REVIEW

Unfaltering boon of Nanotechnology on Plant Growth

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Abstract

In the current paradigm of science, nanotechnology has acquired a remarkable threshold in diversifying its effect on technology. Several approaches have been made towards the frontier of plant growth and enhancement. Nanotechnology proves to be the prime substantial and effective edge in the era of advancing domain. The main prerogative of the article is to showcase the varied prospects of nanotechnology in spite of its certain glitches, which are yet to be tapped in the near future. The amount of knowledge we have received, although being less, has much scope for refinement. To impact the three domains of life - flora, fauna, and mankind, the manifold comprehension of nanotechnology provides humungous opportunity of growth.

Keywords

Nanomaterials, Nanoscience, Microscopy, Spectroscopy, ENPs, Phytotoxicity, Anti-bacterial effect, Nanoherbicides, Nanofertilizers, Biosensor

Introduction

Nanotechnology is the protean as well as integrative area of inquiry and application. The wide range of applications that nanotechnology has to offer and will be providing, speaks of its extensive prevalence, whether it be in the field of agriculture, energy, electronics, medical purpose, healthcare sector, textiles, commuting means, constructions, cosmetics, water treatment etc., nanotechnology has an integral part to offer or rather it has an indispensable role to play.[1-4]

The origin and ideology behind nanoscience and nanotechnology began with a lecture titled, "There's Plenty of Room at the Bottom", by physicist Richard Feynman at an American Physical Society gathering at the California Institute of Technology on 29 December, 1959. Feynman, who is widely recognised for being the Father of Nanotechnology, elucidated nanotechnology to be an exercise in which scientists will be able to manoeuvre and handle individual atoms and molecules. Almost after a decade, Prof. Norio Taniguchi, in his analysis or investigation of ultra accurate machining, conceived the name, "Nanotechnology". It was with the improvement of scanning tunnelling microscope, that the visualisation of individual atoms was made possible and modern nanotechnology started its journey.

Nanoscience is the survey that deals with the occurrence and administration of constituents at atomic, micro and macromolecular levels, in order to comprehend and make use of the properties that differ distinctively from those on a larger picture. This type of extraordinaire and diversity unfolds the new prospects for more knowledge and application.

Nanotechnology, being such an inspiring medium of technology of rising techno-economic archetype, is still in its dawning stage of interpretation, advancement and innovation. Keeping in mind its characteristics, the experimentalists have considered this to be an effective tool of sustaining technology for the long run. As defined by the United States Nanotechnology Initiative (2001,) that nano-technology is the understanding and control of the matter and dimension of roughly 1-100 nanometers, where unique phenomena enable novel application. Encompassing the nanoscience, engineering and technology involves imaging, measuring, modelling, and manipulating matter at this length scale.

Nature has numerous evidence of nanotechnology, based on its capability to work at atomic, micro molecular and supra molecular levels. Nature is the ultimatum in raising nanostructures that provide functional proteins and compounds at cellular level of great importance in life on earth. Biological systems have been considered by some scientists to involve separation and sectionalisation of many structures into a stipulated pattern or device. Some biological systems comprise nanosystems that are dedicated towards particular functions such as mobility, function,etc. The preparation of nanomaterials comprise a straight and artificial way that reaps particles in nanosize range, following grinding, high pressure amalgamation and disruption to diminish the size.[5,6] On the contrary, the bottom up process in the synthesis of nanomaterials that deal with reactive volatile precipitation and solvent displacement.[7] It is very important for deep introspection to understand that nanomaterials due to their enhanced contact surface area might be lethal, an effect which might be absent in its bulk counterpart, mainly in the open agricultural setup.[8,9] Examples include, stable mold with nanomaterials that have nanostructure freely packed to its surface, where it can reasonably be expected to percolate once coming in contact with aqueous medium or air, or when unveiled to rationally anticipated mechanical forces.[10]

The contribution of nanoscience in plant growth and system is acquiring a major importance in the present scientific scenario. Nanomaterial having different physical and chemical attributes can result in improved plant metabolism. Pros and cons of ENPs on the environmental consequences with biological results. Nanoparticles can cause biochemical, physical and physiological changes in plant system and development. Impact of MWCNT and SWCNT on plant architecture, has triggered a scope of in depth study on nanotechnological aspects in plant world. The phytotoxicity, stress, ecological condition are now put in limelight for further research to make nanotechnology a beneficial tool in the improvement of agricultural yield.[11]

2. Categorization of Nanomaterials

Nanomaterials are those particles whose size ranges between 1 to 100nm. The leading types of nanomaterials are— carbonaceous[12], semiconductor, metal oxides[13,14], lipids[5], zero-valent metals[16,17], quantum dots, nanopolymers[18], and dendimers[19] with various types of nanofibres, nanowires and nanosheets.

Nanomaterials have a special physical and chemical propagations, and the ability to enhance plant metabolism. Galbraith et al(2007) and Torney et al(2007) conform that engineered nanomaterials are efficient in effortless transport into leaves, DNA parts and other biomolecules into plant cells[20].

The engineered nanoparticles have been broadly helped in diverse area of science like bioengineering, electronics, textiles, chemical engineering, advancement of green environment, pharmaceutical shipment system in navy machinery. The exclusive asset of ENPs is analysed as broad surface area, large surface energy, and adept quantum restrain.[21,22]

When nanoparticles are disclosed into the environment, ENPs may modify their movement by means of physical, biochemical and biological conversion.It requires great realization that the disadvantages of nanomaterials due to their enhanced contact surface area might be harsh especially in an agro economic set up. Engineered nanoparticles are those particles which contain metals as its main constituent especially metal oxide. The yield of metal oxides and metal nanoparticles could be accomplished by various ways. There are various array of nanoparticulate metal oxides including both single oxides (CeO_2, TiO_2, ZnO, CrO_2, MoO_3, and Bi_2O_3) and binate oxides ($BaTiO_2$, $LiCoO_2$, and SnO). This sequence of metal

ISSN 2229-5518

oxides has modern utilization in UV inhibitory effect and detectable clarity of nanoparticles foam. ZnO and TiO_2 are largely used in cosmetics, suncream, and bottle coatings. In the year 2005-2010, it was recorded that ZnO and TiO_2 have dermatological benefits. To augment the grade of emission, CeO_2 is used as a combustion catalyst in fuels like diesel, and also in oxygen pumps, gas sensor, solar cells and metallurgical ceramics.

Nanoparticles have been broadly classified under two headings – Organic and Inorganic Nanoparticles.

2.1. Organic Nanoparticles :

2.1.1. Micelle :-

Micelles are nanostructures composed of amphiphillic molecules like polymers or lipids. [23] When exposed to aqueous environments, they mask their hydrophobic group inside the structure and unveil the hydrophilic groups. Whereas in a lipid rich environment their structure may set up in a reverse way. [23]

2.1.2. Dendimer :-

A dendimer is morphologically identified by a branched structure grown from one or more cores. The size of these NPs is effortlessly controlled by number of generations that are allowed to breed over these cores.Dendimers offer complication regarding drug incorporation and release, being their synthesis quite time consuming. [24]

2.1.3. Liposomes :-

Liposomes are [illegible] valent liposome are unilamella [illegible] nm. [25].These spherical structures are composed of amphiphilic compounds and present high production cost and content leakage. The main advantage of liposome is that they are completely biodegradable, non-pernicious and non-immunogenic. [26]

TYPES OF NANOPARTICLES

2.1.4. Compact Polymeric Nanoparticles :-

Compact polymeric nanoparticles are nanostructures produced exclusively of innate or artificial polymers. They are generally more stable than liposomes favouring continuous localised drug delivery for weeks, with restricted drug leakage. [23].In these polymeric nanostructures, the therapeutic agent can be eventually linked covalently. Alternatively, it can be adsorbed at the NPs surface or dissolved or enmeshed within the nanoparticles structure (nanospheres) or encoated inside a polymeric shell (nanocapsule). [23, 27]

2.1.5. Hybrid :-

An transitional type of NPs is the core-shell polymer-lipid hybrid NPs. In its structure a biodegradable hydrophobic polymeric core and a lipidic outer monolayer are present [28]. Alternatively, an inner polymeric core encompassed by an external lipid bilayer can be utilised [29]. Core-shell polymer-lipid hybrid NPs bring about the complementary characteristics of both complexes, namely higher stabilised, enriched drug encoated yield and superior in vivo cellular delivery efficacy [30].

2.2 Inorganic Nanoparticles :

2.2.1. Fullerenes :-

NPs can also be easily made of carbon molecules with various highly symmetric and stable forms, called fullerenes (allotrope of carbon)[31]. Buckminsterfullerene (C60), the most referred to as fullerene, is a rigid icosahedron with 60 carbon atoms. In its structure, single bounds form pentagons and double bounds form hexagons[32]. Fullerenes disadvantages, such as the low solubility in organic solvents, are overcome by their unique optic, electric and magnetic properties (such as superconductivity[33]), rendering them important devices in medical diagnosis and imaging [33].

2.2.2. Inorganic materials, for example **gold, silver, platinum and silica**, can also be used to produce NPs.

2.2.3. Quantum Dots:-

Recurrently, quantum dots are delineated as “artificial atoms”. These were one of the first nanotechnologies to be extensively used in biological sciences and are expected to treasure trove some applications in the near future, in a number of commercial consumer and clinical products (Klimov 2007, Valizadel et al.2012).[34,35] QDs present exclusive luminescence properties and electronic characteristics, such as broad and uninterrupted absorption spectra, thin emission spectra and high light stability (Bruchez et al 1998).[36]QDs manifest high wherewithal for identifying cells, discover particles, and accumulating solar energy. However, before we look into the advantage of this new particle we should first figure out the risk of its toxicity to organisms.Nair et al (2011) observed that when rice seeds were treated with CdSe QDs, it was detected that the germination of the seeds were constrained [37]. According to Hoshino et al 2004, QDs can lead to DNA damage and decelerate the germination of cells in culture.[38] It was also noted that cell damage and cell death can be induced by mercapto-undecanoic acid QDs (Shiohara et al 2004)[39].

Although the vulnerability of single walled carbon nanotubules to plant induced benign effects, the cluster of QDs to the nanotubules effectively transform the viability of the tomato plants by significantly stimulating leaf senescence and inhibiting root formation (Alimohammadi et al 2011).[40]Furthermore, it was noted that, when *Arabidopsis* is unveiled to QDs, it induce oxidative stress, as conceded by changes in the GSH/GSSG ratio (Navarro et al 2012).[41]

3.Characterization of Nanomaterials

Characterization of nanomaterials being a part of nanometrology, handles the characterization of the physical and chemical properties the nanomaterials. This helps us to evaluate nanomaterial in their degree of toxicity an usefulness in different genres of life. However, there are several microscopic and spectroscopic mechanism into practice. Metrics, taken into consideration for the characterization of different nanoparticles are size and dispersion, shape, chemical composition and crystal structure, surface area, surface chemistry and charge, solubility.[42]

3.1. UV spectroscopy - It is the method by which light is incorporated by the sample and scattered in the sample is quantified. The measurements of spectroscopy are compared at different wavelengths. Nanoparticles having optical properties can be easily characterized by this method. The measured spectrum is compared expected spectrum with the help of many numerical tools.

3.2. Transmission Emission Microscope (TEM) - It is a tool in microscopy to produce highly magnified images produced by transmission of electrons in the sample. Electrons instead of light is used to illuminate the images produced. Background of the sample plays an integral part in the characterisation of nanoparticles via TEM. Principle behind this is the high electron of the nanoparticles that make the imaging feasible. It is most used to measure metal based nanoparticles and few carbon based nanoparticles like carbon nanotubes, quantum dots, magnetic nanoparticles etc.

3.3. Dynamic Light Scattering (DLS) - This is an important characterisation of nanoparticles based on their colloid nature. Light gets scattered in the colloidal solution and by the analysis of the brownion motion of the colloidal particles. The hydrodynanic diameter measured in this case is larger than the size analyzed in TEM.

3.4. Zeta Potential - It is a physical characterisation that help to quantify the total suface charge of the nanoparticles. It is a measure of the discrepancy in potential between the bulk fluid in which a particle is immersed and the layer of fluid covering the oppositely charged ions on the nanoparticle surface.

3.5. Atomic Absorption Spectroscopy (AAS)- It is the analytical technique that helps in determination of mass concentration of the nanoparticles in consideration. It works on the principle of atomic absorption from light to a specific wavelength. The amount of energy hence absorbed is related to the number of atoms on the light path.

3.6. Fourier Transform Infrared [FTIR] spectroscopy – Determination of the nature and structure of functional group can be conferred by measure of infrared wavelength against light wavelength. This spectra scrutiny can highlight the optical properties of nanoparticles.[43]

3.7. Energy Dispersive X ray analysis (EDX) – it is an analysis technique for surface inspection on nanoparticle, from all sides and proportions. Thus, giving an overall mapping of the nanoparticle surface. It is laborious technique because of the low penetrating power of the X rays.[44]

3.8. Atomic Force Microscope(AFM) – It is a non destructive analyzing technique, with a very high spatial resolution. This makes it ideal for nano range analysis.Images are generated by the feedback system found between the optical detection and piezoelectric scanners.[44]

3.9. Scanning Tunnelling microscopy (STM) – this helps us to study particle surface from scale lateral resolution. It works on the principle of quantum tunnelling, which implies that on the contact of conducting tip to the surface, electrons are tunnelled through the vacuum between them.[44] It is widely used in the characterization of carbon based nanoparticles.

4. Mechanism and Principles in Nanotechnology

Consumption, translocation, and assemblage of NPs dependent on the plant system and the size, kinds, chemical conformation and stability of the NPs. The consumption, bio metabolism and transfer of various NPs in a plant architecture has been earlier demonstrated [45] . The intake, assimilation, and the transfer of organic matter , suspended fullerene C_{70} and MWCNT in rice plants were examined in the past [46]. Black agglomerates of C_{70} were observed. These stocks were obtained more in the seeds and roots as scrutinised to the stems and leaves of the rice. It has been reckoned that the presence ofaggregates of NOM-C70 in leaves led to the transference route of water and the nutrients through the xylem tissue. In the cell membrane specific ion transmitters have been concluded for NPs ascended by the plants [47]. Because of the low surface friction of CNTs, the passage of organic substances into the cytoplasm can be given out [48]. Interplay of ryegrass with NPs has been recorded. The scanning electron microscopy studies confirmed the adsorption and aggregation of the NPs on the root surface [49].

TEM images of root cross-sections of the ryegrass also displayed the occurrence of particles in the apoplast, cytoplasm and nuclei of the endodermal cells. Birbaum [50] detected CeO2 NPs employed on corn leaves, which were absorbed by the leaves, but not transferred to new leaves. Zhu [51] informed the uptake of Fe3O4 NPs by pumpkin seedlings in husbandry culture using a vibrating sample magnetometer. NPs were detected in roots, stems, and leaves of the plants. It was compelling that no uptake was noted when plants were germinated in soils and a reduction in uptake was noticed, when grown on sand. In accordance with the Fe3O4 NPs, growth medium was not taken into prominence, in the soil and sand grains. Incapability of uptake of lima bean plant species, was noticed on treatment with Fe3O4 nanoparticles. the ascent and transmission of Cu NPs in mungbean (*Phaseolus radiata*) and wheat (*Triticum aestivum*) were examined by Lee *et al.,* [52] in the agar growth medium.

It was inferred that the Cu NPs could navigate through the cell membrane and aggregated in the cells. *Cucurbita pepo* when administered with Ag NPs, the Ag concentration in the plant shoots was found to be 4.7 times higher in the plants than those treated with large amount of Ag powder [53]. Cases of biomagnification has been reported in algae and tobacco via nanoparticle treatment[54,55]. NPs assimilated in the cells may be trasferred by means of apoplast or symplast through plasmodesmata. However, the exact methodology by which plants take up NPs and plant specific accumulation of NPs is are still undiscovered and remain unexplored.

Nanomaterial unveils in plant system through numerous pathways, such as peripheral emission from manufacturing orifice in sewage treatment plants [56,57]. In nutrient rich organic compounds from sewage water treatment domain, pesticides employed to agronomy, dyes, textiles, private health purpose, and sudden descent of materials at the time of manufacturing consumer products[58]. When nanomaterials certain excretion from diesel release, sewage water appear at agricultural land have an increased capability to pollute soil, fertility transfer into surface/ground water, and interact with normal biota. Further these nanoparticles can also be commuted to an aquatic system by rainwater bodies miscellany may lead to its buoyancy's imperceptible leaching.

4.1. Role Of Engineered Nanomaterials In Plant Growth By Various Ways –

4.1.1. Carbon Based Engineered Nanomaterials :

An increased production of carbon-based nanomaterials has paved way to its potential discharge in living systems, either willingly, accident in content, and showing more potential of the unsatisfying environmental effects [59]. Amid the carbon nanomaterials, the most volitional materials are fullerene C_{70}, fullerol (C60(OH)20), and carbon nanotubes. Generally carbon-based nanomaterials are measured highly hydrophobic with the proclivity to aggregate, and expected to settle in the living system [60].

4.1.2.Fullerene on Plant Growth :

The fullerene as an aggregate of black blend is more profuse in seeds and roots growth as compared to the leaves and stems of rice seeds [61]. While in mature plants, favourable transportation from the roots to aerial part of plant has become more prominent. Thus, fullerene agglomerates mainly occurring inside or close to the the stems vascular system and leaves, whereby the roots have been deprived of fullerene [62]. The conjunction of fullerene in leaves also states that pathway of nutrients and water through the xylem [63]. It is heralded that individual fullerene nanoparticles invading the root surfaces in accordance to osmotic pressure, capillary forces, and cellular pores through the intercellular plasmodesmata, or by using very much synchronized symplastic routes [64,65]. The fullerene moeties with a calibre of a smaller capacity than the pore size of the cell wall could easily flow and reach to the plasma membrane.

4.1.3.Multi Walled Carbon Nanotubes (MWCNTs) On Plant Growth :

The Multi walled carbon nanotubes (MWCNTs) are 1mm long and 20 nm in diameter [66-69]. And using the seeds and roots arrangement through the genesis of new outlets and water intake in order to build tomato seedlings [70,71]. The rhizome was envisioned before finally racing the epidermal and root hair cell walls and cap of the seedlings [72]. It is also heralded that MWCNTs are impregnated in tomato seeds and enrich the emergence rate by enhancing the seed water intake. The MWCNTs upraised the maturation of seed to up to 90% in 20 days juxtaposed to 71% in the standard specimen and the vegetational biomass [73].

4.1.4. Single Walled Carbon Nanotube (SWCNTs) - On Plant Growth

The acreage of single walled carbon nanotube (SWCNTs) is about 1 to 2 nm in diameter and 0.1 μm in length. water column stoutness in cucumber seedling after handling for 84 h the SWCNTs were found cohere to the outer surface of the main and secondary roots

[74,75]. However, coexisting information are lacking to confirm the translocation of SWCNTs from the root systems to the aerial parts of the plant [76].

4.1.5. Titanium oxide (TiO2): On Plant Growth

The titanium oxide Nanoparticles (TiO_2) are substantially deployed in daily life products, but the probing of their ingestion and translocation in the plant is limited, particularly on food crops [77-79]. TiO_2 size (<5nm), TiO_2, tend to form a chemical bond with most of the no-conjugate ordinary organic matter, translocate, and following the tissue and cells' [78-80]. TiO_2 nanoparticles with nitrate unsheltered in Soybean (Glycine max), intensify the ability to utilise, and stimulate the inhibitor system. For instance, TiO_2 nanoparticles corollary plants showcased 73% increased dry weight, three times raised photosynthetic rates, and 45% chlorophyll revampment as compared to the domination over the cultivation phase of 30 days.
Some studies professed that the TiO_2 nanoparticles low high prospective in sponge up of inorganic nutrients, escalated the disintegration of organic substances, curbing by oxygen free radicals formed during the photosynthetic process, thereby manipulating the photosynthetic rate [81,82]. It is divulged that toxicity of TiO_2 nano particles low due to particle collection and ensuing accumulation. The toxic effect of TiO_2 nano particles is feasibly not imputed by the released Ti^{2+} ions from particles that are capriciously manifested by the finite disbandment of Ti from a TiO_2 specimen [83]. Genomic DNA ascertainment was perceived in the root tips of cucumber after seven days and designated that plants served with 2000-4000mgL−1 of TiO_2 nano particles reduced the genomic DNA compare to the control sample [84,85].

4.2. Mechanism of intrusion of Nanoparticles

Utilizaion of nanoparticles for the designated production of substances hasattained special concentration and is of major insight in the treatment of plant diseases. Examinations were done for observing both the perforation and the movement of iron-carbon nanoparticles in plant cells have been examined in living plants of *Cucurbita pepo*. The nanoparticles were surveyed *in planta* using two different application methods, injection and spraying, and magnets were used to preserve the particles in movement in specific areasof the plant. The sole experimental set up, using correlative light and electron microscopyprovided evidence of intracellular insertion of nanoparticles and their displacement from the application point. Long range movement of the particles through the plant body was also diagnosed, particles having been found near the magnets used to deactivate and centralise them.

Furthermore, cell reaction to the nanoparticles occurence was dignosed. Nanoparticles were competent of puncturing living plant tissues and itinerating to different regions of the plant, although movements over short distances seemed to be advocated.
The outcomes show that the use of carbon coated magnetic particles for administered delivery of substances into plant cells is a attainable application.[86]

5. Nanotechnology and Plant Growth

5.1.Phytotoxicity

Agriculture and plant culture is an prominent ae of development, which has a continuous ardent need of improvement. The growing prominence of the efficiency of nanoparticles has paved it way to be helpful in the progress of agrarian fields[87]. Nanoparticle usage strives for a betterment in application techniques and considerable reduction in amount of plant protection products(PPP), also to mitigate the dearth of nutrients evident during fertilization and other plant processes[88,89]. The carbon based nanoparticles have shown a considerable amount of notability in plant nanotechnology.among them,Multi-walled carbon nanotubes (MWNTs) are the nanomaterials that have grown to be remarkable interest in research field and technological development due to their unique caricature and peculiar properties. However, repetitive usage of nanomaterials in plant architecture can culminate into bioaccumulation with may ultimately lead to toxicity. This gives rise to the concept of phytotoxicity of nanomaterials.[90] Nano-encapsulated agrochemicals are delineated in such a way that id encompasses all the required properties and necessary effective concentration with a judged evaluation of time controlled release in plant body with escalated target activity and little ecotoxicity with safe and elmentary mode of delivery for avoiding repeated application[91-93].

The prime factors guiding the effects of NPs on plants are the properties of the nanomaterials like concentration, size, category, stability [94] Some studies have shown that phytotoxicity aggrevates with particle size. For example, Yasur and Rani (2013) affirmed that all Ag NP treatment groups had no significant effect on the growth of castor, but in the treatments where the Ag was emergent in its bulk form, subdue in the process was observed. This was affirmed by the work of Lee et al. (2010).

Phytotoxicity is a notable cognition in comprehending the potentialhabitual impression of nanoparticles. Profuse analytical data have shown thatmulti-walled carbon nanotubes (MWNTs) are pernicious to plants, but the potential impacts of revelation remain perplexed. The intention of the current survey was to gauge estimatedphytotoxicity of MWNTs at different specific levels with red spinach, lettuce,rice, cucumber, chili, lady's finger, and soybean, based on root and shoot enhancement, cellysis, and electrolyte crevice at the seedling stage. 15 days later of agronomic culturing,the root and shoot extents of red spinach, lettuce, and cucumber were considerably diminished leading to exposure towards particular MWNTs. Indistinguishable toxic sequels occurred regarding cell death and electrolyte leakage. Red spinach and lettuce greatly was responsive to MWNTs, followed by rice and cucumber. Nominal or no adverse effects were observed for chili, lady's finger, and soybean.[95]

5.2. Bacterial effect

With the advancement of Nanotechnology, it is necessary for us to pave non toxic and eco friendly ways of the bio synthesis of nanoparticles. Metal and engineered based nanoparticles, although widely used, face the criticism of being toxic after a particular or excessive usage. However, techniques lilke green synthesis of nanomaterials, i.e. nanomaterials synthesized from plants, which are the green sources. This field of nanotechnology accelerated a new radar of research in the botanical aspect in this feild.

This however, was then further redirected to support the school of thought that nanomaterials can be synthesized via living or biologically sound organism.

This gave rise to research regarding synthesis of nanoparticles via micro-organisms. Microbial synthesis of nanoparticles is extremely advantageous and takes place at an ambient environment and temperature. The size and shape of the nanoparticles can be maneuvered with respect to the micro organism used. Silver nanoparticle is usually synthesized, owing to its remarkable anti bacterial property.[96] These nanoparticles, if administered in plants will ensure, bacterial protection and prevent infection. Also, Zinc oxide nanoparticles are beneficial [97,98].

These nanoparticles are anti pathogenic and hence can be used in a eco friendly scenario. Soil microbes are an integral part of the ecosystem and contribute hugely to the ecological design[89]. Synthesis of Ag ,Zn NPs are usually are usually done from pure cultures of *Escherichia coli, Staphylococcus, Bacillus,* and*Pseudomonas*,etc. in laboratory situations[100-104]. Incoherence of growth in soil bacterial communities have been reported.[104-106] concentration of nanoparticles in restricted amount can result in being sub lethal.[107]

Effectivity of nanoparticles id attributed by have high surface volume ratio, making it highly metabolically effect.(Ying,2011) . The reaction of nanoparticles with the bacterial colony can assessed for enlightening the extent of scope of nanotechnology related to biological synthesis and its farfetched effects.[98] A significant differences were not observed when bacteria like *Burkholderia kururiensis* was growth evaluated in the presence of NPs. On the other hand, *Pseudomonas fluorescens* showcased a slower exponential growth phase when exposed to nanosilver leading to bioaccumulation of these nano subunits[108]. However, a sublime effect of NPs on bacterial development and plant bacterial interactions has been reported in frequent cases.

5.3. Stress

Many chemical and physical changes are endorsed in the plant system, by the interaction of nanoparticles and plant tissue system. Nanoparticles ranging in the size from 1-100 nm can of varied size and have corresponding effects. Smaller the nanoparticles, greater being the surface, can have large scale impact on the plant tissue. However, larger nanoparticles (NP) reach upto the restricted area of the plant tissue system, agitated by the cell thickening and hence have a controlled effect on the plant body. Thus, we can say the smaller NP which are majorly responsible for physical and chemical changes bring about a change in stress impact of the plants.

Metals have a integral role in the life process of the plant working system. Metal derived nanoparticles have showed great prominence in altering plant process and internal environment. This is due to the fact that metals have immense significance role in the physiology in the plant architecture. Chemical interplay results in the production of reactive oxygen species (ROS), disturbance of ion cell membrane transport activity , oxidative deterioration , and lipid peroxidation.[109-112] By different metabolic processes in the plant body, the produced oxygen is reduced to different reactive species like peroxide, superoxide etc. The continual removal mechanism of ROS can get deterred from different environmental and chemical changes. Thus, administration of metal nanoparticles has revolutionized the combatting of biotic and abiotic stresses of the plant body. Infringement of nanoparticles in plant body can increase stress conditions. Both metal and carbon based nanoparticles are able to deliver ROS induced stress. However, few metallic oxide stand as exception.[116-117] Also, the engineered nanomaterials (ENM) pose many adverse effects on the plant growth and may also culminate into nutrient depletion. These may in result to the phenomena of nanoparticle stress conditions.[114-115] A check on photosynthetic efficiency can highlight the stress conditions of the plant body. Nanoparticle stress can occur on physiological and chemical aspects. Some, carbon nanomaterials effect the plant on genetic and proteomic levels. Out of the metal based nanoparticles ,AgNP deserve special mention as its exposure can bring about signaling and metabolic stress in the plants.[113]

Abiotic stress can be induced by CuO and AgO nanoparticles, in greater quantity as accumulation of metals can increase toxicity. However, in little amount it can result in enhanced plant growth in different spheres[117-119]. Bacterial biofilm formation in the root process is not perturbed by the inception of metal based nanoparticles, in spite of the chance of toxicity which can be caused by the presence of metal ions.[122] Drought and excessive salinity have posed a great threat to the agricultural land productivity. Hence, Na(sodium) being a very important metal in the soil system, can help in the improvement of the deteriorating scenario via the use of nano-reclaimants like nano gypsum, nano calcium and magnesium compounds, etc.[123]

5.4. Influence of Metal Nanoparticles :

Nanoparticles of gold (Au), silver (Ag), copper (Cu), zinc (Zn), aluminium (Al), silica (Si), zinc oxide (ZnO), cesium oxide (CeO_2), titanium dioxide (TiO_2) and magnetised iron (Fe) have found its usefulness in agro-economic areas.(Josef and Katarina, 2015) [124].

For the increment of food production, it is imperative to use various technologies in agriculture. Fertilizers composed/manufactured with nanotechnology have extraordinary significance. This study was endeavored to determine the impact of nanotechnology liquid fertilizers on plant growth and development. (Melek et al., 2014) [125]

5.4.1. Copper Nanoparticles :-

CuNPs can be synthesized from onion *(Alluim cepa)* extracted and ultrasonified at 100 degrees Celsius in a water bath. The translucent yellowish green colour indicated the transformation of copper ions into CuNPs. It was reported that wheat crops when administered with CuNPs in diverse concentrations (15-55ppm), 35ppm gives better results in terms of parameters like chlorophyll content, shoot length, root length, germination percentage, dry and fresh root weight, in comparison with the control. Beyond 35 ppm, it was noted that the growth of wheat crops decreased. Hence, it can be deciphered that

CuNPs have the capability to augment the growth of wheat crops till a certain concentration. [126]

Copper –carbon core shell nanoparticles increase Cu intake in 2 year old bald cypress (*Taxodium distichum*) seedlings but there was no considerable effects on the growth specifications of the seedlings after 25 weeks of NP administration (Qi et al). Qi et al also showed that wood administered with copper-carbon core shell nanoparticles are highly defiant to blue strain (*Ophiostoma minus*) and white rot (*Trametes versicolor*) fungi; and Formosa subterranean termite (*Coptotermes formosanus)*. [127]. Contrarily, Lee et al observed toxicity of CuNPs in two crops species namely, mung beans *(Phaseolus radiata*) and wheat (*Triticum aestivum*), as manifested by declined seedling growth rate. [128]

5.4.2. Silver Nanoparticles :-

Silver NPs have exclusive characteristics such as high surface areas, catalytic ability, surface energy, ample reactive sites and stable adsorption, can have vital effects on many organisms chiefly plants that fundamental sources of all ecosystem [129,130]. The catalytic action has been verified by expanded degeneration of starch and amylase enzyme [131]. AgNPs also demonstrate photocatalytic actions. [132]

Withania somnifera, a significant medicinal plant could not comply the demands of classical medicine practice, because of seed dormancy. The seed dormancy was subdued by administering the W.somnifera seeds with NaDC-capped AgNPs for 90 mins, produced germination that was remarkably higher than the control. [133].

AgNPs has been indentified to hinder the ethylene activity.[134]. Ag eradicates undesirable microorganism in farmers soil and hydroponics system. It is applied as foliar spray to forbid fungi, rot, moulds and various other plant diseases. Furthermore, Ag is an excellent plant growth enhancer , including silver salt, silicate and water soluble polymer to radioactive rays.[135]

The administration of AgNPs in the fenugreek seeds enhanced seed germination, mean germination time, seed germination index, seed vigour index, seedling fresh and dry weight.[136].

5.4.3. Titatium Dioxide Nanoparticles :-

TiO_2NPs has a great significance on bacteria, algae, plankton, fish, mice and rats but research should concentrate on the effects of TiO2NPs on plants which is still lacking.

TiO_2NPs augment seed proliferation and endorse radical and plumule growth of canola seedlings (Mahmoodzadeh et al 2013) [137]. As reported by Jaberzadeh et al 2013, TiO2NPs amplify wheat plant growth. [138]

TiO_2NPs coordinate enzyme actions concerned in nitrogen metabolism such as nitrate reductase, glutamate dehydrogenase, glutamine synthatase, and glutamic pyruvic transaminase that support the plants to absorb nitrate and also aids the transformation of inorganic nitrogen to organic nitrogen, materialize in the form of protein and chlorophyll, that escalate the fresh and dry weight of plants (Mishra et al 2014, Yang et al 2006) [139,140]

TiO_2NPs enact as photocatalyst and promote oxidation-reduction reaction. (Crabtree 1998) [141]. TiO_2NPs induced photosynthesis and nitrogen metabolism and hence immensely augment the growth of spinach at a concentration as low as 20mg/l. [140,142,143]

5.4.4. Gold Nanoparticles :-

Researchers noted that AuNPs enhance toxicity in plants by restraining aquaporin function, a group of proteins that support the ascent of a large range of molecules counting water molecules also. (Shah and Belozerova 2009) [144]. Nevertheless, researchers like Barrena et al (2009) in lettuce and cucumber [145],Arora et al (2012) in Brassica juncea [146], Savithramma et al (2012) in Boswellia ovalifoliolata [147] and Gopinath et al (2014) in Gloriosa superba [148] demonstrates that AuNPs boost seed germination.

Neomycin phosphotransferase II gene was imported into soyabean genome by meands of DNA- coated gold paricles. (Christou et al 1998). [149] The benign effects of AuNPs require further analysis to delve into the physical and molecular methologies. According to Kumar et al (2013), AuNPs have a paramount role in seed germination and antioxidant scheme in Arabidopsis thaliana and transformed levels of microRNAs expression that governs various morphological, physiological and metabolic processes in plants. [150].

5.4.5. Sodium Silicate And Silica Nanoparticles :-

Silica is another most predominantely found element in soil which has benign effect on living and non living, and escalate stress resistance in plants. It can boost the production and product quality, abate evaporation of perspiration, raise the stimulation of a few anti-oxidant enzymes and downturn the receptivity of some fungus. Succeeding oxygen, silica is an effective element in earth, that is non-mobile in plants. Despite the fact that silica is not paramount for plants, higher plants require it for having optimum growth (Richmond & Sussman 2003, Ma et al. 2004, Currie & Perry 2007).[151] The influence of silica on plant is akin to intransigence against biotic and abiotic stress (Ma & Yamiji 2006, Liang et al. 2007).[152] Silica is a crucial constituent against salt stress (Zhu et al.2003) [153], manganese toxicity (Shi et al. 2005) [154], boron toxicity (Gunes et al. 2007)[155] and cadmium toxicity (Shi et al.2010) [156], by means of altering the action of antioxidant enzymes.[157]

5.4.6. Zinc Oxide Nanoparticles:-

Zinc has been viewed as crucial micronutrient for metabolic action in plants. It balances the various enzymatic action and enforced in biochemical reactions leading to the development of chlorophyll and carbohydrates. ZnNP is used in discrete agricultural experiments to figure out its outcome on growth, germination and other distinct attributes.[158]

Information proposes that zinc oxide nanoparticles fortify plant growth and development. It has been noted that in peanut, soyabean, wheat, onion, lessened concentration of ZnONP shows benign effect on seed proliferation.[159-162] It has been tested that diverse

combination of ZnONPs on cucumber, alfalfa and tomato; showed incremented in seed germination only in cucumber.[163]
ZnONPs are likely pertinent in the field of bio-imaging and in the construction of printable electronic devices. These NPs can be allowed to be a choice for the creation of antimicrobial textiles. They are also utilized in nano-medicine for oncological purposes.[164]

6. Implementation of Nanoparticle to Enhance Plant Growth and Yield

6.1. Nanoparticles As Growth Promoter

In the previous years, the experimentalists have mentioned the consequesences of NMs on cultivation and developement with the aim to publicise their utility of agricultural applications. Reactivity of NPs with plants caused various corporeal and physiological changes, based on the attributes of NPs. Efficaciousness of NPs depends on their dissolution and it varies significantly. Coherency of NPs is determined by their chemical composition, size, surface area, reactivity, and the concentration at which they respond positively [165]. NPs pose both constructive and dismissive influence on flora However, it is the objective to establish the positive influence of NPs on seed harvesting, photosynthesis and growth. NPs commonly confronted in the agricultural field fall into respective groups: carbon NMs, metal NPs and metal oxides NPs.

6.1.1. Effect of carbon nanomaterials on plants

Among the NPs, carbon NMs have been acknowledged with a significant place due to their individualistic mechanical, electrical, thermal and chemical properties. The tomato seeds when came in contact with MWCNTs, seed harvest and plant biomass incremented significantly [165]. It has been hypothesized that penetration of the cell wall by NPs leads to the rise in water uptake by seeds which enriched germination percentage Sriniwasan and Sarawathi [166] supported that the single walled-CNTs (SWCNTs) act as nanotransporters for portage of coloured molecules and genetic materials into plant cells. Studies state MWCNTs enriched efficiency of water uptake along with Ca and Fe components uptake incremented the germination and growth [167,168]. Seed cultivation improved in barley, soybean and corn when treated with MWCNTs, examiners using Raman spectroscopy and TEM detected nanotube aggregates inside the seed coat [169]. Oxidized MWCNTs raised cell elongation in rhizome and favoured dehydrogenase action [170]. Impact of water soluble carbon dots which induces certain modifications such as seed germination, root growth and elongation. However single walled CNT can cause Phytotoxicity and related destructive attributes.[171-173]

6.1.2. Effect of metal nanoparticles on plants

It's observed that metal NPs enhanced plant development. AgNPs impacted the rhizome size in maize and cabbage plants in contrast with AgNO3 [174]. Au NPs affected the leaves content, area, altitude and glucose and chlorophyll levels that gave improved crop crop yield [175,176]. AuNPs play an integral role to play on germination and antioxidant levels in *Arabidopsis thaliana* [177]. Au NPs enhanced seed growth in *Boswellia avalifoliata* [178]. Biologically calibrated Ag NPs induced synthesis of protein and carbohydrate and degraded the total phenol content in *Baopa monnieri* [179]. Root length increased in barley exposed to AgNPs [180]. Spinach seeds seeped in Ti NPs solution raised fresh and dry weight driving the contents of overall chlorophyll and protein in leaves [181]. Icreasing the two fold caused rise in height and fresh weight of duckweed when reacted with Ti NPs at 0.5 gL-1 conc. [182].

6.1.3. Effect of metal oxide nanoparticles on plants

Numerous studies on the metal oxide NPs' effectiveness on plants are chronicled. Nanosized TiO_2 favoured plant growth when seeds were allowed absorb in NPs or sprinkled with NPs [183]. Parsley seeds treated with nano anatase, enriched cultivation, root and shoot length and chlorophyll levels of the seedling [184]. The maturation rate of salvia enhanced on seeds exposure to TiO_2 NPs [185]. TiO_2 and SiO_2 NPs blend elevated the nitrate reductase activity and favoured the antioxidant system in soybean [186]. In spinach, chlorophyll production, photosynthesis and plant dry weight intensified when treated with TiO_2 NPs [187,188]. Root elongation favoured at certain specificity of ZnO NPs in soybean [189]. Iron oxide NPs enhanced root elongation in pumpkin [190]. Analyis showed iron oxide NPs incremented soybean pod and leaf dry weight [191]. ZnO NPs led to plant germination in the peanut plant [192]. Suriyaprabha [193] described that seed germination improved using nano SiO_2 which led to advanced nutrient flow to maize seeds.

6.2. Nanoparticles In Disease Suppression :

Viruses, bacteria, fungi and nematodes are mainly liable for plant diseases leading to decreased yield and abysmal quality of plant products. Various propositons to manage crop disease are being used including genetic breeding, cultural schemes with sanitation, host indexing, enhanced extermination protocols, newer pesticides, and integrated pest control. Studies state that NPs were applied to extirpate pathogens which incremented crop growth. Jo et al [194] concorded that Ag NPs in 200 mg/l conc. reduced 50% colonies of pathogenic fungi that caused virulence in ryegrass. Lamsal et al [195] stated that use of Ag NPs favoured the disease eradication. Combination of Ag NP with the fungicide flucanazole were figured to be consequent against *Candida albicans,* followed by *Phoma glomerata* and *Trichoderma* sps [196]. ZnO NPs diminished growth significantly of *Fusarium graminearum* in mungbean broth agar [197].

MgO NPs evinced considerable antimicrobial action due to powerful interplay with a destructive layer of bacterial membranes [198]. Chemically obtained Cu NPs denoted increased infectious fungal impedance
in contrast to the fungicide bavistin [199]. Jo et al. [200] stated effective potencies for obstruction of colony production by silver compounds on *Bipolaris sorokiniana* was enhanced than that on *Magnaporthe grisea*. Silver compounds impeded colony formation of *B. sorokiniana* by 50% at optimum levels. Considerable decline in mycelial growth was recorded from spores nurtured with silver NPs [201]. Silver NPs largely declined the number of cultivational fragments relatable to the control at 24 hour germination of spores with a 2.5 ppm solution of NPs. Field tests were conducted with silver NPs (WA-CV-WA138) at various dissolutions to diagnose antifungal activity. The maximum obstructive rate for the growth of pathogen on cucumber and pumpkins pregnated with 100 ppm silver NPs [202].
Gopinath et al [203] in his scrutiny described antimicrobial and larvicidal activity of biologically intermixed Ceo2 NPs (Fig. 3).

6.3. Nanopesticide And Nanoherbicide :

Pesticides and herbicides are genrally used in agriculture to get better crop yield and efficiency. Currently the destructive aspects of conventional pesticides and herbicides on environment are under argument. The bane of pesticides are favouring the growth of pathogen and pest resilence, degrade nitrogen fixation, declination in soil biodiversity, contributes to bioaccumulation of pesticides, pollinator decline and destroys habitat for birds [204]. Hence, utility of NPs reconciles these problems to most extent, its application with herbicides diminishes the amount of herbicides required for weed expulsion. Having the dynamic and necessary delivery system, herbicides are sprayed in the soil in accordance with the soil condition (Gruere *et al*) [205]. Ag NPs have pesticidal affair against infectious fungi, declared to have obstructive consequences on conidial harvesting of genus *Raffaelea* which leads to the imparmenence of oak trees [206].

6.4. Nanofertilizers :

Nanofertilizers are reffered to as NMs which produce nutrients to the plants or provide assistance to accelerate the proceedings of traditional fertilizers. Replacing nanofertilizers with standard fertilizer is befitting as its exercise is to vent out nutrients into the soil stability and in a restricted manner, thereby averting water contamination [207,208]. Hydroxyapatite (Ca5(PO4)3OH) NPs of 16 nm in dimension, integrated by Liu and Lal [209], evince fecundity effect on soybean. Many survey suggest the application of nanofertilizer reflect upon the constructive effect concerning better crop production along with environmental hazard. The application of NPs incremented the growth rate and seed harvest by 33% and 20% respectively, contrary to typical P fertilizer. The result discerns that the underground system of soybean can hydroxyapatite NPs as an influential P nutrient source. Soil amended with metallic Cu NPs considerably has an accrual effect on 15 day lettuce seedling exhibiting a growth of 40% and 91% respectively [210].

Most surveys throws light on the properties of NPs leading to the revelation of the ability of NPs which can enter the plant cells and transfer DNA and chemicals inside the cell [211-213] surveys gave a podium for estimating that NPs can also provide nutrients to the plants in theform of fertilizers. The nano-organic iron chelated fertilizers showcases high absorption, rise in photosynthesis and elongation of laminal surface area [214]. Additionally, nanofertilezers have immense effect on the soil as nanofertilizers can decrement the harshness of the soil and degrade the recurrence of fertilizer application [215]. Manikandan et al stated that nanoporous zeolite applied on N fertilizer might be used as subordinate structures to enhance the potency of N in the crop production system [216]. . Nanofertilizers due to their properties driven features have immense impact in sustainance of agriculture [217]. Therefore fro ... ehend that the use of nanofertilizer re ... ments, minimise the soil to ... cy.

EFFICACY OF NAOFERTILIZERS & NANOPESTICIDES

6.5. Biosensors :

NPs can be employed as a detective medium for diagnosing of plant pathogens. This analysis is in nascent stage in agriculture. NPs sometime deployed as a examinational tool to identify compounds which could help indicate disease. Fundamentally biosensor has emerged from the grouping of a ligand-receptor binding reaction to a signal transducer. It comprise a inquest, bioreceptor and transducer. The interplay between analyte and bioreceptor is structured to perform an effect estimated by transducer, metamorphose the documentation into electrical signal (Fig. 4). Lopez et al [218] recorded that nano-chips are known for identifying single nucleotide alterations of bacteria and viruses. These nano-chips involve fluorescent oligo apprehension probe through which conglomeration can be figured out. *Xanthomonas axonopodis* leads to bacterial spot disease in Solanaceae plant.Yao et al [209] utilised fluorescence silica NPs in amalgamation with antibody to diagnose the microbes displaying potential of NPs for causing disease. It is now evident that nanobiosensors can be used bounteously for intuitive diverse array of fertilizers, herbicides, pesticides, insecticides, pathogens and thus can favour sustainable agriculture by enriching crop productivity.

6.6. Distribution of Nanoscience in different fields of application.

Miscellaneous use of pesticides and fertilizers leads to environmental adulteration, transpiration of pest, disease, virulence and biodiversity loss. Nanotechnology, through the nanomaterial based characteristics, has potential agro-biotechnological applications to propitiate these problems.

The documentation concerning to the impact of nanotechnology in plant and soil system illustrates that, Nanomaterials may help in the formulations of nanomaterials-based pesticides and insecticides, elevation of agricultural yield using bio-conjugated nanoparticles (encoating) for nominal emission of nutrients and water, nanoparticle-mediated gene or DNA transfer in plants for the evolution of insect pest-resistant miscellany and application of nanomaterials for preparation of different kind of biosensors, use of nano clay composite superabsorbent for higher retentivity of soil moisture and essential plant nutrient is effective in revaluation of the drought stress tolerance in the crop.

The nanoclay composite with unprecedented easy outflow and water-retention capability, nontoxic to soil and environment, could be specially utilarian towards agricultural and horticultural applications for high input use proficiency.

7. Advancing Nanotechnology in India

The endeavour to urge the emergence of Nanotechnology in India commenced years ago. Nanotechnology has always gained enough momentum when it is reckoned to constitute a beneficial effect on India. Numerous initiatives have been undertaken in order to make Nanotechnology more prosperous in India. The impact of Nanotechnology is varied in different realms of life. Instances to cite, on how Nanotechnology has been evolutionized in India.

Dating back to 1998, when the 9th Five Year Plan (1998-2002) was established that made its maiden declaration that national facilities and core groups were build to stimulate research and studies in frontier areas of science and technology which comprised superconductivity, robotics, neurosciences and carbon and nano materials. Planning Commission confirmed the quantity of such research and developmental programmes under standard research (GOI 1998).

Nevertheless, this gained impetus with the inauguration of “Programme on Nanomaterials: Science and Devices” in 2000 by the Department of Science and Technology (DST), GoI.

DST introduced special initiative to trigger and brace certain discontinuance projects leading paramount to concrete operations, products and technologies after acknowledging the predominace of nanomaterials and their immense overarching impact on technology (DST 2001).

In 2001-2002, the DST laid out an Expert Group on “Nanomaterials: Science and Devices”. The Government discerned the necessity to actuate a Nanomaterials Science and Technology Mission (NSTM) in the 10th Five Year Plan (2002-07) after taking into account the advancements in nanotechnology. A strategized framework was stipulated for supportive collaboration for futuristic approach in case of both research based and implementation aligned programmes in nanomaterials (DST 2001).

Documentation of the Tenth Five Year Plan (2002-2007) conformed the varied anticipation for operational programmes such as technology for bamboo products, drugs and pharmaceutical study, instrumental development including development of machinery and equipment, seismology, and also nano science and technology (GOI 2002).

Thereafter, the National Nanoscience and Nanotechnology Initiative (NSTI) was established in October, 2001 under the patronage of the Department of Science and Technology of the Ministry of Science. The stimulus for introducing NSTI in 2001 was to instil explorative infrastructure and publicise basic survey in nanoscience and nanotechnology. It mainly was observant on issues correlating with infrastructural betterment, standard research and application based programmes in nanomaterial including drugs, gene targeting and DNA chips. Nanotechnology was adjudged to be a trailblazing technology with influence in almost every facets of life. Enchanted by the never-ending possibilities of nanotechnological applications and in order to further enrich the visualisation of India 13 in nano science and technology, a Nano Science and Technology Mission (NSTM) was envisaged to provide desired momentum to developmental operations in this field (DST 2006).

The Eleventh Five-Year Plan (2007-2012) unremittingly designed project works to curate pose greater impact on socio-economic domain including nano material and nano devices in healthcare and disease. The generous Eleventh Five Year Plan Budget allocated an amount of Rs. 1000 crore for hypothecating the Nano Mission in 2007, with the objective to foster significant developmental changes and enhanced prospect in this arena.

Nano Science Advisory Group (NSAG) and the Nano Applications and Technology Advisory Group (NATAG) were engendered to inculcate structural development, public private partnerships, technological advancement centres and outlets, Human Resource Development, international collaborations, and Academia-Industry partnerships. In the Twelfth Five Year Plan (2012-2017), the government of India consented the prolongation of the Mission on Nano Science and Technology (Nano Mission) for its Phase-II.

The Council of Scientific and Industrial Research, also known as CSIR established 38 laboratories in India solely for extensive research work in Nanotechnology. Nanotechnology has certainly attained an indispensable stance in the Indian Economy and Scientific

Research Department and it is anticipated to gain the pinnacle of progress hence moulding India to emerge as one of role models on global map.[219]

8. Future Prospects

Nanotechnology, being the multi faceted line of discipline having its roots out stretched in almost every field in the proximity of mankind, holds a scope for improvement and development on regular terms. The efficient and dynamic nature of nanomaterials seek an improvement in application and technical aspect in its intricacies. The future research should be based on ways and techniques to diminish the risk factors related to the implications of nanomaterials such as - checking of permissible levels of nanoparticle dosage must be used within safety limit so that it has minimum or no adverse effects which can be achieved by concentration dependent studies in the natural soil system which can accurately reveal the non-toxic dose of various nanoparticles. A particular nanoparticle can have different effects on different kinds of plant. So elaborate study of the nanoparticle is required, which requires further investigation. Various nanoparticle based studies on plants have been made to apprise the varied regards under nanotechnology, but further comprehensive and extensive studies are in demand, to boost up plant growth and development with the least possible adverse outcomes.

9. Conclusion

The inter disciplinary field of nanotechnology has significant prospective in the study of plant sciences. Nanotechnology being both bane and boon, has multi faceted effect on plant growth and development. Studies conducted showed that nanoparticles have a variety of effects on plant physiology, morphology, response, interaction and overall plant growth evolution. It provides attributes to increase the plant productivity and resistance to many internal as well as external properties. Nanotechnology has helped improvising techniques in the field of agronomic sciences and has made it possible to minimize environmental pollution by producing chemical fertilizers and pesticides by utilizing nanoparticles and nano-capsules which has the ability to control or delay delivery in the intrusion of nanoparticles. With the aid of nano sciences, various plant diseases can be detected at an early stage so that tons of food produced can be protected from possible epidemic conditions which has enticed nanotechnologists for ways to safeguard the plants for bacteria, fungi and viral agents. It paves a way for the development of various techniques that take minimum time for detection, can give quick results, are elementary and precise and does not involve complicated techniques for the operation. Research related to nanotechnology involves the development and use of nanomaterials of various compounds. Nanomaterials can be prepared by various biological and biomimetic origins, with the help of varied techniques.

Critical and detailed analysis of appropriate information has unveiled that nanotechnology can have potential perspectives in the detection and diagnosis of a variety of plant diseases. Nanomaterials, microcapsules and nanotubes can efficiently carry high amount of active pesticide ingredients, chemicals which induce host resistance. Enzyme based biosensors which are covered with nanoparticles of various metals like Ti, Au, Ag, etc., may help in quick and accurate diagnosis of plant infection and would also help in detecting the remnant of pesticides. Development of nanopesticides can provide numerous advantages like: it can improve the solubility of pesticides, enhance the shelf-life, reduce the toxicity of pesticides, overcome the resistance of pesticides by the plants, etc,. In depth study and scrutiny of nanoparticle effect and working mechanism will make understanding of the nanomaterials more sound. Nanomaterials have an effect on the future prospect of mankind.

Conflict of Interst Declaration: On behalf of all authors, the corresponding author states that there is no conflict of interest.

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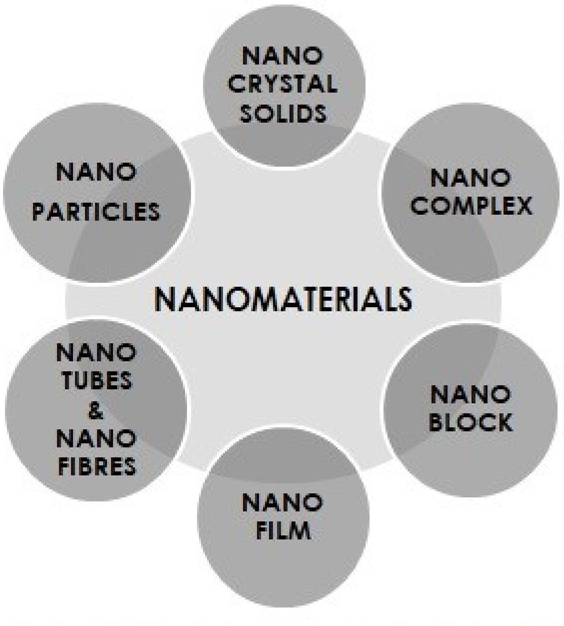

Figure1. Classification of nanomatrials

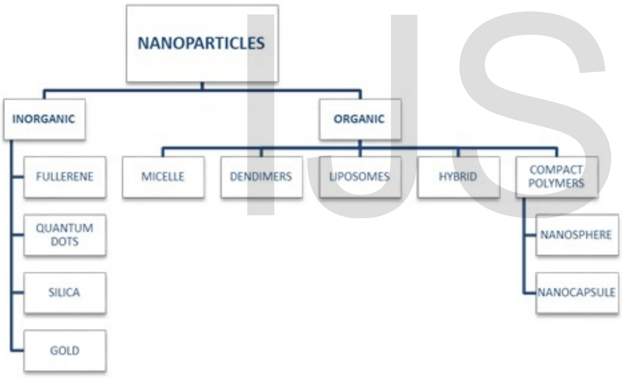

Figure2. Different Types of nanoparticles.

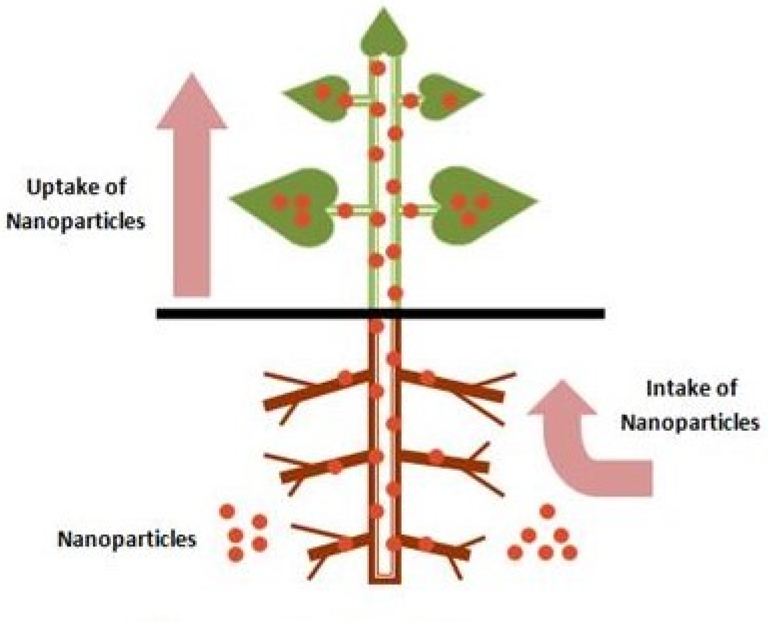

Figure3. A cartoon depicting the entry of nanoparticles in the plant system.

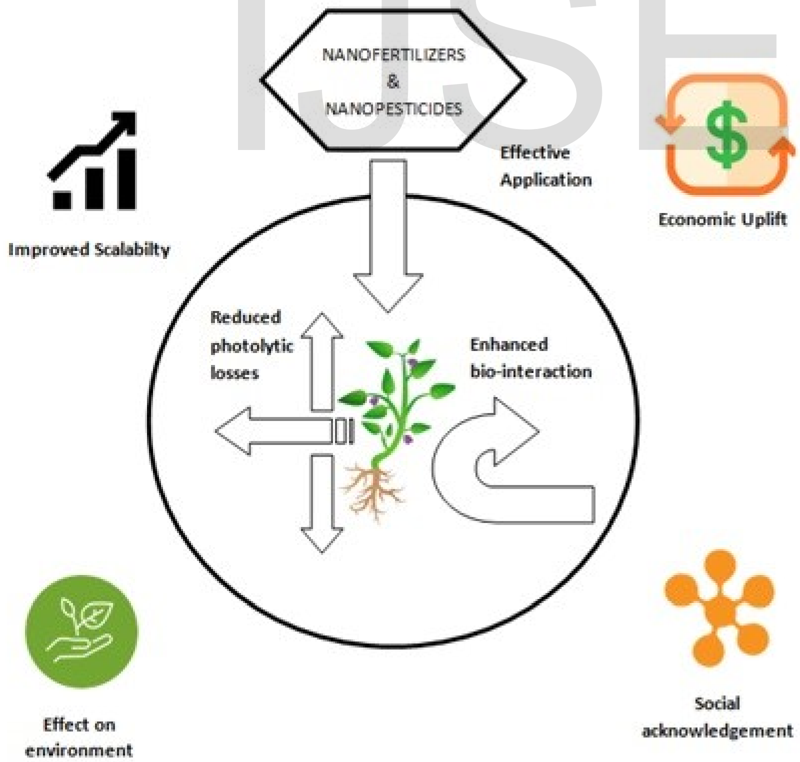

Figure4. A cartoon depecting efficacy of Nanofertilizers and Nanopesticides

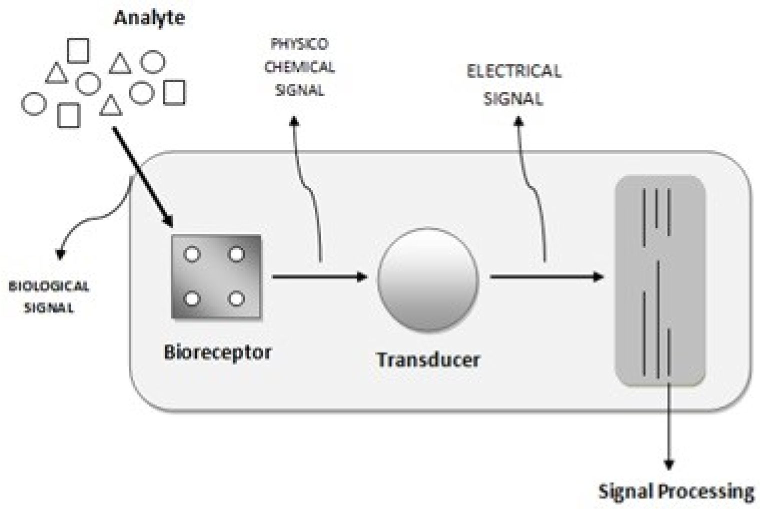

Figure5. A picture depecting the mechanism of biosensor.