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Effect of microgravity on rhizosphere and endophytic microorganisms

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Abstract

Outer space agriculture and planetary colonization are two major goals in space science as well as in agriculture in the future world. It is not an easy task that cultivate crop plants in outer space with limited resources as well as under several abiotic stresses. For cultivate crops in outer space, it is essential to take a better understanding about the behavioral differences as well as physical and chemical compositional changes in the plant bodies as well as the microbiomes that related to the plant root system and some plant tissues such as leaves. Usually, many microorganisms that related to the plant rhizosphere and endophytes behave in different way under the microgravity conditions that has been created within the laboratory conditions for demonstrate the conditions which the earth gravity is not affecting to plant growth and development. As an example, that has been observed, *Pseudochrobacterium kiredjianiae* a type of microorganism that inhibited the rhizosphere increasing the growth of the wheat (*Triticum aestivum* L.) by increasing the root length and biomass accumulation. With the influence of the earth's gravity this *P. kiredjaniae* also behaving in the same manner. But specially under the microgravity conditions, their activities have been enhanced. Like *Pseudochrobacterium kiredjianiae* there is a possibility to change some strain of microorganisms that can be behave on plants with resulting negative effects on the cultivations such as by decreasing the growth rate of the plant. Because of that, the understanding regarding the behavioral changes of the rhizosphere and endophytic microorganisms will be definitely helpful for the future agriculture in space and the colonization programs that based on some other planets such as Mars. Ultimately, studies regarding the studies of microgravity on rhizosphere and endophytic microorganisms will open a new chapter of agriculture in the future generations.

***Key words**: Microgravity, Behavior; Rhizosphere; Endophyte, Agriculture*

Introduction for microgravity

Microgravity can simply define as the condition which people as well as the objects that are appearing as weightless things in the space and artificially created situations under laboratory conditions. In other tern, microgravity can be defined as the condition that feels very small weight in the space. (micro-very small). Usually this condition is feeling by the astronauts who are working in the international space station and traveling through space. sometimes, microgravity is misleading as zero gravity condition. but, there is a very small gravitation pull can be observed in the space (May, 2012) and because of that, it is not a totally weightless condition. With the advancement of the technology, there are many researches regarding the affect of microgravity on human (Unsworth & Lelks, 1998) and plant tissues through more than a decade. Unlike the earth's gravity, microgravity is differently affected to the human's and plant's growth, development as well as metabolism. Usually, due to the microgravity, human bones and tissues get weaker (May, 2012). It also affects to the signaling pathways of the cells according to the molecular biological analysis (Ingber, 1999). This condition is also valid to the plants as how it valid to the human. Because, plants are also living organisms that are growing under the earth gravity. Usually many of the metabolite reactions of the plants are directly depending on the help of earth's gravity such as the root formation, transpiration of the water and the mineral nutrients through the plant body, growth and development of the apical meristem etc. But under the microgravity, plants are facing several challenges to growth of the root system and some of its metabolite pathways. when farming on space, those studies on plants will be highly affected for a sustainable farming as well as they will be important for the future of the space travels and colonization of other planets.

Importance of studying about the behavior of plants under microgravity

Major issue that should think about the space era because due to an unavoidable global issue, dramatic increasing of the global population. In the long period of the earth's history, human was cover only near to 3 million years of time. But within this time, there were more than 80 billion of people were lived and currently there are 10% of them are living (Sadigov, 2022). According to the statistical analysis, world population is more than 7 billion 884 million (Sadigov, 2022). Major reason for the dramatic increasing of the population because due to the imbalance of the births and current deaths. With the increasing of the population, cultivation lands are decreasing over time. However, colonization of a planet is not an exact solution for the increasing of the population. But with the

advancement of the science and the technology through the space exploring can be directly use for the sustainable agriculture. Also, it definitely helps to colonize other planets such as mars and moon.

Now a days, the major task in study of plants in space is to observe and analyze the adaptation of plant tissues for low gravity and the micro gravitation conditions. These studies are important for make the plants as a life -saving organisms in space. Usually the space is a harsh condition with limited number of resources. Under this conditions, plant's ability to recycling of carbon and other trace elements, recycling of carbon dioxide and producing oxygen to breath and provide food for consuming are important for the astronauts who are lining months in the space and continuing researches (Patterson, 2012). As current researches, NASA and ESA are continuing researches based on plants such as *Arabidopsis thaliana* (Patterson, 2012) to investigate about the growth and development of the root under the microgravity condition.

Why microorganisms are important for these studies?

Microorganisms are playing a key role when studying about the growth and development of plants under the earth's gravitation. In all the domains (bacteria, archaea and eukarya) microorganisms can be observable they possess significant role in the ecosystem of the earth. They are ubiquitous and because of that, they can be observed in everywhere around the earth's biosphere (Prosser, et al., 2007). Through the microbial interactions with all the other organisms on land, they possess specific interactions with plants. Usually almost all the plants in the world are possessing some kind of relation with the microorganisms. Rhizosphere, phyllosphere and the endosphere are colonizing by various types of microorganisms (Hassani, et al., 2018).

Microbial interactions with plants can be categorize under different categories. They may be symbiotic, mutualistic, pathogenic or parasitic interactions. As examples, when mycorrhizal fungi are showing mutualistic relationships with their host species, some fungi species such as *Puccinia* sp. Shows parasitic/pathogenic reactions with their particular host. In a sustainable agriculture, studying of all the types of interactions are taking an important role.

Plant-microbial interactions are using for sustainable organic farming in earth. Plant growth promoting rhizobacteria such as *Azospirillum* spp, *Rhizobium* spp, *Azotobacter* spp, *Arthrobacter* spp, *Bacillus* spp, *Clostridium* spp, *Enterobacter* spp, *Gluconoacetobacter* spp, *Pseudomonas* spp and *Serratia* spp (Mishra et al., 2016) as well as mycorrhizal fungi species and bacteria species such as *Frankia* spp. (belonging to actynomycetes family) are some microorganisms that are involving to the promoting of plant's growth and metabolism. Some microorganisms such as zinc solubilizing microbes like *Bacillus* spp. and *Pseudomonas* spp. (Mishra et al., 2016) are important in recycling of the nutrients for the plants in sustainable agriculture. As well as the nitrogen fixing microbes such as *Rhizobium* spp and some cyanobacteria species also important in the well growth of plants. In modern agriculture, these types of microorganisms are using in organic farming such as produce biofertilizers, seed coating techniques, sustainable nutrient recycling processes as well as for decrease the pathogenic infections too. With the advancement of the technology, biotechnology, molecular biology and Recombinant DNA technology like tools are using to transfer economically important microbial genes in to the plant cells and produce new plant varieties.

In the space agriculture, it is crucial to study regarding the microbial activities in order to a sustainable agriculture. All the headed microorganisms are continuing their interactions with plants under the earth's gravitation condition. But the microgravity is a totally different condition without any sense of weight and a combination of extreme conditions. Under the extreme conditions, microbial interactions with their host species are probably may be differ than the interaction in the optimum conditions. Because of that, under the microgravity conditions, those microorganism's beneficial properties could be altered. Because of that reason, studying regarding the rhizosphere and the endophytic microorganisms under the micro gravity condition is a key study for sustainable agriculture.

Rhizosphere and endophytic microorganisms.

Plant rhizosphere is a hot spot of soil microorganisms as well as microbial interactions. There are thousands of various microbial species are growing, developing and dying in rhizosphere region and plant root system is hostage for all of them. Rhizosphere is the narrow region that located around the root system and it secrete various organic components such as carbohydrates, flavonoids and they become the major food source of microorganisms and the driving force for increasing of their population (Raajmakers et al., 2009). In nature, rhizosphere is a region that consist of both beneficial as well as pathogenic microorganisms and contain the organisms that belonging to domain archaea, eukarya as well as bacteria. Some examples for the rhizospheric microorganisms are *Rhizobium* spp. *Bradirhizobium* spp, *Agrobacterium tumefaciens*, *Pythium* spp, *Fusarium oxysporous* etc. (Raajmakers et al., 2009).

In the rhizosphere, particular microbes have different roles. Some of them are beneficial (Mendes, et al., 2013) such as secreting plant growth promoting substances (oxines, cytokines) and enhance the immunity against the pathogens, improve the absorption of mineral nutrients (mycorrhizal fungi) fixing atmospheric nitrogen (*Rhizobium* spp) and modulate the timing of plant flowering (Lu et al., 2018). In other way, some rhizosphere

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microorganisms are pathogens. Crown gall disease (*Agrobacterium tumefaciens* (Raajmakers et al., 2009) Wilting diseases are some examples.

Endophytic microorganisms are hostage the plant tissues and they are belonging to archaea, bacteria or actinomycetes (Nair & Padmavathy, 2013). Like the rhizosphere microorganisms, they also may be symbiotic, neutral or pathogenic organisms. Some of the examples for the endophytic microbes are *Enterobacter* spp., *Colletotrichum* spp., *Phomopsis* spp., *Phyllosticta* spp., *Cladosporium* spp etc. (Nair & Padmavathy, 2013).

In organic agriculture under earth's gravity, both rhizosphere as well as the endophytic microorganisms are very much important as beneficial or pathogenic. But under the microgravity, their behavior can be altering.

Microbial behavior under the microgravity.

Unlike the earth's gravitation, microbial behavior under the microgravity condition is differ. The major change is the decreasing of the number and the speed of colonization of microorganisms become decreasing significantly (Foster et al., 2014). Major reasons for this are the limited number of nutrients, lack of water draining and because of that, the poor aeration of the growing soil. In the cultivation in the space, soil is directly not use as we are seen in earth. Instead of that, plants can be grown on a pillow like structure that containing a clay mixed growth medium and fertilizers (Heiney, 2021). But all the other conditions such as light, carbon dioxide condition as well as the water is supplying artificially and the supplying rates and quantities are differing than the quantities that naturally occurring in the earth. This change could be affected microbes negatively as well as affect to the symbiotic relationship as well.

Pathogenicity

Under the microgravitational condition, microbial pathogenicity usually get increased with the controls under the earth's gravity condition. Because due to the harsh conditions with limited number of resources, microorganisms are usually adapting their best to thrive the environment and as a result of that, their pathogenicity can get increase. Also, under this condition, plant also growing with stressful manner and that will be enhance the pathogenic microbial invitations (Bishop, et al., 1996). As an example, soybean cultivations are usually get infecting with *Phytophthora sojae*, a pathogenic fungus under the earth's gravity. But the virulence of *P. Sojae* is higher in the microgravity condition than the earth's gravity. With the studies of the Soybean and the particular fungi has been proved the higher virulence (Foster , et al., 2014). Also, with the *Acremonium* sp. Fungi has been proved this experimental fact too. Usually under the greenhouse condition, *Acremonium* sp. Can be discovered in wheat plants and they are symptomless. But under the space conditions, they are displaying significant symptoms is seeds of wheat plants (Bishop, et al., 1996). Also, with the study regarding *Neothypodium* spp. fungi and the wheat seeds has demonstrated the same results like the previous case study. The particular also displayed critical symptoms under the space condition, but they were symptomless under earth's gravity (Fu et al., 2017). Usually, the fungi species become the prominent pathogens in space conditions and when they invade plants, it is hard to control the process of the pathogen if they invade their particular plant host.

Growth promotion of plants

Because due to the pathogenic invasions in the plants, it is crucial to study regarding the disease control methods and plant immune system suppression for a healthy and sustainable space agriculture. Like the pathogens are increasing their virulence under the microgravitational condition, there are some microorganisms that increase the beneficial properties for the growth of plants. The studies based on *Pseudochrobactrum kiredjianiae* A4 strain has been proved the disease control properties of the bacterium under the microgravitational condition. Under the studies, *P. kiredjianiae* A4 strain has displayed the antifungal properties by biomass accumulation and the enhance the root growth of the wheat seedlings (Fu et al., 2017). Also, *P. kiredjianiae* A4 is the strain that adapted to the low temperature under the earth's condition (Fu et al., 2017). Because of that, this characteristic also important for thrive the harsh environment in the space too.

Uses of microbial properties under the microgravity

Identifying and examining of the microbial properties under the microgravity condition is basically importance for the sustainable agriculture in the space. Majority of microorganisms in soil as well as inside the plant tissues are altering their properties to thrive the microgravity condition. Because of that, this study will be importance in plant pathology as well as plant microbial interaction studies. Also, the capabilities of usual soil microbes under the extreme conditions, their environmental and physical parameters can be revealing by studying their behavior under the space condition. At last, these studies will be help to protect the lives of the astronauts who leave the earth and habitat the space for months.

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Conclusion

Microbes are fascinating and ubiquities organisms that can be live under various harsh conditions. When consider their symbiotic relationships, plant and microbial interactions are very much important for human because human is directly or indirectly depending on the plant materials. In the modern, sustainable organic agriculture, rhizospheric and endophytic microorganisms are using for increase the yield with organic fertilizers. With the beginning of the space era, people colonize the space and, in that plants, take a special place to save the lives of astronauts. For the sustainable growth and the development of plants, microbial symbiosis is important and their behavioral, metabolite, reproducing and colonization rates are differing with the microgravitational conditions. By studying those properties, the relevant microorganisms or their specific pathways can be used for the sustainable agriculture in space. Also, by studying of the pathogenic microbes, they can be control when an infection occurs under the microgravity condition. By continuing this studies could be able to colonize the space and other planets successfully.

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