A SEMINAR PAPER ON

Agri Nanotechniques for Increasing Plant Nutrients Availability

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ABSTRACT

Nanotechnology is the technique that enhances the precision agriculture and prevents the losses of applied nutrients. Thus it maintains the soil health that helps in sustainable agriculture. The nano techniques have the attributes that ensure more water holding capacity, slow release of nutrients which prevent nutrient losses. But in conventional fertilizer we don`t get much advantage as the nano fertilizers. The results show that nano fertilizer in low concentration helps to increase the different nutrients use efficiency and improve the growth, development and reproduction of crop plants. We come to know different nano techniques which are chitosan, silver nano particle (SNP). As the best nano NPK 10 ppm chitosan which is low in concentration is best for the farmers if they want to utilize it. So, we should practice the application of different nano techniques for our sustainable agriculture.

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CHAPTER I

INTRODUCTION

"Nanotechnology" was defined by Norio Taniguchi of the Tokyo Science University at first in 1974. Nanotechnique, abbreviated to "Nanotech", is the study of manipulating particle on an atomic and molecule level. A nano material (nano powder or nano cluster or nanocrystal) is a little particle with one dimensional not more than 10^2 nm. 1 Nanometer = 10^{-9} m = 1 billion of a meter (Qureshi *et al.*, 2018). Nanofertilizers are the nanoparticles-oriented fertilizers, where delivery of the nutrients is made precisely for maximum plant growth by stimulating the plant capability, have higher use efficiency, making available the plant unavailable nutrients in the rhizosphere, and will be delivered on real time basis into the rhizosphere or can be made utilized to plant by foliar spray (Tarafdar *et al.*, 2015**)**. Agricultural cropping pattern using huge amount of fertilizers, pesticides to achieve more production per unit area but using more doses than optimum of these fertilizers causes several problems like environment pollution and low input use efficiency and reduce quality of food material etc. Despite these problems there is also challenge to feed the growing population of the world (Ghaly, 2009). Therefore, in near future, there is need to increase nutritive agricultural products enhanced with protein and other essential nutrient for human and animal consumption that is why emphasis should be given on production of high quality food with the required level of nutrients and proteins (Ghaly, 2009; Pijls *et al.*, 2009). Natural nanoparticles (< 100 nm) occur widely in the environment, especially in soils (Calabi-Floody *et al.*, 2011; Monreal *et al.*, 2010; Pan and Xing, 2012). It has been suggested that nano clays could be effective in increasing soil water, carbon (C) and nutrient storage capacities, due to their large surface area (Khedr *et al.*, 2006;). The use of nano materials with their unique electronic, kinetic, magnetic and optical properties may enhance C stabilization in soil (Monreal *et al.*, 2010; Floody *et al.*, 2009). Agriculture is an economic activity in which nanotechnology applications are emerging (Scott and Chen, 2013) and as a result, it represents a new emission source of NPs and NMs into the environment and food. The safe and sustainable application of nanotechnology in agriculture requires standards for the application of NMs in crop plants as well as the soil and water used for agricultural activity (OECD, 2014). It is estimated that up to 10 000 tons of TiO_2 and up to 1000 tons of CeO_2, FeOx, AlOx and ZnO (Piccinno *et al.*, 2012) are being manufactured per year, which is expected to increase, resulting in a greater discharge of NPs and NMs to ecosystems (Gottschalk and Nowack, 2011) from point sources that contaminate soil and water or diffuse sources such as those from fuel additives (Cassee *et al*., 2012) or biosolids (Colman *et al*., 2013).The impact of the contribution of NPs and synthetic NMs on human health and on the functioning of complex systems such as soils or ecosystems remains difficult to calculate (Cornelis *et al*., 2014). Some estimates place the emission of NPs to the environment far below the limit of concern (Johnson and Park, 2012) but in fact it is not really known what will happen to all the emissions and how they will interact with each other and with environmental factors and living organisms in the long term (Cassee *et al*., 2011). Silver nano particles (SNPs) are marvelous material having antibacterial, antifungal properties and are used in agriculture such as food security, food packaging and pathogen identification (Quardos and Mar, 2010). It has great influence on plant growth and development such as germination, root-shoot ratio, seedling growth, root growth, root elongation, and senescence inhibition (Ma *et al*., 2010; Shah and Belozerova, 2009). Nano bentonite and nano carbon enveloped with nitrogen fertilizer enhanced the adsorption and transportation of N, P, K to seed and yield of rice dramatically (Wang *et al*., 2011). Use of mineral fertilizers has played an important role for the survival of mankind in terms of increasing yield (Smil, 2001; Stewart *et al*., 2005), maintaining soil productivity and fertility (Balmford *et al*., 2005). Chitosan is a natural pure polymer gained from deacetylation of chitin, that may be obtained from crustaceans, insects, fungi, etc. (Boonsongrit *et al*., 2006). Great impact of chitosan isnoticed on the growth of roots, shoots and leaves of plants for example gerbera (Wanichpongpan *et al*., 2001) and different other crops (Chibu and Shibayama, 2001). After chitosan application showed the yield rose of approximately 17% in two out of three tomato trials, no significant difference in yield of treatments in the carrot or weight of individual carrots was found in average (Walker *et al*., 2004). Among all of the slow release fertilizers (SRF) are synthesized compounds that are water soluble or are slowly broken down by microbial action (Sartain *et al*., 2004). On the other hand, controlled-release fertilizers (CRF) are soluble fertilizers enveloped with materials that limit exposure of the water soluble material and/or release of the resulting nutrient solution by diffusion and osmosis. Thus, the rate of nutrient salvation from SRF is related to water solubility, microbiological degradation, and chemical degradation (Morgan *et al*., 2009) demonstrated that NO_3^- -N leaching was minimized by applying SRF envelpoed with nano-materials in a rotation of wheat-maize (Liu *et al*., 2009). This nano size particles tend to aggregate and aggregate with organic colloids (including dissolved organic matter, polysaccharides, humic materials, and peptidoglycan) and it is suggested that NPs, with their huge surface to volume ratio, could be effective in carbon sequestration in different storage (Khedr *et al*., 2006). Fertilizers become partially available to plants caused by several prohibiting factors like leaching, infiltiration, erosion, photolytic degradation, hydrolysis, and decomposition. So, the lessening of nutrient losses in fertilization and increase in crop yield may be made possible by the adaptation of geniune applications of nano materials present in soil (Siddiqui *et al*., 2015).

Objectives

To know the contribution of nano techniques in precise nutrient management,

To highlight the causes of nanofertilizer use efficiency, and

To be familiar with some nano techniques associated with the plant nutrient availability.

CHAPTER II

MATERIALS & METHODS

This paper is exclusively a review paper so that all of the information has been collected from the secondary sources. During the preparation of the review paper, I went through various relevant books, journals publications etc. The related topics have been reviewed with the help of library facilities of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) and internet browsing. After collecting all the available information, it has been presented as per the objectives of this paper.

CHAPTER III

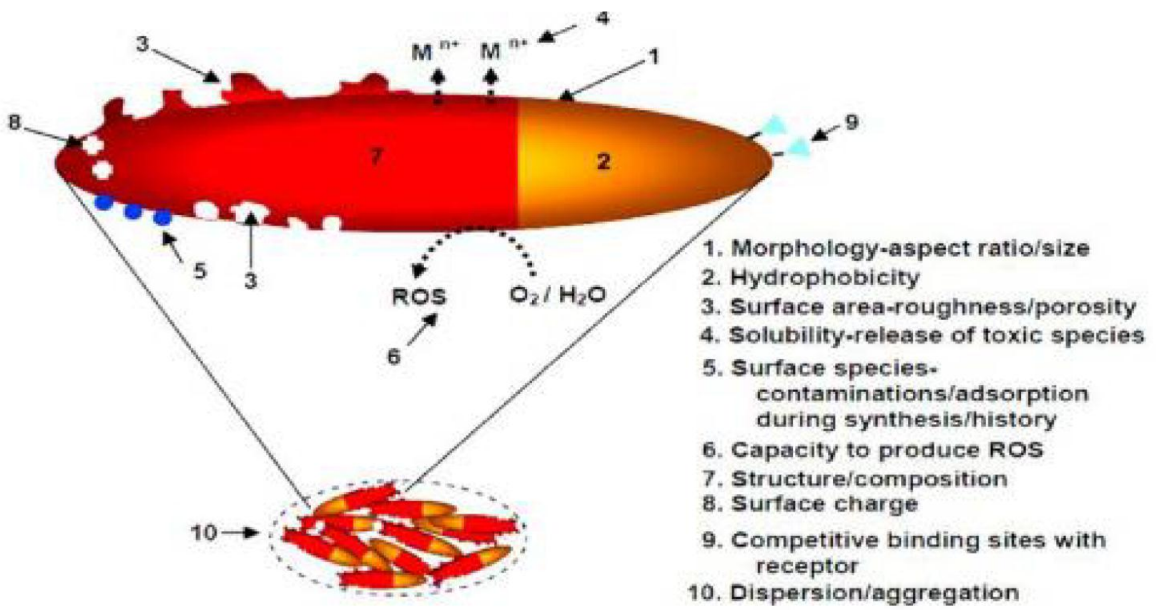
REVIEW OF FINDINGS

Properties of Nano particles

Two principal causes cause the properties of nanomaterials to differ significantly from other materials. They are given below:

i) Increased relative surface area and

ii) Quantum effects



(Somasundaran *et al.*, 2010)

Figure 1: The properties of nanoparticles

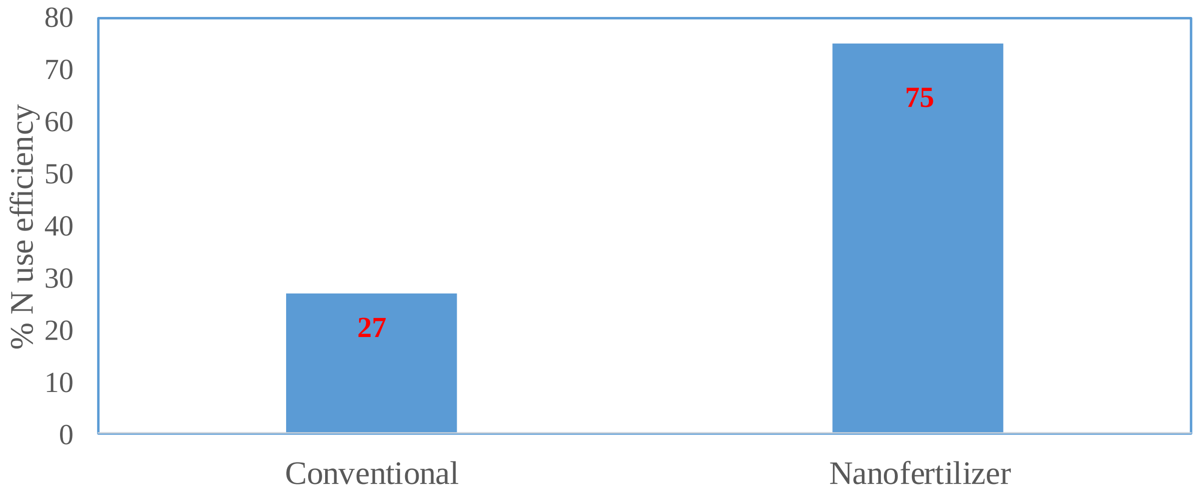
Morphology hydrophobicity or drought tolarance , size, solubility releasing of harmful species, roughness, surface species impurity or adsorption, during synthesis or history, Reactive oxygen species (ROS) O_2 or water, producing capacity of ROS, structure or composition, receptor and dispersion/aggregation are the vital properties of nanoparticles (Somasundaran *et al.*, 2010).

Table1: Comparison of nanotechnology-based formulations and conventional fertilizers applications

Properties	Nano-fertilizers-enabled technologies	Conventional technology
Solubility and Nano-sized formulation of mineral micronutrients	Nano-sized formulation of mineral micronutrients may improve solubility and dispersion of insoluble nutrients in soil reduce soil absorption and fixation and increase the bioavailability	Less bioavailability to plants due to particle size and less solubility
Nutrient uptake efficiency	Nano structured formulation might increase fertilizer efficiency and uptake ratio of the soil nutrients in crop production and save fertilizer	Bulk composite is not available for root resources and decrease efficiency
Controlled release modes	Both release rate and release pattern of nutrients for water soluble fertilizers might be precisely controlled through encapsulation in envelope forms of semi permeable membranes coated by resin-polymer, waxes, and sulfur	Excess release of fertilizers may produce toxicity and destroy ecological balance of soil
Effective duration of nutrient release	Nano structured formulation can extend effective duration of nutrient of fertilizer into the soil	Used by the plants at the time of delivery, the rest is converted into insoluble salts in the soil
Loss rate of fertilizer nutrients	Nano structured formulation can reduce loss rate of fertilizer into soil by leaching	High loss rate by leaching, run off, and drift

Source: (Cui *et al.*, 2010)

To clarify the advantages of nano technique fertilizer over conventional fertilizer nano nitrogen fertilizer shows a tremendous result over traditional nitrogen. The nano clay is fully filled with different nutrients like N, P and K release slowly due interaction of those nutrients with clay particles. Nano fertilizers are capable of releasing Nitrate from urea fertilizer 50 days slower compare to conventional nitrogen (Subramanian and Rahale, 2000)

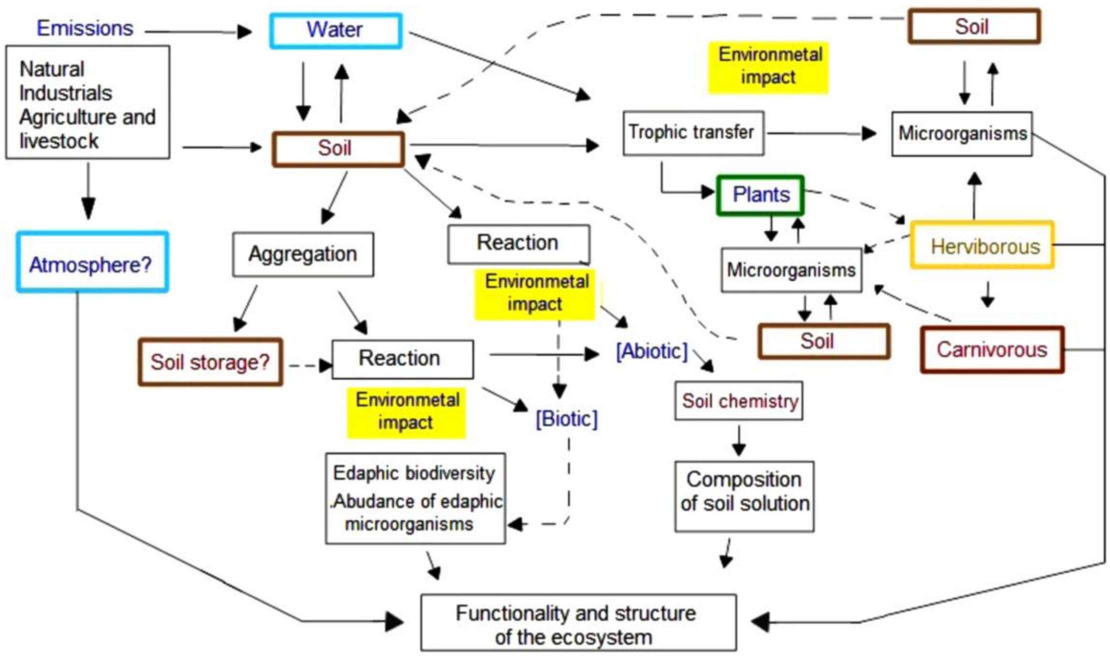


(Source: Jahnavi *et al.*, 2015)

Figure 2: Nitrogen use efficiency (%) of conventional and nano-fertilizer

In figure 2 we can see that % N use efficiency is 27% only in case of conventional N fertilizer. Whereas % N use efficiency is 75% in case of nanofertilizer. So, this indicates that nanofertilizer % N use efficiency is 3 times higher than conventional N fertilizer (Jahnavi *et al.*, 2015).

Flow of nanoparticles and nano materials in ecosystem



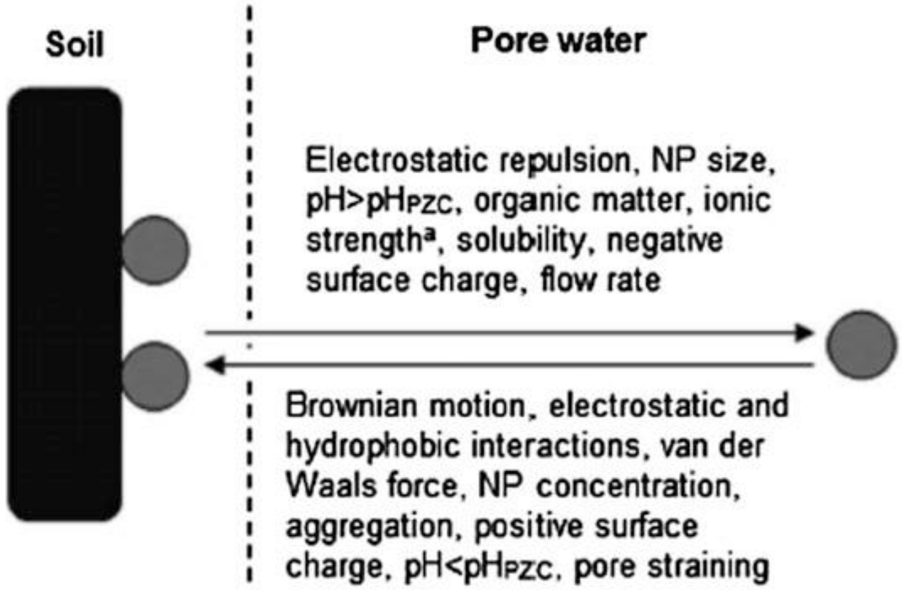
Source :(Díaz *et al.*, 2017)

Figure 3: The dynamic flow of nanoparticles and nanomaterials in ecosystems

Figure 3 shows that, it is analyzed that the consumption of NPs is poor by human and domestic animals. It indicates that NPs are absorbed by microorganisms mostly in the soil, the sediments and roots of plants. They are only transported from the roots to other organisms when they are accumulated (Torresdey *et al.*, 2014). Tropic level is changed when plant parts, microbes and their residue are consumed by arthropods, protozoa, animalia and fish etc (Kim *et al.*, 2016; De et al., 2015). This is happened in case of marine organisms (Fraser *et al.*, 2014) and also occurs in other plant herbivores and carnivores food chains (Kim *et al.*, 2016; De *et al.*, 2015).

Nanoparticle mobility in soil

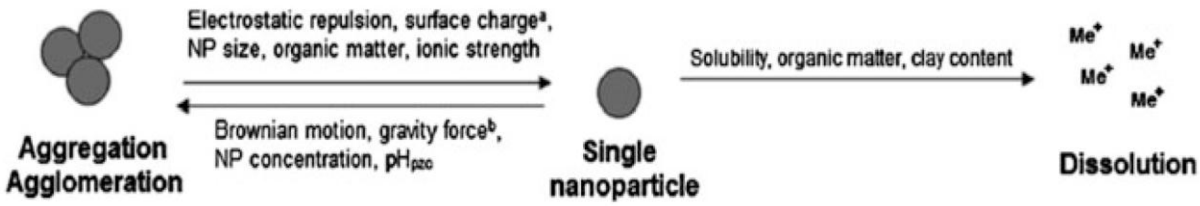
NPs transportation in porous medium and soil attracts more research attention (Lin *et al.*, 2010). NPs mobility in soil depends largely on the interaction between nano particles and soil solid surfaces (Darlington *et al.*, 2009). And that is supposed to be influenced by both physiochemical and environmental factors (Tourinho et al., 2012).



Source: (Tourinho *et al.*, 2012)

Figure 4: Factors affecting the partitioning of nanoparticles between soil and pore water (Not valid for high values of ionic strength; dashed line is the diffusion layer pHPZC = point of zero charge)

Figure 4 shows that the factors are specifically the sedimentation and diffusion of NPs are also sourced by gravity and Brownian motion, respectively (Dunphy *et al.*, 2006; Tourinho *et al.*, 2012). The mobility of NPs in porous soil is maintained by Brownian motion (Lecoanet *et al.*, 2004). Gravitational motion most important during the particles agglomerate and aggregation, then the particles are able to contact with the surfaces of soil particles (Dunphy *et al.*, 2006). Metal-based NPs and soil surfaces interaction also depend on NPs and the soil surface. These types of differences of charges of NPs and soil influence aggregation and electrostatic attraction or repulsion among particles and between particles and soil (Tourinho *et al.*, 2012).



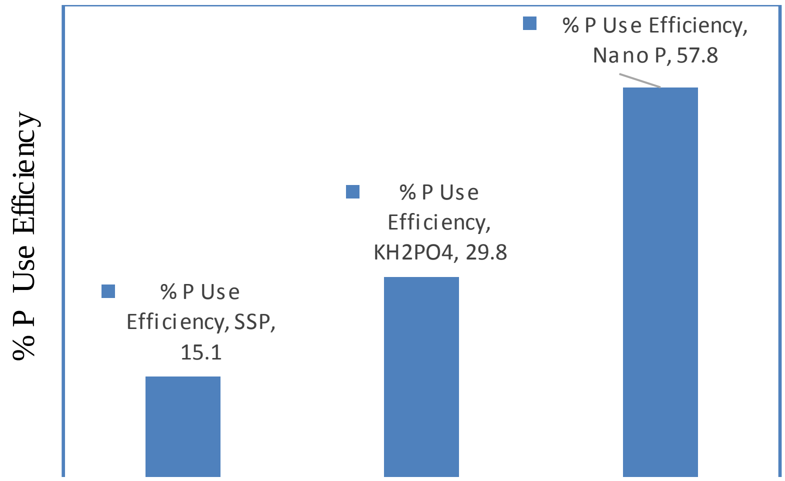
(Tourinho *et al*., 2012)

Figure 5: Factors affecting the processes of aggregation or agglomeration and dissolution of single nanoparticles in the environment

Figure 5 shows that aggregation occurs due to the association of primary particles by strong bonding themselves, whereas agglomeration is associated by weak bonds called van der waals (Jiang *et al*., 2009). Agglomeration and aggregation of NPs are affected by physical forces (Brownian motion, gravity, and fluid motion) and sole characteristics of NPs e.g. surface Properties, particle size etc (Farre *et al*., 2009; Tourinho *et al*., 2012). Particle electrostatic surface charge affects agglomeration and aggregation rates and particle stability and when surface coating is absent then metal-based NPs have charged surfaces arises due to hydroxyl (-OH) groups. Those all charged surface after that can take up and deliver protons and therefore take up dissolved chemical species like metal ions and ligands (Tourinho *et al*., 2012).

Nutrient use efficiency

Nutrient use efficiency may be stated as yield per unit of input. In agriculture it is usually rational to the input of fertilizer, whereas in scientific literature the NUE is often defined as fresh mass or product yield per content of nutrient. Improvement of NUE is an essential pre-requisite for expansion of crop production in marginal lands with low nutrient availability. NUE depends not only on the capability of grown crop to efficiently take up the nutrients from the soil, but also on transport, storage, mobilization, utilization within the plant, and even on the environment. Two major ways may be taken to understand NUE. First one, the response of plants to nutrient deficient condition can be explored to identify processes affected by such deficiency condition and those that may serve to sustain growth at minimum nutrient input. A second strategy makes use of natural or induced genetic variation. Tremendous improvement of NUE was observed in plants after application of nanoparticles. In general, 3-4 times improvement in use efficiency was noticed of P, Zn, Fe and Mg nanoparticles. In figure 6 the effect on P use efficiency is presented (Tarafdar *et al.*, 2016).



Source: (Tarafdar *et al.*, 2016)

Figure 6: Comparison of P use efficiency of single super phosphate (SSP), soluble P (KH_2PO_4) and Nano-P

In figure 6, the results clearly showed that use efficiency of P can be improved many folds when P is applied as nanoform compared to SSP and KH_2PO_4. Here SSP use efficiency is only 15.1%, KH_2 PO_4 use efficiency is 29.8% and Nano P use efficiency is 57.8% which indicates that Nano P is 2 and 4 folds more than SSP and KH_2PO_4, respectively (Tarafdar *et al.*, 2016).

Table 2: Percent (%) improvement in organic acid concentration in the rhizosphere and P uptake by the plant

Crops	Organic acid concentration	P Uptake
Cluster bean	23.2	27.2
Moth bean	19.5	23.5
Mung bean	20.7	22.7
Pearl millet	15.5	17.3
*Nano-P application @ 640 mg ha^{-}		

Source: (Tarafdar *et al.*, 2016)

Table 2 shows that Application of nano P also helps in improving the organic acid concentration in the rhizosphere and P uptake by the plants. Here four crops show the percent improvement of organic acid concentration and P uptake when Nano P is applied @ 640 mg ha^{-1}. In Cluster bean, organic acid concentration and P uptake increases 23.2% and 27.2%, respectively. In moth bean organic acid concentration and P uptake increases 19.5% and 23.5%, respectively. In Mung bean organic acid concentration and P uptake increases 20.7% and 22.7%, respectively. In pearl millet organic acid concentration and P uptake increases 15.5% and 17.3%, respectively (Tarafdar *et al.*, 2016).

Table 3: Percent (%) use efficiency of Zn and Fe (average of four crops)

Micronutrient	Mega particles as fertilizer	Nanoparticle (<20 nm size)
Zn	3.5	78.6
Fe	4.6	81.2

Doses of nano-Zn application 160 mg/ha and nano-Fe 480 mg/ha

Source: (Tarafdar *et al.*, 2016)

Table 3 shows that the use efficiency of the micronutrients like zinc and iron has improved many-fold with the application as nano form (Tarafdar *et al.*, 2016).

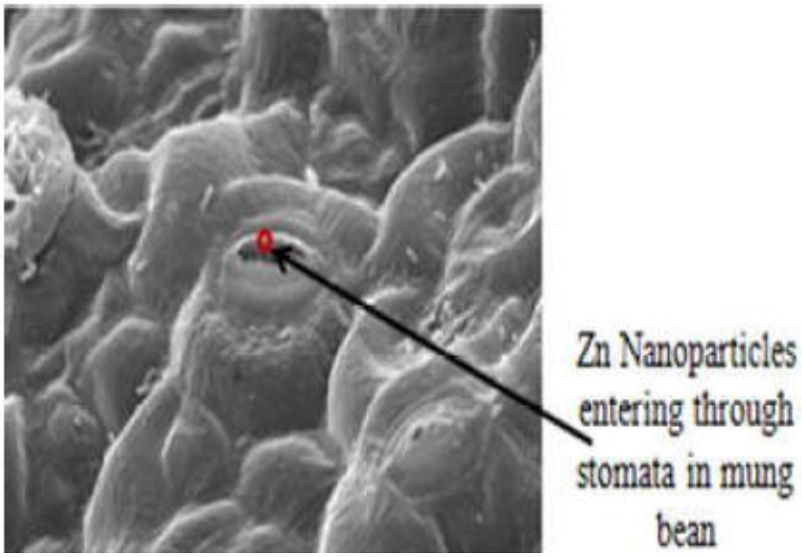
Role of Nanoparticle in stimulation of Enzymes

Table 4: Increase in activity of beneficial enzymes with nano-nutrients application

Beneficial Enzymes	Percent (%)increase in activity
Dehydrogenase	25-68
Esterase	23-90
Acid phosphatase	21-72
Alkaline phosphatase	18-136
Phytase	23-83
Nitrate reductase	12-47
Aryl sulphatase	19-68
Cellulase	48-243
Hemi-cellulase	37-115

Source: (Tarafdar *et al.*, 2016)

Figure 7 shows that Nanoparticles enters through shoot (cuticle, bark, stigma, stomata,) and roots (root tips, rhizophore, lateral root wounds) of the plants. Usually, most entry was found through stomata and cuticle (Tarafdar *et al*., 2016).



Source: (Tarafdar *et al*., 2016)

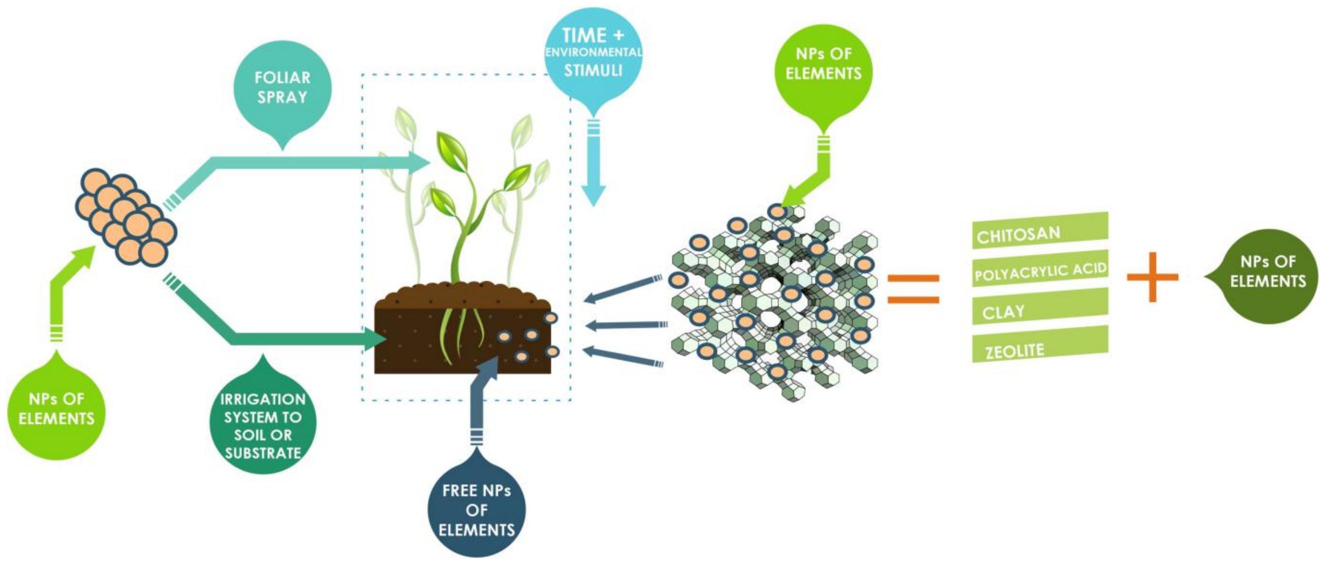
Figure 7: Penetration, movement and accumulation of nano-particles in pulse crop

The nanoparticle goes through cell sap after entering into the cell of stomata. When these particles supposed to transported these trigger various stimulating enzyme systems and most particles may agglomerate to form mega particles on the process and most of them get deposited at the vacuole of the cell (Tarafdar *et al*., 2016).

Use of different nano particles in crops

Among different nanoparticles, nanofertilizer, silver nano particles (SNP) chitosan are more used particle.

In figure 8, on the left side are the nanomaterials of essential nutrients that are directly applied to the soil, irrigation water or the surface of plants, fruits or seeds. On the right side there are recoded nanomaterial like chitosan, polyacrylic acid, clay and zeolite etc that are associated with NPs element and then through controlled release as a function of time or environment (Díaz *et al*., 2017).



Source: (Diaz *et al.*, 2017)

Figure 8: Use of different nano particles and nanofertilizer in crops

Silver nano particle as nanotechnique

Now a day silver nano particles (SNPs) are hypothesized to enhance nutrient use efficiency in plants. The SNPs were synthesized synthetically by redacting silver nitrate with trisodium citrate and size was range from 10-20 nm. Silver nano particles (SNPs) are excellent material having antibacterial, antifungal properties and are utilized in food for sustainable agriculture such as food security, food packaging and pathogen detection (Quardos and Mar, 2010). It has great impact on plant growth and development such as germination, root-shoot ratio, seedling growth, root growth, root elongation, and inhibition of senescence (Ma *et al.*, 2010; Shah and Belozerova, 2009). Nano-bentonite & active carbon coated nitrogen fertilizer maximizes absorption and transportation of N, P, K to yield and seed of rice tremendously (Wang *et al.*,2011).

Here wheat cultivar NARC-2009 is used as the crop to see the N, P, K efficiency then ultimately the effect on morphological and reproductive characteristics.

Table 5: Effect of silver nano particles on nitrogen, phosphorous and potassium use efficiency of wheat cultivar NARC-2009

Treatments	*Nitrogen Use Efficiency (%) ± S.E*	*Potassium Use Efficiency (%) ± S.E*	*Phosphorous Use Efficiency (%) ± S.E*
0 ppm	69.75 b ±0.09	69.00 c ±0.06	68.44 b ±0.06
25 ppm	74.25 a ±0.09	89.03 a ±0.05	72.53 a ±0.06
50 ppm	55.13 c ±0.12	79.25 b ±0.04	61.15 c ±0.11
75 ppm	41.38 d ±0.07	61.06 e ±0.11	46.79 d ±0.03
100 ppm	40.88 de ±0.17	59.41 f ±0.06	47.30 d ±0.06
125 ppm	39.56 e ±0.19	54.50 g ±0.05	43.50 e ±0.08
150 ppm	36.38 f ±0.18	67.88 d ±0.05	41.28 f ±0.04
LSD Values	1.42	0.66	0.6851

Means sharing common letters in column do not differ significantly at 5% probability level.

Source: (Hafiz *et al.*, 2015)

Table 5 shows that the maximum nitrogen use efficiency (74.3%) was noticed with 25 ppm of SNPs. Further rise in concentration of SNPs was associated by significantly decreasing in nitrogen use efficiency. The minimum nitrogen use efficiency (36.4 %) was noticed in 150 ppm of SNPs applied. It showed that maximum nitrogen use efficiency was observed in minimum concentration (25 ppm). Higher phosphorous use efficiency (72.5 %) was noticed in 25 ppm of SNPs followed by control (68.43%). Decrease in phosphorous use efficiency of wheat was noticed by more increase in concentration of SNPs from 50-150 ppm. Lower phosphorous use efficiency (41.3 %) was observed with 150 ppm SNPs application. Potassium use efficiency also significantly in plants used with SNPs. Significantly maximum potassium use efficiency (89.0 %) was observed with 25 ppm of SNPs followed by 50 ppm (79.3 %). Further increase in concentrations of SNPs from 100-125 ppm (59.4 % and 54.5 %) respectively significantly reduced in use efficiency in comparison to control (Hafiz *et al.*, 2015). Slow and controlled release fertilizer coated and blended by nano materials significantly rose nitrogen use efficiency and wheat yield (Zhang *et al.*, 2006).

Wheat growth parameters were greatly affected by use of silver nano particle. Here the parameters were leaf area, shoot fresh weight, shoot dry weight and chlorophyll content.

Table 6: Effect of silver nano particles on leaf area, shoot fresh weight, shoot dry weight and chlorophyll content of wheat cultivar NARC-2009

Treatments	*Leaf Area(cm⁻²)± S.E*	*Shoot Fresh Weight (g)± S.E*	*Shoot Dry Weight (g)± S.E*	*Chlorophyll Content± S.E*
0 ppm	14.96 e±0.13	4.75 a±0.02	0.90 a±0.01	45.09 b±0.01
25 ppm	19.65a±0.13	4.05 b±0.01	0.82 b±0.01	45.58 b±0.01
50 ppm	18.19 b±0.46	4.00 b±0.01	0.73 c±0.01	45.85 b±0.02
75 ppm	17.05 c±0.45	4.04 b±0.01	0.67 d±0.01	51.18 a±0.72
100 ppm	16.26 d±0.18	3.21 c±0.01	0.60e±0.01	46.09 b±0.01
125 ppm	12.73 f±0.16	3.06 d±0.01	0.45 f±0.01	43.55 b±0.01
150 ppm	10.04 g±0.14	2.10e±0.01	0.32 g±0.01	39.75 c±0.02
LSD Values	0.31	0.10	0.03	2.79

Means sharing common letters in column do not differ significantly at 5% probability level.

Source: (Hafiz *et al.*, 2015)

Table 6 shows that higher leaf area (19.7 cm^2) was with 25 ppm of SNPs followed by 50 ppm (18.18 cm^2) SNPs, when in control it was (15.0 cm^2). Further increase in concentration of SNPs reduced the leaf area. Shoot fresh weight and dry weight did not rise after the application of SNPs. At 5% level of significance, higher shoot fresh weight (4.75 g) and dry weight (0.90 g) were recorded in control where SNPs were not applied. The lowest shoot fresh weight (0.10 g) and dry weight (0.03 g) were recorded at 150 ppm of SNPs applied. So, increasing concentration of SNPs significantly decreased shoot fresh weight and dry weight of wheat plant. Maximum chlorophyll content (51.2) was noted at 75 ppm followed by 100 ppm (46.1) of SNPs as compare to control, it was (45.1). The minimum chlorophyll content (39.8) was noted at 150 ppm of SNPs (Hafiz *et al.*, 2015).

Table 7: Effect of silver nano particles on number of grains/spike, 100-grains weight and yield/pot of the wheat cultivar NARC-2009

Treatments	*No of Grains/Spike ± S.E*	*100-Grain Weight ± S.E*	*Yield/Pot (g) ± S.E*
0 ppm	18.5 c±0.18	3.35e±0.012	7.18 c±0.02
25 ppm	29.0a±0.31	4.66ab±0.02	13.25 a±0.02
50 ppm	22.0bc±0.31	4.73a±0.02	12.45 a±0.34
75 ppm	25.0b±0.54	4.40 c±0.02	10.40 b±0.10
100 ppm	22.3 b±0.27	4.43 bc±0.03	10.36 b±0.11
125 ppm	22.5 b±0.34	3.94 d±0.02	9.90b±0.08
150 ppm	11.5 d±0.34	3.78 d±0.03	9.73 b±0.06
LSD values	3.52	0.25	1.77

Means sharing common letters in column do not differ significantly at 5% probability level.

Source: (Hafiz *et al.*, 2015)

Table 7 shows that Effect of different concentration of SNPs on number of grains/spike, 100 grains weight and yield. SNPs applied @ 25 ppm produced significantly greater number of grains/spike (29.0) followed by 75 ppm (25.0). The lowest number of grains/spike (11.5) was recorded with 150 ppm of SNPs applied. Significant differences were observed among treatments for 100 grain weight. Maximum 100 grain weight (4.73 g) was produced with 50 ppm followed by 25 ppm (4.66 g) of SNPs against control (3.25 g). Minimum 100 grain weight (3.78 g) was recorded with 150 ppm treatment at 5% probability level. Maximum grain yield (13.3 g) was obtained with 25 ppm SNPs followed by 50 ppm (12.45 g) as compare to control (7.18 g) where no SNPs were applied Effect of different concentration of SNPs on number of grains/spike, 100 grains weight and yield. SNPs applied @ 25 ppm produced significantly greater number of grains/spike (29.0) followed by 75 ppm (25.0). The lowest number of grains/spike (11.5) was recorded with 150 ppm of SNPs applied. Significant differences were observed among treatments for 100 grain weight. Maximum 100 grain weight (4.73 g) was produced with 50 ppm followed by 25 ppm (4.66 g) of SNPs against control (3.25 g). Minimum 100 grain weight (3.78 g) was recorded with 150 ppm treatment at 5% probability level. Maximum grain yield (13.3 g) was obtained with 25 ppm SNPs followed by 50 ppm (12.45 g) as compare to control (7.18 g) where no SNPs were applied (Hafiz *et al.*, 2015). SNPs increased the yield may be due to growth, stimulating effect of silver (Sharon *et al.*, 2010).

Nano chitosan NPK- fertilizers enhance the nutrient availability and productivity

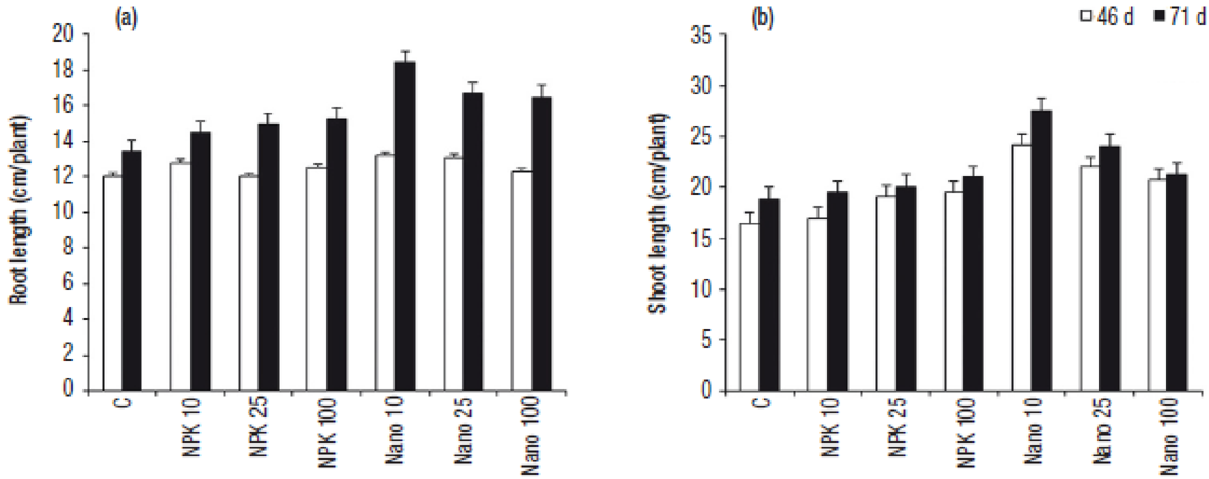
Chitosan is a pure natural polymer made from deacetylation of chitin, which may be obtained from crustaceans, insects, fungi, etc (Boonsongrit *et al.*, 2006). Chitosan poly-methacrylic acid (CS-PMAA) nanoparticles were obtained by methacrylic acid (MAA) polymirazation in chitosan (CS) solution in a two-step process. First one idNitrogen, phosphorus and potassium (NPK) were on the chitosan nanoparticles using the following concentrations 500, 60, 400 ppm respectively (100% concentration means 500 ppm of N, 60 ppm of P and 400 ppm of K in both case of nano and normal NPK solutions and rest of the concentrations were made from the stock solution) (Hasaneen *et al.*, 2014). Here the experiment was done to see the effect of nano modified chitosan NPK fertilizer over bulk NPK fertilizer. Sandy soil was elected as the experimental field as the type of the soil in case of nutrients. So, plant was completely dependent on applied fertilizer for their growth and development.

Table 8**:** Effects of bulk material NPK fertilizer and nanoengineered composite NPK fertilizer (CS-PMAA-NPK) on life span of wheat plants grown on sandy soil

Treatment	Life span	
	Days	Change
Control	170	100
Normal NPK fertilizers	170	100
Nano-NPK fertilizers	130	23.5

Source: (Heba *et al.*, 2016)

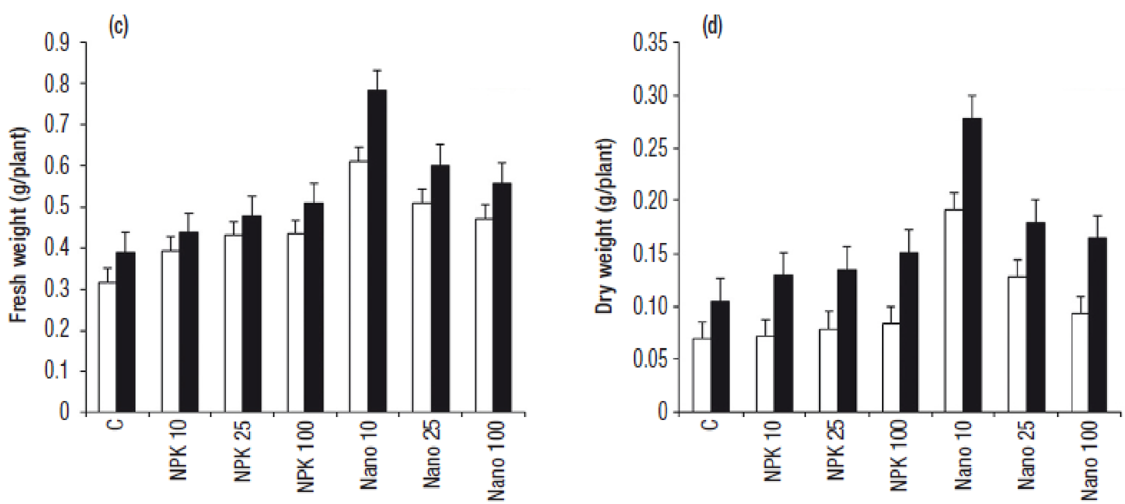
Table 8 shows that the life span of the control and normal NPK fertilized wheat plants grown on sandy soil go at harvesting stage after 170 days from sowing date. On the other hand, wheat plants that was cultivated on sandy soil and treated with chitosan-NPK nanofertilizers obtained the harvesting stage after 130 days from the sowing date. Thus, in this connection, it is worthy to mention that nanofertilizers treatment resulted in the reduction of life span of wheat crop by 23.5% from the normal life span of respective crop. In figure 9 (a-f), it is showed that at all the examined stages, the values of the growth variables were maximum in nanofertilizer-treated plants than in traditional fertilizer treated plants. The following sequence of treatments (Control> Nano 10 > Nano 25 > Nano 100 > NPK 100 > NPK 25 > NPK 10 > C) was maintained in the case of wheat plants grown on sandy soil (Heba *et al.*, 2016).



Source: (Heba *et al*., 2016)

Figure 9: The effect of normal and nanofertilizers on (a) root length and (b) shoot length of wheat plants grown on sandy soil at 46 and 71 days after sowing

Figure 9(a) and 9(b) shows that root length is high in nano 10 after 46 and 71 days after sowing followed by nano 25 and nano 100, respectively. And in case of shoot length, it is same as the root length. Minimum root and shoot length are observed in control condition followed by NPK 10, NPK 25 and NPK 100, respectively (Heba *et al*., 2016).



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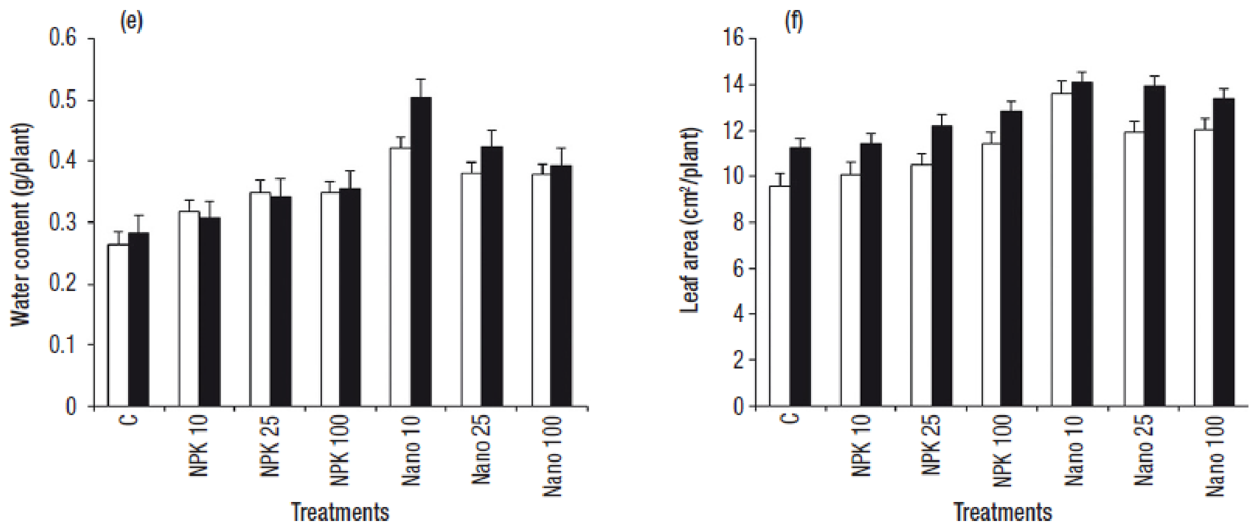
Source: (Heba et al., 2016)

Figure 9: The effect of normal and nanofertilizers on (c) fresh weight and (d) dry weight of wheat plants grown on sandy soil at 46 and 71 days after sowing

Figure 9(c) and 9(d) shows that fresh weight is high in nano 10 after 46 and 71 days after sowing followed by nano 25 and nano 100, respectively. And in case of dry weight of plant, it is same as the fresh weight of plant. Minimum fresh and the dry weight are observed in control condition followed by NPK 10, NPK 25 and NPK 100, respectively (Heba *et al.*, 2016).



Source: (Heba *et al.*, 2016)

Figure 9: The effect of normal and nanofertilizers on (e) water content and (f) leaf area of wheat plants grown on sandy soil at 46 and 71 days after sowing

Figure 9(e) and 9(f) shows that water content is high in nano 10 after 46 and 71 days after sowing followed by nano 25 and nano 100, respectively. And in case of leaf area, it is same as the fresh water content. Minimum water content and leaf area are observed in control condition followed by NPK 10, NPK 25 and NPK 100, respectively (Heba *et al.*, 2016).

Table 9: Effects of bulk material NPK fertilizer and nano-engineered composite NPK fertilizer (CS-PMAA-NPK) on yield variables of wheat plants grown on sandy soil

Yield variables	Control	NPK 10	NPK 25	NPK 100	Nano 10	Nano 25	Nano 100
Shoot length (cm)	30.43	31.66*	32.43*	32.86*	43.56*	38.36*	35.06*
Spike length (cm)	5.80	5.90	5.96	5.99*	7.76*	6.40*	6.23*
Plant height (cm)	36.23	37.56	38.39*	38.85*	51.32*	44.76*	41.29*
Main spike wt. (g)	0.125	0.130	0.135	0.136	0.305*	0.185	0.178
No. of spikelets/main spike	3.00	3.33*	3.75*	4.25*	5.50*	4.33*	4.00*
100 kernel wt. (g)	3.30	3.66*	3.69*	3.93*	4.64*	4.03*	3.98*
No. of grains/ main spike	4.00	4.50*	4.80*	5.25*	8.66*	6.40*	5.78*
Grain yield/plant (g)	2.75	2.83	2.85	3.03*	4.28*	4.10*	3.88*
Straw yield/plant (g)	0.127	0.130	0.136	0.140	0.163	0.151	0.144
Crop yield/plant (g)	4.37	5.02*	5.97*	6.13*	8.28*	7.23	6.95*
Harvest index	21.65	21.76	20.59*	21.64	26.25*	27.15*	26.94*
Mobilization index	33.86	38.62*	43.90*	43.79*	50.80*	47.88*	48.26*
Crop index	0.96	0.96	0.95	0.96	0.96	0.96	0.96

* Mean values are significantly different from control at $p \leq 0.05$.

Source: (Heba *et al*., 2016)

Table 9 shows that the changes of the in-yield variables of wheat plants cultivated on sandy soil applying different treatments. As compared with control values, treatment of the crop grown on poor sandy soil with normal and nano-NPK fertilizer induced significant increment in all yield variables determined. The following sequence of treatments Nano 10 > Nano 25 > Nano 100 > NPK 100 > NPK 25 > NPK 10 > showed that better result C was found for all the yield parameters except for number of spikelets/main spike, for this the following sequence of treatments was Nano 10 > Nano 25 > NPK 100 > Nano 100 > NPK 25 > NPK 10 > C. For harvest index, the following sequence of treatments was: Nano 25 > Nano 100 > Nano 10 > NPK 10 > C > NPK 100 > NPK 25. And the mobilization index: Nano 10 > Nano 100 > Nano 25 > NPK 25 > NPK 100 > NPK 10 > C. In case of crop index, all values were similiar (0.96) but NPK 25 which was 0.95 (Heba *et al*., 2016).

CHAPTER IV

CONCLUSIONS

- Agri nanotechniques play a vital role in our socio-economic life with their blessings by increasing the plant nutrient availability. They reduce the loss of fertilizer that is caused by leaching, runoff, infiltration and erosion etc by precision nutrient management. Here, total input is more efficiently used, so it fulfills the precision nutrient management criteria.

- Today`s burning question is the fertilizer use efficiency enhancement. This is only possible by the use of nanofertilizers. Because they have the properties that can hold more nutrient particles, can retain more water and prevent losses due to leaching, runoff and other factors.

- We have come to know about many nanotechniques that are associated with plant nutrients availability. Such as silver nano particles (SNPs), chitosan etc. nano particles (NPs) and material particles (MPs) which are magnificently useful for our nutrient management policy and ultimately in precision nutrient management.

REFERENCES

Abdel-Aziz, H. M., Hasaneen, M. N., & Omer, A. M. (2016). Nano chitosan-NPK fertilizer enhances the growth and productivity of wheat plants grown in sandy soil. *Spanish Journal of Agricultural Research*, *14*(1), 0902.

Balmford, A., Green, R., & Scharlemann, J. P. (2005). Sparing land for nature: exploring the potential impact of changes in agricultural yield on the area needed for crop production. *Global Change Biology*, *11*(10), 1594-1605.

Bielmyer-Fraser, G. K., Jarvis, T. A., Lenihan, H. S., & Miller, R. J. (2014). Cellular partitioning of nanoparticulate versus dissolved metals in marine phytoplankton. *Environmental science & technology*, *48*(22), 13443-13450.

Boonsongrit, Y., Mitrevej, A., & Mueller, B. W. (2006). Chitosan drug binding by ionic interaction. *European journal of pharmaceutics and biopharmaceutics*, *62*(3), 267-274.

Calabi-Floody, M., Bendall, J. S., Jara, A. A., Welland, M. E., Theng, B. K., Rumpel, C., & de la Luz Mora, M. (2011). Nanoclays from an Andisol: extraction, properties and carbon stabilization. *Geoderma*, *161*(3-4), 159-167.

Cassee, F. R., Campbell, A., Boere, A. J. F., McLean, S. G., Duffin, R., Krystek, P., & Miller, M. R. (2012). The biological effects of subacute inhalation of diesel exhaust following addition of cerium oxide nanoparticles in atherosclerosis-prone mice. *Environmental research*, *115*, 1-10.

Cassee, F. R., van Balen, E. C., Singh, C., Green, D., Muijser, H., Weinstein, J., & Dreher, K. (2011). Exposure, health and ecological effects review of engineered nanoscale cerium and cerium oxide associated with its use as a fuel additive. *Critical reviews in toxicology*, *41*(3), 213-229.

Chibu, H., & Shibayama, H. (2001). Effects of chitosan application on the growth of several crops. Chitin and Chitosan-Chitin and Chitosan in Life Science.

Colman, B. P., Arnaout, C. L., Anciaux, S., Gunsch, C. K., Hochella Jr, M. F., Kim, B., & Unrine, J. M. (2013). Low concentrations of silver nanoparticles in biosolids cause adverse ecosystem responses under realistic field scenario. *PLoS One*, *8*(2).

Cui, H. X., Sun, C. J., Liu, Q., Jiang, J., & Gu, W. (2010, June). Applications of nanotechnology in agrochemical formulation, perspectives, challenges and strategies. In *international conference on Nanoagri, Sao pedro, Brazil*, 28-33.

Darlington, T. K., Neigh, A. M., Spencer, M. T., Guyen, O. T., & Oldenburg, S. J. (2009). Nanoparticle characteristics affecting environmental fate and transport through soil. *Environmental Toxicology and Chemistry*, *28*(6), 1191-1199.

De la Torre Roche, R., Servin, A., Hawthorne, J., Xing, B., Newman, L. A., Ma, X., ... & White, J. C. (2015). Terrestrial trophic transfer of bulk and nanoparticle La2O3 does not depend on particle size. *Environmental science & technology*, *49*(19), 11866-11874.

Dunphy Guzman, K. A., Finnegan, M. P., & Banfield, J. F. (2006). Influence of surface potential on aggregation and transport of titania nanoparticles. *Environmental Science & Technology*, *40*(24), 7688-7693.

Farré, M., Gajda-Schrantz, K., Kantiani, L., & Barceló, D. (2009). Ecotoxicity and analysis of nanomaterials in the aquatic environment. *Analytical and Bioanalytical Chemistry*, *393*(1), 81-95.

Floody, M. C., Theng, B. K. G., Reyes, P., & Mora, M. L. (2009). Natural nanoclays: applications and future trends–a Chilean perspective. *Clay Minerals*, *44*(2), 161-176.

Gardea-Torresdey, J. L., Rico, C. M., & White, J. C. (2014). Trophic transfer, transformation, and impact of engineered nanomaterials in terrestrial environments. *Environmental science & technology*, *48*(5), 2526-2540.

Ghaly, A. E. (2009). The black cutworm as a potential human food. *American Journal of Biochemistry and Biotechnology*, *5*(4), 210-220.

Gottschalk, F., & Nowack, B. (2011). The release of engineered nanomaterials to the environment. *Journal of Environmental Monitoring*, *13*(5), 1145-1155.

Hasaneen, M. N. A., Abdel-Aziz, H. M. M., El-Bialy, D. M. A., & Omer, A. M. (2014). Preparation of chitosan nanoparticles for loading with NPK fertilizer. *African Journal of Biotechnology*, *13*(31).

Jhanzab, H. M., Razzaq, A., Jilani, G., Rehman, A., Hafeez, A., & Yasmeen, F. (2015). Silver nano-particles enhance the growth, yield and nutrient use efficiency of wheat. *Int J Agron Agri Res*, *7*(1), 15-22.

Jiang, J., Oberdörster, G., & Biswas, P. (2009). Characterization of size, surface charge, and agglomeration state of nanoparticle dispersions for toxicological studies. *Journal of Nanoparticle Research*, *11*(1), 77-89.

Khedr, M. H., Omar, A. A., & Abdel-Moaty, S. A. (2006). Reduction of carbon dioxide into carbon by freshly reduced CoFe2O4 nanoparticles. *Materials Science and Engineering: A*, *432*(1-2), 26-33.

Kim, J. I., Park, H. G., Chang, K. H., Nam, D. H., & Yeo, M. K. (2016). Trophic transfer of nano-TiO2 in a paddy microcosm: A comparison of single-dose versus sequential multi-dose exposures. *Environmental pollution*, *212*, 316-324.

Krichevskii, G. E. (2010). Nanotechnologies: dangers and risks. *Inspecting principles for nano technologies and nanomaterials. Nanotekhnol Okhrana Zdorov'ya*, *2*(3), 4.

Lecoanet, H. F., Bottero, J. Y., & Wiesner, M. R. (2004). Laboratory assessment of the mobility of nanomaterials in porous media. *Environmental science & technology*, *38*(19), 5164-5169.

Lin, D., Tian, X., Wu, F., & Xing, B. (2010). Fate and transport of engineered nanomaterials in the environment. *Journal of environmental quality*, *39*(6), 1896-1908.

Ma, Y., Kuang, L., He, X., Bai, W., Ding, Y., Zhang, Z., ... & Chai, Z. (2010). Effects of rare earth oxide nanoparticles on root elongation of plants. *Chemosphere*, *78*(3), 273-279.

Monreal, C. M., Sultan, Y., & Schnitzer, M. (2010). Soil organic matter in nano-scale structures of a cultivated Black Chernozem. *Geoderma*, *159*(1-2), 237-242.

Morales-Díaz, A. B., Ortega-Ortíz, H., Juárez-Maldonado, A., Cadenas-Pliego, G., González-Morales, S., & Benavides-Mendoza, A. (2017). Application of nanoelements in plant nutrition and its impact in ecosystems. *Advances in Natural Sciences: Nanoscience and Nanotechnology*, *8*(1), 013001.

Morgan, K. T., Cushman, K. E., & Sato, S. (2009). Release mechanisms for slow-and controlled-release fertilizers and strategies for their use in vegetable production. *HortTechnology*, *19*(1), 10-12.

Pan, B., & Xing, B. (2012). Applications and implications of manufactured nanoparticles in soils: a review. *European Journal of Soil Science*, *63*(4), 437-456.

Piccinno, F., Gottschalk, F., Seeger, S., & Nowack, B. (2012). Industrial production quantities and uses of ten engineered nanomaterials in Europe and the world. *Journal of Nanoparticle Research*, *14*(9), 1109.

Pijls, L., Ashwell, M., & Lambert, J. (2009). EURRECA–A Network of Excellence to align European micronutrient recommendations. *Food Chemistry*, *113*(3), 748-753.

Quadros, M. E., & Marr, L. C. (2010). Environmental and human health risks of aerosolized silver nanoparticles. *Journal of the Air & Waste Management Association*, *60*(7), 770-781.

Qureshi, A., Singh, D. K., & Dwivedi, S. (2018). Nano-fertilizers: A Novel Way for Enhancing Nutrient Use Efficiency and Crop Productivity. *Int. J. Curr. Microbiol. App. Sci*, *7*(2), 3325-3335.

Sartain, J. B., Hall, W. L., Littell, R. C., & Hopwood, E. W. (2004). Development of methodologies for characterization of slow-release fertilizers. In *Proceedings*.

Scott, N., & Chen, H. (2013). Nanoscale science and engineering for agriculture and food systems. *Industrial Biotechnology*, *9*(1), 17-18.

Sen, J., Prakash, P., & De, N. (2015). Nano-clay composite and phyto-nanotechnology: a new horizon to food security issue in indian agriculture. *Journal of Global Biosciences*, *4*(5), 2187-2198.

Shah, V., & 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.

Sharon, M., Choudhary, A. K., & Kumar, R. (2010). Nanotechnology in agricultural diseases and food safety. *Journal of Phytology*, *2*(4).

Siddiqui, M. H., Al-Whaibi, M. H., Firoz, M., & Al-Khaishany, M. Y. (2015). Role of nanoparticles in plants. In *Nanotechnology and Plant Sciences*, 19-35.

Smil, V. (2002). Nitrogen and food production: proteins for human diets. *AMBIO: A Journal of the Human Environment*, *31*(2), 126-131.

Somasundaran, P., Fang, X., Ponnurangam, S., & Li, B. (2010). Nanoparticles: characteristics, mechanisms and modulation of biotoxicity. *KONA powder and particle journal*, *28*, 38-49.

Stewart, W. M., Dibb, D. W., Johnston, A. E., & Smyth, T. J. (2005). The contribution of commercial fertilizer nutrients to food production. *Agronomy Journal*, *97*(1), 1-6.

Subramanian, K. S., & Sharmil Rahale, C. (2009). Nano-fertilizer formulations for balanced fertilization of crops. *Platinum Jubilee Celebrations of ISSS*, 21-25.

Tarafdar, J. C., Raliya, R., Mahawar, H., & Rathore, I. (2014). Development of zinc nanofertilizer to enhance crop production in pearl millet (Pennisetum americanum). *Agricultural research*, *3*(3), 257-262.

Tarafdar, J., Rathore, I., & Thomas, E. (2015). Enhancing nutrient use efficiency through nano technological interventions. *Indian J Fertil*, *11*(12), 46-51.

Tourinho, P. S., Van Gestel, C. A., Lofts, S., Svendsen, C., Soares, A. M., & Loureiro, S. (2012). Metal-based nanoparticles in soil: Fate, behavior, and effects on soil invertebrates. *Environmental Toxicology and Chemistry*, *31*(8), 1679-1692.

Wang, X. J., Song, H. X., Liu, Q., Rong, X. M., Peng, J. W., Xie, G. X., & Wang, S. J. (2011). Effects of nano preparation coated nitrogen fertilizer on nutrient absorption and yield of early rice. *Hunan Agricultural Sciences*, *11*, 021.

Wanichpongpan, P., Suriyachan, K., & Chandrkrachang, S. (2001). Effect of chitosan on the growth of Gerbera flower plant (Gerbera jamesonii). *Chitin and chitosan: Chitin and Chitosan in Life Science, Yamaguchi, Japan*, 198-201.

Zhang, F., Wang, R., Xiao, Q., Wang, Y., & Zhang, J. (2006). Effects of slow/controlled-release fertilizer cemented and coated by nano-materials on biology. II. *Effects of slow/controlled-release fertilizer cemented and coated by nano-materials on plants. Nanoscience*, *11*, 18-26.