbai, India.

Preparation of plant extracts

Plant extracts were prepared by serial extraction method which involves successive extraction with solvents of increasing polarity from a low polar (Hexane) to high polar solvents (Ethyl acetate and Methanol) to ensure that a wide polarity range of compounds could be extracted. About 50 g of dried powder was soaked in 800 ml hexane for 72 h with intermittent shaking at 120 rpm in a shaker. The extract was filtered through Whatman No. 1 filter paper. The filtrate was dried completely to get a constant dry weight of the extract. The remaining plant residue from hexane extract was dried completely and soaked in 800 ml of ethyl acetate and then methanol...
successively as above mentioned and the extracts were collected. The concentrated extracts were stored at 4 °C for further use.

**Fungal strains**

All the microbial cultures were obtained from Microbial Type Culture Collection and Gene Bank (MTCC), Institute of Microbial Technology (IMTECH), Chandigarh, India and Department of Microbiology, Christian Medical College, Vellore, TamiNadu, India and National Chemical Laboratory (NCL), Pune, India. The fungal strains were Candida albicans (MTCC 227), Candida krusi, Candida tropicalis (MTCC 230), Microsporum gypseum, Malassezia pachydermatis, Trichophyton rubrum 57/01, Trichophyton mentagrophytes 66/01, Epidermophyton floccosum 73/01, Scopulariopsis sp. 101/01, Aspergillus flavus (MTCC 277), Botrytis cinerea and Curvularia lunata 46/0. Fungal strains were stored at 4 °C in Sabouraud Dextrose slants.

**Inoculum preparation**

Fungal strains were subcultured in sabouraud dextrose agar (SDA) and incubated overnight at 37 °C for yeast; 3-7 d at 37 °C for Fungi. Fungal strains were stored at 4 °C in Sabouraud Dextrose slants. The concentrated extracts were stored at 4 °C for further use.

**Antifungal activity by disc diffusion method**

Antifungal disc diffusion was performed according to standard procedure for yeast [18] and filamentous fungi [19]. The extract was dissolved in dimethyl sulfoxide (DMSO). 20 µl of extract with 3 different concentrations (1.25 mg, 2.5 mg and 5 mg) were loaded in the disc and allowed to dry. The sterile Petri plates with SDA medium were swapped with fungal spore suspension. After drying the disc with extracts were placed on the Petri plates. The plates were kept inverted and incubated overnight at 37 °C for yeast; 3-7 d at 37 °C for Aspergillus species or 25 °C for dermatophytes and zones formed were measured and tabulated. The experiment was performed in triplicates and mean values taken as the zone of inhibition which was expressed in millimetres (mm). Fluconazole (10 µg) and clotrimazole (10 µg) were used as positive control. DMSO was used as negative control.

**Determination of antifungal activity by MIC**

The MIC was performed according to the standard procedure for yeast [18] and filamentous fungi [19]. The extracts were dissolved in DMSO. The microtitre plates were dispensed with 100 µl of saubouraud dextrose broth (SDB). The initial concentration of extract was 1 mg/ml and it was serially diluted two-fold. 20 µl of fungal spore suspensions were added to each well. Both with fungal inoculum and DMSO was kept as negative control. Fluconazole and clotrimazole were used as positive control. The microtitre plates were sealed and incubated overnight at 37 °C for yeast, 3-7 d at 37 °C for Aspergillus species or 25 °C for dermatophytes. After incubation, 40 µl of 0.2 mg/ml P-iodonitrotetrazolium (INT) violet was added to all the wells and incubated for half an hour to one hour to note the colour change. When there is any fungal growth, an electron from the living cell is transferred from NADH to INT violet and converted to formazan which gives rise to red colour. The lowest concentration in which red colour is not seen is taken as the MIC of the extract. The MIC values were expressed as mg/ml.

<table>
<thead>
<tr>
<th>Fungi</th>
<th>Zone of inhibition in mm</th>
<th>Ethyl acetate</th>
<th>Methanol</th>
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<tr>
<td></td>
<td>1.25 mg/disc</td>
<td>2.5 mg/disc</td>
<td>5 mg/disc</td>
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<tr>
<td></td>
<td>Hexane</td>
<td>Ethyl acetate</td>
<td>Methanol</td>
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<td>20</td>
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<td>14</td>
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<td>F12</td>
<td>12</td>
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<td>17</td>
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</table>

Note: F1-C. albicans; F2-C. krusi; F3-C. tropicalis; F4-M. gypseum; F5-M. pachydermatis; F6-T. rubrum; F7-T. mentagrophytes; F8-E. floccosum; F9-Scopulariopsis sp.; F10-A. flavus; F11-B. cinerea; F12-C. lunata; nt: not tested; (<) no activity; Flu:Fluconazole; Clot:Clotrimazole.

<table>
<thead>
<tr>
<th>Fungi</th>
<th>Hexane (µg/ml)</th>
<th>Ethyl acetate (µg/ml)</th>
<th>Methanol (µg/ml)</th>
<th>Fluconazole (µg/ml)</th>
<th>Clotrimazole (µg/ml)</th>
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<tr>
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<td>125</td>
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<td>125</td>
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Note: F1-C. albicans; F2-C. krusi; F3-C. tropicalis; F4-M. gypseum; F5-M. pachydermatis; F6-T. rubrum; F7-T. mentagrophytes; F8-E. floccosum; F9-Scopulariopsis sp.; F10-A. flavus; F11-B. cinerea; F12-C. lunata; nt: not tested.
RESULTS
Disc diffusion method
In antifungal disc diffusion method, C. axillaris showed high antifungal activity by forming a zone of inhibition up to 36 mm at high concentration (5 mg/ml). The antifungal efficiency of the hexane, ethyl acetate and methanol extracts of C. axillaris by disc diffusion method was summarised in table 1.

Determination of MIC
After the incubation with INT, the appearance of pink colour was observed in wells which had living fungal cells and well which appeared colourless was indicated the inhibition of fungal growth by the extract of C. axillaris. The MIC values of C. axillaris tabulated in table 2. It showed a wide range of MIC values from 0.25–0.031 mg/ml. Ethyl acetate extract showed high MIC values for many tested fungi.

DISCUSSION
Worldwide fungal diseases are one of the main causes of morbidity and mortality due to fungal infections in human have dramatically increased from superficial to disseminate or deeply invasive due to the increasing immunocompromised population with cancer, organ transplantation, HIV infection, and individuals receiving immunosuppressive treatments. The prolonged immunosuppression with more intensive regimens causes invasive fungal infections in patients undergoing transplants or treatment for malignancies [21]. In the present study, we have investigated 5 yeasts and 7 filamentous fungi which cause various infections in immunocompromised people. In immunocompromised patients, Candida sp. cause invasive candidiasis and attribute 77% death [22]. C. albicans, C. krusei, T. mentagrophytes, B. cinerea, M. gypseum cause dermatophytosis in immunocompromised patients [23]. In immunocompromised patients, M. pachydermatis cause invasive infections and Scopulariopsis sp. cause invasive sinusitis [24 and 25]. A. flavus cause aspergillosis, otitis, keratitis, pulmonary and systemic infections in immunocompromised patients [26]. C. lunata is most common in immunocompromised people and causes keratitis [27].

In our present study for the first time, the antifungal activity of C. axillaris was investigated. Even though plants from Commelinaceae family were investigated for its antimicrobial activity, there are very fewer investigations have been made to prove their antifungal efficacy. The ethanol extracts of C. benghalensis from Commelinaceae family exhibited high antifungal activity than the standard drug at the minimum concentration [28]. C. axillaris showed high antifungal activity against the tested fungal strains. The highest antifungal activity was recorded for ethyl acetate extract against T. mentagrophytes, Scopulariopsis sp., A. flavus and C. lunata. The hexane, ethyl acetate and methanol extracts of C. axillaris were inactive against M. gypseum, T. rubrum and E. floccosum. In this current study, we used two commercial azoles such as fluconazole and clotrimazole which are used to treat infections caused by fungal strains in immunocompromised patients. Fluconazole is a triazone and clotrimazole is an imidazole, are used to treat antifungal infections such as thrush, candidiasis, funguria, ear infections, skin infections, urinary infections and various fungal infections in AIDS patients, bone marrow transplant recipients and leukemia patients [29-36]. Extracts of C. axillaris showed superior activity than fluconazole. Clotrimazole showed sensitivity towards the tested fungal strains. Among these 3 extracts (hexane, ethyl acetate and methanol) of C. axillaris, the ethyl acetate extract showed the highest antifungal activity against C. albicans, C. krusei, M. pachydermatis, T. mentagrophytes, Scopulariopsis sp., B. cinerea and C. lunata. It exhibited the strongest and most potential antifungal activity than hexane and methanol extracts. Tamoukou et al. studied the antifungal activity of ethyl acetate extract of Albizia adianthifolia and isolated compounds with antifungal activity [37]. The ethyl acetate fraction of Garcinia mangostana-Linn pericarp extract showed antifungal activity against candida albicans [38]. Bisht et al. proved the antifungal activity of banana leaf ethyl acetate extract against P. oxalicum [39]. These works support our study, that the ethyl acetate extract of plants can have antifungal principals. Hence this study proved that the ethyl acetate extract of C. axillaris poses more active and potential antifungal compounds that can fight against opportunistic fungal diseases.

CONCLUSION
From the present study, it is clear that the ethyl acetate extract of C. axillaris has great potential antifungal principles. Since ethyl acetate extract showed better activity than the commercially used drug (fluconazole) for fungal infections, it is clear that they should poses active principles with high antifungal activity as well as with better efficacy to replace the older drugs to fight against updating MDR fungal strains. The antifungal activity may be due to the single compound or a synergetic effect of multiple compounds. Phytochemical evaluation and isolation of compounds responsible for its antifungal activity are needed to establish a high potential antifungal drug that can fight against the opportunistic and multidrug resistance fungal strains.

AUTHOR CONTRIBUTION
Conception and design of this study, acquisition of data, analysis, interpretation of data and drafting the manuscript was done by the first author (Anto Suganya Regis). Conception of the study, revising the manuscript critically for important intellectual content was performed by the corresponding author (Jeya Jothi Gabriel).

CONFLICT OF INTERESTS
Declared none

REFERENCES


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