IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES

ISSN PRINT 2319 1775 Online 2320 7876

 Journal Volume 11,Iss 11, 2022

# THE EFFECT OF NANOPARTICLES IN COMBATING PLANT DISEASES IN MAJOR CROPS: A REVIEW STUDY

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Submitted- 15-09-2022 Accepted- 24-10-2022 Published- 28-11-2022.

## ABSTRACT

Plant diseases caused by pathogens are a major threat to global food security. Nanoparticles have been integrated into disease management strategies, serving as both bactericides/fungicides and nano-fertilizers to enhance plant health. With a warming climate, the demand for food production is increasing. Nanoparticles can help manage new disease challenges while reducing the need for active metals and other chemical inputs. Small sizes of the nanoparticles have the potential to target and directly attack virus particles, opening up new possibilities for controlling plant pathogens. Nanoparticles efficiently overcome bacterial, fungal, and other plant pathogens in major food crops. Various types of nanoparticles have been found to enhance crops' resistance to both biotic and abiotic stresses.

**Keywords:** nanoparticles, disease resistance, crops, agriculture

## INTRODUCTION

The global population is on an alarming rise, leading to an urgent and escalating demand for food. However, this surge in demand has also triggered significant environmental degradation and a subsequent decline in crop productivity (Miao et al., 2015). Being immobile, plants cannot evade environmental changes, making them susceptible to abiotic stresses that hamper their growth, development, and productivity (Qu et al., 2016). These stresses can induce alterations in plants'

ISSN PRINT 2319 1775 Online 2320 7876

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physical, physiological, molecular, and biochemical responses, as evidenced by research studies (Song et al., 2012; Gehan et al., 2015).

Nanobiotechnology, a rapidly advancing field in modern materials science, is continually introducing innovative nanoparticles and nanomaterials. Noble metal nanoparticles have revolutionized numerous sectors by augmenting their physical, chemical, and biological properties. As per Esfahani (2006), the global nanotechnology industry is poised for a remarkable expansion, with a projected market size of $90.5 billion by 2021 from $39.2 billion in 2016, at a compounded annual growth rate (CAGR) of 18.2% from 2016 to 2021 (Mishra et al., 2014). Nanotechnologies spearhead a new industrial revolution, with public and private entities announcing substantial hikes in their research and development budgets across diverse industries. Nanotechnology and Nanoscience have made significant strides in just a few decades, proving their fundamental importance in various industrial applications and medical devices such as drug delivery systems, diagnostic biosensors, and imaging probes (Ocsoy et al., 2019). Particularly in the food sector, the integration of nanomaterials has led to a dramatic increase in shelf life, production, packaging, and nutrient bioavailability. This progress in nanobiotechnology instills hope for a future where crop productivity can be significantly enhanced, ensuring food security for the growing global population.

There are three ways of synthesizing nanoparticles: physical, chemical, and biological. Physical and chemical methods are commonly used for this purpose. However, the biological synthesis pathway is preferred over the physical and chemical methods due to various reasons. The major disadvantage of physical and chemical methods is that the former requires more time to achieve thermal stability, consumes much energy, and occupies a large space in the case of the furnace. On the other hand, the chemical synthesis of NPs employs harsh reducing agents like sodium borohydride, sodium citrate, and organic solvents. There are three ways of synthesizing nanoparticles: physical, chemical, and biological. Physical and chemical methods are commonly used for this purpose. However, the biological synthesis pathway is preferred over the physical and chemical methods due to various reasons. The major disadvantage of physical and chemical methods is that the former requires more time to achieve thermal stability, consumes a lot of energy, and occupies a large space in the case of the furnace. On the other hand, the chemical synthesis of NPs employs harsh reducing agents like sodium borohydride, sodium citrate, and organic solvents [Nadaroglu et al., 2017, Jadhav and Shaikh 2019].

Many methods, like chemical methods and biological methods, have been used for the eradication of these pathogens, but they have few limitations as they cause harmful effects on environmental and human health. Therefore, the use of NPs has been considered an effective way to be eco-friendly and inexpensive for the reduction of plant pathogens. Nanoparticles are expected to play a vital role in the management of future plant diseases, and they are expected to provide an environmentally friendly alternative to traditional synthetic fungicides. The nanoparticles are reported to improve plant improvement and exhibit different bactericidal mechanisms (Oves et al., 2013; Aziz et al., 2016; Qayyum et al., 2017; Mahawar & Prasanna, 2018). Green methods are cost-effective, more sustainable, and environmentally friendly for the preparation of metallic NPs (Oliveira et al., 2020; Dobrucka et al., 2016). Nanoparticles have unique properties, and therefore,

ISSN PRINT 2319 1775 Online 2320 7876
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inorganic NPs can be extensively used in industrial, agricultural, and consumer products and medical applications (Schaumann et al., 2015; McGillicuddy et al., 2017).

**EFFECT OF NPs on crops**

**RICE**

Rice is a vital food crop that is consumed throughout the world. Asia is responsible for producing 90.7% of the world's rice, with China being the largest producer. However, rice production is often impacted by plant microbes, such as *Xanthomonas oryzae pv*., which causes bacterial leaf blight, and *Acidovorax oryzae*, which causes bacterial brown stripe. The frequent incidence of these bacterial diseases can significantly reduce rice yield. Currently, bactericides are commonly used to control these diseases, but they have been found to harm human health and natural ecosystems.

It is necessary to find an alternative solution to combat rice bacterial diseases. Researchers have discovered that silver nanoparticles, created using an endophytic bacteria called *Bacillus siamensis* SZT1, can protect rice plants from both bacterial leaf blight and bacterial brown stripe, while simultaneously promoting plant growth [Ibrahim et al, 2019]. Similarly, silver nanoparticles produced using *Bacillus cereus* have proven effective in fighting bacterial leaf blight in rice by increasing the concentration of antioxidant enzyme activity and enhancing plant biomass [Ahmed et al, 2020].

Biosynthesis of MgO and $MnO_2$ nanoparticles by using *Matricaria chamomilla L.* flower extract was found to reduce bacterial brown stripe by perforating the rice plant cells and damaging the cell membrane, which leads to cytoplasmic content leakage[Ogunyemi et al. 2019].

Zinc oxide nanoparticles (ZnO NPs) were synthesized using plant extracts from chamomile flowers (*Matricaria chamomilla L*.), olive leaves (*Olea europaea*), and red tomato fruits (*Lycopersicon esculentum M*.). These nanoparticles showed antibacterial activity against *Xanthomonas oryzae pv. oryzae* (Xoo) on rice plants. ZnO NPs reduced biofilm formation, which protects bacteria from external attacks and helps in bacterial survival from infection. This reduction in biofilm formation significantly affected swimming motility and bacterial cell membranes of Xoo strain GZ 0003. [Bridier A. et al 2011; Ogunyemi et al 2020]

The antibacterial activity of ZnONPs is to mainly interact with the bacterial membrane, which causes the membrane collapsing and rupturing and it also results in leakage of cytoplasm in the bacterial cell [Zhong L. *et al* 2019]. The antibacterial properties of ZnONPs lead to the breakdown of bacterial cell membranes due to oxidative stress induced by Reactive Oxygen Species (ROS) generation. ROS molecules can damage DNA, RNA and oxidize proteins and lipids, thereby leading to bacterial decomposition and death [Krishnamoorthy K. *et al* 2012]. Therefore, ZnO NPs play an important role in combatting bacterial leaf blight disease of rice.

Silver nanoparticles were produced using fresh fruit extract from *Phyllanthus emblica*. These particles were found to inhibit *Acidovorax oryzae* strain RS2 in rice plants. Additionally, the AgNPs significantly impacted biofilm formation and swarming ability, increasing the secretion of effector Hcp in strain RS-2. This was due to damage to the cell membrane, resulting in a reduction of bacterial blight stripe disease. [Masum *et al*., 2019].

Zinc oxide (ZnO) nanoparticles can be synthesized using an extract from fennel seeds. These nanoparticles have been found to be effective against *Xanthomonas oryzae*, a plant pathogen that

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causes bacterial leaf blight disease in rice plants. The ZnO nanoparticles generate three types of ROS (reactive oxygen species) molecules, including singlet oxygen, OH ions, and OH radicals. As a result, the nanospray application of ZnO particles is a promising approach for inhibiting bacterial leaf blight disease[ Nadeem et al., 2020].

Chitosan/$TiO_2$ nanocomposite at the ratio of 1:5 showed the strongest inhibition in growth of rice bacterial pathogen *Xanthomonas oryzae pv. oryzae* (Xoo) [Li *et al* 2016].MgO nano-flowers (MgONFs) were synthesized using aqueous Rosemary extract under controlled conditions and a temperature of 70∘C for 4 hours. Bacteriological tests showed that the MgO nano-flowers effectively inhibited the growth, biofilm formation, and motility of *Xanthomonas oryzae pv. oryzae* is the bacteria responsible for causing bacterial blight disease in rice. The main reason for bacterial cell death was cell integrity collapse, leading to intracellular content leakage. The MgO nano-flowers have been shown to be effective in suppressing bacterial infection[Ogunyemi et al (2019)].

Synthesis of sunlight-mediated silver nanoparticles [AGNPs] by leaf extract of *Azadirachta indica* [neem] showed antibacterial activity against the plant pathogen *Xanthomonas oryzae pv. oryzae* [Xoo][ Mankad *et al* 2018].The neem extract reduced $AG^+$ to $Ag^o$ nanoparticles because of the leaf extract's presence of phenolics, flavonoids, terpenoids, alkaloids, lipids, proteins, and carbohydrates [ *Mittal et al.* 2013]. Neem extract acts as a reducing agent and capping agent, which overcomes post-modification of nanoparticles for stability [Agarwal *et al*. 2015].

ZnO NPs were biosynthesized using coculture and monoculture of *Trichoderma* spp., which inhibits the growth of *Xanthomonas oryzae pv. oryzae* in in vitro conditions in a dose-dependent manner. This method is a new outlook for the management of plant disease in agriculture[Shobha et al. 2020]. Chitosan nanoparticles [CSNPs] and ZnO NPs together show antibacterial activity against *X.oryzae* due to the reduction in biofilm formation and swimming, cell membrane damage, reactive oxygen species production, and apoptosis of bacterial cells better alternative to control rice bacterial disease.[Abdallah et al 2020]. The biofilms and motility swimming was able to protect the bacteria from immune responses by the host and contribute to bacterial resistance during host-pathogen interaction [Bridier et al. 2011].

Synthesis of AgNPs using pomelo (*Citrus maxima*) fruit extract shows an antibacterial effect on *Acidovorax oryzae* strain RS-2. AgNPs ruptures the bacterial cell wall resulting in leakage of cell nucleic acid and proteins and eventually causing cell death. AgNPs also reduces the action of bacterial viability and swarming motility.Moreover, AgNPs treatment leads to down regulation of expression of many type VI secretion system related genes such as T6SS genes.AgNPs protect against the pathogen of bacterial brown stripe.[Ali *et al* 2020].

MgO nanoparticles synthesized using *Acinetobacter johnsonii* strain RTN1 emerged as an antibacterial agent against the rice pathogen Acidovorax oryzae. MgO treatment reduced the cell density and inhibited the bacterial effect. The morphological structure was damaged, leading to the oozing out of nucleic material and ultimate cell death. This nanoparticle-based strategy can be used as a nanopesticide to control bacterial disease in rice[ Khan et al. 2020].

Nanoparticles synthesized using $Cu_2O$-Cu/alginate of copper ions completely inhibited the growth of *Xanthomonas OO* bacteria, which are responsible for the rice leaf blight disease. [Ngoc et al 2021]. Biosynthesized SnO2 nanoparticles and its silver-doped variant were found to have a significant advantage in all experiments. The nanoparticles were found to have an inhibitory effect

ISSN PRINT 2319 1775 Online 2320 7876
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on xanthomonadin and exopolysaccharide formation and showed promise as a treatment for leaf blight disease caused by *Xanthomonas oryzae* in rice. [Sunny and Shanmugam 2021]

Biosynthesis of AgNPs against *Xanthomonas oryzae* pv. *oryzae* (Xoo) significantly impacted biofilm formation, suppressing the disease under greenhouse conditions. Foliar spray of AgNPs significantly reduced the bacterial blight disease in rice plants, as shown by 9.25% DLA (% Diseased leaf area) compared to 33.91% DLA in Xoo-inoculated rice plants [Mishra et al. 2020].

Silver nanoparticles (Ag NP) were synthesized by utilizing leaf extract of rice cultivar Taichung native-1. AgNPs act as strong antibacterial agents by inhibiting the growth of Xoo and colony formation, also enhancing the seedling vigor index. Thus, AgNPs using leaf extract can control and manage BLB disease in the agriculture field [Namburi et al. 2021].

## WHEAT

Wheat is considered as a staple food after rice due to its high nutritional value and diverse uses [Nandy *et al* 2010, Peng *et al* 2011]. Wheat is the most commonly cultivated crop worldwide and it provides 30% and 60% of the population's calories and protein, respectively, according to Chaves et al. (2013). It is the second most important food crop after rice in the developing world. With the increasing demand for food, wheat production is expected to increase by 60% by 2050, as stated by Alexandratos and Bruinsma (2012). However, in order to achieve this, it is necessary to manage pathogens, pests, and abiotic stress that can significantly reduce wheat yield. Fungi are a major group of plant pathogens that cause most of the diseases that occur in agricultural and horticultural crops, according to Agrios (2009). Fusarium head blight disease caused by a fungus, *Fusarium graminearum*, possesses a huge impact on wheat production in the world and infects other cereal crops such as rice, barley, and maize [Dubin et al. 1996, Goswami et al. 2004, Yu et al. 2017]. The fungus also produces some mycotoxins that infect wheat grains, causing a major threat to the safety and health of humans and animals [Wu *et al* 2018.,2019, Lakshmeesha *et al* 2019]. Presently, chemical fungicides are used as the common choice to protect wheat from these fungal pathogens. However, prolonged exposure to fungicides increased the resistance of the fungal strains [Palazzini et al. 2016, Chen.L et al. 2018]. Therefore, nanoparticles (NPs) play an alternative strategy in the inhibition of this pathogen. Various metal and metal oxide nanoparticles have been widely used in agriculture because of their characteristic features such as antimicrobial activity, catalytic activity, and magnetic and electrical properties [Pariona et al. 2019, Maluin et al. 2019].

Silver nanoparticles (AgNPs) show significant inhibition of the hyphal growth of a variety of foliar and soil-borne plant pathogens [Malandrakis *et al* 2019. Biosynthesized AgNPs by using the endophytic bacterium *Pseudomonas poae* strain CO, and then we characterized the AgNPs with strong antifungal activity against *F.graminearum* affecting wheat crops[Ibrahim *et al* 2020].

*Puccinia graminis pv. tritci* is a fungus commonly called the black stem rust of wheat infects cereal crops such as wheat and barley. The synthesis of gold particles [Au NPs] using seed aqueous extract of *Abelmoschus esculentus* is capable of inhibiting the fungal disease *P.graminis* of wheat and *Candida albicans* in human gut and AuNPs can be used in preparing drugs against fungal pathogens [Jayaseelan *et al* 2012].

$TiO_2$ nanoparticles biosynthesized using *Moringa oleifera* aqueous leaf extract are effective against *Bipolaris sorokiniana*, a fungus that causes spot blotch disease in wheat plants. $TiO_2$ nanoparticles

ISSN PRINT 2319 1775 Online 2320 7876



penetrate the fungal outer covering and affect the cell's homeostasis, resulting in cell death. The nanoparticles also inhibit enzyme activity, disrupt cellular signaling pathways, and block receptor sites. [Satti *et al* 2021; Ikram *et al* 2021].

Biological selenium nanoparticles (BioSeNPs) synthesized by *Lactobacillus acidophilus* ML14 suppress wheat crown and root rot diseases caused by Fusarium spp. BioSeNPs confer drought and heat stress tolerance and stimulate wheat growth and yield. SeNPs improve gas exchange, increase photosynthetic pigments, and protect wheat crops from plant pathogenic fungi (Ikram *et al*., 2020). Therefore, BioSeNPs play a vital role in protecting wheat crop loss by CRDs caused by plant pathogenic fungi.

TiO2-NPs produced from plant extracts of *Trianthema portulacastrum* and *Chenopodium quinoa* have shown antifungal activity against toxic plant pathogens. These NPs have also been found to improve plants' morphological, physiological, and biochemical properties, leading to an enhancement in crop yield. TiO2-NPs have demonstrated effectiveness against various fungal species (Rizwan *et al*., 2019]. $TiO_2$-NPs have shown the best results against various fungal species [De Filpo et al., 2013]

Essential oils from Lemon grass (LGO) and Clove (CO) were tested against *Gaeumannomyces graminis var. tritici* (Ggt), the fungus responsible for causing take-all disease in wheat. The essential oils were encapsulated in mesoporous silica nanoparticles (MSNPs) and synthesized using the sol-gel process. Encapsulated MSNPs increase wheat biomass by 17% during drought and salt stress. Encapsulation enhances the solubility and stability of essential oils, enabling them to penetrate fungal cells, resulting in a loss of membrane integrity and destruction of the cells. Encapsulated essential oils have higher antifungal activity than their pure form, requiring lower dosage. The essential oils work by disrupting the fungal cell membrane, altering its permeability, and causing leakage of materials and ions, ultimately leading to fungal cell death. [Sattary et al., 2020; Kalagatur et al., 2018).

**Maize**

Silica nanoparticles showed higher resistance in maize (*Zea mays L.*) against the phytopathogens such as *Fusarium oxysporum* and *Aspergillus niger*. Nanosilica enhances fungal resistance by activating the damping-off mechanism compared to its bulk counterpart (Suriyaprapha et al., 2014). Cu-chitosan nanoparticles increased maize defense against Curvularia leaf spot (CLS) and promoted plant growth (Choudhary *et al*., 2017). The use of Zinc-chitosan nanoparticles encapsulated in maize enhances plant growth and provides resistance against CLS disease by elevating antioxidant and defense enzymes and boosting innate immunity**.** Alumina (Al2O3) and titania (TiO2) nanoparticles significantly reduce the germination percentage, whereas silica (SiO2) nanoparticles and microparticles enhance the same in the maize plants. Root elongation is enhanced by SiO2 nanoparticles and microparticle treatment, whereas inhibition is observed with Al2O3 and TiO2 nanoparticles and microparticles in maize [Karunakaran et al., 2015].

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**Conclusion**

In today's world, with a global population of 7 billion people, we are facing significant challenges in various areas, particularly in food and agriculture. Food is a primary requirement for survival, and there is immense pressure on the agricultural sector to meet the demand. However, there is a pressing need to develop and incorporate sustainable techniques to ensure agricultural crop production. Exploring the potential impact of nanoparticles on crops, soils, and microbial communities is crucial, given the increasing applications of NPs. Nanoparticles (NPs) such as TiO2, SiO2, and Ag NPs can help reduce the harmful effects of biotic and abiotic stress on plants by triggering their defense mechanisms. They do this by stimulating the production of reactive oxygen species (ROS) and causing phytotoxicity. Due to their small size, NPs can easily enter plant tissues and positively impact morphological, physiological, and biochemical processes. This helps promote plant growth and development and improve crop productivity even when plants are subjected to various abiotic stresses. Additionally, NPs have a large surface area, enhancing the absorption and delivery of targeted nutrients to plants.

**REFERENCES**


1. Ahmed, B., Rizvi, A., Ali, K., Lee,J., Zaidi,A., Khan, M.S., Musarrat, J. Nanoparticles in the soil–plant system: a review. Environ Chem Lett 19, 1545–1609 (2021). https://doi.org/10.1007/s10311-020-01138-y
2. Ibrahim, A.S.; Ali, G.A.M.; Hassanein, A.; Attia, A.M.; Marzouk, E.R. (2021)Toxicity and Uptake of CuO Nanoparticles: Evaluation of an Emerging Nanofertilizer on Wheat (Triticum aestivum L.)Plant. Sustainability,14,4914.https://doi.org/10.3390/su14094914
3. Ogunyemi SO, Zhang M, Abdallah Y, Ahmed T, Qiu W, Ali MA, Yan C, Yang Y, Chen J and Li B (2020) The Bio-Synthesis of Three Metal Oxide Nanoparticles (ZnO, $MnO_2$, and MgO) and Their Antibacterial Activity Against the Bacterial Leaf Blight Pathogen. Front. Microbiol. 11:588326. doi: 10.3389/fmicb.2020.588326
4. Ogunyemi, S. O., Abdallah, Y., Zhang, M., Fouad, H., Hong, X., Ibrahim, E., … Li, B. (2019). Green synthesis of zinc oxide nanoparticles using different plant extracts and their antibacterial activity against Xanthomonas oryzae pv. oryzae. Artificial Cells, Nanomedicine, and Biotechnology, 47(1), 341–352. https://doi.org/10.1080/21691401.2018.1557671
5. Bridier, A., Briandet, R., Thomas, V., & Dubois-Brissonnet, F. (2011). Resistance of bacterial biofilms to disinfectants: a review. Biofouling, 27(9), 1017–1032. https://doi.org/10.1080/08927014.2011.626899
6. Yan A, Chen Z.(2019) Impacts of Silver Nanoparticles on Plants: A Focus on the Phytotoxicity and Underlying Mechanism. International Journal of Molecular Sciences; 20(5):1003. https://doi.org/10.3390/ijms20051003
7. Krishnamoorthy, K., Manivannan, G., Kim, S.J. et al.(2012) Antibacterial activity of MgO nanoparticles based on lipid peroxidation by oxygen vacancy. J Nanopart Res 14, 1063. https://doi.org/10.1007/s11051-012-1063-6
8. Masum MMI, Siddiqa MM, Ali KA, Zhang Y, Abdallah Y, Ibrahim E, Qiu W, Yan C and Li B (2019) Biogenic Synthesis of Silver Nanoparticles Using Phyllanthus emblica Fruit Extract and

ISSN PRINT 2319 1775 Online 2320 7876



Its Inhibitory Action Against the Pathogen Acidovorax oryzae Strain RS-2 of Rice Bacterial Brown Stripe. Front. Microbiol. 10:820. doi: 10.3389/fmicb.2019.00820

9. Nadeem, M., Khan, R., Afridi, K., Nadhman, A., Ullah, S., Faisal, S., … Abbasi, B. H. (2020). Green Synthesis of Cerium Oxide Nanoparticles (CeO2 NPs) and Their Antimicrobial Applications: A Review. International Journal of Nanomedicine, 15, 5951–5961. https://doi.org/10.2147/IJN.S255784
10. Li, C. C., Dang, F., Li, M., Zhu, M., Zhong, H., Hintelmann, H., & Zhou, D. M. (2017). Effects of exposure pathways on the accumulation and phytotoxicity of silver nanoparticles in soybean and rice. Nanotoxicology, 11(5), 699–709. https://doi.org/10.1080/17435390.2017.1344740
11. Mittal. A.K., Chisti, Y., Banerjee, U.C(2013). Synthesis of metallic nanoparticles using plant extracts. Biotech advances,Vol 31 (2),346-356.
12. Agarwal,H., Menon, S., Kumar, S.V., Rajeshkumar, S.(2018). Mechanism study on antibacterial action of zinc oxide nanoparticles synthesized using green route.
13. Abdallah Y, Liu M, Ogunyemi SO, Ahmed T, Fouad H, Abdelazez A, Yan C, Yang Y, Chen J, Li B (2020). Bioinspired Green Synthesis of Chitosan and Zinc Oxide Nanoparticles with Strong Antibacterial Activity against Rice Pathogen Xanthomonas oryzae pv. oryzae. Molecules. 25(20):4795. https://doi.org/10.3390/molecules25204795.
14. Khan, A., Shabir, D., Ahmad, P., Khandaker, M.U., Faruque, M.R.I., Din I.S. (2020). Biosynthesis and antibacterial activity of MgO-NPs produced from Camellia-sinensis leaves extract. Mater. Res. Express(8), 015402.
15. Ali, K.A., Yao, R., Wu, W., Masum, M.M.I., Luo,J., Wang, Y., Zhang, Y., An, Q., Sun, G., Li,B. (2020). Biosynthesis of silver nanoparticle from pomelo (Citrus Maxima) and their antibacterial activity against acidovorax oryzae RS-2. Mater. Res. Express(7), 015097.
16. Ngoc, D.T.B., Duy.D.B., Tuan, L.N.A., Thach.B.D., Tho, T.P., Tho, T.P., Phu D.V(2021). Effect of copper ions concentration on the particle size of alginate-stabilized Cu2O-Cu nanocolloids and its antibacterial activity against rice bacterial leaf blight (Xanthomonas oryzae pv. oryzae). Adv. Nat. Sci: Nanosci. Nanotechnol. **12** 013001.
17. Sunny, N.E., Shanmugam ,V.K.(2021). Anti- blight effect of green synthesized pure and Ag-doped tin oxide nanoparticles from Averrhoa bilimbi fruit extract towards Xanthomonas oryzae-the leaf blight pathogen of rice.Inorganic Chemistry Comuunications.133,108866.
18. Mishra S, Yang X, Ray S, Fraceto LF, Singh H.B(2020) Antibacterial and biofilm inhibition activity of biofabricated silver nanoparticles against Xanthomonas oryzae pv. oryzae causing blight disease of rice instigates disease suppression. World J Microbiol Biotechnol. 16;36(4):55. doi: 10.1007/s11274-020-02826-1. PMID: 32180020.
19. Namburi, K.R., Kora, A.J., Chetukuri, A (2021). Biogenic silver nanoparticles as an antibacterial agent against bacterial leaf blight causing rice phytopathogen Xanthomonas oryzae pv. oryzae. Bioprocess Biosyst Eng **44**, 1975–1988 https://doi.org/10.1007/s00449-021-02579-7.
20. Malandrakis, A.A., Kavroulakis, N., Chrysikopoulos, C.V.(2019). Use of copper and zinc nanoparticles against foliar and soil-borne plant pathogens. Science of the Total Environment 670,292-299.

21. Jayaseelan, C., Ramkumar, R., Rahuman, A.A., Perumal,P (2013). Green synthesis of gold nanoparticles using seed aqueous extract of Abelmoschus esculentus and its antifungal activity. Industrial Crops and Products 45,423-429.
22. Ibrahim E, Zhang M, Zhang Y, Hossain A, Qiu W, Chen Y, Wang Y, Wu W, Sun G, Li B.(2020) Green-Synthesization of Silver Nanoparticles Using Endophytic Bacteria Isolated from Garlic and Its Antifungal Activity against Wheat Fusarium Head Blight Pathogen Fusarium graminearum. Nanomaterials;10(2):219. https://doi.org/10.3390/nano10020219.
23. Satti, S.H.; Raja, N.I.; Javed, B.; Akram, A.; Mashwani, Z.-u.-R.; Ahmad, M.S.; Ikram, M.(2021) Titanium dioxide nanoparticles elicited agro-morphological and physicochemical modifications in wheat plants to control Bipolaris sorokiniana. PLoS ONE **,** 16, e0246880.
24. Ikram, M.; Javed, B.; Hassan, S.W.U.; Satti, S.H.; Sarwer, A.; Raja, N.I.; Mashwani, Z.-u.-R.(2021) Therapeutic potential of biogenic titanium dioxide nanoparticles: A review on mechanistic approaches. Nanomedicine, 16, 1429–1446.
25. De Filpo, G.; Palermo, A.M.; Rachiele, F.; Nicoletta, F.P.(2013) Preventing fungal growth in wood by titanium dioxide nanoparticles. Int. Biodeterior. Biodegrad.; 85, 217–222.
26. Rizwan, M., Ali, S., Ali, B., Adrees, M., Arshad, M., Hussain, A., Rehman, M.Z.U., Waris,A.A. ( 2019). Zinc and iron oxide nanoparticles improved the plant growth and reduced the oxidative stress and cadmium concentration in wheat. Chemosphere 214, 269-277.
27. Sattary, M., Amini, J., Hallaj, R.(2020). Antifungal activity of the lemon grass and clove oil encapsulated in mesoporoud silica nano particles against wheat's take all disease.Pesticide Biochemistry and Physiology 170,104696.
28. Kalagatur NK, Nirmal Ghosh OS, Sundararaj N and Mudili V (2018) Antifungal Activity of Chitosan Nanoparticles Encapsulated With Cymbopogon martinii Essential Oil on Plant Pathogenic Fungi Fusarium graminearum. Front. Pharmacol. 9:610. doi: 10.3389/fphar.2018.00610 .
29. Suriyaprapha, R., Karunakaran, G., Kavitha, K., Yuvakkumar, R., Rajendran,V., Kannan, N.(2014). Application of silica nanoparticles in maize to enhance fungal resistance.IET Nanobiotechnology 8(3), 133-137.
30. Choudhary, R.C., Kumaraswamy, R.V., Kumari, S., Sharma S.S., Pal, A., Raliya, R., Biswas, P., Saharan, V. (2016) Cu-chitosan nanoparticle boost defense responses and plant growth in maize (Zea mays L.). Sci Rep **7**, 9754.
31. Karunakaran, G., Suriyaprabha, R., Rajendran, V., Kannan, N.(2015). Influence of $ZrO_2$, $Si0_2$, $Al_2O_3$ and $TiO_2$ nanoparticles on maize seed germination under different growth conditions. IET Nanobiotechnology 10(4):171-7.
32. Song, G., Gao, Y., WU, H., Hou, W., Zhang, C., Ma, H (2012). Physiological effect of $TiO_2$ nanoparticles on Lemna Minor. Environment Toxicology and Chemistry 31(9), 2147-2152.
33. Gehan, M. A., Greenham, K., Mockler, T. C., McClung, C. R. (2015). Transcriptional networks: Crops, clocks, and abiotic stress. Curr. Opin. Plant Biol., 24, 39–46.
34. Ocsoy, I., Tasdemir, D., Mazicioglu, S., Tan, W. (2018). Nanotechnology in Plants. In: Varshney, R., Pandey, M., Chitikineni, A. (eds) Plant Genetics and Molecular Biology.

ISSN PRINT 2319 1775 Online 2320 7876

 **Journal Volume 11,Iss 11, 2022**

Advances in Biochemical Engineering/Biotechnology, vol 164. Springer, Cham. https://doi.org/10.1007/10_2017_53.

35. Mishra, V., Mishra, R.K., Dikshit, A., Pandey, A.C (2014). Interactions of Nanoparticles with Plants: An Emerging Prospective in the Agriculture Industry. Emerging Technologies and Management of Crop Stress Tolerance.Volume 1: Biological Techniques.159-180.
36. Nadaroglu, H., Alaylı Güngör, A., & İnce, S. (2017). Synthesis of Nanoparticles by Green Synthesis Method. International Journal of Innovative Research and Reviews, 1(1), 6-9.
37. Jadhav, S.D. and Shaikh, I.A (2019).Synthesis of Nanoparticles an Overview, a Review article. International Journal of Trend in Scientific Research and Development 3(3),2456-6470.