

## EFFECTS OF GLOBAL-WARMING AND CLIMATE-CHANGES ON ATMOSPHERIC FUNGI SPORES DISTRIBUTION

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**ABSTRACT.** Atmosphere is described as the gas and vapor layer surrounding the earth under the gravitational force. Atmosphere is composed of 78.50 % Nitrogen, 21.01 % Oxygen, 0.04% carbon-dioxide, water vapor and Nobel gases. In addition to ground, air and sea transportation vehicles, those noxious gases and particulates are released into atmosphere from houses and industry. In the past century, increased population, uncontrolled and inappropriate urbanization dramatically affected the content of atmosphere, which resulted in thinning of ozone layer and global warming. All these then turn into climate changes related problems. Besides chemical particulates, a variety of biological particulates are released into atmosphere as well. Major biological particulates in atmosphere are fungi spores and splits of fungi hyphae. Fungi can grow on any organic matter under humid conditions including shoe leather, which can tolerate low light and low temperature that makes them most widely distributed living group. Even though Fungi can release toxin and allergic agents cause infection to human, animals and plants. In contrast to this, the Fungi can be used as fermentation, bio-conversation, antibiotics and enzyme production, and biological control agent. Alteration in physical and chemical composition of atmosphere can affect soil chemistry and morphology. Similarly, the alteration can affect life-cycle, distribution and ecological performance of fungi as well. Recent field studies have revealed that transfer of increased chemical pollutants in atmosphere to soil and water structures poses negative effects on symbiotic mushroom species. Increased carbon-dioxide content of atmosphere trigger expansion of vegetation periods and increase in biomass, which turns into extension of vegetation period of symbiotic fungi. Besides, global warming alters vegetation period of a variety of fungi species. According to experimental and modelling studies done on filamentous fungi species (commonly seen in atmosphere), increased hyphae production, extended sporulation period and decreased spore synthesis were reported in response to increase in atmospheric temperature. In the light of current knowledge, it can be speculated that elongated exposure of fungi spores and hyphae will be faced, and even unprecedented allergen species will be identified in response to the altered atmospheric stress parameters.

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## 1. INTRODUCTION

Atmosphere is described as the gas and vapor layer surrounding the earth under the gravitational force. Atmosphere is composed of 78.50 % Nitrogen, 21.01 % Oxygen, 0.04% carbon-dioxide, water vapor and noble gases. In addition to ground, air and sea transportation vehicles, those noxious gases and particulates are released into atmosphere from houses and industry. In the past century, increased population, uncontrolled and inappropriate urbanization dramatically affected the content of atmosphere, which resulted in thinning of ozone layer and global warming. All these then turn into climate changes related problems.

Global-warming is described as the increase of temperature resulted from natural or man-driven reasons in the atmosphere close to the earth. Temperature of the earth is related to the amount of exposed and reflected light, vapor-content in atmosphere and the adsorbed heat by the atmosphere [1,2]. Short-waved lights coming from sun are reflected by the soil as long-waved lights that are absorbed by the gases in atmosphere which are then re-sent back to earth. This phenomenon is called greenhouse-effect, which is overwhelmingly supported by the vapor in the atmosphere. In addition to water-vapor, CO<sub>2</sub>, CFCs, methane, nitric oxides and ozone are among the driving force of global-warming with their recent increasing content in atmosphere. Particularly, CFCs (Chlorofluorocarbons) can absorb the high energy containing short-waved lights (8-12 nm), that are reflected by the atmosphere, and re-sent them back to the earth. Within 160000-year period, atmospheric CO<sub>2</sub> content were between 200 and 300 ppm. However, industrialization has increased the CO<sub>2</sub> level up to 409 ppm, whose level will reach up to 600-800 ppm level in parallel to the current trend. It is projected that the temperature of earth will increase 3.5-5 °C by 2100 in response to the increased CO<sub>2</sub> levels. As a consequence of the temperature increases, water-vaporization will increase while fresh-water resources, ice content of high mountains and arctic regions will decrease. Besides, this will influence ocean-streams as well [3,4]. Melting of arctic ice masses will increase level of ocean between 20-60 cm and alternate ocean-streams, which will then turn into alteration of climate changes and air-streams on the continents. These phenomenological changes will cause draught on some continents while the others will struggle with floods [1,3-5]. It is estimated that this process will be too fast that all the living organisms might not adapt the changing conditions that will cause their extinction. No doubt that plants and fungi will be amongst be most widely influenced organisms under these forecasted changes. In this paper, effects of global-warming and climate change on fungi are discussed.

## 2. FUNGI KINGDOM

Up to hundred thousand of fungi species have been characterized, whose projected number of taxa is 1.5 million. Fungi can be single- or multiple-cellular eukaryotic organisms. Their cell walls contain chitin. Fungi are heterotroph organisms that use exoenzymes to breakdown and then assimilate the nutrients from the organisms on which they are living. A variety of fungi can grow sexual and asexual growth cycles, while sexual growth cycle was not observed for such fungi species. Fungi can be classified with 5 phylum as Chytridiomycota, Zygomycota, Glomeromycota, Ascomycota and Basidiomycota based on sexually growth while for those whose sexually growth cycle haven't been characterized an umbrella definition as Deuteromycetes (Fungi Imperfect) is used. Fungi have very widespread distribution and life-forms with their absorption-based feeding and ability of sexual and asexual growth potentials. Most of the fungi species can grow on dead plant and animal bodies as saprotrophic. This will allow cycling of minerals and organic matter. In contrast to this, some of the fungi species can follow symbiotic life on plants and animals [6,7].

In the following section, the effects of daily-based and seasonal meteorological changes and long-term atmospheric changes along with climate changes and global-warming on fungi kingdom will be discussed.

## 3. EFFECTS OF GLOBAL-WARMING AND CLIMATE-CHANGES ON FUNGI DISTRIBUTION AND ATMOSPHERIC SPORES CONCENTRATION

Besides chemical particulates, a variety of biological particulates are released into atmosphere as well. Major biological particulates in atmosphere are fungi spores and splits of fungi hyphae. Fungi can grow on any organic matter under humid conditions including shoe leather, which can tolerate low light and low temperature that makes them most widely distributed living group. The studies show that fungus spores are found in the atmosphere in the whole year except for the days when the land is completely covered with snow [8-13].

Temperature, precipitation, relative humidity and such other meteorological parameters as wind affect fungi growth and concentration and distribution of fungi spores in the atmosphere. Studies have revealed that daily-based and seasonal

changes in these parameters greatly affect concentration and distribution of fungi spores in the atmosphere. Besides, micro-climatic changes also contribute to the alteration of the spore-types and concentrations [14-16].

*Ganoderma*, *Leptosphaeria* and *Didymella* are of wet and warm weather fungi, whose concentrations are high in day-time and at early hours. In contrast to this, Spores of *Cladosporium*, *Alternaria* and *Epicoccum*, which prefer hot and draught weather, are high at hot and dry summer weathers [17-26].

Likewise, all the living organisms, fungi species will be greatly affected in response to changes in the atmospheric concentration of CO<sub>2</sub>, N<sub>2</sub>O, CH<sub>4</sub>, CFC and nitric oxide species.

Global-warming and climate changes will increase atmospheric carbon-dioxide and nitrous compounds, which will turn into extended vegetation period, biomass increase and shifts in living species. Besides, it is forecasted that a variety of species will extinct. Due to the fact that fungi are parasitic and symbiotic organisms, negative effects seen on their targets will cause adverse-effect on the fungi species.

Mitchell et al. [27] reported that global climate changes in response to increased CO<sub>2</sub> concentration, nitrous compounds and decreased species variety triggered increases in leave pathogenic fungi species. Based on the current findings, it is speculated that the effect will be more dramatic in future and greatly affect plant and human populations.

Wolf et al. [28], studied the effect of CO<sub>2</sub> at four concentrations as 300, 400, 500 and 600 µmol/mol on spore content, spore-size and allergen protein content of *Alternaria alternata* and *Cladosporium phlei* species that were grown on *Phleum* plants. The study revealed that 500 and 600 µmol/mol CO<sub>2</sub> concentrations caused increased in *Phleum* biomass while *A. alternata* produced 3-times more spores and 2-times more allergen proteins. However, spore production by *C. phlei* did not show dramatic increases while allergen protein content did not show changes.

Anne Cotton et al. [29], studied the effect of the increased CO<sub>2</sub> and O<sub>3</sub> on the Arbuscular Mycorrhizal fungi (AM), that prefer mutualist live on the plant roots, grown in the roots of *Glycine max* (soybean). The 5-year period study showed that elevated CO<sub>2</sub> concentrations altered the composition of AM fungi communities while increased O<sub>3</sub> concentrations did not show any effect on AM fungi

communities. Similarly, number of Gigasporaceae and Gigasporaceae communities increased under elevated CO<sub>2</sub> concentrations in comparison to the control groups.

14-month period study done by Klironomos et al. [30] under 350 and 700 ppm CO<sub>2</sub> concentrations along with 45 and 348 mg N . g<sup>-1</sup>. d<sup>-1</sup> nitrogen content on *Populus tremuloides* leaves showed that under high CO<sub>2</sub> and low nitrogen concentrations such species as *Cladosporium*, *Aspergillus*, *Penicillium*, *Fusarium* increased spore production up to 5-times.

Morgado et al. [31], studied the long-term effect of summer temperatures on Ectomycorrhizal fungi (EM) grown in dry and humid tundra habitats in arctic regions. The study showed that *Cortinarius* species were the dominant species in humid tundra regions while *Tomentella* species were overwhelmingly observed in dry tundra region. Increases in temperature decreased the observed species in humid tundra area while mobilization of the species and shifts in localization were observed. A variety of species disappeared while biomass of the remaining species increased.

Damialis et al. [32], studied the effects of temperature and nutrition on *Alternaria alternata*, *Aspergillus niger*, *Botrytis cinerea*, *Cladosporium cladosporioides*, *Cladosporium oxysporum* and *Epicoccum purpurascens* species, whose spores are the most common spores in the atmosphere. The temperature of the different experimental sets were set to 10-year averages temperatures of England belong to the years of 1980s, 1990s, 2000s and year of 2100, where species were incubated under different nutrient concentrations. According to the findings, the species expect *E. purpurascens* (which has high growing capacity) and *A. alternata* (which has high competition capacity) showed faster growth under low nutrient conditions. Except *E. purpurascens*, the rest of the species increased spore production capacity in response to increase in nutrient content, which decreased in relation to elevation of the temperature. Exceptionally spore concentration of *C. Cladosporioides* increased at the expected temperature of 2010-year. Fungi can grow faster and enhanced hyphae production while delayed and decreased spore production were reported in accordance with the increase of temperature, which is beneficial for the patients suffering from asthma and allergy.

Kauserud et al. [33] did a study done between 1940-2006, in which 34000 herbarium fungi species arise in fall were studied. From 1980 to 2006, 13-day delayed appearance of fungi species were observed. The delay period was longer for the species arising earlier in comparison to the species appearing lately. Geographically, in northern and terrestrial regions appearance of the fungi was earlier in comparison to the ones growing in southern and nearby ocean areas. The overall results of the study showed that global-warming effect the vegetation period of the fungi species, and which will be continuing effect in the future as well.

In the study done by Kauserud et al. [34] in England and Norway between the years of 1960 and 2007, 6000 herbarium fungi samples and 34 field species grown in spring were examined. 30% of the species were either effected in terms of vegetation period or growth-location. 18-day earlier appearance of the fungi species were observed for both England and Norway. The study revealed that global warming caused earlier fructification body formation for the fungi species grown in spring in the late 50-years.

In the study done by Kauserud et al. [35] in Norway between the years of 1940-2008, 66.520 Fungarium samples of 271 species belong to 43 genus were examined in terms of vegetative body size, spore-size, spore-color and fungi feeding pattern. The data of collection date, location and climatic properties of collection location were entered into a statistic program to statistically analyze the above mentioned parameters. According to the findings, early arising species gave 2-times bigger spores and were dominant in inner terrestrial areas while small spore possessing fungi species were dominant in the regions close by Ocean in Norway. These revealed that spore size and factors determining the climate have close relation. For example, spores in terrestrial areas contain more water in order to guarantee hyphae formation while the ones nearby the ocean did not show this type of needs.

#### 4. CONCLUSION AND SUGGESTIONS

- a. Fungal spores are not seasonal allergens, which are around all the year. Therefore, it is not possible to avoid them, but we can count their quantities in the atmosphere.
- b. In the last 200-year period, greenhouse gases increased dramatically, which increased global warming up to 1 °C. In the next 100 years, the increase will continue and bring prominent climate changes.

- c. Even though the effects of the changes are not fully forecasted, it is believed that it will affect all the living organisms. Vegetation will shift from Equator to the poles between 150-500 km.
- d. Similar to the all living groups, fungi will be affected by this alteration.
- e. Increased CO<sub>2</sub> concentration will increase plant growth and biomass while number of fungi species will decrease and growth and biomass of such fungi species will increase. However, increased nutrient content will cause enhanced vegetative hyphae production and decreased sporulation.
- f. Alteration the temperature levels, extension of fungi vegetation periods will be observed, which will then turn into that human will be exposed to the extended period of spore related noxious conditions.
- g. Alteration in the environmental conditions will trigger arises of new allergen molecules.

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