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Impact of Nanosilica Particles on Vegetative Growth: A Review Study

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Abstract

Agricultural food manufacturing is at a high risk due to extreme climate changes, diseases and environmental pollution. Drought stress is a significant worldwide issue that has adverse effects on the growth of plants, photosynthesis and consumption of nutrients with large amounts of losses in yield. Farmer facing these severs issues who must maintain plant production stability. They are examining reliability solutions which can increase crop production, also causing no pollution to environment. Traditional fertilizers are used to increase strength of plant growth, but they are less efficient because of short term and do not dynamically adjust the needs of plants. So early studies suggested that silica nanoparticles might be the best option to reduce certain adverse effects and increase seed germination. There is a still unknown how these nanoparticles transport into plants Moreover, effects of silica nanoparticles are still not known exactly. The aims of this review to discuss the effect of nano silica to improve drought and nutrient stress resistance on plants through the positive effects on plant growth, hydration, antioxidant activity and silicon effect on nutrient efficiency.

Keywords: Nano silica particles, plant growth, crop improvement, agriculture

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1. Introduction

As reported by Food and Agriculture Organization (FAO), by 2050, there will be 9 billion humans live on the earth as well as food manufacturing will need to increase by 70% to meet this demand. Nowadays, biotic and abiotic stresses like drought, severe weather, salt, diseases and pests cause crop loss worldwide [1]. Abiotic stressors affect crop output, resulting in an annual loss in crop production which ranging from 51-82%. To increase agricultural production, farmers frequently use pesticides and fertilizers, which pose a major risk to the environment. Eco friendly technology should be developed to help plants that overcome biotic and a biotic stressors, maximize crop yield and ensure agricultural sustainability [2]. The Silicon (Si) is secondary most universal element in the earth's crust may contribute 0.1–10% of the dry weight of surface plants. The majority of plants are unable to obtain silicon dioxide (SiO_2), alumina-silicates and crystalline silicates which are the most common forms of silicon. Mono silicic acid which occurs naturally in the soil is the only form of silicon that plants can absorb, but the concentration is variable depending upon the pH, characteristics, organic compounds, raw material and quality of the soil [3]. When mono-silicic acid builds up in plant tissue above a certain threshold, SiO_2 precipitates.

Then it is deposited in cell walls, plant stone, biogenic silica and trichomes aside from parts of cell that are actively growing. Silicon is widely recognized as a valuable element that provides benefits for plant growth and mitigation of various biotic and abiotic stressors, despite not being acknowledged as a necessary nutrient. Nano-particles are used extensively in agriculture due to their special qualities, such as shape, surface reactivity, size and water soluble [4]. Consider nanoparticles as intelligent nano scale materials that will assist in the controlled release nano-fertilizers, enhance nutrient utilization efficiency, release nano-pesticides and nano-herbicides under specific circumstances, lessen environmental stress, protect nature and promote sustainable agricultural systems [5]. The use of nano resources for plant stress reduction, disease prevention and crop development has been comes up in previous studies [6]. Nano silica or silica nano particles is one of novelties in nanobiotechnology. The last five years have seen an increase in research on these particles and an analysis of their advantages over the use of bulk silica for plant growth. One important approach to raise the effectiveness of conventional Si fertilizer for crop development is nano biotechnology. Nanoparticles are much more reactive because of their small size (1-100nm) [7].

Nanoparticles have the potential to replace conventional bulk fertilizers in agriculture. Because of their small size and superior absorption capacity which enable them to easily penetrate plant cell walls. Silicon nanoparticles can significantly affect the production of stress enzymes, cell wall lignification and silicon accumulation [8]. Silica nano particle mainly absorbs by plants through apoplectic pathway. Silicone is insensitive to nano-silica. It is consumed at higher rate than other silicones, even though the mechanism is not exactly known [9]. It is well known that silica enhances plant strength, increases agricultural productivity and offers resistance to a variety of stresses. Numerous studies have also demonstrated that silica can decrease negative effects of salt and drought stress on plants by increasing net photosynthetic rate, transpiration efficiency, specific enzyme activity and leaf water loss. Applied SiNPs to plants in two ways, by adding them into soil and by leaf spraying application. Plants absorbed these nanoparticles through roots where they converted into shoot and forming polymers. It is less expensive, environment friendly and required in small amount [10]. Application of nanosilica is highlighted in this article which describes improvements in plants production. It is also describing how these nano silica particles assist crops to fight against diversity of stressors such as biotic.

2. Function of nano-silica in plant growth

Plant growth, yield and stress resilience mechanisms were all effectively enhanced in many crops by the usage of nano-fertilizers [11]. There are certain benefits using nano fertilizers such as increased reactivity, targeted delivery and required in small amount due to large surface area and tiny measurements [12]. Nano silica supplementation has been enhanced plant growth under environmental stress by increasing the amounts of carotenoid and chlorophyll, relative water content (RWC), soluble carbohydrates and antioxidant enzyme activities [13]. Reduce the negative effect of harmful metals when treated seed with silica nanoparticles also increases the plant strength and nutrient absorption [14]. Photosynthetic efficiency and protein level in wheat plants can be increased by the usage of mesoporous silica nano particles [15]. Nano-fertilizer are more significant than conventional complement because they enhance water uptake and crops strength (Figure 1) [16].

2.1. Approach of Nano silica Particles

Silica nano particles applied to plants by various methods and size of these nano particles ordinary lower than 20nm [17]. To increase silicon uptake in hydroponics modes, roots are immersed into nutrient solutions after nanoparticles are adulterated in nutrient solutions. In another technique, in which liquid mixture of nano-silica particles were sprayed on plants, this method is recognized as foliar application, where they are consumed through stomata and leaf epidermal cells. After consumption, structural rigidity of plants increase due to binary coating formed on epidermal cell layer [18]. Moreover, silica nanoparticles impact better when applied to soil rather than on plant leaf. In apoplectically manner, silica nano particles travel from root to above portion, move through apoplast then reach at vasculature. Symplastic pathways such as wall penetration, phagocytosis or carrier protein mediated diffusion through which silica nanoparticles move to pant [19]. After being taken into cytoplasm, nanoparticles move through plasmodesmata. These nanoparticles approach xylem will be transported to shoots and those that cannot enter into xylem will be settled down at casparian strip [20]. Interestingly, developing organs such as fruits, flowers, and seeds have ability of absorbing liquids in phloem with high efficiency and thereby lay down nanoparticles. These organs were found to be well absorbing silicon nanoparticles that improved germination rates, index of vigor and strength and biomass accumulation of seedlings. Uptake, translocation & accumulation of nano-silica particles influenced by plant species such as age, growth environment, nanoparticle size, shape, chemical constituent and stability in solution [21].

2.2. Growth Characteristics

Due to protoplasm dehydration, photosynthesis, development of cell, reduce relative turgidity, mitosis as well as strong relationship between nutrient absorption and water retention, plants grown under water stress have much worse growth characteristics than those grown under irrigation [22]. It was found that applying silicon in the form of nanoparticles enhance plant growth and development more effectively than applying commercial silicon fertilizers in large quantities [21]. With the incorporation of nanosilica, enhancement in growth features was reveal in many crops such as maize [23],rice [11],wheat [24] and cucumber [25]. By improving overall health and productivity, these nanoparticles can be applied topically as well as in soil to enhance plant resistance to dry spell (Tables 1, 2). Addition of nano silica may have caused crops to grow better under drought stress by increasing chlorophyll production, enzyme activity and stomatal regulation as well as changing crop's pose to help them get more light & changing structure of membranes [22].

2.3. Photosynthetic Efficiency

With the help of nano-silicon particles through soil, leaf spray and seed priming, Photosynthetic rates enhanced in many crops [26]. By the increase of Ribulose 1,5-bisphosphate carboxylase or oxygenase function and synthesis, silica nano nutrition to drought stressor plants shows that the increase in chlorophyll production, carotenoids in plants and improving photosynthetic activity efficiency [27]. It increases the enzymatic photosynthetic efficiency, related hereditary material as well as stimulating photosystem II efficiency and assist in maintaining size, quantity and stability of chloroplast. It is also improved stiffness by the accumulation of silicon in leaves which may produce rigid straight blades also enhance plant surface area, consumption of CO_2 as well as photosynthetic efficiency. It also modify gas exchanger which lower the leaf autolysis, improve pigmentation, chlorophyll content, rate of electron flow and enzyme in barbatus as well as lemon grass [21-28]. The possibility that applied nano particles might cause DNA damage in chloroplast and mitochondria. Furthermore they highlighting relationship among plant tissues and physiochemical properties (Figure 2) [29].

3. Impact of Silica Nanoparticles on Crops and Vegetables

There is a negative impact of silica nano particles on plant and food system. This negativity is based on certain factors such as size, stability and concentration. It was found that high doses of silica nanoparticles have negative impacts on wheat growth. Some studies also showed that high content of silica nanoparticles reacted with insect resistance cotton, significantly reduction in biomass of root and shoot [30]. It is also observed that silica nano particles have toxicity and carcinogenicity on *Allium cepa*. Irregularity in chromosomes with the reduction in root height, germination index with

Silica nanoparticles did not influence bacterial and fungal populations in the soil. The same silica nanoparticle ceased to be phytotoxic to *Arabidopsis* plants when the pH was changed. Similar findings were also reported that there is no significant impact on the microbial community of soil. So, it can be supposed that the impact of nano-silica on microbes is not investigated completely and numerous another research is necessary. Some studies also show that there is either no effect or adverse effect with regard to concentration, size, shape, plant species and growth conditions. Excessive and incorrect dosage of nanoparticles may cause many problems like membrane rapture and inadequate nutritional uptake. Some previous studies proved that high level of silica inhibit seeding growth and negative physiological effects [33-35].

3.1. Grain Output and Quality

Owing to reduction in crop yield when drought stresses have negative effect on growing and breading attributes. Many approaches are used for increasing crop yield but the technique which is more effective named nano-silica nutrition, is used to improve plant yield and characteristics under environmental stresses. Previous studies show that, crops yield magnitude was noted from 15-50%, protein content (8.49%), crop yield (28.6%) and straw yield (19.1%) increased when nano silica nourishment at 400ppm and also improved nutrient absorption, moisture content and solar radiation [36-38]. The previous studies shows that sharp increase in cultivating range (twice that of the control) was distinguished, which related to improve carbohydrates aggregate originating from silicon nanoparticles that generate higher photosynthetic efficiency [39]. The application of silicon has valuable effects, which increases the crop yield and maximum uptake of nitrogen. Under water stress, silica nourishment increases output and growth criteria when investigating the impact of foliar nano-silica application on rice. By the enhancement of certain properties such as antioxidative defense system, osmotic adjustment compounds and protecting cellular integrity during post-stress recovery, silicon nourishment reduces negative effect of lack of water (Figure 3). They are not plays an important role only in plant yield but also improve attributes of plants production such as rice, vegetables and fruits [26-40].

4. SiNPs used for Pathogens and Diseases

Silica acts as physical barrier to both fungal and bacterial pathogens, because it settles below the tissues or leaf covers and prevents entry of fungal and bacterial pathogens and `extensively used is silica nano particles via systematic monitoring. In green house production to control pests, SiNPs are successfully used with surface changes. In order to recurrence of plant diseases like *Pyricularia oryzae* and *grisea Sac*, *Helminthosporium sorokinianum, Rhizoctonia solani Kuhn* and confine the expression of pathogens, a second layer of cuticle is produce when SiNPs directly react with plant cell wall [41-42]. For improving a crop's resilience

mitotic index as the silica nanoparticles increased in size. Silica nano particles showed no adverse effect on rice growth [31]. Silica nanoparticles prove to be non-toxic on potato root upon variable concentration nano-silica [32]. According to previous studies in *Arabidopsis thaliana*, silica nanoparticles (50 nm and 200 nm) were toxic to the organism based on the pH of the solution in which they were exposed and not on the size of the particles.

to a variety of diseases, such as bacterial, fungal and nematode diseases, used silica nano particles. Si infusion may be solved issues of fungal contamination, particularly destruction of fungal spore. SiNPs are extensively used which have antifungal effects to minimize plant disease owing to fungi. SiNPs are used to reduce a number of serious diseases, including brown spot, sheath blight, rice grain discoloration and brown spot. Furthermore, they have also been illustrated to hinder early blight tomato and black root caused by *Alternaria solani.* They have also been used to inhibit occurrence of cucumber foliar spots and powdery mildew. The Previous studies, discovered that fungal infections such as rice burst and brown blight were also treated with the help of SiNPs [1-43].

5. Application

There are several applications of SiNPs in agriculture sector. In agriculture sector, these nanoparticles are gaining attention because of improving efficiency and sustainability due to their unique characteristics. They enable new applications for plants growth because they have exceptional physical, chemical and structural attributes. SiNPs are environmentally friendly due to biocompatibility, in contrast to traditional agrochemicals. These nanoparticles can be used as nano herbicides, nano fertilizers and nano-pesticides, distant from impact on plant development and growth. The Advantages of using SiNPs over the ordinary particle size of Si fertilizer. Due to small size and high surface area and solubility of SiNPs have unique physics and chemical properties. They can easily move through crops cell membrane and impact on plant growth activities. Depending on properties, there are various causes which lead to physical and physiological changes when plants interact with SiNPs. Impact of SiNPs varies from plant to plant and based on their concentration [44-45]. Studies showed that effect of Cadmium (cd) and Arsenic (As) on rice seedling development is restrictively reduced by application of SiNPs. They also reduced cd and As moved reactive oxygen species generation & translocation from root to shoots in rice seedling [46].

Besides the delivery of organic and inorganic fertilizers to their assigned to their place, SiNPs have been observed to control the release the fertilizers into soil and water. These nanoparticles are also investigated for pathogens application in two ways. SiNPs were sprayed directly on insects in field or insect larvae .Also commercial pesticides are injected in mesoporous silica nanoparticles (MSNs) to regulate the pesticide release and activity against pests [47]. SiNPs applying on protected maize which shows an increase in metabolic defense related substance including phenolic and chlorogenic acid. It is also decrease the damage which is caused by rice armyworm [48]. The studies also showed that, when SiNPs apply in field, there is a reduction in family of pests in faba beans and soya beans by attracting insect predators.

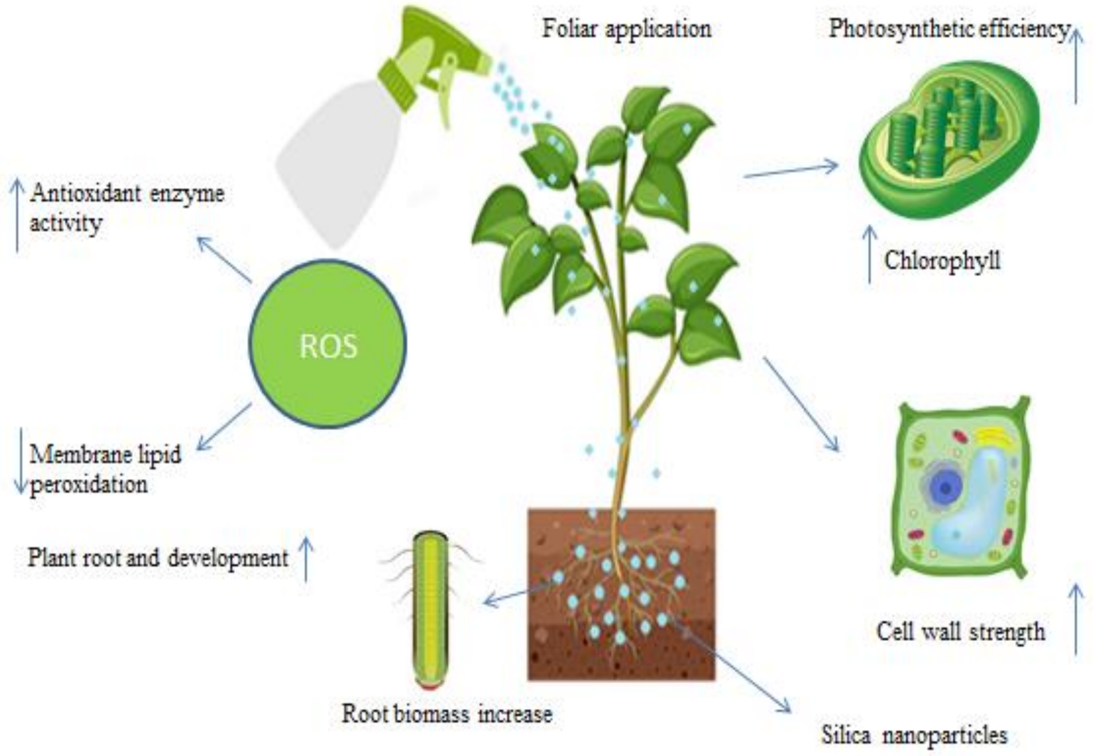

Figure 1. Transportation of nanoparticles in plants.

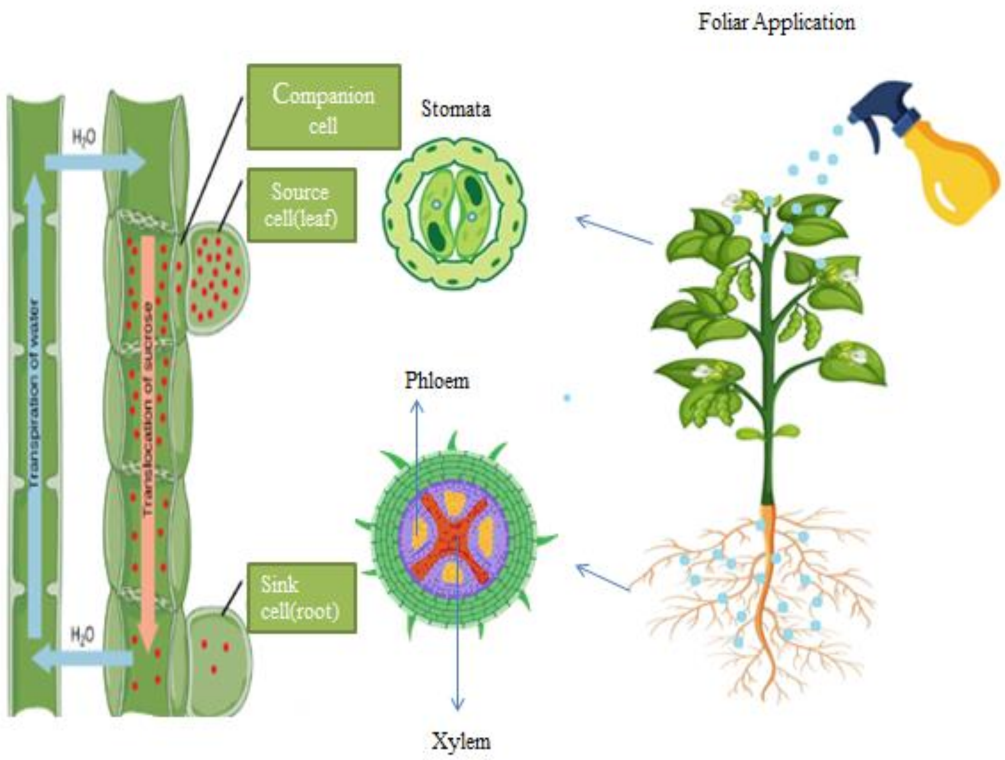

Figure 2. Nanoparticles in various parts of plants.

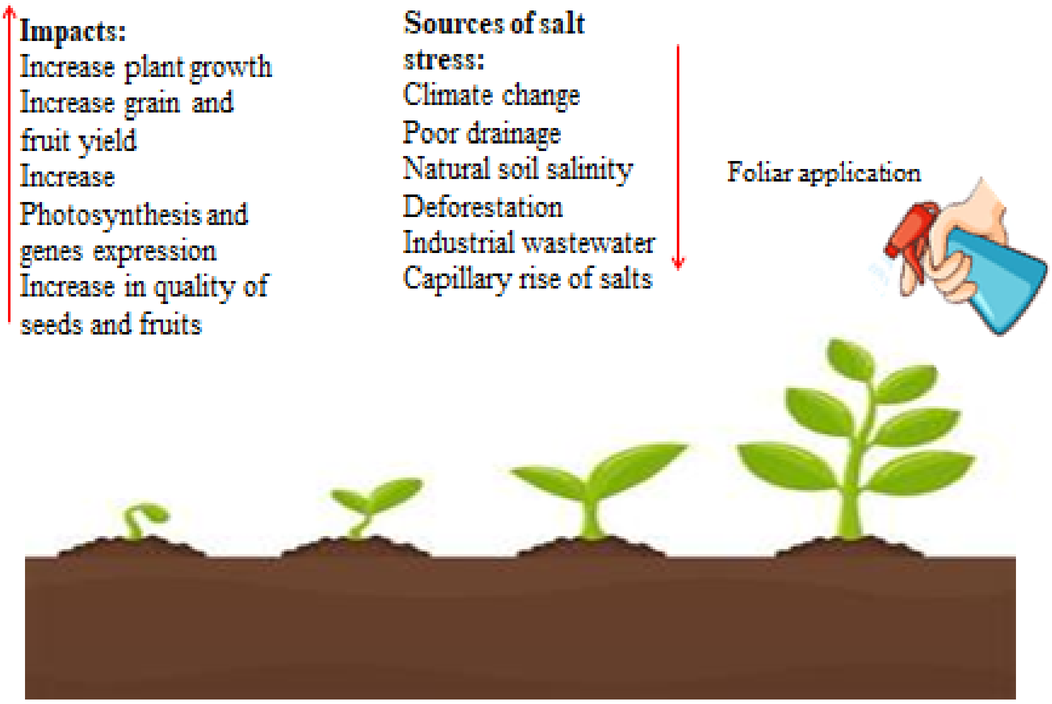

Figure 3. Impacts of SiNPs.

Table 1: Function of Nano-silica in alleviating moisture stress in plant growth

Plant	Method	Dose	Advantages	References
Rice	Foliar	100-800ppm	Enhance growth, photosynthesis, free radical scavengers Root and shoot growth increase. Decrease water loss	[51]
Maize	Foliar	200-300ppm	Increase level of silicon, nitrogen and potassium in root and shoot due to this PS-II and D_2 aquaporin protein was up-regulated. Osmotic Pressure down regulated (OSM-34).	[52]
Wheat	Foliar	40-200mg	Enhanced gas exchanger characteristics. Improved Photosynthetic activity, osmolyte production, germination%, Photosynthetic properties, water uptake and grain yield, nutrient absorption. Leaf area index antioxidant properties.	[53-54]

Table 2: Function of Nano-silica in horticulture crops

Vegetables	Mode	Dose	Advantages	References
Brinjal	Foliar	300ppm	Plant length increase, Hydrogen Peroxide and lipid peroxidation reduce by biomass and yield Increase Ca, Mg, K and Si uptake	[37]
Cucumber	Foliar	$300 mgI^{-1}$	Sodium and Potassium ratio increase Sodium accumulation reduce in root and shoot by chlorophyll content Fruit, Oxidative stress is down regulated	[25]
Sugar beet	Foliar	2Mm	Hydrogen peroxide decrease. Photosynthetic rate, antioxidant enzyme activities, flavonol, chlorophyll biosynthesis improved	[29]

These nanosilica particles are powerful antifungal agent [49]. Application of SiNPs, are applied in cucumber which improves plant growth, nutrient uptake and drought resistance under insufficient water supply. The previous studies show that nano silica of 100ppm increase nutrient such as iron and zinc status, reducing the prolin level with increasing chlorophyll content. With the improvement in water soil features, these nanosilica particles improve water usage efficiency. Cucumber yield and characteristics increased when immersed Si^{+4} levels in soil increase [50].

6. Conclusions and Future Prospective

High speed environmental changes and the essential to use fertilizers have e greater stress of drought and nutrient imbalance in soil causing decreased productivity and growth of plants. SiNPs is an emerging phenomenon that might resolve issues like food shortage without contaminating environment. To tackle these changes, the use of nano silica has turned into a prospective technology in alleviation, protecting these environmental pressures. Nano-Silica has various kinds of functions on plant physiology showed significant development in the chemical process, growth parameter, redox regulator, membrane constancy, crop productions quality and yield. This review also focused on how nano-silica plays vital role in plants and fights against several stresses. These nanoparticles have been successfully used to alleviate the adverse effect of nutrients deficiency and toxicity by regulating the nourishment availability in soil, their uptake and translocation in plants by incorporation vascular absorption through the regulation of genes and nutrient specific transporters. Nano silica plays a significant role in decreasing drought stress. Nano silica is a synthetic substance that comprises small particles that are highly reactive to different factors like oxygen, water and light. These nanoparticles are alternatives of various other fertilizers such as chemicals fertilizers and give green environment. It also solves problems regarding to agriculture such as strength, productivity and drought. Furthermore, studies are required on nano-silica to carry out large scale monitoring of agriculture over a diversified farming system designed to investigate environment safety and its impact all over the life cycle.

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