Published in the Russian Federation
European Journal of Molecular Biotechnology
Has been issued since 2013.
ISSN: 2310-6255
E-ISSN 2409-1332
Vol. 5, No. 3, pp. 149-156, 2014

DOI: 10.13187/ejmb.2014.5.149
www.ejournal8.com

UDC 57

Effect of Climate Change on Plant-Microbe Interaction: An Overview

[1] Swati Tyagi
[2]* Ramesh Singh
[3] Shaily Javeria

[1-3] Centre of Excellence for Sanitary and Phytosanitary (SPS), Department of Plant Pathology, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut 250110, India
*Corresponding author: spsprojectrkvy@gmail.com

Abstract

Climate change is one of the major issues affecting all of us on our planet. Predicted increase in temperature and decrease in precipitation due to climate change may add complexity and uncertainty to plant and agricultural systems and threaten their sustainable management. It is well known that beneficial plant-associated microorganisms may stimulate plant growth and enhance resistance to disease and abiotic stresses. Climate change will also influence crop quality and the dynamics of the relationships between pests/diseases and crops. Changes in climatic factors like temperature, solar radiation and precipitation have potentials to influence crop production. This now makes it possible to test whether some general patterns occur and whether different groups of plant-associated microorganisms respond differently or in the same way to climate change.

Here, we review and discuss how the climatic parameters including atmospheric CO_2 and temperature influence the plant–microbe interaction in polluted soils. This review shows that predicting how plant–microbes interaction responds to altering climatic change is critical to select suitable crop plants that would be able to produce more yields and may tolerate multi-stress conditions.

Keywords: Climate change; Agriculture; Plant – Microbe interaction and Microorganisms.

Introduction

The soil is the third largest global stockpile of carbon and, together with plants, contains around 2.7 times more carbon than the atmosphere. As a result, there is much concern that climate change will augment the decomposition of this carbon, potentially shifting soils from being carbon sinks to sources of atmospheric carbon dioxide and thereby accelerating climate change—the so-called carbon cycle feedback. On the contrary, there is much current debate about the potential to increase the capacity of soils to sequester carbon from the atmosphere and hence mitigate climate change. Recent studies reveal that both of these processes, namely the loss and gain of carbon in soil, are strongly regulated by plant–microbial–soil interactions.

Soil is as an excellent medium for the growth and development of plants as well as microbes and plant-microbe interaction in soil is either beneficial or harmful. The beneficial plant-microbe interactions are caused by symbiotic or non-symbiotic bacteria and a highly specialized group of fungi (mycorrhizal fungi). Beneficial plant-associated microbes are known to stimulate the plant growth and enhance their resistance to degenerative diseases and abiotic stresses. Bacterial genera such as *Azospirillum*, *Bacillus*, *Pseudomonas*, *Rhizobium*, *Serratia*, *Stenotrophomonas* and *Streptomyces* fall under this category. These are popularly known as plant growth promoting rhizobacteria (PGPR).

Growth promoting substances are produced in large quantities by these soil microorganisms that influence indirectly on the overall morphology of the plants. Mycorrhizal fungi, on the other hand are known for its symbiotic associations with the roots of many different plants ranging from garden vegetables up to the trees of old growth forests..

World population continues to grow, resulting in significant increases in urban development and agricultural, economic and industrial activities. Deforestation and habitat destruction are accelerating rapidly to accommodate the need for open space to support increasing population growth. Accompanying this are increased emissions of gases from agriculture, combustion of fossil fuels, and industrial processes. This has resulted in changes in the chemical composition of the atmosphere. Concern about increased emission of gases into the atmosphere focuses on the possible or potential effects of accumulation of these gases above levels that can be tolerated and balanced by the self-regulating processes and dynamics of the atmosphere.

Carbon is the key source for the growth of many microorganisms and change in climate has severe affect on the growth of different microorganism through different ways likely wise either of direct or indirect path. In regard of direct effects, recent studies show that even subtle warming (by approximately 1°C) can directly stimulate microbial activity causing an increase in ecosystem respiration rates in subarctic Pearland.

Fungi and bacteria play crucial roles in ecosystem function including decomposition of dead biological material, mineral nutrient cycling and as pathogens of plants and animals. In the last few years, more attention has been paid to direct climate change on these microbes if they are exposed to sunlight (such as on foliage surfaces or litter). Changes in species composition and biodiversity of these microbes in response to climate change have been documented and many of these changes appear to be related to how well species and strains of these fungi and bacteria tolerate [1-3].

Beneficial fungi that infect plant roots and assist in absorption of nutrients (termed mycorrhizae), although not exposed to solar radiation, might be indirectly affected by UV-B exposure of the host plant shoots [4-5]. Bacteria and fungi can also be pathogenic for both plants and animals, although Beneficial microorganisms and plant pathogens have received more attention than animal pathogens with respect to climate change [6-8].

Plant growth, disease incidence, productivity can be increased or reduced by several environmental factors. Increasing disease severity is thought to primarily involve modifications in the host plant tissues, while decreased severity appears due either to host plant changes or direct damage to the pathogen [8].

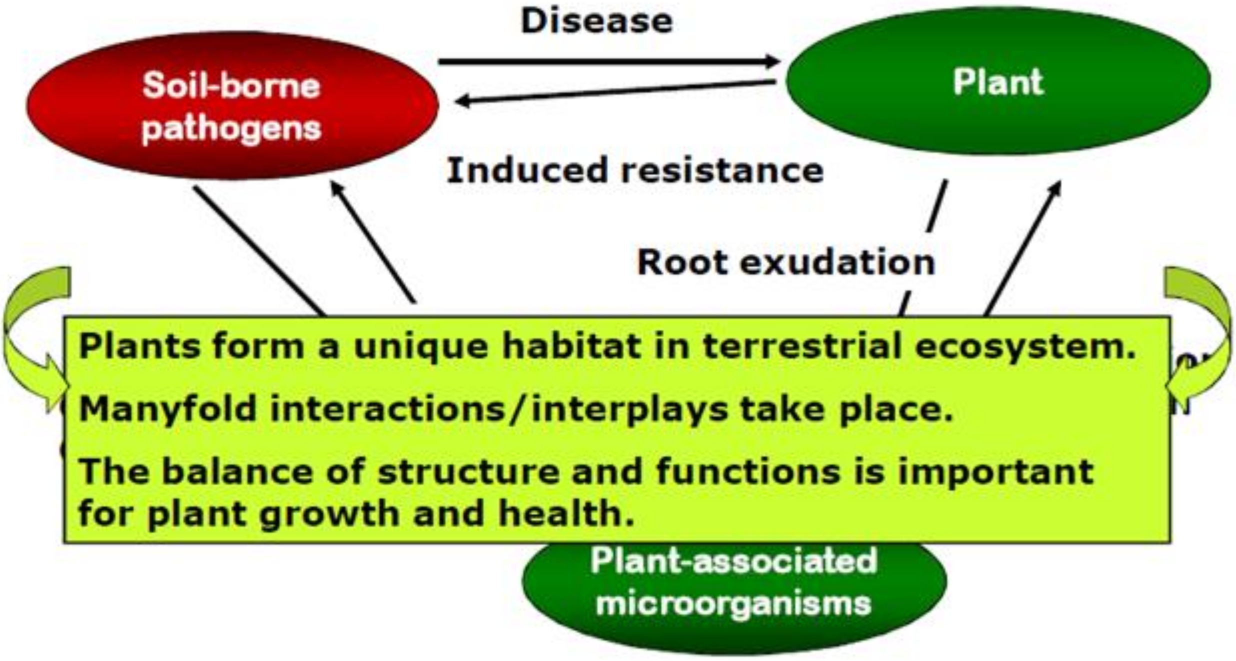


Figure 1. Plant – microbe interaction

Pathogens of insects and other animals may also be influenced by climate change. Studies involving biological control of insect pests using pathogens provide some indication of how change in climatic factors like UV rays, green house gas emission, water supply etc. may affect pathogens.

In general, there remains much uncertainty about how soil organisms directly respond to warming. For instance, it is unclear whether increases in microbial activity and carbon cycling in response to warming will be sustained due to short-term depletion of fast-cycling soil carbon pools, or whether soil communities will adapt to a warmer world [9].

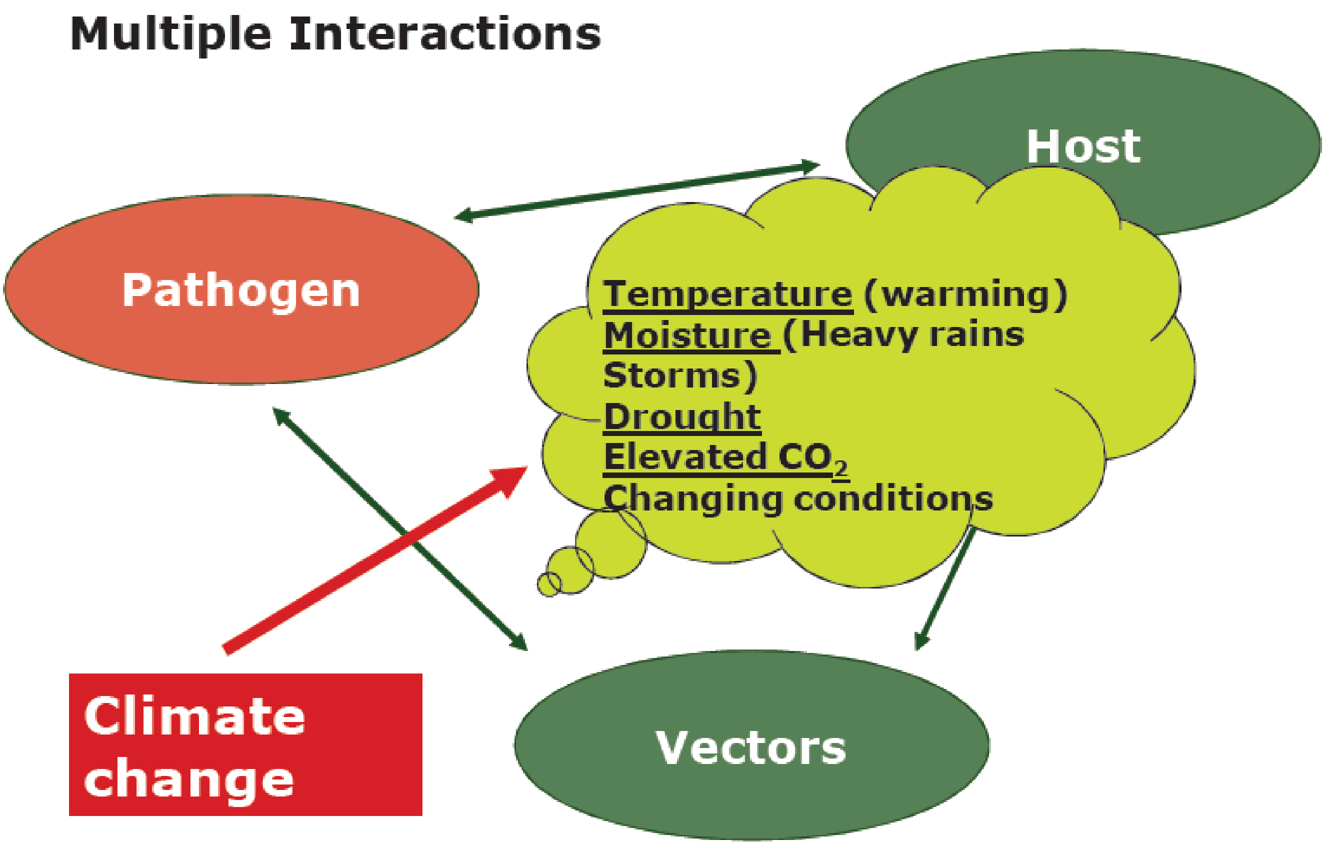


Figure 2. Interaction among climate change –pathogen and plants

Here, we review and discuss how the climatic parameters including atmospheric CO_2, temperature and drought influence the plant–microbe interaction in polluted soils. This review shows that predicting how plant–microbes interaction responds to altering climatic change is critical to select suitable crop plants that would be able to produce more yields and may tolerate multi-stress conditions.

Effect of carbon dioxide (CO_2)

Tropospheric concentration of CO_2 continuously projected to increase from 355 ppm (v/v) to 710 ppm, by the year 2050. Enormous studies have been done on the beneficial effects of elevated CO_2, concentrations on biomass production, probably due to increased water use efficiency. There is a relatively large number of studies on the beneficial effect of increased concentration of atmospheric CO2 on plant growth. Much less is known about CO_2, effects on the incidence and severity of biotic diseases of plants.

In the last few years, approximately 3,000 reports have been published on the subject (Jones & Curtis, 2000; Loladze, 2002). High CO_2 concentration results in benefits for plant growth, although there might be differences among species to species. Several authors reached the same conclusions with different crops, natural ecosystems and forest species.

Most soil-inhabiting fungi tolerate more than 10–20-fold increases in atmospheric CO, concentration. Some typical soil-borne plant pathogens like species of ***Phytophthora, Aphanomyces, Sclerotium*** and different pathotypes of ***Fusarium oxysporum*** have been found to be well adapted to and even multiply better at high CO* and low O2 levels.

CO2 enrichment promotes changes in plant metabolism, growth and physiological processes. There is a significant increase in the photosynthetic rate and a decrease in the transpiration rate per unit leaf area, while total plant transpiration sometimes increases, due to the larger leaf area (Jwa & Walling, 2001; Li et al., 2003). Stimulation of growth by carbon dioxide has been attributed to CO, fixation by the fungi. Carbon dioxide can be used as additional C-source by some fungi and incorporated into organic acids, like oxaloacetic acid, fumaric or citric acid, thus entering the Krebs cycle to be utilized for energy supply and growth (Tabak & Cooke, 1968; Wells & Uota, 1970). Isolates of ***Rhizoctonia solani*** and ***Pythium irregulare*** were inhibited by CO2 concentrations exceeding 510 %. Griffin and Nair (1968), however, reported that an isolate of ***Sclerotium rolfsii*** had reduced mycelial growth at near ambient CO ***Rhizopus stolontfer, Cladosporium herbarum, Botrytis cinerea, Aspergillus niger*** and ***Alternaria tenuis*** were inhibited at CO, concentrations exceeding 5–10 %.

Soilborne diseases have been studied either by fumigating the soil containing inoculums or by incubating plants in enriched CO* atmospheres while growing in infested soil. In most cases, however, experiments were made with realistic CO* concentrations only for soil air composition, but far too high compared with the atmospheric CO_2. Carbon dioxide favors soil bome infections by ***Fusarium*** spp., especially the incitant of snow mold of cereals, and the members of the ***F. oxysporum*** group.

In a study it was found atmospheric concentration of O2 normally inhibits CO2 absorption by plants, and triggers photorespiration. With a rise in CO2 concentration, the inhibition of photosynthesis by O2 tends to decrease due to an increase in the CO2:O2 ratio. The number of infected barley seedlings grown in that soil was significantly greater than those from soil fumigated with normal air.

Other root diseases caused by ***Pythium splendens*** or ***Thielaviopsis basicola*** on poinsettia were not affected by elevated CO, atmospheres in the greenhouse (Zornbach & Schickedanz, 1987). Undoubtedly, the prevalent effect of a global rise of CO, on biotic diseases will be exerted via changes in the physiological and morphological status of the host plant.

Few studies were conducted in controlled conditions, which might not reflect plant responses in the field, where there are variations and interactions among temperature, precipitation, and other factors.

The increase in plant biomass production, i.e., the increase in production of shoots, leaves, flowers and fruit, represents more tissue that can be infected by pathogens. Increased carbohydrate contents can stimulate the development of sugar-dependent pathogens, such as rusts and powdery mildews. Increases in canopy density and plant size can promote higher growth, sporulation and spread of leaf infecting fungi, which require high air humidity, but not rain, as rusts, powdery mildews and leaf necrotrophs. The increase in crop residues can represent better survival conditions for necrotrophic pathogens. The reduction in stomatal opening can inhibit stomata invading pathogens, such as rusts, downy mildews and some necrotrophs. The shortened growth period and accelerated ripening and senescence can reduce the infection period for biotrophic pathogens, and increase the necrotrophic pathogen populations. The increase in root biomass increases the amount of tissue that could be infected by mycorrhyza or soilborne pathogens, but can compensate the losses inflicted by the pathogens. Higher root exudation can stimulate both pathogens and antagonistic microbiota in the rhizosphere (plant growth promoters).

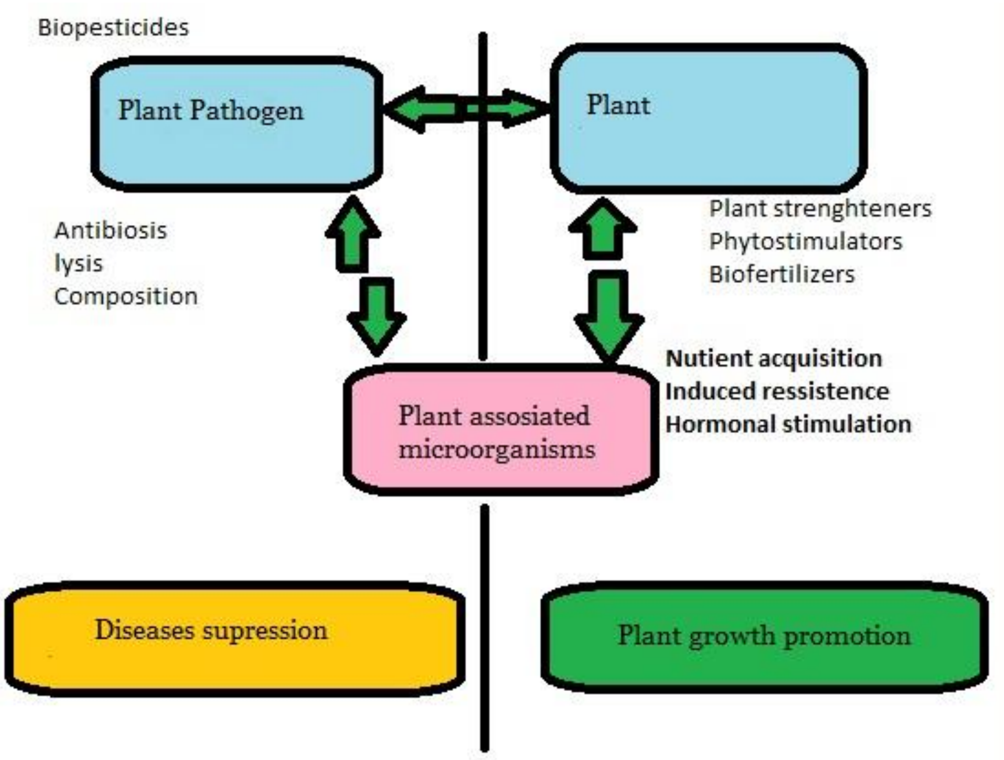
Effects of temperature

Global warming, a gradual increase in planet-wide temperatures due to CO2 and other greenhouse gasses has long been known to affects the physiology, development, growth and productivity of plants. It is well known that the temperature that is higher than the ideal increases the transpiration and stomatal conductance, but decreases the photosynthesis resulting in significant reduction in the plant biomass yield (Djanaguiraman et al., 2010; Qaderi et al., 2012).

Studies have considered the effects of temperature on plants as well as on microorganisms and it was found that only few studies that have deal with the interactive effects of higher temperature on plants in soils (Li et al., 2012). In general soil warming can affect the nutrient through altering release of soluble metal ions in to soil solution via decomposition of SOM, lysis of microbial cell and the destruction of soil aggregates, thereby changing metal bioavailability, its uptake and distribution in plant tissues.

It has also been reported that elevated temperature can increase the release of trace elements from organic to exchangeable complex through enhancing the soil enzymatic activity (Sardans and Penuelas, 2006) and thereby increasing plant metal uptake.

It is known that the elevated temperature increase the active sites on the root surface and/or change the lipid composition of the plasma membrane (Lynch and Steponkus, 1987) and thereby its fluidity, and so facilitate both passive and active metal flux through the membrane (Fritioff et al., 2005). Since trace elements (e.g., Cu, Zn and Fe) have important roles in a large number of enzymes regulating many physiological processes, the higher enzyme activity and protein syntheses in temperature-increased environments may allow for greater metal uptake at additional uptake sites on membranes or an increased release of molecules facilitating metal uptake. However, it is also found decreased Cd, Pb, Fe, Zn and Cu concentrations in tubers on increased temperature and suggested which was related to dilution effect due to temperature induced growth rate of tubers. This result indicates that higher temperature greatly influences the element uptake or its accumulation (e.g., Cu, Zn and Fe) in plants through enhancing physiological processes and consequently the nutrient demand.



Conclusions and recommendations

The effects of climate change on plant growth in metal polluted soils will be complex, particularly plant species with narrow ranges of tolerance to various stress factors may have difficulty adapting to future climatic conditions. Since the direct and/or indirect effects of climate change on heavy metal mobility in soils may further hinder the ability of plants to adapt and make them more susceptible, further research is required to assess and predict how both climate change and heavy metals will influence the biomass production, metal accumulation and eco-physiological response in plants. The outcome of such studies will improve our understanding of interactions between external stress factors and biological processes and provide a stronger scientific background to counteract negative consequences of climatic changes on plants growing in metal polluted soils.

Several plant-associated microbes which are tolerant to various stress conditions including drought, heavy metals and temperature, were identified. Moreover, these microbes might have various plant growth promoting traits necessary to establish the plants under the conditions prevailing in metal polluted soils. In general, the climatic changes particularly the CO2 increases plant growth and improve plant–microbe interactions. It is likely these benefits will also occur in plants growing in metal polluted soils, but data to support this are lacking. Moreover, it is yet to be determined whether plants growing in metal contaminated soils under altered environmental conditions release more root exudates and thereby alter colonization/ survival potential of specific stress tolerant and/or plant beneficial microbes.

Thus, attempts should be made to assess and predict how the future climate change will influence the diversity, distribution, and activity of soil microbes and their capable of contributing to the overall plant growth and/or phytoremediation potential in metal polluted soils. This will provide not only an improved knowledge on biodiversity and microbial community structure, but also how climate change influences the plant–microbe–metal interactions in polluted soils.

Recent experiments have demonstrated that the e[CO2] and/or inoculation of plant-beneficial microbes is a successful tool to improve the plant growth and heavy metal phytoextraction process in polluted soils. However, the issues of the harmful effects of climate change on the production and quality of food and feed are scarcely considered. Thus, determining the impacts of climate change on various factors (metal bio-availability, microbial diversity, etc.) potentially altering the biomass production and heavy metal accumulation in crop plants is of critical importance. Moreover, such knowledge is required to develop soil management strategies for food crops to adapt future climatic change as well as to reduce the entry of heavy metals into the food chain.

Finally, though the evidence gathered so far demonstrates that climate change is likely to have a significant impact on plant growth, the exact consequences of future climate change on plant–mictrobe interaction are difficult to predict due to the complex interactions between various climate parameters (e.g., CO2, temperature) and soil physic biochemical properties (soil nutrition, microbial diversity, heavy metal concentration, etc.,). Therefore, research involving the interactive effects of various environmental factors on plant response to climate change on different type of soils is required before generalizations can be made.

References:

1. Johnson D., Campbell C. D., Gwynn-Jones D., Lee J. A. and Callaghan T. V., Arctic soil microorganisms respond more to longterm ozone depletion than to atmospheric CO2, *Nature*, 2002, 416, 82–83.
2. Djanaguiraman M, Prasad PVV, Seppanen M. Selenium protects sorghum leaves from oxidative damage under high temperature high stress by enhancing antioxidant defense system. Plant Physiol Biochem 2010;48:999-1007.
3. Fritioff A, Kautsky L, Greger M. Influence of temperature and salinity on heavy metal uptake by submersed plants. Environ Pollut 2005;133:265-4.
4. Braga G. U. L., Flint S. D., Miller C. D., Anderson A. J. and Roberts D. W., Variability in response to UV-B among species and strains of *Metarhizium* isolated from sites at latitudes from 61 _N to 54 _S, *J. Invertebr. Pathol.*, 2001, 78, 98–108.
5. Braga G. U. L, Flint S. D., Miller C. D., Anderson A. J. and Roberts D. W., Both solar UVA and UVB radiation impair conidial culturability and delay germination in the entomopathogenic fungus *Metarhizium anisopliae*, *Photochem. Photobiol.*, 2001, 74, 734–739.
6. Zaller J. G., Caldwell M. M., Flint S. D., Scopel A. L., Sala O. E. and Ballaré C. L., Solar UV-B radiation affects below-ground parameters in a fen ecosystem in Tierra del Fuego, Argentina: implications of stratospheric ozone depletion, *Global Change Biol.*, 2002, 8, 867–871.
7. Jacobs J. L. and Sundin G. W., Effect of solar UV-B radiation on a phyllosphere bacterial community, *Appl. Environ. Microbiol.*, 2001, 67, 5488–5496.
8. Van de Staaij J. W. M., Rozema J., Van Beem A. and Aerts R., Increased solar UV-B radiation may reduce infection by arbuscular mycorrhizal fungi (AMF) in dune grassland plants: evidence from five years of field exposure, *Plant Ecol.*, 2001, 154, 171–177.
9. Li Y, Zhang Q, Wang R, Gou X, Wang H, Wang S. Temperature changes the dynamics of trace element accumulation in Solanum tuberosum L. Clim Chang 2012;112: 655–72. Lieffering M.
10. Lynch DV, Steponkus PL. Plasma membrane lipid alterations associated with cold acclimation of winter rye seedlings (Secale cereale L. cv Puma). Plant Physiol 1987;83: 761–7.
11. Shapiro M. and Domek J., Relative effects of ultraviolet and visible light on the activities of corn earworm and beet armyworm (Lepidoptera: Noctuidae) nucleopolyhedroviruses, *J. Econ. Entomol.* 2002, 95, 261–268.
12. Searles P. S., Kropp B. R., Flint S. D. and Caldwell M. M., Influence of solar UV-B radiation on peatland microbial communities of Southern Argentina, *New Phytol.*, 2001, 152, 213–221.

13. Qaderi MM, Kurepin LV, Reid DM. Effects of temperature and watering regime on growth, gas exchange and abscisic acid content of canola (Brassica napus) seedlings. Environ Exp Bot 2012;75:107–13.

14. Rajkumar M., Narasimha M., Prasad V., Swaminathan S, Freitas H. Climate change driven plant–metal–microbe interactions Environment International 53;2013: 74–86

15. Moody S. A., Newsham K. K., Ayres P. G. and Paul N. D., Variation in the responses of litter and phylloplane fungi to UV-B radiation (290–315 nm), *Mycol. Res.*, 1999, 103, 1469–1477.

16. Sardans J, Penuelas J. Introduction of the factor of partitioning in the lithogenic enrichment factors of trace element bioaccumulation in plant tissues. Environ Monit Assess 2006;115:473–98.