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NANOTECHNOLOGY IN SUSTAINABLE AGRICULTURE: ROLE OF GOLD NANOPARTICLES IN WHEAT PRODUCTION

Khadija Waseem*[1], Muhammad Ahsan[1], Hammad Rasool[1], Usama Saleem[2] and Muhammad Ahmad[1]

1. Department of Agronomy, University of Agriculture Faisalabad, Pakistan
2. Department of Entomology, University of Agriculture Faisalabad, Pakistan

*Corresponding Author: **dijawaseem57@gmail.com**

ABSTRACT

Nanotechnology is an encouraging technique for growing agricultural viability and efficiency. Gold nanoparticles (AuNPs) play an important role among all other nanoparticles because these particles have special chemical properties like a large surface area, balance, and biological compatibility. By seeing their performance in plants' roots, shoots, photosynthesis, mineral and nutrient uptake, seed germination, and resilience against adverse weather conditions, AuNPs have become an innovation in sustainable wheat production. Moreover, several other types of nanoparticles are also used in agriculture and present the principles of nanotechnology. AuNPs can properly increase the production of wheat, improve resource efficiency, and reduce the use of traditional agrochemicals by killing wheat pests, efficient nutrient delivery, and crop monitoring. However, the use of nanoparticles faces several challenges because they can contaminate water, soil, or the atmosphere, which poses a major health risk to farmers and limits the use of nano-pesticides and nano-fertilizers in agriculture. In this article, we will mainly discuss the fundamentals and types of nanoparticles and the mechanism of action of AuNPs in crop protection.

Keywords: AuNPs, Nanotechnology, Wheat, Sustainable Agriculture, Wheat Production

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Introduction

Wheat (*Triticum aestivum* L.) is one of the major staple foods and cereal crops all over the world as well as in Pakistan. The agriculture sector contributes 18.9% to Gross Domestic Product and plays an important role in the economy. There are many biotic and abiotic factors responsible for reduced wheat productivity. Many insect pests are associated with wheat, which attack at different stages of the crop, cause damage, and ultimately result in yield reduction. Wheat crop is attacked by aphids, Wheat weevil, Wheat midges, Cereal leaf beetle, White grubs, Termites, Grasshopper, Hessian fly, Flea beetles, Armyworm, Wheat stem sawfly, *Helicoverpa armigera,* and Pink Graminous Stem Borer [1, 15, 16]. Through the application of effective pesticides and herbicides, the regulation of soil features, wastewater management, disease detection, nano fertilizers, and nanotechnology are one of the promising technologies that could increase agricultural output [2].

(AuNPs) have garnered a lot of interest and are being used extensively in a number of fields. Because of their spherical form, enormous specific surface area, and rapid modification by functional groups, AuNPs have become an emergent topic of intense research. In order to properly understand and utilize AuNPs' potential, it is imperative to maximize the scientific method as their demand keeps rising [3, 15].

Due to their particular features, nanoparticles are widely exploited in agricultural production through foliar spraying and soil application. By using nanoparticles, agricultural chemicals can be used more effectively and produce less pollution. However, incorporating nanoparticles into agricultural production may pose concerns to the environment, food, and potentially human health. Therefore, it is necessary to pay attention to the absorption, migration, and transformation in crops, and to the interaction with higher plants and the plant toxicity of nanoparticles in agriculture. Particle size, surface charge, concentration, exposure duration, and plant species are some of the variables that affect the uptake and transport of nanoparticles by plants. Numerous channels, including stomata, root hairs, and leaf surface fissures, allow nanoparticles to enter the plant system. Once inside the plant, nanoparticles can migrate through the plant system by diffusion, bulk flow, and phloem loading. Numerous parameters, including the size and shape of the particles, their surface characteristics, the pH of the solution, and the presence of other ions or compounds in the solution, might affect the transport of nanoparticles [4, 17, 18].

This article aims to list the importance of the wheat crop and the challenges wheat faces due to insect pests that damage the wheat crop. And nanotechnology helps in controlling the attack of insect pests.

Fundamentals of Nanotechnology

The process of combining the fundamental characteristics of the physical, chemical, and biological sciences at the nanoscale is known as nanotechnology. Physically, the size is decreased; chemically, new connections and chemical characteristics are controlled; and biological functions, like drug bonding and delivery at specific locations, are generated at the nanoscale**.** In a gray area known as a mesoscopic system, nanotechnology connects classical and quantum mechanics. The medical sector uses this mesoscopic technology to create natural nanoassemblies for treatment and diagnosis, including agricultural goods, nanomedicine, and nanotools**.** Precision farming methods that improve plant nutrient absorption and pathogen detection against agricultural diseases have been made possible by nanotechnology. The use of zeolites and nanoclays, which are useful in soil nutrient broths and soil fertility restoration, is improving fertilizers. Additionally, contemporary ideas of smart seeds and seed banks are designed to germinate in environments that are conducive to their survival; in these situations, nanopolymeric combinations are employed as coatings [5, 15, 19].

There are different types of nanoparticles, their composition, key properties and agricultural applications which are discussed below in the table.

Table 1: Types of Nanoparticles

Types of Nanoparticles	Composition	Key Properties	Agricultural Applications	References
Gold Nanoparticles (AuNPs)	Gold (Au)	High Stability, Biocompatibility	Biosensors and Disease Detection	(Karnwal et al., 2024)
Silver Nanoparticles (AgNPs)	Silver (Ag)	High Surface Area, Potent Antibacterial Activity	Treatment of Seeds, Fungal Illness	(Shahid et al.,
Zinc Oxide Nanoparticles (ZnO NPs)	Zinc Oxide (ZnO)	UV Protection, Vital Supply of Micronutrients	Increased Crop Development, Improved Seed Germination	(Al Jabri et al., 2022).
Titanium Dioxide Nanoparticles	Titanium Dioxide (TiO	Chemical Stability, Photocatalytic Activity	Resistance to Stress, Degradation of Pollutants	(Nagaraj et al., 2025).

Mechanism of Gold Nanoparticles in Wheat Plants

AuNPs were created to enhance plant physiology and seed growth. Nanogold has a major effect on the average germination percentage. The germination percentage rose from 106.87 to 120.73% when the nanogold

concentration increased from 25 to 100 ppm. The fastest-growing plants were those treated with 100 ppm nanogold [12, 18, 19]. AuNPs can reduce the amount of oxidative stress genes and proteins when pathogen triggers reactive oxygen species burst. This demonstrates how AuNPs might boost plant development by striking a balance between defense response and growth [12]. This is important because under ambient environmental conditions, plant cells produce ROS at low concentrations, including superoxide radical (O_2.-, hydrogen peroxide (H_2O_2), hydroxyl radical (OH), single oxygen (1O), peroxy radical (ROO.) and alkoxyl radicals (RO.). However harsh environmental circumstances cause an excessive amount of ROS to be produced [12, 15].

Challenges and Future Prospects

Nanotechnology has advantages in wheat production as well as also have disadvantages ROS oxidize biomolecules (lipid, carbohydrates, proteins, enzymes, DNA), they harm molecular and cellular components and kill plants [13]. The use of nanopesticides and nanofertilizers in agriculture poses a major health risk to farmers because they can contaminate water, soil, or the atmosphere [15,16,17]. Plant growth is predicted to be hindered once NPs build up in the soil, and they may also build up in edible tissues. Following their release into the agro-environment, the NPs go through a number of changes that could be hazardous to humans and plants [7].

Nanotechnoloy has potential to improve the agricultural productivity in wheat plants by using gold nanoparticles that work against insect pests. Future studies should concentrate on deciphering the intricate mechanism of metal nanoparticle biogenesis and developing engineered NPs with reduced toxicity, enhanced health advantages, and regulated size and form. Increasing the application of plant-based metallic nanoparticles in related domains also requires attention [14].

Conclusion

(AuNPs) plays a significant role in raising or growing sustainable wheat production by helping in root and shoot development, photosynthetic activity, biocompatibility, and by providing resilience against environmental changes. (AuNPs) can reduce the amounts of oxidative stress genes and proteins. Use of AuNPs encourages the efficient use of agricultural inputs which increases productivity. Apart from (AuNPs) there are other types of nanoparticles which play different roles in plant physiology. Excessive use of gold nanoparticles can contaminate water, soil and atmosphere. The use of nano-pesticides in agriculture can cause harm to human health, environment and soil health. To ascertain the best application techniques, suitable concentrations, and long-term environmental effects, more research is required. Gold nanoparticles have potential to enhance sustainable wheat production with right handling and scientific validation.

References

[1] Hussain D, Asrar M, Khalid B, Hafeez F, Saleem M, Akhter M, Ahmed M, Ali I, Hanif K. Insect pests of economic importance attacking wheat crop (Triticum aestivum L.) in Punjab, Pakistan. International Journal of Tropical Insect Science. 2022 Feb;42(1):9-20.

[2] Neme K, Nafady A, Uddin S, Tola YB. Application of nanotechnology in agriculture, postharvest loss reduction and food processing: food security implication and challenges. Heliyon. 2021 Dec 1;7(12).

[3] Khan S, Sher Khan R, Khalid A, Gul M, Brekhna, Wadood A, Zahoor M, Ullah R. Biomedical and agricultural applications of gold nanoparticles (AuNPs): a comprehensive review. Zeitschrift für Physikalische Chemie. 2024 Aug 27;238(8):1383-412.

[4] Wang X, Xie H, Wang P, Yin H. Nanoparticles in plants: uptake, transport and physiological activity in leaf and root. Materials. 2023 Apr 14;16(8):3097.

[5] Malik S, Muhammad K, Waheed Y. Nanotechnology: a revolution in modern industry. Molecules. 2023 Jan 9;28(2):661.

[6] Altammar KA. A review on nanoparticles: characteristics, synthesis, applications, and challenges. Frontiers in microbiology. 2023 Apr 17;14:1155622.

[7] Ansari MA. Nanotechnology in food and plant science: challenges and future prospects. Plants. 2023 Jul 6;12(13):2565.

[8] Karnwal A, Kumar Sachan RS, Devgon I, Devgon J, Pant G, Panchpuri M, Ahmad A, Alshammari MB, Hossain K, Kumar G. Gold nanoparticles in nanobiotechnology: from synthesis to biosensing applications. ACS omega. 2024 Jul 5;9(28):29966-82.

[9] Shahid A, Faizan M, Raza MA. Potential role of silver nanoparticles (AgNPs) and zinc nanoparticles (ZnNPs) for plant disease management.

[10] Al Jabri H, Saleem MH, Rizwan M, Hussain I, Usman K, Alsafran M. Zinc oxide nanoparticles and their biosynthesis: overview. Life. 2022 Apr 18;12(4):594

[11] Nagaraj K, Radha S, Deepa CG, Raja K, Umapathy V, Badgujar NP, Parekh NM, Manimegalai T, Devi LA, Uthra C. Photocatalytic advancements and applications of titanium dioxide (TiO_2): Progress in biomedical, environmental, and energy sustainability. Next Research. 2025 Mar 1;2(1):100180

[12] Movahedi A, Taghimolaee M, Ghayebpanah S, Monajemi F, Ghanbari M, Nemat Farahzadi H. A review of the effect of nanoparticles on reactive oxygen species production in different plants. Journal of Engineering and Applied Research. 2024 May 1;1(1):131-63.

[13] Sachdev S, Ansari SA, Ansari MI, Fujita M, Hasanuzzaman M. Abiotic stress and reactive oxygen species: Generation, signaling, and defense mechanisms. Antioxidants. 2021 Feb 11;10(2):277.

[14] Nadaf SJ, Jadhav NR, Naikwadi HS, Savekar PL, Sapkal ID, Kambli MM, Desai IA. Green synthesis of gold and silver nanoparticles: Updates on research, patents, and future prospects. OpenNano. 2022 Nov 1;8:100076.

[15] Mustafa MS, Fatima K, Khan NA, Noor R, Idrees L, Shafiq S, Rasool S, Ateeb M, Hameed MB, Mustafa M. Nanotechnology in pest management: a focused review on the role of silver nanoparticles against cotton pest Pectinophora gossypiella.

[16] Mustafa MS, Ali MF, Naveed A, Manzoor MA, Mustafa M, Nasir MT, Aziz F, Arshad S, Ashraf MF, Saleem U. Integrating biodiversity in agroecosystems: a multidisciplinary approach linking entomology, biotechnology, crop improvement, and plant health. In: Jamil M, Abbas A, Tariq A, Zahra I, editors. Explicable Agriculture: Microbial Ecology, Bio-Innovations and Crop Production. Faisalabad (Pakistan): Unique Scientific Publishers; 2026. p. 282–289. https://doi.org/10.47278/book.TL/2026.469

[17] Hameed MB, Asghar K, Ahmed S, Iqbal U, Ahmed M, Abbas T, Murtaza A, Muneeb-ul-Rehman M, Hayyat M, Samad N. Multidisciplinary approaches to enhance rice yield in South Asia and contrasting agroecosystems: genetic, agronomic, and environmental perspectives. In: Jamil M, Abbas A, Tariq A, Zahra I, editors. Explicable Agriculture: Microbial Ecology, Bio-Innovations and Crop Production. Faisalabad (Pakistan): Unique Scientific Publishers; 2026. p. 170–176. https://doi.org/10.47278/book.TL/2026.307

[18] Hameed MB, Tariq N, Batool H, Shabbir A, Hameed H, Tariq M, Bano N, Abid J. AGRONOMIC AND GENETIC STRATEGIES FOR ZINC BIOFORTIFICATION OF MAIZE FODDER: IMPLICATIONS FOR DAIRY COW NUTRITION AND HEALTH. Genetics and Molecular Research. 2026 Jul 7.

[19] Afzal MA, Shahzadi N, Saadat S, Seemab R, Sajjad I, Tariq N, Ashraf SR, Tahir S, Kharl HA. CRISPR-Cas9 genome-editing technology: a transformative tool for curing human disorders. Journal of Medical & Health Sciences Review. 2025 Jul 29;2(3).