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Biotech programs on the International Space Station

The International Space Station is a manned space station in low Earth orbit (near 407.3 km), the inclination of which is 51.63°, and the period of its rotation around the Earth is about 90 min. The ISS is used as a multi-purpose space research complex. An international partnership of space agencies provides and operates the elements of the ISS. The principals are the space agencies of the United States, Russia, Europe, Japan, and Canada. Beginning of operation in 1998 and till now. The constant free fall of the ISS causes a state of weightlessness, which is described as microgravity and is somewhat different from the state of complete weightlessness. One of the main goals of the ISS is to conduct the wide range of experiments in the unique conditions of space flight: microgravity, vacuum, cosmic radiation [1].

Experiments with growing plants on the ISS are an important part of the experiments on board. There are seven Plant Growth Systems on ISS: Advanced Astroculture (ADVASC), Biomass Production System (BPS), Lada, European Modular Cultivation System (EMCS), Plant Experiment Unit (PEU), Advanced Biological Research System (ABRS), Veggie [2].

The ADVASC was used for growing first and second generations seeds of *Arabidopsis Thaliana* in 2001–2002 and for growing soybean plant in space in 2002. Analyses of the produced seeds showed that the seeds were healthy and the germination rate was comparable to commercial seeds in terrestrial agriculture. With help of the BPS the Technology Validation Test (TVT) and the Photosynthesis Experiment and System Testing and Operation (PESTO) experiments were conducted on ISS board. These experiments showed the identity of the rate of photosynthesis and transpiration in the cultivation of plants in terrestrial conditions and space. Genetically modified dwarf peas grown during five experiments with Lada Plant Growth system in 2003–2005. These experiments investigated the morphological and genetic parameters of plants of several space generations. The EMCS was used for GRAVI, GENARA, MULTIGEN and TROPI and other experiments of plant growing and plant physiology in space in 2005–2007. The Japanese Plant Experiment Unit (PEU) was used for Space Seed experiment aimed to grow Arabidopsis from seed to seed in different conditions. One of the first experiments conducted within the ABRS (launched in 2009) was the investigation of the Transgenic Arabidopsis Gene Expression System (TAGES). The VEGGIE is the Food Production System (NASA), launched in early 2014. VEGGIE is the first system designed for food production rather than plant experiments under microgravity [2].

The following experiments concerning biotech were performed on the Russian segment of the ISS: the “Calcium” — study of the effect of micro-

gravity on the solubility of calcium phosphates in water; the "Phoenix" — study of the impact of space factors on the state of the genetic apparatus and the survival rate of dried lymphocytes and bone marrow cells; the "Cascade" — study of the processes of cultivation of cells of various types; "Biodegradation" — study of the initial stages of colonization by microorganisms of the surfaces of structural materials in a closed environment for the ISS crew. "Electronic nose" — study of the development of bacterial and fungal microflora on the surfaces of materials in space flight using a portable gas sensor system E-NOS; "ARIL" — the effect of PCF on the expression of interleukin-producing strains 1α, 1β, ARIL; "Bacteriophage" — study of the impact of space flight factors on bacteriophages; "Biodegradation" — the initial stages of degradation and biodegradation in space; "Biofilm" — study of the regularities of biofilm formation in conditions of weightlessness; "Biorisk" — study of the influence of space factors on the state of systems "microorganisms-substrates;; in relation to the problem of environmental safety of space technology and planetary quarantine; "Bioemulsion" — research and development of an autonomous closed-type reactor for obtaining biomass of microorganisms and biologically active substances without adding additional ingredients and removing metabolic products; "Constant-2" — study of the influence of space flight factors on isolated enzyme-substrate systems; "Conjugation" — working out the process of transfer of genetic material by the method of conjugation of bacteria; "Microbiological monitoring" — study of the nature of the formation and spread of microorganisms in the habitable compartments of the ISS [3–4].

Investigation of the influence of microgravity conditions on the intensity of grain growing were studied also in [5].

1. https://www.nasa.gov/mission_pages/station/main/index.html
2. *Zabel P., Bamsey M., Schubert D., Tajmar M.* Review and analysis of over 40 years of space plant growth systems // Life Sciences in Space Research. — 2016. — 10. — P.1–16.
3. http://www.gctc.ru/
4. https://www.energia.ru/
5. *Корнієнко І.М., Маджд С.М., Міхєєв О.М., Черняк Л.М., Барановський М.М., Чубко Л.С.* Вивчення впливу умов мікрогравітації на біологічні об'єкти // Academician L.S.Berg — 145. International Conference. Bender. — Bender: Eco-TIRAS, 2021. — P.136.