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Role of Microbes in Crop Resilience

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Climate change is one of the important factors that pose serious threat to a sustainability. Seasonal shifts, vagaries of rainfall and other ecological disturbances affect crop production and overall agricultural turnover. Natural hazards, like landslides, floods, drought, storm, etc., not only disrupt the ecosystem, but also reduce crop yield. Crops subjected to extreme climatic conditions make them susceptible to biotic stress.

Biotic stress refers to the negative impact caused by microorganisms, insects and weeds on the growth, development and yield of plant. All these factors put together influences food availability, which in turn has a negative impact on nutritional and livelihood security. It also results in qualitative and quantitative loss of crops, resulting in economic loss for farmers. To withstand climatic challenges and biotic stress, scientists use biotechnological tools and specific traits of certain beneficial microorganisms to develop resistant crops.

The term 'crop resistance' denotes the ability of the crops to withstand stressful conditions. It also refers to the ability of the crops to regain its vigour and yield potential in a short time after the stress period.

Beneficial role of microbes

There is a wide range of beneficial microbes that help in improvement of crop production. Nitrogen fixing bacteria like *Rhizobium, Azotobacter, Azospirillum*, etc. form symbiotic relationship with crops to convert atmospheric nitrogen into fixed nitrogen. Phosphate solubilizing bacteria like *Pseudomonas, Bacillus*, etc. solubilize inorganic phosphorus to soluble compounds. These microbes improve soil fertility and enhance nutrient cycling. The process of decomposition is carried out by microbes, where essential nutrients are released back into the soil. The soil particles are bound together by the action of microbes that reduces soil erosion and improves soil structure. Ethylene, auxins and gibberellins are plant growth hormones that stimulate root and shoot growth, are produced by phytohormone-producing microbes like Rhizobacteria. Beneficial microbes can be used to prevent microbial infection in crops. Various biocontrol agents are derived from microbes including bacteria, virus, fungi and nematodes. It helps keep pest population in check by producing toxins and causing diseases in them. The important mechanisms involved are parasitism, predation and antibiosis. Some popular bio-pesticides:*Bacillus thuringiensis, Pseudomonas fluorescens, Trichoderma viride* and *Beauveria bassiana*. Biofertilizers suppress phytopathogens, increases nutrient availability and soil organic matter and restores soil nutrient cycling.

Negative role of microbes

While microorganisms offer numerous benefits, some, known as phytopathogens, pose significant threats to plant health. It includes bacteria, fungi, virus, viroids, protozoa, etc. that have detrimental effects on agricultural productivity. Many organisms are disease-causing pathogens. They infect plants, causing impaired growth, yield loss and plant death.

Fig 1: Biofertilizers (Source: HRS, Ooty)

A wide range of diseases are transmitted through air, water and soil. Some common diseases include powdery mildew, rust, root rot, bacterial blight and leaf mosaic. These microbes directly damage plant tissues and disrupt nutrient and water flow. Microbial infection in plant can also lead to production of toxins like furocoumarins aflatoxins, glycoalkaloids, etc. Ergot caused by *Claviceps* sp. is a significant problem in rye, oats and related crops. Consumption of ergot-infected grains can be fatal. It causes constriction of blood vessels, tissue death and hallucinations in humans.

Microbes compete with crops for essential minerals, water and space. Post-harvest losses are another key challenge. The spoilage of harvested crops duringstorage and transportation leads to economic loss. Microbes like *Aspergillus flavus* and *Penicillium* produce mycotoxins that contaminate food, posing risk to human and animal health. Soil fertility is also reduced due to microbial activity.

Role of biotechnology in agriculture

Farmers and scientists have long sought to manipulate plants and animals to develop desirable traits. However, with evolution of biotechnology, this has become attainable and more targeted. Agricultural biotech-nology is a technique combining genetic engineering, genetic mapping, molecular biology and micro-propagation to modify plants, animals and even microorganisms.

It has revolutionized the agriculture sector. It is faster and more precise than conventional breeding. Specific properties or characteristics of microorgan-isms can be added to the host to promote growth, develop desirable qualities in terms of colour, flavor, size, growth rate and nutritional content and develop resistance against pests and diseases. The growing demand for food is a significant challenge driven by various factors like population growth, pressure on agriculture land, land degradation and climate change.

Agricultural biotechnology is a potential tool to ensure food security and sustainability. It helps develop crop varieties that can grow and yield well with limited resources, under different stress conditions and using lesser synthetic fertilizers. The main goal is to improve agricultural productivity, to increase yield, to maximize nutrient use efficiency, to provide biotic and abiotic stress resistance and bio-fortification.

Biotechnology plays an important role in developing stress-resilient crops and to create more productive and nutritious crops. Biotechnology can contribute to sustainable agriculture practices by improving resource use efficiency and reducing environmental impact. While agricultural biotechnology offers immense potential, it is crucial to address concerns related to biosafety considerations.

Rigorous scientific evaluation and regulatory oversight are essential to ensure the safe and responsible use of this techno-logy.

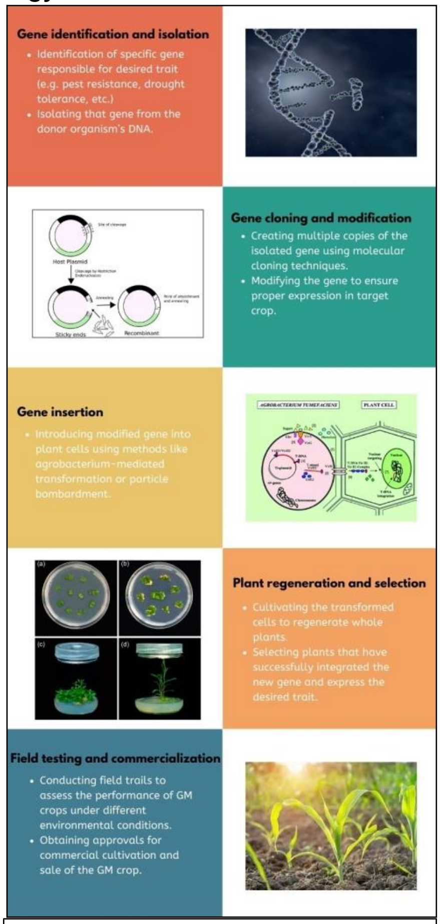

Fig 2: Steps involved in agricultural biotechnology

Role of microbes in developing resilient crops

As discussed earlier, microorga-nisms play an important role in enhancing agricultural prod-uctivity. Nitrogen-fixing bacteria, phosphate-solubilizing bacteria and mycorrhizal fungi aid crops in nutrient uptake. Plant growth-promoting microorganisms produce plant hormones like auxins and gibberellins. Antagonistic microbes like entomopathogenic fungi, entomopathogenic nematodes, baculoviruses, Chaetomium, etc. suppress and eliminate plant pathogens and pests, thereby reducing the need for chemical fungicides and pesticides. Microorganisms are employed in the formulations of biofertilizers, biopesticides and biocontrol agents. Beyond these applications, microorganisms also play a significant role in biotechnology. Specific gene traits identified in certain microorganisms are used to develop crops with enhanced growth, yield and other desirable characteristics.

Some of the examples are as follows:

Bt cotton

It is genetically modified crop that has been developed to produce its own insecticide. It is engineered by using the genes of the soil bacterium *Bacillus thuringiensis*. The bacterium produces Bt toxins that are harmful to various lepido-pterans, especially boll-worms. Specific genes from Bt bacteria are inserted into the plant's genome. The plant cells, thereby, produce proteins that is toxic to the pests. This has facilitated lower pest damage, lesser use of chemical pesticides and increased yield.

Golden rice

Vitamin-A defici-ency can lead to blindness, malnutrition and impaired immunity. Golden rice was developed to address this issue that was common in many developing countries. It is created through genetic engineering, where genes from daffodils (*Narcissus pseudo-narcissus*) and bacteria (*Pantoea ananatis* and *Esch-erichia coli*) are introduced in the genome of paddy. These genes encode enzymes for the biosynthesis of beta-carotene, a precursor of Vitamin A.

Glyphosate-resistant soya

Glyphosate is a non-selective herbicide that is used to control over 300 weed species. It kills plants by blocking the EPSPS enzyme, an enzyme involved in the biosynthesis of amino acids, vitamins and many secondary plant metabolites. GR soybean contains a gene from soil bacteria like *Streptomyces viridochromogenes* and *Streptomyces hygroscopicus* that helps in the resistance to glyphosate. This gene allows the crop to survive while subjected to the exposure of the herbicide, while the weeds get killed.

Drought-tolerant corn

Bacillus subtilis is a beneficial bacterium that is used to promote plant growth and improve stress tolerance. A specific gene from this bacterium is inserted into the crop genome. This helps activate a protein that helps reducing the effect of drought in the growth and yield of the crop. This bacterium induces production of proline and sugars in plants that help maintain cell turgor.

Genetically modified (GM) papaya

It is also known as Rainbow papaya. It is a genetically modified variety resistant to papaya ringspot virus (PRSV). It was developed by introducing a gene from the PRSV into the crop genome. This gene produces a protein that disrupts the ability of the virus to replicate and makes the plant resistant.

Rapeseed and *Beauveria bassiana*

Researchers are studying the symbiotic relationship between rapeseed and *Beauveria bassiana*. The growth of the fungus in the plant tissue triggered a remarkable increase in flavonoid biosynthesis and compounds known for multiple plant benefits including anti-oxidant properties. Techniques are being developed to reduce reliance on chemical pesticides.

Conclusion

Biotechnology is a promising tool for improving soil health and nutrient cycling. By harnessing the potential of genetic engineering, scientists can develop crops with enhanced traits. While concerns about biosafety and ethical implications exist, careful regulation is necessary to ensure responsible use of the technology. Advanced biotechnological tools and growing understanding of beneficial microbes pave way to enhance crop resilience, food security and a sustainable future.