International Journal of Aquatic Science
ISSN: 2008-8019
Vol 12, Issue 02, 2021

The Effect Of Nanoparticles Of Zinc Oxide And Titanium Oxide In Controlling Plant Pathogens

Mena Waleed Hatem

Plant Protection Department, Agriculture Engineering Sciences College, University of Baghdad, Iraq

Email: menawaleedh@gmail.com

Abstract*: Nanotechnology has gained a lot of attention in recent years due to its wide applications and the use of nano chemicals are promising factors for plant growth and nutrition and protection from plant diseases. It is preferable to use nanoparticles because they are effective, less expensive and more stable compared to chemical pesticides. Nanomaterials have been used to improve plant growth in addition to Protect it from pests and diseases after harvest, and the most important of these materials used are zinc and titanium, as these materials activate the defense enzymes in the plant. This reference study deals with the latest studies on the importance of both nano-zinc oxide and nano-titanium oxide for plants and their role in combating plant diseases.

Key words: diseases , agriculture , plant , concentrations, prokaryotes

1. INTRODUCTION

The increasing demand for safe and healthy food and the risks of food shortages looming on the global horizon due to the increase in population growth. Also, the many risks that threaten agricultural production, including climate fluctuations, diseases and others, prompted all these circumstances to search for new, non-traditional ways to advance agricultural growth, strengthen the existing strengths, and reduce the negative influences that the agricultural sector is exposed to (Mclements, 2000) . Nanotechnology is described as a multidisciplinary technology and has many applications. It contributes a lot to the completion of production, manufacturing, storage, packaging and transportation of products. This technology has been used in the production of smart fertilizers that are distinguished and their prices are low relative to the quantity used and the ease of spraying them in addition to its health impact on plants, humans and soil. Compared with traded chemical fertilizers (Biswal et al., 2012). Studies have indicated that some nanoparticles have a beneficial effect on some plant species by encouraging seed germination, increasing yield yield and reducing plant diseases (Servin et al., 2015).The uptake and transport of nanoparticles within the plant depends on many factors, including the surrounding conditions, chemical and physical properties of nanoparticles and the type of plant. The important physical characteristics of nanoparticles are size, composition, crystallization state, surface charge, surface activity, magnetic properties, hydrophobicity, and hydrophobicity (Cifuentes et al., 2010) .

research aims:

1. Nanotechnology and agriculture.
2. The role of nanoparticles in plant growth.
3. The importance of zinc oxide nanoparticles for plants.
4. The importance of nanoscale titanium oxide for plants
5. The role of nano-zinc oxide and nano-titanium oxide in combating plant diseases.

Nanotechnology and agriculture:

Nanotechnology is concerned with the study and treatment of structures, tools, and phenomena at the nano level (ie, less than 100 nanometers), and the nanoscale is a unit of measurement of one billionth of a meter where this scale can be used to estimate small units such as the atom and its molecules. Nanoparticles are called Nanoparticles or Nanocapsulated or Nanocomposites according to the purpose of the application and that the particles at the nanoscale (less than 100 nanometers) change the chemical, physical and natural properties of the nanocomposite from the original compound (Knauer et al., 2009).

In recent years, many studies and research have appeared that dealt with the introduction of nanotechnology in the agricultural field, which is called Agro-Nanotechnology, some of which had positive effects, including unless changes occur that can be referred to, including the latest morphological and histological changes that led to the emergence of undesirable characteristics and the most important studies The most promising is the use of nanotechnology in preserving food, combating insect pests, monitoring places of insect infestations inside agricultural fields, reducing agricultural yield losses, and purifying soil from heavy elements that impede plants' absorption of nutrients and water. It also helps purify water from heavy materials suspended in it in a way that exceeds the reverse osmosis process. And at a lower cost (Nalwa, 2003).It is now possible to use nanomaterials in agricultural fertilization as an effective alternative to traditional fertilizers at competitive prices and in smaller quantities. It can also be stored for longer periods due to its high stability under different conditions. It also enters the process of treating some of the less economically important nanoproducts through the so-called nanobioprocessing and the prevention of insect infections and pathogens from By strengthening the defenses of plants by genetic modification inside the plant cell in what is called nanogenetic modification or modification in the forms of pesticides to make them more effective and less harmful compounds and more widespread in what are called Nanocides. It is also possible to synthesize nanomaterials from some plants, which reduces their harm to humans and reduces the cost of their extraction, such as extracting nanostructured silica from rice straw and ensuring that they reach the entire target places in the plant. Due to wind or rain, so we had to re-application again, which may cause some negative effects, such as soil and water pollution, and an increase in the amount of the remainder in the plant, which indirectly affects humans and mammals ,This prompted the use of nanocapsulated capsules to encapsulate pesticides and chemicals with a nano compound that has high solubility and penetration into the plant, stability and stability within the application space. As a result of its small size and rapid spread (Dutta et al., 1995). The use of nanostructured silica particles as a coating to protect traditional pesticides from the decomposition and demolition act by surrounding weather factors, such as the use of silica nanostructures as a coating for the pesticide vermactin .Which reduces the process of decomposition of pesticide compounds and increases its survival inside the environment and its ability to store for longer periods under different conditions, where the material with the nanostructure is on the outside and the active substance of the chemical pesticide inside it, meaning that the nanomaterial acts as a carrier only for the pesticide and from the results it became clear that the release of the pesticide was ideal, which bodes well. With wide applications in the future to produce various templates for nanocarriers, on the other hand, nanomaterials were used as an alternative to traditional fertilizers or as carriers for their components because of their distinctive characteristics, including increased control and control of the steering process and the ability to increase the plant response to nanofertilizers. It is also a suitable mechanism for the process of transporting compounds to the target places in The plant, whether roots, fruits, leaves, or all plant parts (Morris, 2005).

In an experiment, traditional fertilizers coated with some nanomaterials such as Claypolyster, Humus-polyster or Playticstrach were used on wheat crop. The nanostructured fertilizers had safe effects on the seeds and increased the germination rate to 99%, which increased the growth and quantity of the crop and this is due to the ability of nanocomposites to Access and penetration of seeds and increase their vitality by improving their absorption of important organic substances and improving their vital functions (Morris, 2005).Nano-devices with distinct properties have been used to make agricultural systems smart and with them it is possible to use devices that show the state of healthy plants and potential diseases before they appear to the farmer. Drug delivery to humans (Dutta & Hofamann, 2005 . As a successful use of flakes or nanoparticles as anti-pathogens (fungi - bacteria - nematodes - protozoa - viruses) and others, silver nanoparticles were used to eliminate diseases caused by pathogenic fungi, where silver nanoparticles were able to penetrate the wall of fungal cells and parasites such as rot diseases in crops Various vegetables as silver nanoparticles cause the hyphates to separate from the walls of the fungus or the collapse of the hyphates as a whole. It also reduces the growth of conidia and their ability to expand, grow and spread and inhibit fungal growth. Experiments show that microorganisms have become more sensitive to these compounds over time (Dutta et al., 1995).Many researches indicated the possibility of benefiting from nanotechnology to improve the characteristics and properties of many biological control agents such as fungal and bacterial preparations and their by-products that are pathogenic to insects, as well as the preparations used in combating various plant pathogens, as it is possible to protect biological control agents such as bacterial and fungal preparations from the effects of ultraviolet radiation. As well as protecting it from drought and lack of moisture and increasing the ability of preparations to withstand inappropriate storage conditions and maintain the stability and stability of enzyme products, inhibitors and antibiotics, which are among the promising biological control factors in combating pests, and the delivery of genetic materials to the plant such as DNA or double strand of RNA from Through the technique of RNA interference, RNA interferance is one of the most promising technologies for plant improvement (Morris, 2005).

The role of nanoparticles in plant growth:

Nano-applications of techniques that have the potential to improve the effectiveness of agricultural active materials (the active part in a fertilizer or pesticide) (Zhao et al., 2012) and nano-applications in agriculture can include the form in which agrochemicals are transported and delivered (Manimegalai et al., 2011) and systems Sensitivity of monitoring environmental stresses (Scott, 2007) and nature of crop (Kanuer & Bucheli, 2009).Although the adsorption mechanism of nanoparticles is not fully understood, there is a conviction that it is affected by the properties of nanoparticles themselves, and there are some of these molecules that act as complexes with cell membrane protein transporters or root secretions , as a result are transferred to the plant regulation (Yadav et al., 2014)

The roughness of a hydrophobic surface or surface charge can result from binding to surfaces and uptake into cells. There are two ways for root adsorption of nanoparticles, namely Apoplastic and Symplastic (Deng et al., 2014). Plant cell walls consist of a component tissue with voids of 5-20 nanometers (Deng et al., 2014) . Epidermal wall cells in roots limit the arrival of macromolecules that are larger than the pore size and that nanoparticles that carried out through the follicular cell walls can diffuse between the cells of the walls as well plasma membranes and are subject to osmotic pressure and capillary forces (Lin et al., 2009) . Nanoparticles can enter cells by binding with protein carriers out of apoaporins, which is a membrane protein that acts as water channels and ion channels, or through cellular phagocytosis, or through perforation of the cell wall and the creation of new pores (Rico et al., 2011) . Depending on the shape of nanoparticles, such as carbon nanotubes, they can enter cells and the cytoplasm (Wild and Jones, 2009) .While they become inside the cytoplasm, the nanoparticles effectively interfere together surroundings through different forces such as Van der Waals forces, electrostatic forces , Siturk forces, and this process results from Binding of proteins on the surfaces of nanoparticles with the formation of a protein halo or coronal protein (Nel et al. , 2009) .Studies have shown that some types of nanoparticles are useful for some plant species by encouraging seed germination, increasing plant productivity and reducing plant diseases (Fervin et al , 2015) .It was observed that when the low-germinating seeds were treated with nano-titanium oxide, they became better germination compared to untreated seeds (Feizi et al., 2013).The explanation behind the encouragement of germination and growth could be through the stimulation of ROS, which increases resistance to stress and increases the entry of water and oxygen into the nanoparticle capsules (Khot et al., 2012) .This leads to accelerating seed germination, in addition to the fact that some nanocarbon compounds contain iron and aluminum as impurities, which can stimulate germination instead of the positive effect of some nanomaterials at very low concentrations. , 2014). There are confirmations for some plants when spraying it on the leaves or treating the seeds with it (Feizi et al., 2013). Studies confirmed the role of nano-nitrates in activating a number of enzymes, an increase in plant growth, photosynthesis and chlorophyll formation. A study showed that root elongation is an adaptive development for plants that have been exposed to nano-complexes and led to closing their pores and reducing the water absorption of maize plants growing in a nutrient solution. (Asli & Neumann, 2009) .In a study, it was found that carbon nanotubes encouraged the elongation of the roots of seedlings and seed germination of some plants such as onions, cucumbers, wheat, mustard and tomatoes (Chichiricco and poma, 2015).In tomatoes, the addition of nano-carbon increased the rate and speed of germination and biomass of tomato plants through the entry of these compounds into the seeds (Khodakovskaya et al., 2009). There are studies indicated the possibility of genetic alteration of some protein water channels in soybeans, maize and barley (Lahiani et al., 2013) .Some studies have found limited concentrations of some palladium , gold nanoparticles and higher concentrations of silicon nanocopper and a mixtur (nanogold , nanocopper) can increase the ratio of the upper parts to the roots after 15 days of incubating the lettuce seeds (Shah and Belozerova, 2009) .
With this, the nanoparticles themselves, which have a positive effect on some plants, can have a negative effect on other plants, and the magnetic nanoparticles were encouraged by the chlorophyll content of soybean plants (Ghafariyan et al., 2013) .Carbon nanoparticles transported and accumulated in bitter melon Momordica charantia and improved dry matter yield, water content, fruit length and number (Kole et al., 2013) silica improved tomato seed germination (Siddiqui and Al-whaibi, 2014). And the assert of plant growth through the role of nanoparticles (silver - zinc oxide - magnesium oxide - silicon - titanium oxide) in

preventing infection with some diseases through its antimicrobial role (Servin et al., 2015). There is an anti-fungal effect, such as the role of copper nanoparticles in this Domain (Kanhed et al., 2014). The addition of rare earth elements such as alfalfa and its group has been widely used in fertilizers because of its positive effect on yield, giving a dark green color to the vegetative part, high root production, increasing the speed of root development and improving the color of fruits (Yuan et al., 2001). Here, it necessitate said that several researchers and authors encourage the employ some nanoparticles in agriculture, despite the fact that they are toxic to humans and animals. Therefore, there was a need for environmental monitoring and regulation of instructions for the manufacture of fertilizers or nanocomposites in agriculture, from preparation to handling, and to having harmful effects on the enviroment and society. The materials used are environmentally friendly (Paterson et al., 2011) .

The importance of zinc oxide nanoparticles for plants:

Zinc oxide has gained great attention by researchers because of its great properties such as good conductivity, chemical stability, catalytic properties, and most importantly, being an anti-fungal, anti-bacterial and anti-viral without causing toxicity, which made zinc oxide particles medical, industrial and agricultural applications (Ambika and Sundrarajan, 2015).

The first person to use the name zinc for the element Zn was the Swiss chemist Paracelsus in the middle ages in the early fifteenth century AD. It is the most abundant mineral on Earth and is the fourth most common mineral in use today. Zinc, like any other element, is necessary for life and is important in the multiplication of animal and plant cells and microorganisms, and the deficiency of zinc is one of the micronutrients in plants (Grewal, 2001).The deficiency of zinc in the soil of some crops such as wheat, rice and corn has led to a severe loss in production, as the World Health Organization estimated that one third of the world's population is at risk of zinc deficiency, so eating plants treated with zinc soil may compensate for zinc deficiency in humans and animals (Cak-mak et al. , 2000). The deficiency of zinc in plants is related to other vital functions in the plant such as water absorption, plant hormone activity, and absorption of other nutrients (Beveridge et al., 1980) . Zinc also affects growth and reduces the effect of mycotoxins and other microorganisms, as zinc has been used to combat many plant diseases and protect plants from plant diseases. The sources of zinc for the plant in addition to it may be formative, but the plant can obtain it in the form of fertilizer (Kazemi-Dinan et al., 2015). The use of zinc should be within the permissible limits on the plant to avoid toxicity (Bouain et al., 2018). The most common zinc fertilizers are inorganic salts, zinc oxide, zinc sulfide, and zinc carbonate (Haydor et al., 2012) .Some zinc compounds can pose health risks, and organic compounds such as zinc chelates are five times more effective than inorganic compounds (Alvarez et al., 1996). It is preferable to put zinc with the seeds when planting, or it can be used as a foliar spray, or zinc can be mixed with chemicals such as fungicides, or it can be added with irrigation water (Crawfard et al., 2018). Use zinc salt as a systemic herbal fungicide (Frey, 2011). Also, adding zinc to the fungicide slows down the decomposition of the pesticide, and it was found that benzimidazoles increased the efficiency of the pesticide against the plant pathogenic Erwinia bacteria, and that the decrease in soil acidity and the increase in N leads to the availability of zinc in it (Auld, 2001).There is a positive relationship between the absorption of zinc and nitrogen, as the presence of NH_4 raises the acidity of the roots and can reduce the accumulation of zinc in some crops. Also, fertilizing with zinc reduces the phosphorous content of the plant and increases the element boron, and that the presence of zinc reduces the toxicity of boron, and the presence of potassium increases the absorption of Zinc by the roots of the plant and that the presence of zinc reduces the toxicity of cadmium and that the use of iron with zinc reduces the toxicity of zinc to the plant (Ambika and Sundrarajan, 2015) .Zinc nutrition plays a central role in defending the plant against damage caused by ultraviolet rays, as well as an important role in the reaction of hypersensitivity against plant pathogens, and that zinc is one of the important elements of the plant and its deficiency appears in the new growth of the plant as it appears in the form of stunting, changing the color of new leaves It turns white to dark green according to the plant. Zinc deficiency results in broken buds, poor growth of pollen tubes, weak seeds and change in fruit color (Cakmak, 2000) .

The importance of titanium dioxide nanoparticles for plants:
Nanoparticles are very useful in agriculture, as they can reduce the harmful effect of plant diseases . Nanomaterials are used in the form of fertilizers added to plants. Accordingly, nanofertilizers are divided into types:
a) Nano-fertilizers with macronutrients.
B) Nano-fertilizers with micronutrients, which consist mainly of oxides such as Zno, Cuo, Fe2o3.
c) Nutrient-enhanced nanomaterials such as zeolite.
d) Plant growth enhancers that contain unpredictable action such as Tio2 and carbon nanotubes (Feidantsis et al., 2020).
The nano fertilizers are characterized by effective plant penetration through foliar spraying or addition to the soil, as it leads to the promotion of plant growth (Kaya, 2014). Although the function of titanium in plant cells is not fully understood, the use of very low concentrations of it leads to the improvement of some physiological functions of the plant, especially the processes of photosynthesis and plant growth when used as a foliar spray (Jaberzadeh et al., 2013) .Metal oxides are used as an alternative to fine chemical fertilizers, as they have important functions in cell division and maintenance of the cell membrane and are important in the process of photosynthesis and protein synthesis in addition to plant resistance to stress (Jabeen et al., 2018) . Nano titanium oxide is considered one of the new generation of nanofertilizers, as there are many researches that have proven the role of titanium oxide in fixing nitrogen, improving seed germination and improving plant growth. It was found in a study that the use of titanium oxide led to raise in the production of proteins and raise in photosynthesis (Lu et al., 2002) .In a study, concentrations of 2, 5 and 10 mg/liter (ppm) of nanoscale titanium dioxide were used in the physiological and biochemical response of two genetic types of chickpea Cicer arietinum that differed in their sensitivity to cold at 4°C (Mohammani et al., 2013) . They found that the contents of hydrogen peroxide and MDA, electrolyte leakage index (ELI) increased under cold stress in both genotypes the evidence of harm was higher in the sensitive type than the resistant ones in plants treated with nano-titanium dioxide. The decrease in hydrogen peroxide level led to a say content of MDA and ELI. Compared to the control plants, these changes occurred more effectively and efficiently in the type of resistant than sensitive plants (Mohammadi et al., 2013). Scientific experiments showed that titanium oxide nanoparticles in its rutile and anatase forms produced effective oxygen sources in spinach (Fenoglio et al., 2009).

The role of nano-zinc oxide and nano-titanium oxide in combating plant diseases:
Plant diseases pose a threat to food security, so it was necessary to find agricultural methods to overcome these diseases and maintain agricultural production, and one of these methods is to improve plant nutrition and thus improve plant health. Zinc is one of the micronutrients in all living organisms, which has an important role in growth as well as in plants To defend itself against pathogens, zinc is one of the modern methods of plant defense (Catalina et al.,

2019) .Studies indicate that the essential and beneficial elements for plant health directly affect the plant by activating the plant's defenses such as callose – lignin – phenols – phytotoxins and indirectly by changing the secretions of the roots and the pH of the roots (Dantoff et al,.2007) .Recent studies have confirmed an interest in relationship amidst macronutrients , plant resistance to diseases, and attention has focused on the effect of nitrogen, phosphorous and potassium due to their low availability in the soil and the increase in the plant's need for them (Amtmann et al., 2008) .The roles of micronutrients in plant defense are mostly manganese, copper, iron and zinc (Fones and Preston, 2013). Zinc is a catalytic and structural protein cofactor in hundreds of enzymes and has a major role in DNA replication. The protein content in eukaryotes represents 9% and 5% in prokaryotes (Sinclair and Kramer, 2012).Studies have indicated that zinc is a second messenger in cells, regulating many pathways within them (Goldberg and Lippard, 2018). Zinc plays an important role in the plant's defense against many pathogens, and this varies according to the plant, as well as the different pathogens and their ability to overcome the defenses of the plant host in addition to the environmental conditions. The study showed that zinc fertilization reduces the appearance of disease symptoms, and zinc can be used as preventive sprays to maintain On plant diseases (Helfenstein et al., 2015) . Zinc is an important element for the effectiveness of a large number of important enzymes in plant growth and development, including the enzymes responsible for the genetic transcription of DNA, and the high effectiveness of zinc was noted in inhibiting a number of plant diseases. Relationship with plant disease resistance. Zinc encourages root growth in plants, which improves their resistance against a number of pathogens, such as Fusarium - Rhizctonia - Macrophomina - Pythium (Fayyad and Abbas, 2018). A study on the beet plant showed that the use of nano zinc oxide at a concentration of 100 mg / 1 liter led to a reduction in the infection of the pathogen Fusarium oxysporum f. sp. Betae and Rhizctonia solani increased to 86% compared to the control treatment that was not treated with nano-zinc oxide (El-Argawy et al., 2017). In another study, when treating the roots of tomato with nano zinc oxide, it was found that it protected them from disease, in addition to an increase in root length, leaf area, proline content and an increase in the rate of photosynthesis when it was used at a concentration of 8 mg / 1 liter (Faizan et al., 2018) . Titanium oxide mixed with silica was also used to combat powdery mildew on grapes (Yao et al., 2007). It was also found that the use of titanium oxide in irrigation water treatment led to the elimination of many bacterial and fungal diseases, as it is believed that titanium oxide has the ability to destroy the membranes of pathogens cells. Through strong oxidation processes, studies have shown that the strong oxidation reaction of titanium oxide targets organic compounds. At the same time, studies have confirmed that the studies conducted to know the efficiency of titanium oxide in combating plant diseases, including the fight against bacteria Xanthomonas oryzae pv oryzae that causes bacterial leaf blight in rice, as well as Cercospora that causes brown spot disease on cowpea leaves (Owolade & Ogunleti, 2008) . Safe on the surface of the plant (Frazer, 2001). It was also found that the use of titanium dioxide by adding it to the soil of cowpea plant leads to an increase in its productivity compared to untreated plants (Benson et al., 2002). Nano-titanium dioxide was used to control powdery mildew diseases on zucchini squash caused by Erysiphe fungus and downy mildew caused by Pseudoperonospora cubensis (Soubeih & Agha, 2019)

2. CONCLUSIONS

Nanotechnology is one of the important technologies means in modern agriculture and agricultural production of food, it is considered an important economic force in the near future. Agricultural there is a focuses on food productivity the perpetuate and protection of crop production.Nanotechnology availability modern agricultural chemicals and means of delivery to improve crop productivity and reduce added quantities of chemicals. What is ready of these chemicals is effective in encouraging crop productivity and eliminating or reducing diseases and insects. However, high additions of agricultural chemicals can lead to poisoning and pollution. The development and addition of fertilizers and nanopesticides can be one of the effective options in encouraging agricultural production globally and reducing chemical inputs. The addition of nanomaterials led to a significant reduction in the quantities added, and then reduced the negative impact caused by fertilizers and industrial pesticides. Therefore, what is required here is to speed up research in this field and provide these products in a commercially accessible manner to farmers, and certainly after ensuring their safety on food and the environment.

3. REFERENCES

McClements , D.J., Decker, E.A.2000. Lipidoxidation in oil in water emulsions : impact of molecular environment on chemical reactions inheterogeneovs food system . J. Food. Sci;65:1270-1282.
Biswal, S.K., Nayak, A.K., Parida , U.K., Nayak, P.L. 2012. Applications of nanotechnology in agriculture and food sciences . IJSID. 2(1):21-36.
Roche R, Hamdi H, White J. C. Bindraban P, DimkpaC . 2015. Areview of the use of engineered nanomaterials to suppress plant disease and enhance crop yield . J Nanopart Res 17: 1-21.
Cifuentes Z, Custardoy L, De La Fuente J M, Marquina C, Ibarra M R , Rubiales D, pere Z – De- Luque A. 2010. Absorption and translocation to the aerial part of mangmentic carbon – coated nanoparticles through the root of differenent crop plants . J Nanobiotechnol 8: 26.
Dutta, I.M.Reaney , P.R.I.Cabarrocas and Hofmann. 1995. Nanomaterials , Nanostructuctured mater. (6). 843.
Dutta and Hofmann.2005. Nanomaterials electronic Book.
Nalwa. H.S.2003.Encyclopedia of Nanoscience and Nanotechnology Stevenson ranch, American scientific publishers.
Knauer, K. and Buchell , T. 2009. Nano-materials the need for research in agriculture . Agraforschung . 16 (10) : 390- 395.
Morris V.J.2005. Is nanotechnology going to change the future of food technology . Int. Rev. food Sc. Technol. 316-18.
Paterson G, Macken A, The mas K V. 2011. The need for standardized methods and environmental monitoring programs for anthoropogenic nanoparticles . Anal methods 3: 1461- 1467.
Zhao M, Liu L, Her R . 2012. Nano-sized delivery for agricultural chemicals . In: Tiddy G, Tan R (eds) Nano- formulation . Royal society of chemistry , Cambridge , pp 256- 265.
Manimegalai G, Kumar SS, Sharma C. 2011. Pesticide mineralization in water using silvernanoparticles . Int J chem. Sci 9 : 1463- 1471.
Scott N R . 2007. Nanotechnology opportunities in agriculture and food systems . Biological and Enviromental Engginerering , Cornell university NSF Nanoscale science and engineering grantees conference , Arlington http://www.nseresearch.org/2007/overviews/Day3-scott;pdf.Accesses 19 Apr 2014.