GREEN SYNTHESIS OF SILVER NANOPARTICLES AND ANTI-OXIDANT ACTIVITY IN PLANTS UNDER SEMIARID CONDITION – A REVIEW

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ABSTRACT
As much as utility needs are increasing, environmental-risk substances like insecticides are increasing as well. Biotechnology and nanotechnology industry possesses some hazardous effects but the improvements in biosynthetic nanoparticles have minimized these risks. The usage persona of nanoparticles is booming quickly even within the agricultural sector. Silver nanoparticles are postulated for improving the effectiveness of nutrient utilization in wheat plants. Wheat is globally consumed as staple food and grown for multipurpose e.g. grains, seeds and animal feed. This review article is explaining the significance of green synthesized Ag nanoparticles to boost up the nutrient use efficiency of wheat and also enhance the growth and development of plants. Biosynthetic silver nanoparticles have greatly improved numerous attributes of growth and yield, nutrient absorption and efficiency in the nutrients use of wheat crop. This review states the antioxidant activity of wheat crop and also checks the effect of green synthesized silver nanoparticles in drought tolerance in semiarid conditions. These nanoparticles were able to excite the growth of wheat and increase its yield significantly when applied in soil with 25 ppm particle size. A few experiments were performed on wheat to analyze the outcomes of green synthesized Ag nanoparticles and their anti-antioxidant activities and this review a significant work to describe the research gaps in this respect.

Keywords: Antioxidant activity, silver nanoparticle, heat stress, drought tolerance, wheat yield.


INTRODUCTION
Wheat (Triticum aestivum L.) shares its part to 33% among the cereal’s consumption around the globe. It is holding its grip in the world trade by 68% share of its production, highest in account to all other crops collectively (Šramková et al., 2009; Abid et al., 2014). The statics ranked it second in cereal production worldwide after maize in 2018, with yield of 763 M tons and production as 30.9 M tons ha⁻¹ (FAO, 2020). More than 10 billion people from 120 countries including South Asia, America and Europe, consume it as a staple food product because it contains essential nutrition elements of human diet i.e. carbohydrates (Mathur et al., 2019). Moreover 60% world’s protein and 20% calories necessities are achieved by wheat grains yet wheat straws being a byproduct comes under consumption of animal feed additionally. In GDP of Pakistan the wheat contribution is about 2.2% and wheat

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production is 25.6 M tons in 2018-19 (IndexMundi, 2019). Utilization of latest techniques in improving yield and nutritional value of wheat crops was triggered by its consumption as staple food (Thorny Chanu and Upadhaya, 2019). Its low production can be caused by plant stress to which use of nanoparticles can act as growth promoters (Karamian et al., 2020). A large area of wheat production of 15 M ha comes under sever influence of drought every year (Adrees et al., 2020). Devastatingly expansion of nanotechnology field of science has pretension of both positive and negative socio-economic and socio-ecological intimidation reflected by scientists, governments and social activists’ responses (da Costa et al., 2016; Stone et al., 2018). Several nanoparticles like Ag, Fe, Cu, Si, Al, Zn, ZnO, TiO₂, CeO₂, and Al₂O₃ and carbon nanotubes were identified as having harmful impact on plant growth although possessing antimicrobial characteristics (Shukla et al., 2019). Prodigal production, consumption and then improper exclusion of these nanoparticles lead to polluted ecosystem. However, passage of time has flourished the nanotechnology in such a vast level that nanoparticles (NP) has become an obligatory section of industrial, medical and consumer products (Sohail et al., 2019). NPs with certain modifications i.e., with one dimension between 1 and 100 nm has raised strength in beneficial way by excessively being used in semiconductors, microelectronics, catalysts, fillers, drug carriers, cosmetics and food industry (Behrens et al., 2017; Boros and Ostafe, 2020). With such small size these particles has discrete property of vast surface area to volume ratio that produce distinctive physical and chemical characteristics than bulk substance that has helped in promotion of optical, electrical and magnetic field of study (Ahmad et al., 2017). Magnetic gradient has an edge of directional stimulus to translocate diamagnetic elements in microgravity environment during seed sprouting (Iderawumi and Friday, 2020).

Industry of nanotechnology stands on nanoparticles, which are derived from reactive responses of toxic elements. Many physical and chemical techniques in literature been described for NPs synthesis but mostly have limited applications due to use of toxic compounds and economically as well (Gubala et al., 2018). These toxic reactions which produce sols and by-products requires to be neutralized before excretion in the environment otherwise cause particle aggregation (Barbasz et al., 2016). The rapid increase in human population and increased urbanization have made it difficult to supply everyone with the essentials of life (Iderawumi, 2019). However, a lot of eco-friendly efforts has led to a “green synthesis” phenomenon which exploits the bacterial, algal, fungi and vascular plants use effectively (Shunin et al., 2018). Biosynthetically produced NPs have adopted an alternative status in contrast to physical and chemical synthesis procedures in nanotechnology (Peter Amaladhas et al., 2012). This unprecedented technique can cope with the global issue of food safety and food security in an eco-friendly manner, which will meet the devastatingly growing hunger by abundant quality food production (Abd-Elrahman and Mostafa, 2015; Singh et al., 2015). The participation of NPs in agriculture and the food chain improved this field by detecting diseases, disease resistance, targeted delivery, and enhancing the efficiency of plants to absorb more nutrients; withstanding environmental pressures and efficient processing and storage systems. Moreover, anabolic and catabolic series of reactions in which NPs are combined with proteins, help in translocation, clearance and phagocytic activity which in response stimulate spectrum of cell responses e.g., cell activation, inflammation, reactive oxygen species generation and cell death (Chattopadhyay et al., 2015; Guo et al., 2016). It provides a new aspect for the selection and allocation of resources that maximizes product significance (Vimbela et al., 2017).

NPs instinctively exist in ambiance without any undesirable properties. Currently, NPs are assimilated through different methodologies that include physical, chemical, and biological techniques, to achieve the required properties and are called engineered NPs (ENPs). ENPs are utilized in various fields like medicine, environment, industries and agriculture. Micro-sized NPs were reported least toxic when compared to their smaller complements by some researchers.
(Asharani et al., 2011; Schluesener and Schluesener, 2013). But, in metal elements AgNPs are most persuasive to cell surface due to more surface area in contact to outer space and its existence in between 1 and 100 nm which promote its efficiency to next level of utility (Saldanha et al., 2017; Nasrollahzadeh et al., 2019). Nanosilver are occupying compulsory status in agriculture and food industry because of their utilization in variety of products (Vimbela et al., 2017). Most importantly, AgNPs are now excessively being used in food security, pathogen detection, postharvest preservation and food packaging (Obiazikwor and Shittu, 2018; Mufamadi and Mulaudzi, 2019). Additionally, nanosilver can induce responsive impact on metabolic, respiratory and reproductive processes in microorganisms (Lok et al., 2007). Physiological and chemical mechanisms of plants are highly influenced by AgNPs activities. Seed germination, seedling growth, shoot development, root extension, root-shoot ratio and senescence stoppage were promoted by nanosilver use (Shah and Belozerova, 2009; Sirelkhatim et al., 2015). Its effects were reportedly found significant in asparagus plants leaves treated for extended maintenance period (from 2 to 21 days). Moreover, fiber, ascorbate and chlorophyll contents were enhanced in treated leaves in this period (An et al., 2008). Nitrogen use efficiency is reported to be ineffective in response to nanosilver, yet other nanoparticles such as TiO2 improved the growth by enhancing nitrogen uptake in spinach plants (Jhanzab et al., 2015; Awais et al., 2020). Phytochemical reactions extremely influenced by silver NPs as Silver (Ag+) ions bond with halide ions as well as various compounds are attracted to silver ions e.g. proteins, amino acids, lipopolysaccharides, RNA and DNA and many biochemical analysis are frequently performed using this property (Tsai and Frasch, 1982; Blum et al., 1987; Shevchenko et al., 1996). Ag+ ions discharged from the AgNPs surface can stop enzyme activities of respiration in plants and create oxidative stress by generating ROS (Oukarroum et al., 2012; Radhakrishnan et al., 2018). Findings on the effects of AgNPs on higher biological cells had shown that decreased mitochondrial activities, cell membrane injury and amplified oxidative stress led to cell damage (Gorczyca et al., 2015; Bagherzadeh Homae and Ehsanpour, 2016). This manuscript is designed to comprehend the green synthesized AgNPs exposure on wheat and collective assessments by previous researches on its antioxidant activity on wheat and also the AgNPs effect in drought tolerance in semiarid conditions. Although very minute work is present on this objective yet a new researcher will able to get boosted to promote this work by taking this review article as first step.

**Silver nanoparticles effects on wheat seedlings**

In the open environment agriculture soils are treasure of AgNPs existence and these contaminants are directly prone to field crops. However, their existence shape, magnitude, chemical modifications, interconversions, uptake, transport mechanisms and phytotoxic impacts with pertinent evidences are in the stage of exposure. Ag with its different sources act diversely on wheat plants in its distribution, speciation, phytotoxicity markers and metal homeostasis controlling genes expression. Likewise, oxidative stress and defense against pathogenic attack response varies with Ag varied source (Hernández et al., 2017; Si et al., 2017; Nogueira-Lopez et al., 2018). Sulfurized (Ag2S-NPs) silver NPs form of Ag reduced the wheat plant uptake and translocating ability because Ag2S-NPs are unstable while exposure to the roots of plants. Rather, Ag2S caused more impacts on ecological services and some on crop quality and yield, due to rhizospheric activity of plants in agriculture soil (Fig. 1) (Pradas et al., 2017).
Fig. 1. Impacts on ecological services and some on crop quality and yield, due to rhizospheric activity of plants caused by Ag₂S-NPs (Pradas et al., 2017).

When the genomic and proteome changes of wheat seedlings were analyzed, the molecular response of pristine metallic Ag-NPs was significantly positive. Introduction of 10 mg L⁻¹ AgNPs has ability to severely affect the growth of seedlings and develop morphological changes in the tip cells of root but didn’t generate DNA polymorphism. They may alter the exhibition of various proteins, which are primarily required in primary root and shoot metabolism and cellular defense (Vannini et al., 2014).

Activities of different antioxidant components on wheat

Antioxidant compounds are present in different form that involves enzymatic and non-enzymatic mechanisms. Enzymatic antioxidant components include superoxide dismutase (SOD), peroxiredoxins (Prxs), catalase (CAT), guaiacol peroxidase (POX), glutathione peroxidase (GPX) and ascorbate-glutathione (AsAGSH) cycle enzymes i.e., dehydroascorbate reductase (DHAR), monodehydroascorbate reductase (MDHAR), glutathione reductase (GR) and ascorbate peroxidase (APS). While, non-enzymatic antioxidant components contain major cellular redox buffers ascorbate (AsA) and glutathione (GSH). Moreover, carotenoids, tocopherols and phenolic compounds are considered in non-enzymatic antioxidant components (Caverzan et al., 2016).

These antioxidants are originated from leaves in wheat plants in response to the metal NPs activity which affects physiological activities of plants significantly including germination, metabolism and growth. On this account, antioxidant enzymes, proline and GSH activity was enhanced in stress sensitive verity (Raweta) and stress tolerant verity (Parabola) of wheat treated with AgNPs at a concentration of 20 ppm. This raised the proline contents in wheat plants which increased the cell volume. Moreover, at this rate of application, intercellular application of GSH was recorded highest (Barbasz et al., 2016). Increased exposure causes severe phytotoxicity, dwarfism, low seed weight and plant biomass due to high accumulation of AgNPs in roots rather shoots and seed. Simultaneously, crop quality is reduced due to decreased arginine and histidine contents by 13.0 and 11.8%, respectively caused by AgNPs-induced phytotoxicity (Fig. 2) (Yang et al., 2018).
Biogenic AgNPs (B-AgNPs) derived from fruit extract of *Phyllanthus emblica* L. has characterized as growth promoter in wheat when applied at seedling stage. These phytochemicals capped AgNPs promote early seedling by decreased ROS toxicity and providing protection against oxidative stress. By controlling natural antioxidant through B-AgNPs ROS toxicity can be attenuated which responds in form of root elongation, higher root cell sustainability and increased biomass. On top of that, no toxicity was reported as compared to chemically synthesized AgNPs which is specifically associated to them (Kannaujia et al., 2019). Biosynthesis technique of AgNPs is emerging which increased total phenolic and total flavonoids compounds in AgNPs-containing plant extract of *Chenopodium murale*. So it can also commercially been applied for production of potential antioxidant and antimicrobial AgNPs (Abdel-Aziz et al., 2014). With regards to osmotic stress, nanosilver are able to cause oxidative stress in plant cells. ROS activity is countered by activating both enzymatic and non-enzymatic antioxidant pathways in nanosilver sensitive wheat verities leaving no effects on non-sensitive verities (Barbasz et al., 2016).

**Influence of AgNPs on plant growth**

Nanosilver influences in diversified manors with different concentrations and different crop species. Its impact on wheat (*Triticum aestivum*), Brassica (*Brassica juncea*) and cowpea (*Vigna sinensis*) varies with variably increasing application through foliar spray. Root nodulation and optimum growth enhancement occurred at 50 ppm application of nanosilver in cowpea while shoot elongation at 75 ppm in Brassica reported leaving no effects on wheat in either case of applied AgNPs (Fig. 3). Rhizospheric activity of bacterial diaspora in soil is also influenced by crop species grown and varies with different concentrations of nanosilver (Pallavi et al., 2016). The foliar spray of nano-fertilizer resulted in significant morphological effect on various crops such as cucumber, lettuce, ryegrass, tomato, grape, wheat, corn, alfalfa, soybean, radish, spinach, onion and pumpkin (Sekhon, 2014).
Fig. 3. Nanosilver influence with different concentrations on different crop species. P = soil without plants, C = cowpea, W = wheat, B = Brassica. 0, 50 and 75 determines applied AgNPs in ppm (Pallavi et al., 2016).

In hydroponically grown plants, AgNPs serve as phytotoxic element by reducing the shoots and roots extent in wheat using dose-dependent method. Higher levels of Ag ions reduce plant growth by accumulating in shoots and causing an oxidative stress in roots. Sequential events occur by aggregation of oxidized glutathione and gene expression which encodes metallothionein and is a part of detoxification of metal ion sequestration (Dimkpa et al., 2013).

**Silver particles improve progress of wheat plants in semiarid conditions**

Semiarid regions pertain harsh seasons of winter and summer. Calculated, careful and scientific use of nanosilver proved to be boosted growth and yield development of wheat. Significant growth parameters, germination ratio, leaf area, chlorophyll contents, number of grains per spike, 100-grain weight, and fresh to dry weight ratio and root biomass increased grain yield of wheat under semiarid conditions. Although the seed germination of wheat plants was not affected, the application of nanoparticles of different sizes showed accumulation in the roots (Larue et al., 2012). Chemically reduced silver nitrate with tri-sodium citrate produces 10-20 nm sized AgNPs which proved to be toxic in its higher amount of application than 25 ppm. Soil application of NPs proved to increase seminal roots of wheat plant (Fig. 4) (Razzaq et al., 2016).

Fig. 4. Soil application of AgNPs proved to be toxic when applied higher than 25 ppm (Razzaq et al., 2016)

Several studies expressed biosynthetic AgNPs as best suited growth promoters in wheat. However, under heat stress they also proved to be growth regulators. At trifoliate stage of wheat, AgNPs synthesized by *Moringa oleifera* plant extract were applied at concentrations of (25, 50, 75 and 100 mg/L). Heat stress parameters were also set from 35 – 40°C temperature for 3 h/day. Under zero application of NPs and heat stress, leaf number (2%), leaf area (12%) and leaf fresh and dry weight decreased 0.02% and 0.01% respectively. Simultaneous reduction in shoot length...
(6.2%), root length (2.5%), root number (1.8%) and fresh and dry biomass by 1.2% and 0.16%, respectively were reported. However, AgNPs not only increased morphological growth of wheat plants but also protected plants against heat stress with application rate of 50 and 75 mg L\(^{-1}\).

Leaf number, leaf area and leaf fresh and dry weight was improved by 4.8%, 33.8%, 0.15% and 0.18%, respectively. While shoot length (26.1%), root length (5.4%), root number (26.1%) and fresh and dry biomass by 2% and 0.60% were higher respectively (Fig. 5) (Iqbal et al., 2019).

**Fig. 5.** Biosynthetic AgNPs resulted as growth promoters in wheat under heat stress.  
A) Plant fresh weight and dry weight. B) Shoot length, root length and root number. C) Leaf area and leaf number. D) Leaf fresh weight and dry weight (Iqbal et al., 2019)

**Future research prospective**

In the past decade, scientists have made substantial development to understand the sources, destination, and impacts of NP in the environment. In addition to study the environment related concentration of NP and monitoring the fate of NP during biological analysis, there are a number of outstanding issues that are further required a spot light. There is an urgent need for a more systematic method to reveal the effect of soil characteristics (comprised of saturated and unsaturated systems) on the fate of NP, and thus reveal the risk of NP contaminating the groundwater.

The effects of NPs on communities, ecosystems, ecosystem functions, and interactions across ecosystem boundaries under current and future exposure situations requires critical attention. Especially for slightly soluble or insoluble nanoparticles that may sediment in certain environmental compartments by the passage of time, it is recommended to conduct surveys to assess their impact on aquatic and terrestrial ecosystems considering multiple years of (repeated) exposure.

Green synthesized NPs express efficient properties like rigidity, permeability, thermal stability, solubility and
biodegradability. Biosynthesized NPs have large surface area that can maximize the affinity to the target. They are also used to enhance plants nutrient uptake, deliver active ingredients to specific sites and processes of water treatment. This green synthesis of NPs has much higher potential in agriculture sector that needs strict scrutiny to employ and understand all of its benefits.

CONCLUSION

This manuscript exhibited the different responses of wheat plants to starting nanoparticles, and emphasizes the significance of transformed NPs into plant research. In summary, green synthesized AgNPs have a significant potential to enhance the growth and yield of crops in a dose-dependent method. Nevertheless, a comprehensive experimental study is needed to determine the most appropriate concentration, size and application method of green synthesized silver nanoparticles in order to achieve higher growth and maximum wheat yield under semi-arid conditions.

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REFERENCES CITED


IndexMundi, 2019. Pakistan wheat production by year. United States Department of Agriculture.


Singh, S., B.K. Singh, S. Yadav and A. Gupta. 2015. Applications of


