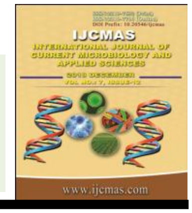
Int.J.Curr.Microbiol.App.Sci (2018) *7*(12): 1763-1770

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 7 Number 12 (2018)**
Journal homepage: http://www.ijcmas.com



Review Article https://doi.org/10.20546/ijcmas.2018.712.205

Nanotechnology in Agriculture: A Review

Himangini Joshi[1], Dharmendra Meena[2*] and Harish Kumar Tank[3]

[1]Department of Agronomy, [3]Department of Genetics and Plant Breeding, Rajasthan college of Agriculture, MPUAT- Udaipur, India
[2]Department of Agronomy, Agriculture Research Station, Keshwana, Jalore, Agriculture University, Jodhpur, India

**Corresponding author*

Keywords

Nanotechnology in agriculture, Pesticide, Fertilizers,

Article Info

Accepted:
15 November 2018
Available Online:
10 December 2018

A B S T R A C T

Agricultural production needs to maximize on sustainable basis to meet the continuously increasing food demand of mushrooming population. Producing more and quality food from diminishing land and water while sustaining agricultural resource base in an environment friendly manner is a formidable challenge of this century. Nanotechnology is a versatile field and has found application in almost all existing field of science. Nanotechnology research and development is directed towards understanding and creating improved materials, devices and systems that exploit nanoscale properties. It has great potential in biological applications such as nutrient delivery, biosensing and tissue engineering. Nanoparticles have potential applications in agriculture viz. detection of pollutants, plant diseases, pest and pathogens; controlled delivery of pesticide, fertilizers, nutrients and genetic material; and can act as nanoarchitects in formation and binding of soil structure. Nanotechnology has the ability to create a great revolution and transformation in food supply system in a global scope. Micronutrient fertilizers can increase the tolerance of plants to environmental stresses like drought and salinity. It has been postulated that nanoparticles are more effective, can be utilized in agriculture for the precision farming and enhance productivity of crops. Nanofertilizers or nano-encapsulated nutrients might have properties that are effective to crops, due to release the nutrients on-demand, controlled release of chemical fertilizers that regulate plant growth and enhanced target activity. Nanoparticles have unique physicochemical properties and key potential to boost the plant metabolism.

Introduction

Agricultural production needs to maximize on sustainable basis to meet the continuously increasing food demand of mushrooming population. Producing more and quality food from diminishing land and water while sustaining agricultural resource base in an environment friendly manner is a formidable challenge of this century (Zia *et al.,* 1991). Target oriented, cheaper and efficient technologies have to be employed for sustainable increase in production of wheat crop (Khot *et al.,* 2012). Nanotechnology is a versatile field and has found application in almost all existing field of science (Zheng *et* *al.*, 2005; Shah *et al.*, 2009; Zhang *et al.*, 2003). Nanotechnology research and development is directed towards understanding and creating improved materials, devices and systems that exploit nanoscale properties (Nanoscale science energy and technology subcommittee, 2007). It has great potential in biological applications such as nutrient delivery, biosensing and tissue engineering (Borm *et al.*, 2006; Oberdorster *et al.*, 2005). Nanoparticles have potential applications in agriculture viz. detection of pollutants, plant diseases, pest and pathogens; controlled delivery of pesticide, fertilizers, nutrients and genetic material; and can act as nanoarchitects in formation and binding of soil structure (Ghormade *et al.*, 2011).Nanotechnology has the ability to create a great revolution and transformation in food supply system in a global scope (Andreta, 2003; Sharma *et al.*, 2005). Micronutrient fertilizers can increase the tolerance of plants to environmental stresses like drought and salinity (Baybordi, 2006). It has been postulated that nanoparticles are more effective, can be utilized in agriculture for the precision farming and enhance productivity of crops (Reynolds, 2002; Raskar *et al.*, 2014). Nanofertilizers or nano-encapsulated nutrients might have properties that are effective to crops, due to release the nutrients on-demand, controlled release of chemical fertilizers that regulate plant growth and enhanced target activity (De Rosa *et al.*, 2010; Nair *et al.*, 2010). Nanoparticles have unique physicochemical properties and key potential to boost the plant metabolism (Giraldo *et al.*, 2014). Efficiency of nanoparticles is determined by their chemical composition, size, surface covering, reactivity and most importantly the dose at which they are effective (Khodakovskaya *et al.*, 2012).

Synthesis of nanoparticles

Different protocols have been designed for synthesis of nanoparticles but three major methods are physical, chemical and biological method. The physical method (top-down approach) includes methods like diffusion, irradiation and thermal decomposition *etc* (Reddy *et al.*, 2006). Moderate reaction conditions and convenient synthetic manipulation have rendered chemical methods an attractive option for accessing nanoparticles (Bhattacharjee *et al.*, 2011). Both microorganisms and plants have long demonstrated the ability to absorb and accumulate inorganic metallic ions from their surrounding environment (Shankar *et al.*, 2004). These attractive properties make many biological entities efficient biological factories capable of significantly reducing environmental pollution, recycling of agricultural waste and reclaiming metals from industrial waste (Gowramma *et al.*, 2015 and Makarov et al 2014). Furthermore, plant based biosynthesis is a relatively straightforward process that can be easily scaled up for large scale production of nanoparticles (Mittal *et al.*, 2013). Bacteria synthesis nanoparticles through various biological strategies such as redox state changers, efflux systems, intracellular precipitation and accumulation of metals or by extracellular formation of complexes (Dhillon *et al.*, 2012).

Stenotrophomonas species of fungi have the potential to be used as an efficient candidate for plant growth promotion (Suckstorff *et al.*, 2003 and Schmidt *et al.*, 2012), bioremediation (Binks *et al.*, 1995; Boonchan *et al.*, 1998), elemental cycle (Ikemoto *et al.*, 1980) and biocontrol phytopathogens (Berg *et al.*, 1994; Kobayashi *et al.*, 1995; Nakayama *et al.*, 1999 and Dunne *et al.*, 2000). In addition, they also produce antibiotics, volatile compounds and fungal cell wall degrading enzymes indicating their contribution to biocontrol activity against several soil-born plant pathogens (Ryan *et al.*, 2009 and Zhang *et al.*, 2001). They also revealed that S. maltophilia act as a target board for antifungal activity and high degree of salt tolerance due to presence of glucosyl glycerol osmolyte (Hagemann *et al.,* 2008). Extracellular biosynthesis of AgNPs is via extracellular enzymes such as nitrate reductase enzyme or other active biomolecules (Sadowski *et al.,* 2008 and Kalimuthu *et al.,* 2008) that help in transferring the electron to silver ions and reduction of AgNPs occurs (Duran *et al.,* 2005). Moreover, biosynthesized nanoparticles being equally competent to those nanoparticles generated by physical and chemical methods provide safe and environment friendly approach for plant nutrition and disease management (Mishra *et al.,* 2015; Krishnaraj *et al.,* 2012 and Gopinath *et al.,* 2013). Phenolic compound that present in plant extract behave as a hydrogen donators, reducing agents, singlet oxygen quenchers and also metal chelating agent (Ravindra *et al.,* 2011).

Nanofertilizers and their smart delivery

Various studies had been carried out to understand the effect of nanoparticles on growth of plants. For example *Lu et al.,* studied the effect of mixture of nano-SiO_2 and nano-TiO_2 on soybean seeds and found that these mixture of nanoparticles increases germination and growth of soybean by improving nitrate reductase activity of soybean. Hong et al and Yang *et al.,* reported that at appropriate concentration of nano-TiO_2 was enables to promote photosynthesis, nitrogen metabolism and enhance growth of spinach. Nano sized zinc has a major role in cell defenses against reactive oxygen species and as a protective factor against several chemical compositions of oxidation such as membrane lipids, protein, chlorophyll and enzymes (Carkmak, 2000) and also play a key role in controlling the production and toxicity of free radicals that can damage membrane lipids and sulphydryl groups (Alloway, 2004) by supplying more effectively at site of action. Similarly, Prasad reported that, groundnut seeds treated with nanoscale zinc oxide particles with a concentration of 1000 ppm have shown significantly increment in germination, shoot length, root length and vigor index over the control samples. Haghighi *et al.,* (2012), in tomato and Siddiqui *et al.,* (2014) in squash reported that nano-SiO2 improved seed germination and stimulated the antioxidant system under NaCl stress. Exogenous application of nano-SiO_2 and nano-TiO_2 increases seed germination of soybean by enhancing nitrate reductase (Lu *et al.,* 2002) and also by promoting seeds ability to absorb and utilize water and nutrient efficiency (Zheng *et al.,* 2005). It enhances the plant growth and development by increasing gas exchange and chlorophyll fluorescence parameters, such as net photosynthetic rate, transpiration rate, stomatal conductance, PS-II potential activity, effective photochemical efficiency, actual photochemical efficiency, electron transport rate and photochemical quench (Siddiqui *et al.,* 2014; Xie *et al.,* 2011). Gao *et al.,* (2006) tested that spinaciaoleracia treated with nano-anatseTiO2 induced 2.67 times more activity of rubisco carboxylase than that of control. Nano blended organic iron chelated fertilizer increased 3.5 times more photosynthesis, 70% more leaf area and 20-200% production by increasing nutrient use efficiency (Moghadam *et al.,* 2012). Study of Hafeez et al., (2015) revealed that Cu-nanoparticles have the potential to enhance growth and yield of wheat but their effect is concentration dependent. Soaking of cotton seeds in silver nanoparticles produced favorable effects and reduced the amount of fertilizers applied by half (Vakhrouchev *et al.,* 2007). Raskar and Laware (2014) found that optimum concentration in necessary for yield enhancement so quantification is important in case of nanoparticles. The application of slow or controlled release fertilizer coated and felted by nanomaterials were reported that improve grain yield along with an increase in protein content and a decrease in soluble sugar content in wheat (Nangula *et al.,* 2010; Ding *et al.,* 2009).

Characterization of nanoparticles

The optical characterization of biosynthesized nanoparticles can be done by Uv-visible spectroscopy due to surface Plasmon resonance property (Sastry *et al.,* 1997 and Jain *et al.,* 2008). Structural analysis or crystallinity of nanopaticles confirmed by X-ray diffraction (Dorofeev *et al.,* 2012). The morphological investigation was carried out by using SEM and TEM analysis, where as possible stabilizing or reducing agent can be recorded from FTIR analysis (Kasthuri *et al.,* 2009).

Drought resistance phenomenon

Water deficit can cause negative reversible and irreversible physiological changes of plant state in the vegetative and reproductive periods of plant development (Szegletes *et al.,* 2000; Zhu *et al.,* 2002; Lawlor *et al.,* 2002 and Yordanov *et al.,* 2000). At the same time, the cost of fertilizers and irrigation increase in connection with the rising cost of primary resource every year. In this regard, to address the issue of increase of productivity and sustainable environmental management of agriculture, new environment friendly approaches that do not require large expenditures are needed (Kang *et al.,* 2009). The relative cheapness of production of nanoparticles can solve this issue (Narayanan *et al.,* 2012) as well as the low consumption of these preparations upto the crop area and low level of phytotoxicity (Batsmanova *et al.,* 2013). Under drought condition the level of lipid peroxidation was evaluated by accumulation of thiobarbituric acid reactive substances (TBARS) (Andreyeva *et al.,* 1988). After presowing treatment with Cu-Zn nanoparticles seeds associated with increased activity of antioxidative enzymes SOD and CAT and decrease level of TBARS, made wheat plants more resistant to drought (Taran *et al.,* 2017). Under stress, nano-SiO_2 improves leaf fresh and dry weight, chlorophyll content and proline accumulation. These nanoparticles can be transported through epidermal cells, or owing to their small size, they can contact with high molecular compounds of cells. At the same time it has proved possible the intercellular transport through plasmadesmata (Zhai *et al.,* 2014). Furthermore, the inclusion of nanoparticles in photosynthetic metabolism was conformed.

In particular, gold nanoparticles can be an artificial electron acceptor and a donor in photosynthesis (Barazzouk *et al.,* 2005). The enhancement of the chlorophyll a to chlorophyll b ratio under nanoparticle action may indicate a change in the stoichiometry of light-harvesting complexes of photosystem I and II (Green *et al.,* 1996). After drought action nanoparticles demonstrated the well adaptation mechanism (Havaux *et al.,* 1999). Different forms of zinc oxide nanoparticles were increased leaf area of maize plant by the induction of IAA under stressed condition (Taheri *et al.,* 2015).

Nanoscience is leading to the development of a range of inexpensive nanotech applications for enhanced plant growth. Nanoparticles requires more comprehensive experimentation to determine the best concentration, mode and time of application in addition to exploring underlying physiological mechanism responsible for enhanced growth and yield.

References

Alloway, D. 2008. Zinc in soils and crop nutrition published by IZA and IFA Brussels, Belgium and Paris, France, 135p.

Andreyeva. L. I., Kozhemyakin, L. A., Kishkun, A. A. 1988. Modification of method of lipid peroxides determination in the test with thiobarbituric acid. *Lab Work* 11:41–43.

Barazzouk, S., Kamat, P. V., Hotchandani, S. 2005. Photoinduced electron transfer between chlorophyll a and gold nanoparticles. *J PhysChem B.* 109(2):716–723.

Batsmanova, L. M., Gonchar, L. M., Taran, N. Y., Okanenko, A. A. 2013. Using a colloidal solution of metal nanoparticles as micronutrient fertilizer for cereals. *Proc. Int. Conf. Nanomaterials Appl. Properties*, 2(4).

Baybordi, A. 2006. Zinc in soils and crop nutrition. *Parivar press,* pp. 179.

Berg, G., Knaape, C., Ballin, G. and Seidel, D. 1994. Biological control of *Verticillium dahlia* KLEB by naturally occurring rhizosphere bacteria. *Arch Phytopathol Dis Prot*29, 249–262.

Bhattacharjee, C. R., Pukayastha, D. D., Bhattacharjee, S. and Nath, A. Homogeneous chemical precipitation route to ZnO nanosphericals. ISSN 7 (2011): PP. 122-127.

Binks, P. R., Nicklin, S. and Bruce, N. C. 1995.Degradation of RDX by *Stenotrophomonasmaltophilia*PB1.*Appl Environ Microbiol*61, 1813–1822.

Boonchan, S., Britz, M. L. and Stanley, G. A. 1998. Surfactant enhanced biodegradation of high molecular weight polycyclic aromatic hydrocarbons by *Stenotrophomonas maltophilia*. *BiotechnolBioeng*59, 482–494.

Carkmak, I. 2000. Possible roles of zinc in protecting plant cells from damage by reactive oxygen species. *New Phytol*, 146: 185-205.

Ding, Y. and Wu, Q. 2005. Preparation of seed coating agent containing nanoparticles with low toxicity and high efficiency. *Chinese patent.*

Dorofeev, G. A., Streletskii, A. N., Povstugar, I. V., Protasov, A. V. and Elsukov, E. P. 2012. Determination of nanoparticle sizes by X-ray diffraction. *Colloid J* 74(6), 675–685.

Dunne, C., Moenne-Loccoz, Y., de Bruijn, F. J. and O'Gara, F. 2000. Overproduction of an inducible extracellular serine protease improves biological control of *Pythium ultimum* by *Stenotrophomonas maltophilia* strain W81. *Microbiology* 146, 2069–2078.

Duran, N., Marcato, P. D., Alves, O. L., De Souza, G. and Esposito, E. 2005. Mechanistic aspects of biosynthesis of silver nanoparticles by several *Fusarium oxysporum* strains. *J Nanobiotechnol.,* 3(8), 1–7.

Gao, F., Hong, F., Liu, C., Zheng, L., Su, M., Wu, X., Yang, F., Wu, C, Yang, O. 2006. Mechanism of nano-anatase TiO2 on promoting photosynthetic carbon reaction of spinach. *Biological trace element research*, 111, 239-253.

Gopinath, V. and Velusamy, P. 2013. Extracellular biosynthesis of silver nanoparticles using *Bacillus* sp. GP-23 and evaluation of their antifungal activity towards *Fusarium oxysporum*. *Spectrochim, Acta A Mol. Biomol. Spectrosc.,* 106, 170–174.

Gowramma, B., Keerthi, U., Mokula, R., Rao, D. M. Biogenic silver nanoparticles production and characterization from native stain of *Corynebacterium* species and its antimicrobial activity. Biotech 2015, 5, 195-201.

Green, B. R., Durnford, D. G. 1996. The chlorophyll-carotenoid proteins of oxygenic photosynthesis. Annu Rev Plant Physiol Plant Mol Biol. 47:685–714.

Hagemann, M. 2008. The plant-associated bacterium *Stenotrophomonas rhizophila* expresses a new enzyme for the synthesis of the compatible solute glucosylglycerol. *J Bacteriol*190(17), 5898–5906.

Havaux, M., Niyogi, K. K. 1999. The violaxanthin cycle protects plants from photooxidative damage by more than one mechanism. *Proc. Natl. Acad. Sci. USA*, 96:8762–8767.

Hong, F., Yang, F., Liu, C. 2005.Influences of nano—TiO2 on the chloroplast aging of spinach under light. *Biological trace element research*, 104(3): 249-260.

Hong, F., Zhou, J., Liu, C. Effect of nano-TiO2 on photochemical reaction of chloroplasts of spinach. 2005. *Biological trace element research*, 105(1-3): 269-279.

Ikemoto, S., Suzuki, K., Kaneko, T. and Komagata, K. 1980.Characterization of strains of *Pseudomonas maltophilia* which do not require methionine. *Int J SystBacteriol*.30, 437–447.

Jain, P. K., Huang, X., El-Sayed, I. H. and El-Sayed, M. A. 2008. Noble metals on the nanoscale: optical and photothermal properties and some applications in imaging, sensing, biology, and medicine. *AccChem Res.* 41(12), 1578–1586.

Kalimuthu, K., Suresh Babu, R., Venkataraman, D., Bilal, M. &Gurunathan, S. 2008. Biosynthesis of silver nanocrystals by *Bacillus licheniformis*. *Colloids Surf B Biointerfaces*, 65, 150–153.

Kang, Y., Khan, S., Ma, X. 2009. Climate change impacts on crop yield, crop water productivity and food security. *Prog Nat Sci.*, 19: 1665–1674.

Kasthuri, J., Veerapandian, S. and Rajendiran, N. 2009. Biological synthesis of silver and gold nanoparticles using apiin as reducing agent. *Colloids Surf B Biointerfaces*, 68(1), 55–60.

Khot, L. R., Sankaran, S., Maja, J. M., Ehsani, R., Schuster, W. 2012. Applications of nanomaterials in agricultural production and crop protection: A review. *Crop protection*, 35: 64-70.

Kobayashi, D. Y., Gugliemoni, M. and Clarke, B. B. 1995. Isolation of chitinolytic bacteria *Xanthomonas maltophilia* and *Serratia marcescens*as biological control agents for summer patch disease of turf grass. *Soil Biol. Biochem.*, 27, 1479–1487.

Krishnaraj, C., Ramachandran, R., Mohan, K. and Kalaichelvan, P. T. 2012. Optimization for rapid synthesis of silver nanoparticles and its effect on phytopathogenic fungi. *Spectrochim Acta A Mol. Biomol. Spectrosc.*, 93, 95–99.

Laware, S. L. and Raskar, S. V. 2014. Influence of zinc oxide nanoparticles on growth, flowering and seed productivity in onion. *International journal of current microbial app sci*. 3:874-881.

Lawlor, D. W., Cornic G 2002. Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. *Plant Cell Environ* 25:275–294.

Lu, C. M., Zhang, C. Y., Wen, J. Q. and Tao, M. X. Research on the effect of nanometer materials on germination and growth enhancement of Glycine max and its mechanism. 2002. *Soybean science*, 21(3): 68-172.

Makarov, V. V., Love, A. J., Sinitsyna, O. V., Makarova, S. S., Yaminsky, I. V., Taliansky, M. E., Kalinina, N. O. Green nanotechnologies: synthesis of metal nanoparticles using plants. *Acta Naturae*, 2014, 6, 35-44.

Mishra, S. and Singh, H. B. (2015b).Silver nanoparticles mediated altered gene expression of melanin biosynthesis genes in *Bipolaris sorokiniana*. *Microbiol Res* 172, 16–18.

Moghadam, A., Vattani, H., Beghvaei, N., Keshavarz, N. 2012. Effect of different levels of fertilizer nano-iron chelates on growth and yield characteristics of two varieties of spinach. *Research journal of applied sciences, engineering and technology* 4 (12), 4813-4818.

Nakayama, T., Homma, Y., Hashidoko, Y., Mitzutani, J. and Tahara, S. 1999. Possible role of Xanthobaccins produced by *Stenotrophomonas* sp. strain SB-K88 in suppression of sugar beet damping-off disease. *Appl Environ Microbiol*65, 4334–4339.

Nangula, P.U., Oelofse, A., Duodu, K.G., Bester, M. J. and Faber, M. 2010. Nutritional value of leafy vegetables of sub-saharan Africa and their potential contributing to human health: A review, *journal of food composition and analysis*. 23: 499-509.

Narayanan, S., Sathy, B. N., Mony, U., Koyakutty, M., Nair, S. V., Menon, D. 2012.Biocompatible magnetite/gold nanohybrid contrast agents via green chemistry for MRI and CT bioimaging. *ACS Appl Mater Interfaces*. 4:251–260.

Prasad, T., Sudhakar, P., Sreenivasulu, Y., Latha, P. and Munaswamy, V. 2012. Effect of nanoscale zinc oxide particles on the germination, growth and yield of peanut. *Journal of plant nutrition*, 35: 905-927.

Raskar, S. V. and Laware, S. L. 2014.Effect of zinc oxide nanoparticles on cytology and seed germination in onion. *International journal of current microbial app sci.* 3: 467-473.

Reddy, V. R. 2006: Gold nanoparticles: synthesis and applications. *Synlett*, 11pp.1791-1792.

Reynolds, G. H. 2002. Forward to the future nanotechnology and regulatory policy. *Pacific research institute*, 24: 1-23.

Ryan, R. P. 2009.The versatility and adaptation of bacteria from the genus *Stenotrophomonas*. *Nat Rev* Microbiol 7(7), 514–525.

Sadowski, Z., Maliszewska, I. H., Grochowalska, B., Polowczyk, I. and Ozlecki, T. 2008.Synthesis of silver nanoparticles using microorganisms. *Mater Sci-Poland*, 26, 419–424 .

Sastry, M., Mayya, K. S. and Bandyopadhyay, K. 1997. pH Dependent changes in the optical properties of carboxylic acid derivatized silver colloidal particles. *Colloids Surf A Physicochem Eng Asp* 127, 221–228.

Schmidt, C. S., Alavi, M., Cardinale, M., Muller, H. and Berg, G. 2012. *Stenotrophomonasrhizophila*DSM144 05T promotes plant growth probably by altering fungal communities in the rhizosphere. *BiolFertil Soils* 48, 947–960.

Shah, V. and Belozerova, I. 2009.Influence of metal nanoparticles on the soil microbial community and germination of lettuce seeds, water, air and soil pollution, 197 (1-4), 143-148.

Suckstorff, I. and Berg, G. 2003. Evidence for dose-dependent effects on plant growth by *Stenotrophomonas* strains from different origin. *J Appl. Microbiol* 95, 656–663.

Szegletes, Z. S., Erdei, L., Tari, I., Cseuz, L .2000. Accumulation of osmoprotectants in wheat varieties of different drought tolerance. *Cereal Res Commun.* 28:403–410.

Taheri, M., Qarache, H. A., Qarache, A. A., Yoosefi, M. 2015. The effects of zinc-oxide nanoparticles on growth parameters of corn (SC704).*STEM Fellowship* J. 1(2):17–20.

Vakhrouchev, A. V., Golubchikov, V. B. 2007. Numerical investigation of the dynamics of nanoparticle system in biological processes of plant nutrition. *Journal of physics*: *Conference series*, 61(1): 31-35.

Yang, F. Hong, W. and You, W. 2006.Influences of nano—anatase TiO2 on the nitrogen metabolism of growing spinach. *Biological trace element research*, 110(2): 179-190.

Yordanov, I., Velikova, V., Tsonev, T. 2000.Plant responses to drought, acclimation, and stress tolerance. *Photosynthetica* 38:171–186.

Zhai, G., Walters, K.S., Peate, D. W., Alvarez, P. J. J., Schnoor, J. L .2014. Transport of gold nanoparticles through plasmodesmata and precipitation of gold ions in woody poplar. *Environ Sci Technol Lett.* 1(2):146–151.

Zhang, W. X. Nanoscale iron particles for environmental remediation: an overview. 2003. *Journal of nanoparticle research*, 5(3-4): 323-332.

Zhang, Z., Yuen, G. Y., Sarath, G. &Penheiter, A. R. 2001.Chitinases from the plant disease biocontrol agent, *Stenotrophomonas maltophilia* C3. *Phytopathology* 91, 204–211.

Zheng, L. F., Hong, Lu, S. and Liu, C. Effect of nano-TiO2 on strength of naturally aged seeds and growth of spinach. 2005. *Biological trace element research*, 104(1), 83-91.

Zhu, J. K. 2002. Salt and drought stress signal transduction in plants. *Ann Rev Plant Biol*. 53:247–273.

How to cite this article:

Himangini Joshi, Dharmendra Meena and Harish Kumar Tank. 2018. Nanotechnology in Agriculture: A Review. *Int.J.Curr.Microbiol.App.Sci.* 7(12): 1763-1770.
doi: https://doi.org/10.20546/ijcmas.2018.712.205