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REVIEW ARTICLE

A Brief Review of the Impact of Silver Nanoparticles on Agriculture and Certain Biological Properties: A Case Study

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Abstract

Nanotechnology is progressively becoming a popular field of research because it has been successful in changing our agricultural and food systems. According to research published by the UNFAO, agriculture as well as its derivatives would be in high demand sooner or later, owing to nutritional changes. Nanoparticles have been reported to be used in an agricultural sector, because of its capacity to encourage crop growth and yield. Among metal nanoparticles, Silver Nanoparticles (AgNPs) are attracting a lot of attention. We have highlighted some of the agricultural uses of AgNPs, which include pest management, plant disease detection, crop enhancement, and crop production.

Key Messages

With the increasing population, one of the most important aspects of government policy is making the food safety to all. Hence, the efficiency and yield of the agricultural activities need to be improved to fulfil the requirement. Nanotechnology plays very important role in agriculture and can be a game changer in the life of farmers as well as the general population.

Keywords: Silver nanoparticles, Pest control, Plant disease detection, Crop improvement, Crop productivity

1. Introduction

The world population is now approximately 7.3 billion with Asia being major contributor. About half of the countries suffer daily food shortages. S & T has played a vital role in raising agricultural production over the years and the agriculture industry contributes significantly to the national economy. The agriculture sector has been successful in respond to the increase in demand for agricultural products. In recent decades, the agricultural landscape has faced a number of difficulties including diminishing farm profitability, natural resource depletion, the emergence of new pests and diseases, as well as climate change and global warming [1]. To overcome these difficulties an importance on research like technology generation, diffusion and as well as human resource development is required. The possible for technology to transform health protection, care, textiles, information and communication technologies, and energy has been widely emphasised [2].

Nanomaterials have already been proved to boost agricultural output in a variety of ways by

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researchers [3,4]. Plant development and protection are improved by using Fe, Ag, Carbon nanotubes, Mn, Zn, Cu, Mo, TiO_2 and other metals as nano fertilisers and nano pesticides [5]. As a result, it is possible to conclude that appropriate innovations in nanomaterials applications in the agricultural sector will be challenging phenomena in the future. The potential to revolutionise agricultural activities and food production as well as assisting in the proper sustainability of agricultural products is important.

The current review summarised the use of AgNPs in pest control, crop improvement, and disease detection, to boost crop yield, sustainability, and yield. Antifungal and antibacterial AgNPs are used in agricultural crop protection and these particles help regulate plant nutrition [3]. In aqueous solution AgNPs are extremely stable and dispersive, it's applied to the leaves as a foliar spray, keep plants healthy, yeasts, moulds, rot, and a slew of additional illnesses that affect plants. Furthermore, AgNPs are an effective plant growth stimulator; it offers a revolutionary disease-management strategy, and nutrient loss minimization in fertilisation through improved nutrient management. Plant disease management is one of AgNPs most important applications. When compared to synthetic fungicides, silver has numerous mechanisms of inhibitory action against microbes; it may be used to manage a variety of plant illnesses with reasonable safety [6]. There are several applications of AgNPs for plants protection and production [7], which are listed below:

- ✓ Soil health improvement
- ✓ Seed germination
- ✓ Micronutrient delivery for plant growth promotion
- ✓ Fertilizer delivery for balanced and sustained mutation
- ✓ Pesticide delivers for crop protection
- ✓ Herbicides delivery for weed eradication
- ✓ Delivery of genetic material for plant transformation
- ✓ Nanosenors

In modern agriculture, artificial chemical antimicrobials are routinely utilised to control plant infections. Agriculturists are agricultural scientists are aimed at more environmentally benign then less capital-intensive methods. AgNPs are increasingly being as an alternative to antibiotics, they're employed as antimicrobial agents, chemically created insect repellent. As a result, the focus of this paper is on investigating the potential applications of AgNPs in agriculture filed.

2. Eco-friendly synthesis of AgNPs

AgNPs may be synthesised using a wide range of chemical and physical processes. There remain a number of significant issues that make them "unfavourable" synthesis processes. In which biological techniques are exploited to manufacture AgNPs has arisen as a result of the search for such a technology. The production of nanoparticles is completed by a broad range of microorganisms and plant species using reduction/oxidation processes [8–11]. Photochemical interact with the substances to produce nanoparticles that we want nontoxic stabilizing agent, solvent medium, and eco-friendly. Figure 1 Depicts a Diagrammatical representation of AgNPs synthesis using plants extraction.

3. Plant development and AgNPs

Feregrino-Perez AA et al. (2018) reported on their study the AgNPs have an important effect on grain sprouting then seedling development are pretentious through size, characteristics, then concentration [12]. Parveen A et al. (2015) reported on their study the *Pennisetum glaucum* seedlings develop at a slower rate as a result, the germination rate of these seeds was increased by 2-h pre-sowing conduct with AgNPs at 20, 50 mg concentrations [13].

The growth response of AgNPs in *Brassica juncea* was studied using various concentrations such as 25, 50, 100, 200 and 400 ppm being shown to be the most effective with a favourable effect on fresh and dry weight, root and shoot length [14]. In cowpea, a 50-ppm concentration caused in indirect growth stimulation then improved root nodulation [15].

Tomaszewska-Sowa M et al., (2018) reported the 30 g/ml AgNPs increased root development in *Oryza sativa* but 60 g/ml inhibited root growth. Rice, maize, and bean growth were stimulated water hyacinth protein content increased when at 30 mg/L, AgNPs were replaced by 100 mg/L Ag-NPs [16]. Salama HM, (2012) observed that at higher doses, increased development growth was inhibited [17]. Jasim B, (2017) reported that the exogenous dealing of Fenugreek length of shoot and root, biomass, and number of leaves were all enhanced by AgNPs at 0.2 mg [18]. Almutairi ZM et al., (2015) reported that the seedling exogenously administered Ag-NPs were connected to in a concentration-dependent way, amplified biomass and root length, of maize, zucchini, in addition watermelon [19].

On Lupinus seedlings, AgNPs at 100 mg/L boosted as biomass as well as length of shoot and root [20]. AgNPs increase root branching in *Triticum*

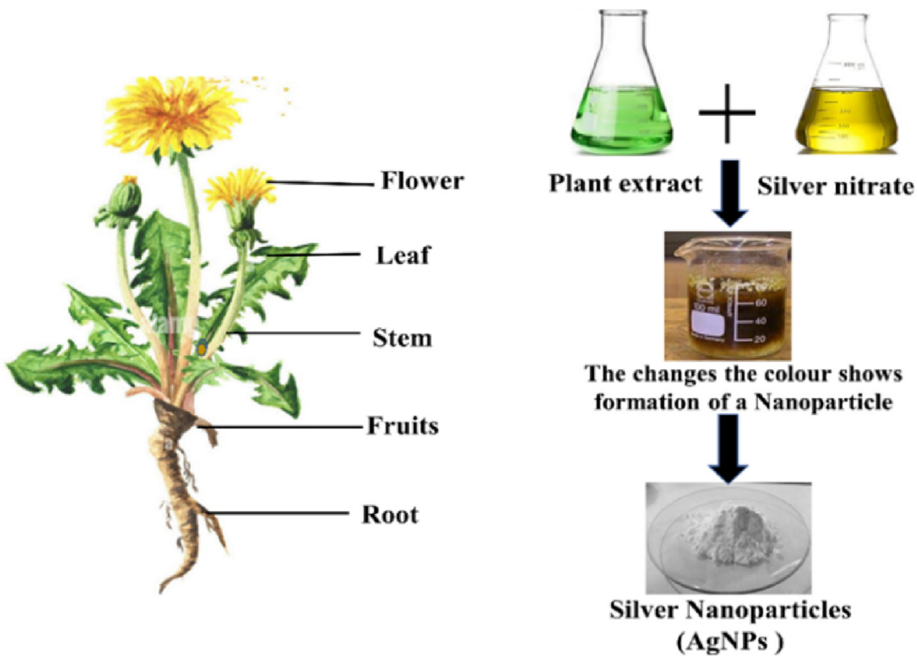

Fig. 1. Graphic representation of AgNPs synthesis using plant extraction.

aestival at doses of 300 and 500 mg/L, and all values were lowered [21]. Sharma, P et al., (2012) reported that the maize plants with AgNPs have improved morphological and biochemical characteristics (Antioxidant enzymes, chlorophyll, carbohydrate and protein content) [22]. Stampoulis D et al., (2019) reported that the hydroponic solution, the effects of AgNPs on root development and seed germination in zucchini plants [23]. They claimed that while no harmful impacts were discovered in a short-term trial. A long-term analysis revealed a drop seed germination and root development in zucchini plants as a result of AgNPs. Because of the limited area in closed containers, incorrect gas, particularly ethylene cannister consume significant impact happening in plant growth.

4. Crop productivity improvement

Plants morphology changed dramatically after exposed to AgNPs, the most typical measures used to assess the phytotoxicity of AgNPs in plants are growth potential like seed germination, Leaf surface area and biomass. Jiang H S et al., (2012) discovered plant biomass was lowered; shoot development was hampered, and caused root abscission in *Spirodela* [24]. AgNPs reduced in rice, shoot and root length, as well as biomass, have been studied [25]. Stampoulis D et al., (2009) reported the AgNPs (>100 mg/L) hindered seed germination and lowered biomass in zucchini plants [26]. Other research reported comparable results on AgNPs toxicity on biomass accumulation, seed germination, root and shoot promotion in *Arabidopsis Brassica nigra* [27]. The summary of collated descriptions of AgNPs' effects on plants (Table 1).

5. Diagnostics for farming

Commercial fertilisers such as urea and nitrate are widely used nowadays, although they are hazardous to plants and microorganisms. AgNPs contain a variety of unique features and as a nutrient for plants, they may be utilised to improve the efficiency of nutrient absorption. This is due to higher surface area than traditional particles and allow for slower agrochemical release. In comparison to bulk silver, nano-silver enhances nutrient uptake from the soil, it can be used to safeguard crops, and they could potentially be used as nano fertilizers. Thus, the use of AgNPs to promote seed germination in a range of plants has been proposed. Gosavi VC et al., (2020) stated that the nano manures help to reduce nutrient losses by allowing nutrients to be released gradually and efficiently, and also can help plants absorb more nutrients from the soil [46]. Wagi S et al., (2019) reported that the *Alliumcepa* was used to create a green nano fertiliser [47]. reported that the Triticum aestival L. was treated with nanoparticles, their psychostimulatory effect remained assessed, NPs enhance the development of *T. aestival* L., resulting in considerable increases in the length of

Table 1. Summary of collated descriptions of AgNPs effects on plants.

Species	Size (nm)	Concentration (mg/L)	Impact	Reference
Lemna minor L.	20 to 100	500	Plant growth is stifled.	[28]
Oryza sativa	25	50, 500, and 1000	The cell wall of root cells has been broken, and the vacuoles have been injured.	[29]
Vicia faba	60	12.5 25, 50, and 100	The number of chromosomes in a person's body. Abnormalities and micronuclei increased, whereas the index of mitosis decreased.	[30]
Brassica juncea	190–1100	0, 25, 50, 100, 200 or 400	Improved photosynthetic quantum efficiency and chlorophyll content; increased antioxidant enzyme activity, leading in lower amounts of oxygen-reactive species	[22]
Phaseolus radiates; Sorghum bicolor	5–25	25 0, 5, 10, 20, 40	Inhibition of plant growth.	[31]
Triticum aestival	10	0.5, 1.5, 2.5, 3.5, 5	Expression of a detoxification-related metallothionein gene was induced.	[21]
Cowpea	60–100	0–20	After being exposed to Ag_2S^{-}NPs, In the root and shoot tissues, Ag accumulated as Ag_2S, decreasing growth by up to 52 percent.	[32]
Arabidopsis thaliana	41	100–5000	Ca_2^+ in the cytoplasm was increased, which blocked plasma membrane K^+ efflux and Ca_2^+ inflow currents.	[33]
Wolffia globose	10	1, 2, 5, 8, 10	Malondialdehyde (MDA) levels are higher, while SOD activity is higher.	[34]
Vicia faba L.	5–50	0.8	Reduced shoot and root length; slowed the nodulation process; caused root nodule withering early.	[35]
Triticum aestival;	35–40	50, 75	Brassica shoot characteristics improved at 75 ppm.	[36]
Raphanus sativus	2	0, 125, 250, and 500	The 500 mg/L treatment resulted in shorter shoot and root lengths, as well as significantly lower Ca, Mg, B, Cu, Mn, and Zn concentrations	[37]
Mustard (Brassica sp.	47	1, 3 mM	*Brassica* seedlings' development has slowed due to oxidative stress.	[38]
Cucumber	35, 73	10	Genes involved in ethylene signalling are unregulated system; reduced growth.	[39]
Trigonella frenum-graecum L.	200–800	1	Enhancement the diosgenin synthesis and plant growth	[18]
Soybean; Rice	17.2 ± 0.3	0, 0.1, 0.5, 1 and 30 (Soybean); 0, 0.1, 0.5, 1 (Rice)	Malondialdehyde and H_2O_2 levels in leaves have increased.	[40]
Capsicum annuum	12.9 ± 9.1	0.01, 0.05, 0.1, 0.5, 1	Plant height and biomass dropped, whereas overall biomass increased. Cytokinin levels in the verdures increased significantly.	[41]
Pisum sativum	20	1000, 3000 μM	Glutathione reductase (GR) and Dehydroascorbate Reductase (DHAR) activity are both inhibited.	[42]
Wheat	25–70; 7.5–25.0	10, 20, 40, 50	Caused chromosomal abnormalities come in a variety of forms.	[43]
Bryophyte	37.4 ± 13.4 (AgNPs-B a)	500 to 1000	The protonema's development was inhibited, and the thylakoid was altered.	[44]
Lemna minor	79.0 ± 8.0	0.05–2	Decreased the pace of growth and the number of fronds per colony.	[45]

the shoots, the length of the roots, the number of leaves, and the fresh meat's weight [48]. Khan I et al., (2019) described the effect of AgNPs on pearl millet cultivated on MS basal medium (*P. glaucum* L.) supplemented with different quantities, the following parameters were employed in the study: T1, T2, T3, T4, and T5 (Control, 20, 40 60 and 80 ppm respectively) experiment investigated in vitro trail [49]. The effects of AgNPs were evaluated by looking at pearl millet seed germination, seedling development, and biochemical profile, which were all substantially altered (p 0.05) and shown in compared to the other treatment under T3 of AgNPs, to be superiors T3 had the best seedling vigour index, shoot and root length and biomass accretion are all factors to consider. The largest grain output was achieved using AgNPs, which resulted in a considerable increase in leaf area, with four replications and seven graded doses were utilised in a completely randomised approach (0, 25, 50, 75, 100, 125, 150 ppm). On the other hand, grain yield was reduced at levels of 25 ppm and 75 ppm. Wheat responds to AgNPs in two ways: it is stimulated and it is inhibited [50].

Pests are becoming a greater danger to the agricultural industry, because decreases the crop yields and worse product quality. Nanotechnology can be used to help in pest control, AgNPs is a harmless, safe, and better weapon for fighting pests, and pesticide delivers a high dose of insecticides to the target plant. Sayed AM et al., (2015) reported that the entomopathogenic bacteria *Bacillus thuringiensis* Kurosaki was used to make biocompatible silver nanoparticles (Btk-AgNPs), in this study Btk AgNPs synthesised by Btk were tested against cabbage looper, Larvae of *Teichopsia ni (*Hübner) *Agrotis ipsilon* and black cutworm, larvae (Hufnagel) [51]. Btk-synthesised AgNPs (s) formed with Btk-fabricated AgNPs made with Bt pellet were much more pathogenic against T. ni larvae than an epsilon larva.

Allahvaisi S et al., (2016) reported that the insecticidal activities of neem (*Azadirachta indica*) are extracted in this study, Air-dried leaves are fermented with rice wash, as a bio pesticide, male *Bactrocera dorsalis* were treated with crude Fermented Neem Extract (FNE), %FNE Copper nanoparticles (CuNPs) had the same impact as the positive control, resulting in an 83.33% mortality rate in adult male fruit fly after 24 h, the therapy with 20% FNE-AgNPs had a 100 percent death rate [52]. According to the results of the larvicidal activities, the extract containing AgNPs the most effective therapy, with a 100% death rate after a 24-h exposure. Its reported that the customers' complaints of food contamination due to stored pests including insects, mildew, and harmful fungus tainted packaging's after only a brief period of storage [53]. Cereals are one of the most essential goods that are kept in storage. Efficiency on proliferation of fungal and pests when AgNPs are added to packing polymer was tested in batch studies in this study. Because of its economic importance in the packed cereals storage industry, the pest *Sitotroga cerealella* is being investigated extensively. To apply AgNPs, we employed the finest packing Polymer (PP) available. The findings revealed that AgNPs had a toxicant impact on insects in addition to being able to optimally omit toxic microorganisms.

Fouad H et al., (2021) reported their study the AgNPs effectively using to produce two distinct ligands in were investigated. Tetrakis-pyrene (p-benzoic acid) (TBAPy) and 2,1:4:1terphenyl-3,3,5,5 tetracarboxylic acid (H4L) were utilised as reducing agents [53]. According to insecticidal studies, with an average lethal dosage (LC50) of 810 mg/L. At a high dose of 2000 mg/L, H4L toxicity increased, and their LC50 reached 786 mg/L at 168 h later. At a low concentration of 20 mg/L, H4L−AgNPs were similarly extremely dangerous, with an LC50 of 3.9 mg/L at 168 h after treatment. TBAPy−AgNPs, on the other hand, remained fewer harmful at the same concentration, with an LC50 of 4.6 mg/L. These findings show that manufactured AgNPs containing the deuce ligands could remain a safer than less expensive alternative to conventional pesticides for protecting rice plants against pest.

Rouhani M et al., (2013) reported that the Silica Nanoparticles (SiO_2) and AgNPs tested on *Callosobruchus maculatus* (C maculatus) larvae and adults on cowpea seed with various concentrations. These Nps were synthesised by solvothermal method with different concentration (1, 1.5, 2, and 2.5 g kg^{-1}) to treat *C. maculatus* [54]. In the trials, the LC_{50} values for SiO_2 and AgNPs were adults received 0.68 and 2.06 g kg^{-1} cowpeas, while larvae received 1.03 and 1.00 g kg^{-1}. Result shows Both nanoparticles where are extremely effective on adults and larvae. with mortality rates of 100% and 83%. The findings also demonstrated that SiO_2 nanoparticles can be a useful tool in *C. maculatus* pest management programmes.

Vadlapudi V et al., (2017) reported that the *Sitophilus oryzae* L and *Lesser Grain Borer*, the manufactured AgNPs had modest effect bactericidal efficacy against *Xanthomonas campestris* and *Ralston solanacearum* on stored pests with varied degrees of inhibition at all doses, as demonstrated by their zone of inhibition [55]. As a result, these AgNPs might be utilised to combat agricultural pests and diseases in the future. Ghazy et al., (2021) find out their study the latent aids of utilising AgNPs and binary biological treatments to prevent soft rot illness in sugar beets (*Beta vulgaris* L) [56], for antibacterial activity, the zones of inhibition were 100 ppm AgNPs required 4.33 cm, 0.43 cm for 100% algal extract, and 0.2 cm for bacterial treatments respectively. Furthermore, the illness incidence percentage of bacterial soft rot was considerably reduced in all conducts in equally pot and field studies.

6. Antimicrobial potential

The treatment of fungal infections in crops for human consumption is extremely important economically. Special efforts have been made to establish harmless supervision approaches that are fewer damaging to living organisms, with an emphasis on overwhelming artificial fungicide shortages. AgNPs high bio-efficacy prompted ago-scientists to investigate the particles' potential as a treatment for a variety of plant pathogenic illnesses. Jo YK et al., (2009) investigated antifungal medication effects of different on two plant-pathogenic pathogens, fungus like *Bipolarissorokiniana* and *Magnaporthe grisea* [56]. Silver ions and NPs had a considerable influence regarding the colony development both of these pathogens according to in vitro Petri dish studies. *B. sorokiniana* had greater effective doses of silver compounds suppressing colony formation by 50% (EC50) than *M. grisea*. They have been shown to impact spore colony formation and disease progression. Both studies on in vitro and in vivo plant pathogenic fungal, nanoparticles with silver ions have high in-plant effectiveness with preventative activity. This is due to silver's direct contact with germ tubes and spores as a result, their viability is hampered.

Kim SW et al., (2012) reported on the Nano-size silver colloidal solution was tested as an antifungal agent for a variety of plant diseases at doses of 10, 25, 50, and 100 ppm on WA-CV-WA13B, WA-AT-WB13R, and WA-PR-WB13R, WA-PR-WB13R. On agar plates made of Potato Dextrose Agar (PDA), malt extract agar, and corn meal agar, 18 distinct plant pathogenic fungi were treated with these nanoparticles. AgNPs have antifungal activities against these plant diseases at varied levels, treatment with WA-CV-WB13R AgNPs at 100 ppm resulted in highest inhibition of most fungi, with PDA having the most noticeable influence [57]. Ocsoy I et al., (2013) found that in vitro studies in plants, DNA-directed AgNPs produced on Graphene Oxide (GO) inhibited *Xanthomonas perforans* cell viability. The Ag@dsDNA@GO composites exhibit remarkable antibacterial activity in culture [58]. Narayanan KB et al., (2014) described the manufacture of metal nanoparticles from turnip leaf extract and their interactions *Gloeophyllum abietinum*, *Gloeophyllumtrabeum*, *Chaetomium globosum,* and *Phanero chaetesordida* are examples of wood-degrading fungi [59]. The nanoparticles inhibited the growth of wood-degrading fungus throughout a greener-synthesised nanoparticle were proven to be powerful antifungal agents against wood-degrading fungal infections.

Yokes Babu M et al., (2014) investigated that laboratory uses of the marine bacteria *shewanella algae bangaramma* biosynthesised AgNPs vitro. Both larvicidal besides bactericidal properties were discovered in the particles [60]. Varghese MV et al., (2009) studied of silver compared to six separate Anastomosis groups (AGs) of Rhizoctonia solani infecting cotton plants treat antifungal properties [61].

The utilisation of new nano bioconjugation of silver and cysteine as possible anti-mycobacterial drugs was another advancement in the research. silver nitrate was measured at 0.0019 mol/L is used to make cysteine capped AgNPs, Cysteine capping agent were prepared from silver nitrate by reduction of a sodium borohydride. Because of the increased activity of the anti-mycobacterial activity of cysteine was determined by its ability to bind AgNPs (17 ppm Ag in Cys) was boosted from 10 ppm to 100 ppm around 6 ppm permitting the employment of numerous compounds as additional bio-active substances covering agents [62].

The majority of the nanoparticles formed were examined in-vitro based on silver metal conjugation [63]. It also reported that dehydration of 5-amino-resorcylic acid hydrochloride (AR) was used to make bioactive silver capped nano-conjugates. In comparison to unbound drug molecules, these nano-conjugates demonstrated dramatically increased biological activity Inhibition of antimicrobials (antibacterial, antifungal), antioxidants, and enzymes (cholinesterase, xanthine oxidase, urease, carbonic anhydrase, chymotrypsin) characteristics. Ali SM et al., (2015) reported that AgNPs were usage to control the land snail. The synergistic impact of produced AgNPs as antifungals snails and their environment were subjected to in a lab experiment, AgNPs were used. Which lowered their activity and long-term stability (20% of AgNPs treated snails died). In snails, AgNPs have been shown to be effective against a number of plant disease caused by the fungi. The current learning's findings could possibly be developed upon as a new route for exploiting the snail as a bio-indicator of pollution [64].

7. Conclusion

Nanotechnology is an exciting new field; AgNPs have been identified as a possible contender in agriculture due to their unique properties. AgNPs have been shown to boost crop output while also protecting it from bacterial, fungal, and insect attack/infestation is a term used to describe an infestation of insects. AgNPs are also utilised to extend the life of the product fresh agricultural items plus fruits and vegetables in the form of "nano-packages". AgNPs are gaining popularity. We have highlighted some of the agricultural applications of AgNPs, such as pest management, plant disease detection, crop enhancement, and crop product.

Competing Interests Declaration

The authors declare that they have no known competing financial interests or personal relationships that could appear to have influenced the work described in this paper.

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