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Evaluation of nanotechnology against stored insect pest *Callosobruchus Chinensis Linnaeus*

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Abstract
Azukibean beetle, *Callosobruchus chinensis* (L.) (Coleoptera: Bruchidae), is a primary stored grain insect pest that infests the whole grain. It causes serious hazards and major economic losses to stored grain crops annually. To control and manage this pest, Integrated Insect Management (IPM) is used such as biological, chemical, Cultural, physical etc., but these methods fail to control such pests. Recently, nanotechnology has emerged as a promising tool for pest management due to their effectiveness and eco- friendly nature. However, in many sectors metal nanoparticles are being increasingly used, so this approach is a better option and also cost efficient and environmentally friendly approach. One of the best methods for production of green nanoparticles by using organism and plants seem to be the best option for the biosynthesis of nanoparticles which are characterized by using techniques such XRD, SEM, TEM, Zeta Potential, FTIR and UV-spectroscopy etc. Green nanoparticles of metals like Ag, Mo, Si, Fe, and other metals gave a remarkable result for controlling pulse beetles. NPs are having good characteristics like safe, energy efficient and less toxic, so these features have received great attention in recent years. NPs are less harmful for environment because NPs are safe, energy efficient and having fewer toxic routes towards environment and human health. This study is not only meant to provide an overview of the green synthesis of nanoparticles but also to present an essential view of synthesis with environmental concerns.

Keywords: *C. chinensis*, pest, metal, nanoparticles, plant extracts

Introduction

India is a premier pulse growing country and the pulse is the great source of protein, carbohydrate and minerals. About 840 million people in the world are undernourished due to insufficient intake of protein, amino acids, vitamins, and minerals in their daily diet. Percentage of proteins (20-40%), carbohydrate (50-60%), calcium and iron (Ofuva and Akhidue, 2005) [34] also found in pulses. In the global pulse market, approximate production is 60 million tonnes. The pulses grown area was 723 lakhs with the production of 644.08 lakhs tonnes and a productivity of 890 kg/ha in 2010. India is the largest producer and consumer in the world. The production of pulses in India was approximately 17.29 million tonnes in 2010. Which is record production. There are 171 countries which produce pulses and among these countries India contributed at around 32, 24 % (Sharma, 1984). The total pulses grown area is about 25.25 million hectares and production are only 16.47 million tonnes (Directorate of economics and statistics; Anonymous, 2016). In India daily consumption of pulses is around 45 gm and the World Health Organisation (WHO) recommends 80 gm pulse consumption for a single individual. And we need around 38 million tonnes of pulses in 2018 (Anonymous, 2012). The Food Agriculture Organisation (FAO) of the United Nations and the International Food Policy Research Institute (IFPRI) presented a report that food demand capacity will be increased to 70%. The production of pulses decreased every year, around 15-20 percent production was lost due insect infestation and around 8 % production was lost in storage. In storage store products are infected more than 200 species of insects and mites. The loss due to the infestation of pulse beetles was recorded at around 12 %. Insects which belong to the Orders Coleoptera and Lepidoptera are the most common insects which damage the stored grain products. (Girma, 2006) [13].

C. chinensis (Linnaeus) (Coleoptera: Bruchidae) is one of the important and major pests for grain legumes and also considered as a most destructive pest in many tropical and subtropical countries. *C. chinensis* causes damage of around 93.33 % in different pulse crops. (Parsai, 1999). In agriculture huge numbers of pesticides are used, so there is a challenge to reduce pesticide usage while maintaining proficient levels of pest control. Synthetic insecticides are deleterious to man, livestock and the environment. Nanotechnology holds great potential in many fields and it is predicted as a technology to lead the way towards sustainable, environment-friendly development in the coming years and having great opportunities for sustainable development. Indian agricultural growth has declined from about 3.6% in 1985–1995 to less than 2% in 1995–2005 targeting 4% annual growth in the agricultural sector for 2020. The major concern is food grain production due to decline rate. In agriculture use of nanomaterial is an emerging new field and it needs a good quality of research and social and ethical repercussions of nanotechnology use in agriculture have to be considered and before commercialization and field application, the toxicity of nanomaterials has to be evaluated (Pramanik, 2020). Thus, biological synthesis of nanomaterials means, which has the advantages of nanotoxicity, reproducibility in production, easy scaling -up and well-defined morphology etc. In particular, several microorganisms, including bacteria, fungi and yeast as well as plants have been synthesized for the production of metal green nanoparticles. It can check detection and sensing of pollutants and help in the development of new technology for remediation. *C. chinensis* also affects the seed quality and protein content. (Modgil and Mehta, 1996) [29]. *C.chinensis* is distributed throughout the tropics and subtropics region whereas in tropical Asia they are the dominant species among all the stored grain insects. The pulse beetle, *C.chinensis* Linn. (Coleoptera: Bruchidae), is a major pest of cowpeas, chick pea, lentils, green gram, and black gram. These all are economically important leguminous grains. (Raja *et al*. 2000) [40].

Life cycle and rearing of *C. chinensis:* Taxonomic placing of *C. chinensis* is under the class Insecta and a holometabolous coleopteran commonly known as Adzuki bean weevil/ pulse beetles/ Cowpea bruchid/Chinese bruchid. The life cycle of *C. chinensis* is very short and completed in around 29 -39 days in an optimal condition on different pulses. The life cycle of the *C. chinensis* is divided into different stages like eggs, larva and pupa and adults inhabiting the same place. (Chiranjeevi and Sudhakar, 1996) [10].

The rearing of *C.chinensis*: in laboratory conditions requires ideal abiotic factors such as temperature, humidity, food and other factors. The culture of pulse beetles was conducted on chickpeas at room temperature and the size of the jar was 25x15x10cm. The jar was filled with seeds and adults for oviposition. The jar was closed with a muslin cloth and tied up with rubber bands. These jars were kept in ambient condition at 23 degree centigrade and Relative humidity was 70-75 % in the laboratory. Pure culture was maintained during the experiment. (Jaiswal *et al*., 2019) [16]. Characters distinguishing *C.chinensis* (L.), *C. maculatus* (F.) and *C. analis* (F.) are described. It was found that *C. chinensis* was the weakest of the three species when all three developed in the same seed, but in mixed cultures *C. chinensis* nearly always prevailed eventually (Raina, 1970) [39].

Effects of plant properties on test insects: *C.chinensis* is a major pest, so to control this pest, many methods are applied such as biological, physical, mechanical, cultural, chemical methods etc. A study which revealed that larval *parasitoids Anisoptermalus calandrae* and *Lariophagus distinguendus Pteromalidae* were effective to reduce bruchid larval population comapire to predatory mites *Amblyseius swirskii* (Acari: Phytoseiidae) and *Blattisocius tarsalis* (Acari: Ascidae). (Garcia, 2020) [12]. The seeds extracted from Acorus calamus either in the solvent $CHCl_3$ and CH_3 OH were found to be effective (Chandel, 2017) [8]. The pesticidal efficacy of locally available leaves of botanicals like neem (*Azadirachta Indica*), datura (*Datura* and gave good LD50 values against *S. oryzae* and *C. chinensis* (Ali Hasan, 2019). Plant powder of the sweet flag (*Acorus Calamus* L.) was expressed to be the best in protecting pea seeds against *C. Chinensis* (Kaur, 2018) [24]. Aerial parts of *Cichorium intybus* (L.) gave highest repellents to early emerging adults of pulse beetles. The results revealed that repellent biopotential property is found in extracts of *stramonium*), marigold (*Tagetes erecta*) and garlic (*Allium sativum* L.) tablet powders was assessed on pulse beetle (*C.chinensis* L) through adult mortality and emergence, oviposition performance, seed damage, weight loss and germination of chickpea (*Cicer arietinum*). Results showed that datura leaf powder was affected by adult mortality, controlled oviposition and adult emergence of pulse beetle with lowest seed weight loss followed by neem. (Jahan *et al*.,2020) [15]. The efficacy of *Ocimum sanctum* L. against *C. chinensis* L. (Coleoptera: Bruchidae). Plants were extracted with petroleum ether, methanol, ethanol and water by using Soxhlet apparatus and tested against adults of *C. chinensis*. The leaf extract of *O.sanctum* was evaluated for their adult mortality, oviposition deterrence and adult emergence of *C. chinensis*. The results revealed that, among the solvent extracts petroleum ether was found to be significantly superior over rest of the solvent extracts, registered the highest percent of mortality (84%) at 5% conc. to assessing the effectiveness of four indigenous plants powder as protectant of stored chickpea seeds from the attack of pulse beetle (*C.chinensis* L.). (Murasing *et al*., 2017) [32]. Plant powders were prepared from neem leaf (*Azadirachta indica*), black pepper (*Piper nigrum* L.), clove (*Caryophyllus aromaticus* L.) and methi (*Trigonella foenum graecum* L.). In all these plants, Clove powder was found to be most effective in protecting chickpea seeds from the attack of pulse beetles. The result indicated that doses of clove powder could be used as a protector of chickpea seeds in storage. (Ahmed et al., 2016) [1]. The essential oils of Cone-bearing sage (*Meriandra strobilifera* B.), eucalyptus (*Eucalyptus sp*.), lemon grass (*Cymbopogon citratus* L.) and sweet flag (*Acorus calamus* L.) were evaluated against pulse beetle *C.chinensis*(L). They are effective against pulse beetles up to months of treatment where the sweet flag recorded the maximum mean mortality (Kumar *et al*., 2018) [20]. An experiment shows the significant effectiveness of three different edible oil - black seed (*Nigella sativa*) oil, sesame (*Sesamum indicum*) oil, soybean (*Glycene max*) oil, on green mung pulse, *VIgna radiata*. The study revealed the effect of these oils on ovicidal activity and oviposition. And black seed oil was more effective. (Akter *et al*., 2019) [2]. Some wooden plants (*Bursera delpechiana*, *Cinnamomum cassia*, *Aniba rosaeodora* and *Illicium verum*) oils of these plants from different parts and major components, trans-anethole, trans-cinnamaldehyde, linalool, linalyl acetate and methyl salicylate were tested on pulse beetle, Result shows that *I.verum* and *C. anisatum* two major components; trans-anethole and methyl salicylate were shown some effective results against pulse beetle and useful in storage condition. Found that essential oil from Artemisia Annua L. affected several enzymes of pulse beetles and played a role in delaying the generation. (Chiluwal *et al*.,

2017) [9]. *Ziziphus jujuba* plant is bark used to isolate Betulinic acid, a triterpenoid. Betulinic acid affected larval instars. Betulinic acid disrupted the cuticle as it affected the tanning of the cuticle and also influenced the larva-like over- aged larva in which the pupa is present in form of either partial or complete damage. The results demonstrated that Betulinic acid affect the larval and pupae structure. Betulinic acid causes disruption of larval structure and inhibition of growth which cause rapid halting of growth. Betulinic acid show more effect on the 4^{th},5^{th}, instar and pupae of *C.chinensis*. (Madhavi *et al*., 2019) [23]. In a laboratory seed treatment experiment on pigeonpea (*Cajanus cajan* (L.) Millsp.) cv. TS3R. was conducted with nano insecticides. Different recommended seed treatment insecticides viz, malathion, fenvalerate, emamectin benzoate, thiodicarb, sweet flag and neem seed kernel powder insecticides were synthesized to nano form using a high energy planetary ball mill. The Pigeonpea seeds were treated with different nano and found that it is very clear that nano-based insecticides have a significant (0.1 %) impact on the seed quality improvement (Raghu, 2017) [38].

Preparation of green nanoparticle: There are several methods to prepare green nanoparticles. Which is categorised into two main types: bottom -up method and top -down methods. Methods for preparing nanoparticles based on the material. In top-down methods there is need to break suitable bulk materials into smallest fine particles by size reducing various techniques like grinding, milling, sputtering, thermal and laser abreaction, etc. in the bottom top approach chemical and biological methods are used. (Mathur 2017) [26]. The major method to synthesize NPs are physical and chemical methods but the synthesis of nanoparticles with these methods are very costly, having dangerous toxic effects on the environment. This green and cleaned approach has been utilized as an alternative to other hazardous methods. It has proved that the green synthesis of nanoparticles with specific biological action is a less costly, less dangerous, less time-consuming method and needs less labour (Latif *et al*., 2019). Green synthesis of nanoparticles includes vitamins, algae, fungi, and plants are very popular nowadays. (Baruwati *et al*., 2009) [7].

Vitamins: Ascorbic acid forms uniform green nanoparticles in combination with Ag and Palladium to form nanospheres, nanowires etc. Vitamin B2 is used as the reducing agent for the synthesis of the nanowires and nanorods (Nadagouda *et al*., 2006) [33]

Bacteria and Actinomycetes- Silver nanoparticles of different compositions were successfully synthesized by *Pseudomonas stutzeri*, *Staphylococcus aureus* (Menon, 2017) [28].

Fungi: Fungi also have a high tolerance level, high binding capacity, and bioaccumulation capacity just like bacteria and they are easy to handle in the research field. Fungi can be used to synthesize a different type of nanoparticles (NPs) like *Verticillium* , *A. flavus* (Mukherjee, 2001) [31]. Silver nanoparticles biosynthesis from Ag nitrate solution by the fungus *Trichoderma viride*. (Fayaz, 2010) [11].

Plants and Phytochemicals - In an exploration of different antioxidant constituents of the extracts of blackberry, blueberry, turmeric, and pomegranate, the pomegranate was found to have the ability to produce most uniform size and shape of nanoparticles of Au and Ag in the range of 20-500 nm. These nanoparticles could be used for the management of cancer and antioxidant therapy. Biological nanoparticles from the peel of fruits of mango (*Mangifera indica*), Papaya (*Carica papaya*), and Pomegranate (*Punica granatum*) and vegetables, Bottle gourd (*Lagenaria siceraria*), Cucumber (*Cucumis sativus*) and Potato (*Solanum tuberosum*) were synthesized (Tripathi and Sirohi 2016) [48].

Characterization of nanoparticles: In the characterization of nanoparticles different type of parameters are important but mainly two parameters studied are the size and shape, Size and Shape are most important in characterisation of NPs. while other measurements are size distribution, degree of aggregation, surface charge, surface area, distribution and organic ligands present on the surface of the particles which may affect other properties and possible application of the nanoparticles. Besides, the crystal structure of the nanoparticles and their chemical composition is thoroughly investigated as the first step after nanoparticle synthesis (Mourdikoudis, 2018) [30]. Some metrics of the nanoparticles are as follows:

Size and dispersion: Particle size is an external feature and to measure a range of sizes of particles use dispersion. Nanoparticle's size must be less than 100 manometers. To measure size, physical properties are used such as velocity and electrical mobility and for nanoparticle size study with electron microscopy is a good option. FTIR spectroscopy is also a good option to identify the property of functional groups and identify which functional group is attached with nanoparticles; these groups might be responsible for stabilization and reduction of nanoparticles. Techniques such as electron low -pressure impactors, mobility analysers and cascade impactor are used for air-bone nanoparticles and techniques such as size exclusion chromatography, centrifugal sedimentation, atomic force microscopy, X-ray diffraction, atomic force microscopy, laser diffraction, field-flow fraction are used for dry materials, for size characterization techniques such as electron microscopy, force microscopy, and x ray-diffraction are popularly used (Stefaniak *et al*., 2017) [44].

Shape: A shape is a morphology of a particle includes cracks, ridges, or pores like surface topography and for size measurement of nanoparticle techniques like Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM) and Atomic Force Electron Microscopy (AFEM) are in use TEM is a very strong technique and useful technique with high-resolution power to study quality, shape, and size. Transmission electron

microscopy can provide enormous information which is related to materials. TEM provides information about materials morphology and also Provide information about microstructure, and chemical properties at nanoscales. (Sun *et al*., 2020) [45].
Chemical composition and crystal structure- The chemical composition nanoparticles means the arrangements of atomic elements and techniques such as X-ray fluorescence, X-ray diffraction, atomic absorption spectroscopy, X-ray absorption spectroscopy, nuclear magnetic resonance spectroscopy, SEM and TEM are used. Spectroscopy is the easiest technique to certify the formation of nanoparticles which shows some absorbance spectrum of the colloidal sample and is shown by the appearance of a clear area around the disc. (Anandallkshmi, 2015). Surface area-There are many techniques for surface chemistry but X-ray photoelectron and Auger electron spectroscopy are used mostly.
Solubility-In a solution solubility is a measurement of the degree to which material dissolved in solution and techniques like atomic absorption spectroscopy, inductively coupled plasma optical emission, inductively coupled plasma mass spectroscopy are the important techniques. Zeta potential is another technique which measures the difference of electrostatic potential between the dispersion medium and fluid. Surface charge of nanoparticles Zeta potential is the key parameter that controls electrostatic interactions in particle dispersions in a colloidal solution as measured by zeta potential. (Kaszubssa, 2010) [17].

Application of green nanoparticles on test insects: To study the effect of silver-green nanoparticles prepared by using curry leaves on *C. chinensis* (L.) to check the seed damage, seed weight loss and mortality in the insect of *C. chinensis*. The effect of AgNPs on pulse beetles, *C. chinensis, was* studied by rearing the insects, evaluating bioassay concentration of AgNPs against soybean seeds. The adult mortality was observed and found that AgNPs were effective for pulse beetles (Yerragopu *et al*., 2019) [52]. The experiment was checked for the insecticidal activity of two types of silica nanoparticles (normal silica and nano-silica particles) on *C. Chinensis*. These types of silica NPs were demonstrated for the insecticidal activity against *C. Chinensis*. It was found that with silica NPs with the increase in the concentration, exposure time increases the insect mortality and the value of LT50 is less for nano-silica and therefore nanoparticles of silica are more in use due to its biologically active nature. Nanoparticles of silica are found to be very useful against *C. Chinensis* is used in IPM for other stored grain pests. (Mesbah *et al*., 2017) [27]. The green nanoparticles of zinc oxide (ZnO) were used against various *Callosobruchus spp*. The ZnO nanoparticles were synthesized by using *Pongamia pinnata* leaf extract and the pesticidal effect showed that fecundity and hatchability of *C. malcatus* were affected by ZnO. Results showed that ZnO NPs significantly delay the larval- pupal development period and 100% mortality in *C. maculatus*. It was also observed that ZnO NPs affect various enzymes in the midgut of insects, decreasing enzymes like cysteine protease, glutathione, s-transferase, and etc. (Malaikozhundan *et al*., 2018) [25].

Toxicity analysis of green nanoparticles: Nanoparticles have been studied for causing cell toxicology, immunotoxicity, and genotoxicity. Many nanoparticles influence human life, especially the childhood stage. Nanotechnology is emerging as a major scientific and economic field but a variety of hazards present which affect human health and the environment. Nanoparticles have a very small size so that they may bind and transport toxic chemicals. There is an experiment which was conducted by researchers that showed some results about the toxicity of nanoparticles. The major distribution and high concentration of nano-TiO_2 in the environment have lifted worry about their potential toxic effects on crops. To analyse potential toxicity of nano-TiO_2 study the potential toxicity on hydroponically-cultured rice (*Oryza sativa* L.). Animal and human studies showed that potentially cultured rice (*Oryza sativa* L) showed remarkably disorganized antioxidant defence system due to exposure to nano TiO_2 and around 150 metabolites noticed decrease in normal metabolites concentration such as sucrose, isomaltose, glyoxylic acid and concentration of glucose. Basic energy-generating ways including the tricarboxylic acid cycle and the pentose phosphate pathways uplifted the biosynthesis formation of most of the well-known fatty acids, amino acids, and secondary metabolites which increased the crop quality. The result suggested that the metabolism of the rice plant is distinctly distributed after exposure to nano TiO_2 and has mixed effects on yield quality of rice. (Wu *et al*., 2017) [51]. In this experiment nanoparticles of TiO_2, Fe_2O_3 and CuO were selected for study and their long-term impact on the wheat grains. It was observed that CuO NPs have some kind of inhibitory effects on grains, TiO_2 NPs showed neutral results while $Fe2O_3$ NPs played a significant role. In wheat cysteine and tyrosine amino acids increased by exposure of Fe_2O_3 and TiO_2 nanoparticles which thereby increased amino acid nutrition of the protein in wheat but CuO NPs had negative effect by reducing amino acids like leucine, histidine, and threonine of wheat (Wang *et al*., 2019) [50]. A study revealed the effects of nano TiO_2 on cadmium toxicity in cowpea. The result showed that chlorophyll b was promoted due to nanoparticles and after spreading nano TiO_2 cadmium content was found to be less in roots, shoots, and grains. Additionally, nano TiO_2 promoted increased levels of Zn, Mn, and Co and stressed enzymatic activity in both roots and leaves. It was estimated that the daily intake quantity of cadmium recommended by WHO excessed by intake of nano TiO_2 treated plants. Nano TiO_2 interventions cannot reduce dietary health risk in seeds but no potential risk was observed in leaves and foliar application of nano TiO_2 pretends significant ameliorative potential for Cd toxicity in cowpea (Ogunkunle *et al*., 2020). Effects of nano TiO_2 in lentils were investigated for the effects on stress enzyme, vigour index, mitotic cell cycle, and seeds germination. Seeds germination results showed that a low concentration of nano TiO_2 promotes seeds germination, biomass, and vigour index but at higher concentration it reduces the photosynthetic pigments.

Nanoparticles formed Reactive Oxygen Species (ROS) which proved that nanoparticles increase stress enzyme and aberrant mitotic cell divisions and the results were reported to be dose-dependent (Shahwar *et al*., 2019) [42]. To evaluate the effects of nano TiO_2 and nano SiO_2 on *Vicia faba* L. which is a major source of carbohydrate the experiment was conducted and revealed that nano TiO_2 showed no effect on vigour index and root length. There was no significant difference reported for miotic analysis. Results showed that nano TiO_2 was more toxic compared to nano SiO_2 (Thabet *et al*., 2019) [46]. Nanomaterials of different substances and their toxicity against humans is a major concern at present. Scientists proved that if the size of nanoparticles is less than 10 nm then nanoparticles act like gas and easily enter the human body and easily disturb the normal physiological environment of the body. (Vishwakarma V. *et al*., 2010) [49]. To studied the effect of TiO_2 nanoparticles (NPs) with the help by using cDNA-amplified fragment length polymorphism (cDNA-AFLP) technique on cold tolerance (CT) in two variety chickpeas (*Cicer arietinum* L.). These two varieties have genotypes (Sel96Th11439, cold tolerant, and ILC533, cold susceptible). Study revealed that TiO2 NPs have significant importance for controlling the damages and enhancing the crop productivity in cold tolerance varieties and TiO2 NPs against CS-induced oxidative stress. (Amin *et al*., 2017). This study related the cyto-genotoxic effect of the synthesized titanium dioxide (TiO_2) NPs on plants. The seeds of *Vicia faba* were treated with different concentrations of TiO_2 nanoparticles. When seeds treated with higher concentrations of TiO_2 affect the meiotic activity such as stickiness and the separation of univalent and bivalent chromosomes at metaphase were noticed and causes a notable increase of chromosomal abnormalities in the reproductive parts of the plant. The present study emphasizes the synthesis of zinc oxide (ZnO) and magnesium oxide (MgO) nanoparticles (NPs) via a simple, eco-friendly and low-cost approach. (Kushwah *et al*., 2019). A study was considered to know the effects of Zn and Fe NPs with seed polymer coating at different concentrations in pigeonpea and found the beneficial effects of these nanoparticles. These NPs on higher concentration show some kind of inhibitory effects on seedling and germination and according to results Zn NPs can be used to pigeon pea seeds to enhance seed quality. (Korishettar. P *et al*., 2016) [19].

The Aloe *barbadensis Mill* (Aloe-Vera) leaf extract was utilized as a source of capping and reducing agents for the synthesis of ZnO and MgO NPs. Further, the impact of as-synthesized NPs on *Vigna radiata* (mung bean) and *Cajanus cajan* (red gram) seeds was evaluated. A notable gain in the germination rate of MgO and ZnO NPs treated seeds were detected. (Rani *et al*.,2020) [41]. A study on the growth of mung bean (*Vigna radiata* L.) plants with the help of four different metal nanoparticles (ZnO, SiO_2, Fe_2O_3 and MgO). MgO NP-treated roots show significant increased density and fibrosity of the roots due to formation of a unique globular structure on the surface of roots. The nanoparticles of MgO on mung beans can be a model system for investigating beneficial interactions of nanoparticles with plants. (Mahawar, 2018) [24]. This study signifies the positive impact of biogenic CuNPs. CuNPs have positive effect on plant growth and also increased the nutrition and enhanced seed germination so according to scientists CuNPs have abilities be used as a nano-fertilizer (Jahagirdar *et al*., 2020).

Scientist synthesized molybdenum nanoparticles by using fungus *Aspergillus tubingensis* TFR29. The result shows that nano Mo- which is synthesized with the fungal protein show positive impact on chickpea. The application of nano Mo on chickpea showed noteworthy changes in root area and root length. NPs of Mo also increased beneficial enzymes and microbial activities in the rhizosphere and also showed significant improvement on biomass and grain yield. There is a huge possibility of commercialization these NPs by the agricultural industry for the future purpose. (Thomas, 2017) [47].

Conclusion

India is a large country with a huge number of peoples. A large number of people are unnourished due to the bad quality of grains.

People faced vitamins, carbohydrates, and protein deficiencies due to the lower quality, less amount of grain production and poor storage facility. Many pests' damages stored grains of which C. Chinensis is a major pest. To control pests, we use integrated pest management, but somewhere these methods fail to control these beetles and show some toxic effects on human beings and the environment. Nowadays nanotechnology, which is a newly emerging branch has a lot of potential to solve many problems concerning humans. There is a way to control C. chinensis through green nanoparticles and some scientists are working in this direction but need more good research. Nanoparticles have some toxic effects on humans as well as the environment, so we need to create a balance between the reduction of the toxicity of nanoparticles and application of the green nanoparticles. Nanotechnology is working for improving agricultural productivity.

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