THE GLOBAL CLIMATE CHANGES AND ROLE OF NANOTECHNOLOGY IN AGRICULTURAL PRACTICE

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Abstract

Since the 18th century, as human activity intensified, climate changes on our planet became global. These changes create complications of different nature in different areas. There are three important categories of action for reducing the risk of global climate change: reducing emissions, adapting to climate impacts, and financing required adjustments. The plant world is the most important among the living systems affected by global climate changes. That is why adapting plants to these changes, in other words, increasing their durability, is one of the most important issues of modern horticulture. It has already been proven that nanotechnology plays an important role in increasing plants' resistance to environmental factors (temperature, salinity, drought, radiation, etc.). In the presented review article, the scientific articles of recent years have been analyzed and it has been shown that nanoparticles play an important role in plant development, productivity, important physiological and biochemical, molecular processes and resistance to stress factors. The number of studies and investigations dedicated to this field is observed with exponential growth. In the article, the research of recent years and the results obtained from our own experiences are highlighted. It has been shown that nanoparticles can produce both positive stimulatory and toxic effects in plants, depending on their type, physical and chemical properties, dose, exposure time and application methodology. It has been noted that nanoparticles play an important role in the mineral nutrition of plants, protection, and formation of effective responses to stress factors.

Keywords: nanotechnology, nanoparticles, plants, stress factors, drought, salinity.

I. Introduction

Since agriculture operates as an open system where energy and substances are freely exchanged, the production processes here are unique. The most affected by the consequences of global climate change is the agricultural industry. Therefore, concern about the potential effects of long-term climate change on agriculture has grown significantly in the past decade and has been the subject of many studies. These studies are mainly devoted to the elimination of possible physical effects associated with climate changes in crops and livestock. Although the methods and technologies used in agricultural production have an ancient history, each of them has always kept its relevance. Nanotechnology, determined to gain the status of technology of the 21st century, penetrates all areas of human activity in terms of its application. In recent years, the application of nanotechnology in agriculture has been noted as a major issue in the economic interests of all countries of the world from the point of view of investment. Research conducted by nanotechnology in the fields of plant physiology and biochemistry, agronomy, plant protection, productivity, product quality and packaging is giving positive results. To increase productivity in agriculture, nanotechnology offers new effective agrochemical agents, fertilizers, pesticides and herbicides, tolerance methods, smart packaging technologies.

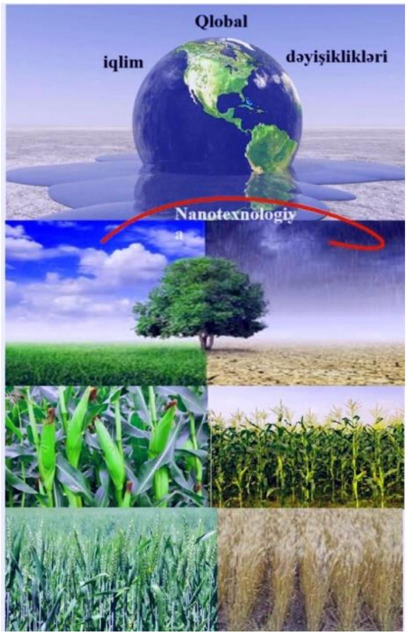

Figure 1: *Global climate change and nanotechnology*

The applications of nanotechnology in agriculture to increase productivity, improve production technologies, and modernize irrigation and agro technical methods include (1) the use of Nano forms of agrochemicals in the application of pesticides and fertilizers to improve and increase yields; (2) the application of Nano sensors in plant protection for identification of disease and chemical toxicant residues; (3) application of Nano devices for genetic engineering technology in plants; (4) application of Nano sensors in the diagnosis of plant diseases; (5) application of Nano technological methods in animal health, animal husbandry, poultry production; and (6) use of nanomaterials in post-harvest storage and packaging. What results of research conducted in the field of nanotechnology can be used in the application of intensive technologies in agricultural practice?

II. Interaction of nanoparticles with plants.

NPs can enter plants from air, soil, irrigation water, and seeds. NPs entering the organs and tissues and cells of plants cause many morphological and physiological changes depending on their characteristics. The effectiveness of NPs is determined by their chemical composition, size, surface coverage, reactivity and, most importantly, the effective dose. Studies have shown that NPs can have both positive and negative effects on plant growth and development, resistance to stress factors, and disease protection. In our experiments and the research of other scientists, it was determined that NPs can enter the seeds of plants, are absorbed from the endosperm layer of the embryo and migrate from the roots to the above-ground organs [1, 2].

From our experiments [2] and from the results of experiments by Lv. Christie and Zhang [3], it was clear that NPs penetrate the seeds and improve their water absorption, which leads to an increase in the intensity of seed germination. Nano hydrates can penetrate plant roots through osmotic pressure, capillary forces and pores (5-20 nm) in the cell wall [4]. The effects of some nanoparticles on plant development and important physiological processes are listed in Table 1.

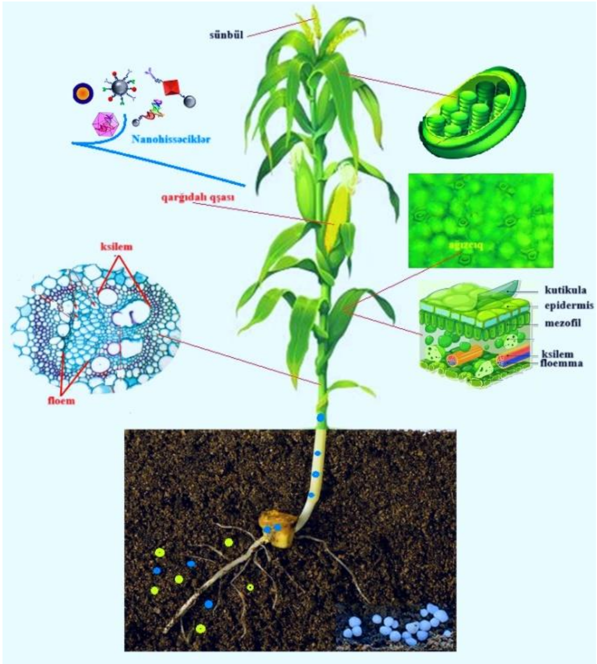

Figure 2: *The main areas of accumulation and action of nanoparticles in plants: root, seed, stem, leaf*

Table 1: *Effects of some nanoparticles on the plant developments and important physiological processes*

Nanoparticles	Plant variety	Possible effects and mechanism	References
Zn O	*Pennisetum americanum*	It increases the activity of certain enzymes	[5]
	Onion, Rice, Wheat	Disruption of cell metabolism, reduction of root length and reduction of plant biomass.	
Cu O	*Egeria densa*	Accelerates lipid oxidation, increases SOD and catalase activity	[6]
Ag	Tomatoes, pigeon peas	It enhances root length, plant height, dry and fresh weight of seedlings, and intensity of photosynthesis	[7]
	Lactuca sativa	It can accumulate in the leaves, it does not show any phytotoxic effect Accelerates the growth of sprouts Does not affect soil environment	[8]
	Phaseolus radiates *Sorghum bicolor* *Daucus carota L.*	Reduces germination rate, increases seed number, protein, chlorophyll content and H_2O_2 Strengthens root regeneration	
Au	*Xrizantema, gerbera & primrose*	Increases productivity, germination rate, growth and radical scavenging activity	[9]
	Arabidopsis thaliana	Increases germination, plant height, leaf length, diameter without showing toxicity at 5.4 ppm	
	Allium cepa L.	It increases the average length of roots, biomass, and reduces the number of leaves of seedlings	
Al_2O_3	*Nicotiana tabacum*	Reduces biomass but increases K+ uptake, increases macronutrient uptake	[10]

		in roots and leaves	
SiO_2	*Solanum lycopersicum* L.	It enhances the activity of a number of enzymes in the leaves and seeds, and also promotes the absorption of nitrate	[11]
TiO_2	Spinach	Increases Fe, P and K content in leaves, improves photosynthetic performance and Fe and P availability, accelerates plant growth	
Fe_3O_4	*Triticum aestivu*	Prolonging the exposure time accelerates plant growth, has a positive effect on VC content, and does not increase fruit weight.	[12]
γ-Fe2O3	*Cucumis melo*		

III. The role of nanoparticles in the resistance of plants to stress factors

The most serious problems caused by global climate changes in agriculture are related to drought and soil salinization. Both of these stress factors cause serious changes in plant organs, tissues, and important physiological processes (growth and development, photosynthesis, respiration, mineral nutrition, etc.) and ultimately stop the life activity of plants, reduce their productivity, and in most cases lead to their destruction. Experiments show that the application of nanoparticles in solving this problem can play an important role in plants' fight against stress factors. The results of experiments performed with the application of nanoparticles in recent years show that various metal-based nanoparticles, carbon nanotubes, and nitrogen oxide nanoparticles increase the resistance of plants to stress factors and are a promising field of research. In this type of experiment, it is possible to clarify the mechanism of the effect of nanoparticles on plants and the role of nanoparticles in the formation of responses to various stress factors. Plants develop early stress signalizing mechanisms to counter abiotic stressors and increase tolerance. When plant cells are stressed, they form and amplify secondary signals such as calcium, reactive oxygen species (ROS), phospholipids, and nitric oxide (NO), as well as various protein kinases. These signals include SnRk1 kinases that alter the expression of about 1000 stress-sensitive genes, ABA and ethylene plant hormones that act as key signals for stomatal closure and plant defense responses during drought stress [13]. These stress signals activate transcription factors, which further activate various stress-response genes to cope with the harsh effects of abiotic stress.

Salinity stress and nanoparticles. 20% of cultivated lands worldwide (35% in Azerbaijan) face salinity stress, which is the main type of abiotic stress factor, and this amount is increasing day by day due to global climate changes. Salinity is mainly caused by an excess of sodium chloride (Na Cl). High levels of Na Cl cause at least three types of problems for higher plants: 1) a higher osmotic pressure in the external environment (in solution), compared to the intracellular osmotic pressure, 2) high concentrations make it difficult to absorb and transport nutrient ions such as Na, K, and Ca, 3) Both Na and Cl ions can have direct toxic effects on membranes and enzyme systems. To combat salt stress, plants are well equipped with a defense system of various antioxidant enzymes including superoxide dismutase (SOD) and peroxidase (POD). Using the achievements of nanotechnology to reduce the negative effect of salt stress is one of the urgent issues of the day. The contribution of nanoparticles to the solution of this problem in the research of scientists is promising. From the results of our experiments with cotton plants, it is clear that when cotton seeds are treated (coated) with Al nanoparticles, they grow well in saline soils. In the initial stages of plant development, the amount of chlorophyll a and b pigments in the leaves increases, Al nanoparticles reduce the increased activity of key enzymes such as ascorbic peroxidase during salt stress. This decrease is slight in polyphenol oxidase but appreciable in guaiacol peroxidase enzyme. Hussain and Abu-Baker [14] sprayed a solution of Zn O nanoparticles on the leaves of a cotton plant irrigated with seawater to reduce the negative effect of salinity. It was clear from their experiments that application of Nano-Zn O reduced phosphorus (P) uptake and translocation to leaves, resulting in lower P/Zn ratio. They suggested that extra dose of P-fertilizer with Nano-Zn should be used to overcome P/Zn imbalance.

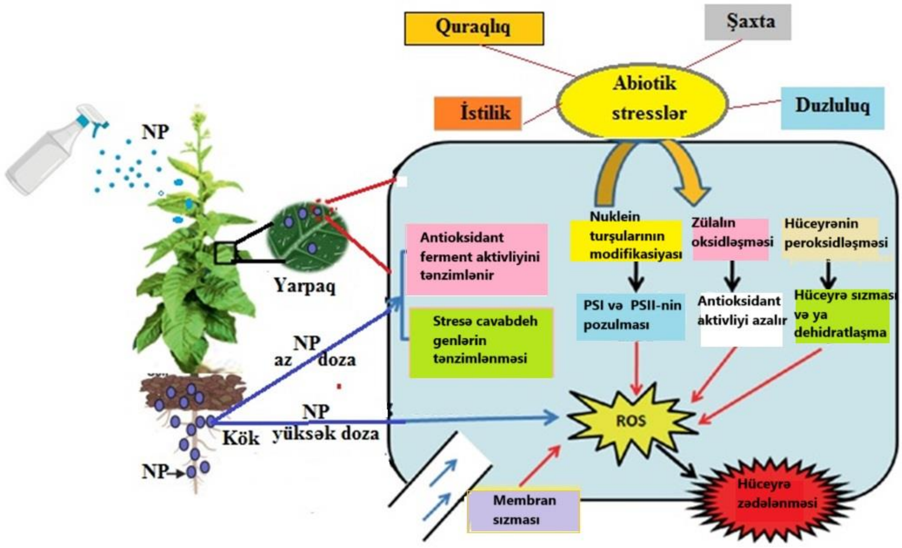

Figure 3: *Effects of nanoparticles on plants under stress conditions*

Avestan et al., [15] used SiO_2 nanoparticles to overcome the effect of salinity stress in their experiment. They managed to improve the morphological and physiological changes in strawberry plants during salt stress using SiO_2 nanoparticles. They found that nanoSiO_2 increased chlorophyll content in salt-stressed plants and maintained better leaf relative water content (RWC) and relative water conservation (RWP) compared to control.

Drought stress and nanoparticles. Plants on our planet have been constantly fighting water stress for millions of years, from the moment they emerged from water to land. As drought occurs, most higher plants are forced to adjust their life cycles to tolerate or avoid this stress. Therefore, drought has been the main driving factor for the evolution and diversification of arid plants. This important environmental factor always remains the main obstacle to agricultural production. For plant physiologists, the concept of "drought" does not simply mean lack of water, it means (1) low soil moisture; It means (2) high evaporation potential, (3) high-temperature conditions, (4) high solar radiation, (5) increased soil hardness, (6) lack of mineral elements, and (7) accumulation of salts in the topsoil.

Experiments show that as a result of the application of nanoparticles to plants in drought conditions, antioxidant enzyme activity increases, phyto hormone levels improve, and important changes in physiological properties occur, and as a result, the effect of drought on plants is reduced. The effects of Fe_2O_3, Zn O and TiO_2 nanoparticles on the development, productivity, biochemical and morpho-physiological parameters of plants under drought conditions were investigated in our experiments with corn plants grown in field conditions. It was determined that nanoparticles have a stimulating effect on plants grown in drought conditions. Plants whose seeds were treated with TiO_2 nanoparticles grew more intensively regardless of drought stress and plant height increased by 1.5 times compared to the control. The height increase was 1.6 times greater than the effect of Zn O nanoparticles, and 1.17 times greater than the effect of Fe_2O_3 nanoparticles. GPX activity significantly increased in the drought variant. This was 20-25 per cent higher than the activity under irrigated conditions. Nanoparticles also reduced GPX activity in the drought variant. At this time, the effect of Zn O nanoparticles was greater. Application of Zn O nanoparticles to soybean plants under drought conditions increases seed germination percentage, application of Cu and Zn nanoparticles to wheat plants increases relative humidity and antioxidant enzyme activity, stabilizes photosynthetic pigment content in leaves, reduces accumulation of thiobarbituric acid, reagents, and consequently reduces stress effects. Application of SiO_2 nanoparticles under drought stress reduces superoxide radical generation and membrane damage but increases shoot length and relative water content in barley. Application of Cu O nanoparticles to maize under drought conditions increases leaf water content, plant biomass, anthocyanin, chlorophyll and carotenoid content. Drought stress increases the negative effect of Cd element in wheat plant, but as a result of application of Zn O nanoparticles, the effect of both Cd and drought stress is weakened. The results of the experiments showed that the use of silver nanoparticles increases the germination percentage of lentil seeds and the growth rate of seedlings under drought conditions [16].

IV. Conclusion

A review of the scientific literature shows that nanotechnology, which has found many different fields of application in the last few decades, has begun to form a powerful scientific field. Nanotechnology is used in medicine, agriculture, industry, environment, engineering, and electronics, and is revolutionizing various fields. Nanotechnology is emerging as an important technology to strengthen and modernize agriculture in particular, which is an important tool to overcome food poverty and malnutrition, and the consequences of global climate change. A large number of extensive studies have determined that nanoparticles can provide beneficial effects on the development and growth of plants, increase productivity, and help eliminate biotic and abiotic stress factors. In perspective, the use of nanotechnology will create a powerful platform and enable a safe and stable future in sustainability, productivity, quality, diagnostics and smart packaging. It will be able to minimize product losses. The most effective way to understand the nature of the mechanisms of application of nanomaterials is to cooperate with such fields of science as molecular biology, plant physiology, plant biotechnology, cytology, soil physics along nanotechnology. Such collaborations can be useful for promoting multidisciplinary projects that can be implemented worldwide. In order to deepen the physiological research on nanotechnology, new ideas about the mechanism of tolerance to various abiotic stresses in plants are formed. The application of nanotechnology should be commercialized from the laboratory to the agricultural fields.

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