INTRODUCTION

'Sustainable food security' – denotes the story of all living organisms. A story beyond all the scientific development, technical advancements, and social modernization. Looking back, there was no need for food security. There was no need to give extra attention or importance to producing our own food. The soil was fully fertile, the water was pure, and the air was healthy. Nevertheless, we are the only reason to create a situation where these three words become the world's primary motto (Seay-Fleming 2023). Our increasing population is horribly wasting natural resources without recycling them, piling up the existing problems. We are reluctant to fulfil our general responsibility to save 'Mother Nature'. We are making 'Mother Nature' polluted, dirty, and suffocating by directly disposing of toxic substances in the open environment and contaminating the soil, water, and air. Additionally, converting the big forests to bare land by cutting down the trees (the central filter system of nature) makes the problems even worse. The contaminated environment with the diminishing fertile lands is insufficient to feed the enormous population. In this scenario, the economically weaker countries are suffering to feed their country's people properly (Roy et al., 2023).

The environment imposes various stress factors (abiotic – salinity, drought, heavy metal contamination, flood, cold, high-temperature; and biotic – insect, virus, bacteria, fungus) on the crop plants, resulting in a massive reduction in the production rate as well as their nutrient profile (Haggag et al., 2015). Various chemical fertilizers, pesticides, and fungicides have been used on the soil to overcome these stress effects and increase yield. However, the excessive use of these interventions made the croplands infertile and the waterbodies polluted. The toxic chemicals accumulate in edible crop portions, negatively impacting food digestion and the overall health of humans and all animals. That is why these commercial agrochemicals need to be replaced with better products to boost sustainable crop development and, most importantly, to lower environmental hazards (Hassaan and El Nemr, 2020).

In this context, nanotechnology has emerged as an alternative in the agricultural sector. Nanotechnology-based agrochemicals are being tested on a laboratory scale, considering crop improvement efficiency, stress ameliorating capacity, nutrient use efficiency, and non-toxicity (Kim et al., 2018). Various metallic, organic/biogenic, and polymeric nanoparticles are being evaluated to prepare the nano-formulations in this context. The outcome of the studies assures nanoparticles' excellent capabilities to produce nano-agrochemicals that will be way more efficient for crop development when applied in a minimal quantity than the commercially available agrochemicals (Singh et al., 2021). In this regard, efforts are being made to engineer nanoparticles to improve the availability of nutrients, water, and soil microbial flora, which will help improve plant health even in the presence of stressed environments (Rai et al., 2018). The emerging innovations in the technology have also facilitated the manipulation of nanoparticles by conjugating them with beneficial biochemicals, micronutrients, and bioactive compounds through 'adsorption or surface functionalization' of these substances on the outer surface of nanoparticles or through 'internalization or encapsulation' of these substances inside the core of nanoparticles (Sarkar et al., 2022). Different strategies can also be devised to improve the potential of nanoparticles by developing nano-formulations or nano-fertilizers with slow/controlled/sustained release of the beneficial elements for optimal plant uptake without any leaching or wastage (Beig et al., 2022).

Considering all the scenarios, the present work attempted to evaluate the potential of silica nanoparticles and their development into nano-formulations for the efficient management of plant growth and development along with yield improvement under salinity stress. Thus, two important legume crops – lentil (*Lens culinaris*) and soybean (*Glycine max*) were selected. Further, the most abundant element in soil – silica in the form of silica nanoparticles (SiNPs) – considered one of the most environmentally safe nanoparticles, was synthesized to evaluate their stress-alleviating properties. Moreover, the surface functionalization of SiNPs was performed with sugar molecules – glucose and trehalose to increase their stress-alleviating potential, decrease the synthesized SiNPs' toxicity level, and develop these functionalized nanoparticles into nano-formulations with better release of sugar molecules for managing the stress responses in plants efficiently.

The broad objectives of the present study in this connection are presented below –

- Optimization of the synthesis of silica nanoparticles (SiNPs) and their characterization.
- Evaluation of the different concentrations of SiNPs for the alleviation of NaCl-induced salinity stress in lentil (*Lens culinaris*).
- Evaluation of the different concentrations of SiNPs for the alleviation of NaCl-induced salinity stress in soybean (*Glycine max*).
- Functionalization of SiNPs with sugar molecules and their characterization.
- Comparative study of sugar-functionalized SiNPs and bare SiNPs in the alleviation of salinity stress in legumes.
- Evaluation of the toxicity of synthesized SiNPs and its prospect for the development of cost-effective nano-formulations.