ROLE OF NANOPARTICLES IN DROUGHT STRESS MANAGEMENT

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Agriculture plays a vital role in providing food worldwide and serves as the backbone of emerging economies. Application of fertilizers has become indispensable for boosting soil fertility and crop yields. To enrich soils with essential nutrients farmers mostly depend upon chemical fertilizers in the soil. However, leaching often leads to low nutrient utilization efficiency, resulting in substantial financial losses and diminished soil fertility. In recent times, nano fertilizers (NFs) are viewed as efficient nutrient delivery option compared to conventional fertilisers. This innovative technology could be pivotal in achieving sustainable development goals, such as eradicating hunger, ensuring food security, and enhancing the sustainability of global agricultural practices. Nanoparticles possess larger surface area and the ability to retain a significant amount of nutrients before gradually releasing them (Singh et al., 2021). Application of specific nanoparticles, such as Si NPs, $CuFe_2O_4$ NPs, and SiO_2 NPs, can positively impact plant growth by increasing nutrient uptake, enhancing enzymatic activities, and improving soil nutrient availability. Abiotic stress factors like shift in temperatures, drought, salinity, waterlogging, and heavy metals can play significant role in altering plant's physiological, morphological, and biochemical processes, thereby affect global agricultural productivity. This article deals with role of nanoparticles in managing drought stress.

DROUGHT

Drought stress conditions are playing a significant challenge as they subject plants to various unfavorable stresses at different levels morphological, physiological, and molecular. This adversely affects plant growth, physiology, and ultimately yield. Drought stress primarily arises from the closure of stomata, leading to oxidative stress. This, in turn, triggers an increase in the production of reactive oxygen species (ROS) within chloroplasts and mitochondria. Consequently, the photosynthetic process is impaired due to changes in chlorophyll and other photosynthetic pigments, resulting in the cessation of plant growth which was depicted in (Figure 1). Furthermore, increase in drought stress in arid and semi-arid regions leads to soil salinization and calcification, further diminishing productivity. In India majorly affected states with drought are Rajasthan, Gujarat, Maharashtra, Andhra Pradesh, Telangana, Tamil Nadu, Uttar Pradesh, Madhya Pradesh, Bihar, Odisha, Jharkhand and Chhattisgarh.

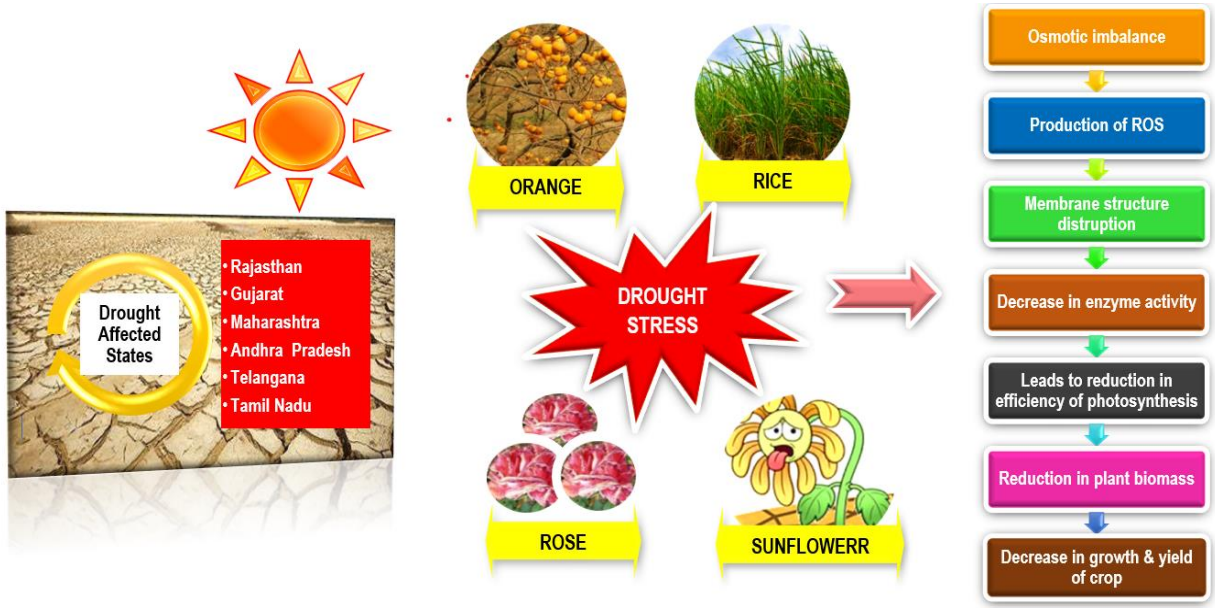

Figure 1: Impact of drought stress in growth and development of different crops

TRANSPORTATION MECHANISM OF NANO FERTILIZERS

NFs are ideal for both soil application and foliar spray. When spraying NFs onto the green canopies or leaves, uptake primarily happens through the cuticle, stomata, and hydathodes. On the other hand, in soil application, plants access the NF particles through root tips, lateral roots, root hairs, and the outermost layer of the roots; known as the rhizodermis like source to sink model. Transport through apo plastic (spaces outside of cells) and symplastic (uninterrupted network of cytoplasm) pathways and the endocytosis process (cells take in external materials by surrounding and enclosing them, and moving them into the interior of the cell) NF particles get transported from soil to the plant cell through xylem and phloem. After entering the plant cell, nanoparticles promote adjustment of osmolytes, stimulate antioxidant production, plant hormones and regulate the stomatal opening. The process all together leads to the increase in the photosynthetic activity and further growth and development of crop plants (Figure 2).

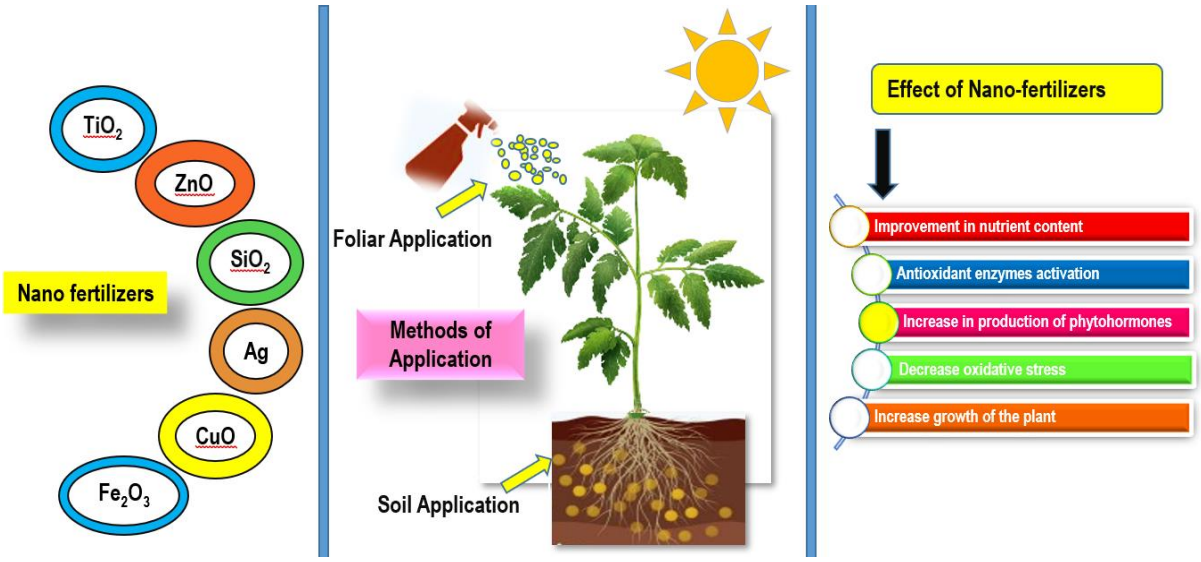

Figure 2: Advantages of different Nano-fertilizers for crop growth

SUCCESS STORIES

A few studies were only carried out on the management of drought stress by using nanoparticles. Sutuliene et al. (2023) observed MoO_3 nanoparticles enhanced plant height, nodule count, and antioxidant activity in pea plants. Alluqmani and Alabdallah (2023) studied the effect of Carbon nanoparticles (6ppm) on chili seedlings maintained at 35% field capacity. Their study showed reduced effects of dehydration in seedlings by controlling their osmoprotectants, water status, chlorophyll content, and enzymatic antioxidants A brief description of successful management of drought stress using nanoparticles given in Table 1.

Table 1. An outline of success stories of Nanoparticles for drought stress management

NANO PARTICLES	CROP	METHOD OF APPLICATION	CONCEN-TRATION	TYPE OF TRAIL	RESPONSE	REFERENCE
ZnO	Soybean	Added to the seedling's nutritional solution	0, 0.5 & 1.0 g L^{-1}	Petri dishes	lowered the seed residual weight and accelerated the seed germination	Sedghi et al. (2013)
Si	Hawthorn	Added to the seedling's nutritional solution	0, 10, 50 & 100 mg L^{-1}	Pot culture	increased plant tolerance while maintaining essential physiological and metabolic processes. changes in chlorophyll and contents of carotenoids	Ashkavand et al. (2015)
TiO_2	Canola	Soil application	500, 1000 & 2000 mg kg^{-1} as soil amendment	Pot culture	improved the total chlorophyll (total Chl), carotenoids (Car), stomatal conductance (gs), photosynthetic rate, superoxide dismutase activity, proline content, catalase (CAT) activity, ascorbate peroxidase (APX) activity, and proline content.	Faraji et al (2020)
Chitosan	Wheat	Soil and foliar application	0, 30, 60 & 90 ppm (during tillering, stem elongation & heading stage)	Field	enhanced biomass, crop yield, RWC, chlorophyll content, photosynthetic rate, catalase and super oxide dismutase activity, and leaf area	Behboudi et al. (2019)

CONCLUSION

Application of NFs is a favorable approach for tackling drought stress in plants. These tiny fertilizers offer numerous advantages, including enhanced nutrient uptake, better soil moisture preservation, osmotic regulation, ant oxidative characteristics, hormonal equilibrium, and regulated stomatal behavior. By utilizing these mechanisms, Nano fertilizers strengthen plants to withstand the challenges posed by drought, promoting agricultural sustainability and mitigating the detrimental effects of water scarcity on crop production.

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