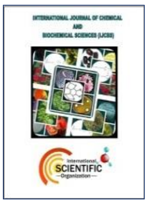
International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page: www.iscientific.org/Journal.html



Effect of nano-fertilizer and growth hormones on different plants

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Abstract

In the developing countries, agriculture sector is very important sector in the economy. So, the use of nanofertilizers causes an increase in nutrients use efficiency, reduces soil toxicity, minimizes the potential negative effects associated with over dosage and reduces the frequency of the application. Hence, nanotechnology has a high potential for achieving sustainable agriculture, especially in developing countries. Some potential applications of nanoparticles in agriculture are reviewed in this manuscript, especially in the field of fertilizers. Plant growth regulators (PGRs) contain synthetically produced organic chemicals and naturally occurring chemicals in large groups. Exogenous application of them brings improvements in different economically important and market desirable characteristics. They contain various factors that take part to the efficiency of plant growth regulators and application method contribute important role to determine the effectiveness of plant growth regulators. They carry various application methods of PGRs but the most useful are foliar sprays, pre-plant soaking and drenching while various factors are responsible for efficiency of each method including mode of absorption of PGRs by various parts of plants, application method and environmental factors. This article presents a review of the role of Indolebutyric Acid (IBA), Gibberellic Acid (GA_3), Abscisic Acid (s-ABA), Salicylic Acid (SA), Indoleacetic Acid (IAA), N-Acetyl Thiazolidine 4-Carboxylic Acid (NATCA) on different plants in different conditions.

Key words: Nanofertilizer, Plant growth regulators, Nanotechnology, Agricultural

Full length article **Corresponding Author*, e-mail: 2014as1614@uaf.edu.pk

1. Introduction

In order to meet the developing requirement for food, agricultural land per unit area required to accomplish greatest efficiency and a product of the highest quality. It is realized that the nutrition of the plant is a standout amongst the most important factor to control the effectiveness and quality of agriculture. Soil nutrient rates impact the quality of yield [1]. In stable agricultural land, the soil is exceptionally poor in nutrients, therefore inadequate. Hence, producers fertilize the soil, fight bugs, irrigate and process agricultural activities to make the soil increasingly capable. Fertilization among these activities remains fundamental concern consistently [2]. However, the an excessive amount of utilization of fertilizers is the requirement for additional land outside the general population and the environmental health of the unwanted impacts reported, for example soil salinity, expansion of heavy metals, eutrophication of water and increment of nitrate, to be considered as far as air contamination in the air of gases containing nitrogen and sulfur, which can give rise to troubles like the greenhouse effect [3-5].

Science, engineering and nanoscale technology, which is more widely known with the new term 'nanotechnology', is a promising multidisciplinary field that can have an enormous potential impact on our society [6]. The nanofertilizers facilitate the slow and constant release of nutrients and, therefore, decrease the loss of nutrients and improve the efficiency of the use of nutrients [7]. Better development of high technology agriculture fields could meet by nanotechnology; intelligent nanotools are used for its preparation that leads to accurate management and control of inputs, containing pesticides, water and fertilizers. Revolution in agriculture practices occur by more improvements in such techniques, which leads to possibly contribute significant enhancement in both quality and quantity of yields, and decrease in the impact of modern agriculture on environment [8]. Nanotechnology use in agriculture and the industry of food can renovate the sector with new tools for the recognition of diseases, directed treatment, improving the capacity of plants to take up nutrients, fight diseases and withstand environmental pressures and powerful frameworks for preparing, storage and packaging [9]. Nanotechnology has also established its capacity to change the hereditary association of crop plants, thus helping to advancing improve crop plants [10]. The relationship among nanotechnology and agricultural sciences can be investigated in the subsequent fields: Need for security in agricultural and nutritional framework; intelligent systems for the avoidance and treatment of plant diseases; making new apparatuses for advancement in cell and organic research; Recycling of waste acquired from agriculture. By utilizing nanotechnology, the development capacity of the plants increases and the best yield time is resolute to accomplish the maximum yield [11]. Structure system of plant hormones is a discrete combination of small molecules, which results from many necessary metabolic pathways. As a significant regulators of plant growth and arbitrate response to both biotic and abiotic stress, these compounds are responsible [12]. Hormones also act to put together different environmental signals with endogenous growth programs [13]. During first half of twentieth centuary, the "classical" phytohormones, recognized, are auxin, cytokinin, absicisic acid, ethylene and gibberellins [14]. Furthure renowned additional compounds as hormones are brassinosteroids, salicyclic acid, jasmonate, nitric oxide and strigolactones [15]. For different development processes during plant growth, many hormones are responsible. This responsibility is seen in the contribution of hormone synthesis, transport and signaling processes, also in many interactions among hormones for controlling growth responses. But some hormonal responses are not concerned with gene regulation, through post-translational modifications all are related to inflection of gene expression, by control of excess transcriptional or repressor factors, also their actions [16].

2. Nano-fertilizer and plant growth

However most of the studies have emphasize the harmful nanoparticles impacts on plants [17-18]. Some investigations recommended that nanoparticles directed at a safe dose can help to promote plant development and in general performance [19-20].

2.1. Metal Nanoparticles

Different nanoparticles, for example, silicon (Si), palladium (Pd), gold (Au), and copper (Cu) impact seed germination of lettuce (*Lactuca sativa*). At different concentration range these nanoparticles show positive effect for example palladium as well as gold at lower concentration, silicon and copper at higher concentration, and gold and copper in combined mixture form [21]. In soybean (*Glycine max*) seed germination rate increased after treating with nanocrystalline powder of iron, cobalt, and copper at minute quantity as compared to control. A markable increase in the chlorophyll index, number of nodules, and crop yield was also abserved [22]. Foliar spray of gold nanoparticles showed positive effect on *Brassica juncea*, it increased stem diameter, plant height, number of pods, number of branches, and seed yield. The treated plants redox status also improved by gold nanoparticles [23]. The SiO_2 nanoparticles significantly increase maize (*Zea mays)* plant dry weight, level of organic compounds such as proteins, chlorophyll and phenols. Silicon nanoparticles have unique physicochemical attributes and they enter into plants and impect the metabolism of plants, like wise improve plant growth and yield under pressure environmental conditions [24]. Although some growth parameters of safflower (*Carthamus tinctorius*) such as canopy spread, stem diameter, plant height, ground cover and the number of achenes in capitulum extensively enhanced by SiO_2 nanoparticles [25].

2.2. Nano-Iron Oxide Particles

A previous it was observed that the treatment of soybean (*Glycine max*) with Nano-iron oxide at higher concentration (0.75 g l^{-1}) had increased leaf + pod dry weight and highest grain yield obtained at lower concentration (0.5 g l^{-1}). Nano-iron oxide increased 48% grain yield in comparison with control [26]. The seedling of mung (*Vigna radiata*) showed positive effect when treated with Nano-ZnO, nano-FeO and nano-ZnCuFe-oxide particles and also displayed good growth over control [27]. The plant growth and yield of cucumbers (*Cucumis sativus*) could improve by the foliar utilizations of fluid nano fertilizer, the highest yield (149.17 t ha-1) occurred in Ferbanat 4.0 L ha^{-1} application [28]. Some development parameters of Saffron (*Crocus sativus*) such as number of flowers, flowers performance, yield of wet and dry stigmas, amount of chlorophyll a, total chlorophyll, yield of dry leaf, concentration of leaf iron and total iron significantly increased by nano iron chelate [29].

2.3. Multi-Walled Carbon Nanotubes (MWCNTs)

Multi-walled carbon nanotubes (MWCNTs) had been accounted for to be able to amplified the development and seed germination of tomato (*Solanum lycopersicum)* [30]. By utilizing the multi-walled carbon nanotubes the plant development and seed germination expanded in mustard ***(Brassica)*** plant. Oxidized Multi-walled carbon nanotubes were more compelling at lower concentration than the non-oxidized MWCNTs for the germination list and relative root prolongation [31].

2.4. TiO_2 Nanoparticles

The photosynthetic proesses of spinach (*Spinacia oleracea)* under both visible and ultraviolet light had been expanded by utilizing the nano-TiO_2 particles because of the crucial role of TiO_2. TiO_2 also expanded development in spinach [32]. At the point when seed of spinach *(Spinacia oleracea*) treated with TiO_2 nanoparticles, they increased 73% dry weight, multiple times higher photosynthetic rate, and 45% augmentation in chlorophyll. The improvement in photosynthetic rate was expected to the increase in absorption of inorganic nutrients which expanded the use of natural substance and quenching of oxygen-free radicals [20].

2.5. ZnO Nanoparticles

Foliar use of ZnO nanoparticles on development and antioxidant system of chickpea (*Cicer arietinum)* seedlings was studied briefly. Chickpea seedling development had positive effect at lower application (1.5ppm) of ZnO nanoparticles. In addition, ZnO nanoparticles expanded biomass expansion because of lower receptive oxygen species levels as set apart from lower malondialdehyde content [33]. Likewise the lower concentration (1,000ppm) of nano zinc effectively affected plants, however at higher concentarion (2,000ppm) it demonstrated toxic effect. Additional, during field experiments, the utilization of multiple times lower amount of ZnO nanoparticles contrasted with the recommended amount of $ZnSO_4$ recorded 29.5 % higher yield of pod [34]. Root lengthening in soybean (*Glycine max*) at 500 ppm concentration however decrease in size at higher concentration of ZnO nanoparticles had been observed [35]. ZnO and CeO_2 nanoparticles at concentration (400 ppm) increased fruit quality, starch content and could change the carbohydrate pattern of Cucumber (*Cucumis sativus*) [36].

3. Growth hormones and plants growth

3.1. Indolebutyric Acid (IBA)

In a study, it was investigated that indolebutyric acid (IBA) increases the marigold (*Tagetes erecta*) flower size, leaves per plant, plant hight, root size, and non-bloom flower at lower concentration (100ppm). Flower size increased at optimum concentration (300ppm). Leaf size and roots per plant increased at higher concentration (400ppm). Maximum branches were observed at medium (200ppm) concentration [37]. The appropriate concentration of IBA and Naphthaleneacetic acid (NAA) before cutting, improve the survival rate of cuttings of Chinese rose. In production, 250 mg/L solution of equal amounts of NAA and IBA dipped the cuttings for 2-3 s greatly improve the survival rate and the production efficiency [38].

3.2. Gibberellic Acid (GA_3)

Lentil *(Lens culinaris*) plants development expanded 43%, by Gibberellic acid (GA_3) while development retardants (Prohex-Ca and Topflor) repressed it by 34% as estimated. Gibberellic acid (GA_3) as well expanded the lentil plant height, while diminishing the seed weight per plant and seeds weight. Indole-acetic acid (IAA), Prohex-Ca or Topflor diminished lentil per plant dry weight. Predominantly GA_3, IAA and kinetin broadly improved specific phenolic compounds (gallic acid and rutin) which are fundamentally utilized as an primary source of naturally occurring antioxidants [39]. Different growth parameters of African marigold (*Tagetes erecta*) considerably enhanced by different concentrations (50,100 and 200 ppm) of Gibberellic acid (GA3) for example height, number of fundamental branches, basal measurement of plant, number of flower per plant, weight of flower, size of flower and flower yield per plant over control. Additionally early flowering and long duration of flowering also occurred at all concentration of GA3 [40].

3.3. Abscisic Acid (s-ABA)

Abscisic acid (s-ABA) was constantly valuable at reducing water loss and extending shelf life for all species treated (impatiens, seed geranium, petunia, marigold, salvia, and pansy). The treatment of bedding plants before transport and transaction with abscisic acid maintain high-gradeability even under harsh deficiency stress environment [41]. Reduction in transpiration and water use in tomato *(Solanum lycopersicum)* significantly enhanced by abscisic acid drenches (125–2000 $mg \cdot L^{-1}$) so abscisic acid treated plants leaves had lower relative water content (RWC) as compared to control plants at 24h after the abscisic acid drench. The leaf relative water content of control plants is 97%, while plants treated with abscisic acid had relative water content 57% to 62%. Abscisic acid induced wilting which was due to the reduction in root conductance and theorized that Abscisic acid affects aquaporins in the roots, preventive water uptake [42].

3.4. Salicylic Acid (SA)

It is reported that, biomass accumulation, number of inflorescences and flavonoid content of marigold plant was significantly expanded due to linear utilization of Salicylic acid (SA). Before the reproductive stage exogenous use of salicylic acid brought about higher biomass production of marigold plants and by expanding complete flavonoids content in the inflorescences increased the value of the raw material [43]. Salicylic acid increased the antioxidant activity of the leaves of *Alternanthera tenella* and can also be recognized to the increase in betacyanin content, which are compounds with standard antioxidant action [44].

3.5. Indoleacetic Acid (IAA)

Ripening of avocado fruits (*Persea Americana*) had clearly effected by Indoleacetic acid (IAA). Indoleacetic acid invigorated respiration and prompted preclimacteric ethylene generation, at higher concentrations (100 and 1000 μm), which bringing about quickened ripening of the fruits. However, the ripening of fruits was delayed, the climacteric respiration and ethylene creation was disguised at the low concentrations (1 and 10 μm) [45]. *Pythium ultimum* symptoms on tomato plant were controlled by the Indoleacetic acid (IAA). The harshness of the side effects brought about by *Pythium ultimum* inside the rhizosphere of plantlets expanded by the low concentrations of IAA (0–$0.1 \mu g ml^{-1}$), while higher concentrations ($10 \mu g ml^{-1}$) applied either by drenching to the developing medium or by showering on the shoot, decreased the side effect caused by this pathogen [46].

3.6. N-Acetyl Thiazolidine 4-Carboxylic Acid (NATCA)

Forchlorfenuron (CPPU) (5 and 10 ppm) and N-acetyl thiazolidine 4-carboxylic acid (NATCA) (50 and 100 ppm) and their combinations were applied to Apricot (*Prunus armeniaca* L.) at pink bud and petal fall stage. The minimum (27.03 %) fruit drop was observed in tree receiving 50 ppm NATCA at petal fall stage and NATCA at 100 ppm at pink bud stage decreased titratable acidity and increased the total sugars, reducing sugars and non-reducing sugars content of fruit [47]. Foliar spray of CPPU at 10 ppm enhanced the vegetative quality like tree height (17.40 %), tree spread (22.17 %), and tree volume (27.82 %) over control. However NATCA (100 ppm) at petal fall stage an increase the fruit set (52.71%) and fruit retention (38.12%) [47]. Foliar spray of (NATCA) on apple cv. Starking Delicious at petal fall stage (1.0ml/L followed by 1.5ml/L) recorded maximum fruit set (22.73% and 28.68%), L/D ratio (0.93 and 0.98) and colour of fruit (62.50% and 76.58%). Lowest fruit drop (17.78% and 16.36%), highest yield (102.50 and 89.13kg/tee) and fruit weight (137.62g and 144.15g) was recorded in trees sprayed at petal fall stage (1.0ml/L followed by 1.5ml/L) 30 days after petal fall stage.

4. Effect of nano fertilizer and growth hormones

Nutrient recovery by crops remains relatively low (e.g., about 50% for N). Since, a nanoparticle is a particle with at least two dimensions below 100 nm, nanofertilizers could soon offer a technological solution to the nutrient-loss problem, thereby aiding technologically-minded farmers and subsistence farming. Nanofertilizers refer to nanoscale-dimension products that deliver nutrients to crops. These nutrients can be i) encased inside nanomaterials for example nanotubes or nanoporous materials, ii) covered with a thin defensive polymer film, or iii) conveyed as particles or emulsions. Germination and seedling development, physiological activities including photosynthetic movement, nitrogen metabolism, mRNA articulation, protein level, and positive changes in genes articulation, have improved by nanoparticles and nanotubes in numerous crops (sunflower, common bean, and maize, among others) which indicating their potential use for increasing crop yields. Nevertheless, additional research is necessary in sort to realized the effect of nanofertilizers on the genetic, physiologic, and morphologic changes in crops, as well as their effect on soil microbial communities, symbioses, physicochemical soil properties, and pollution. One may speculate that the creation and improvement of fertilizers at nanoscale scope could have a deep impact on energy, the economy and the environment. Assumption although, the scientific, technical, and agricultural projects linked with nanofertilizers should be include side effects in order to accurately determine progress and shape a sustainable future [5].

Plant Growth Regulators are substances which can manipulate growth and development in plants. Plant height, leaf number, leaf area index, dry mass, chlorophyll content, photosynthetic parameters, seed yield, oil yield, nutritional status etc can be influenced by plant growth regulators [48]. The spectacular achievements in sex modification of plants have been reported from several quarters by the application of auxins. Ethylene can regulate ripening, senescence, abscission, epinasty, swelling and elongation, hypertrophy, dormancy, hook closure, leaf expansion, flower induction, sex expression and exudation [49]. In cases, where auxins promote femaleness, an application of GA will promote the formation of male flowers. It was reported that application of GA3 induced early flowering and more inflorescence per plant [50]. It is evident that Plant Growth Regulators exhibit a positive impact on different vegetable crops, specifically those belonging to the family cucurbitaceae. Hence, they can be utilized commercially for enhancing productivity of such crops and thus fulfill the demand of the market. However, there is much scope to investigate the effect of these phytohormones on other economic plants [51].

5. Conventional fertilizers versus nano-fertilizers

Conventional or traditional fertilizers are generally applied on the crops by either showering or spreading. Be that as it may, one of the fundamental factors that choose the method of utilization is the final concentration of the fertilizers that achieve the plant. In the practical circumstance, because of draining of synthetic compounds, float, overflow, dissipation, hydrolysis by soil moisture, photolytic and microbial degradation the much lower concentration (well underneath the desired concentration) achieves the objective site. Feasible and economic losses happens, because it had been evaluated that around 40–70 % of nitrogen, 80–90 % of phosphorus, and 50–90 % of potassium substances of applied fertilizers was lost in the environment and couldn't achieve by the plants [52]. These issues have been caused because of steady utilization of fertilizer and pesticide which destructively influences the natural nutrient balance of the soil. Environmental pollution brought about by extreme utilization of chemicals as fertilizers and pesticides irritating ordinary flora and fauna. That's why, to satisfy the crop nutrient necessities and to lessen the risk of environmental pollution, it is very essential to upgrade the utilization of chemical fertilization. Therefore, it tends to be invaluable that different methods of fertilization be also tested and used to supply essential nutrients for plant development and yield production, as maintenance the soil structure in good shape and the environment clean [53]. To expand the nutrient use competence and decrease the cost of environmental contamination nanotechnology has given the possibility of investigating nanoscale or nanostructure materials as fertilizer transporter or controlled-discharge vectors for working of the smart fertilizers as new facilities [54]. Nanomaterials coatings on the surface of fertilizer particles grasp the material more intensely because of higher surface pressure than the conventional surfaces which help in controlled discharge [55]. Utilization of nanotechnology in agriculture is a significant characteristic to release of agrochemical for example, fertilizer supplying macronutrients and micronutrients to the plants. Nano-fertilizers show controlled discharge of agrochemicals, site targeted delivery, decline in poisonous quality, and improved nutrient utilization of delivered fertilizers [56]. These attributes of nanoparticles are because of their high surface area to volume proportion, high solubility, and specific focusing because of small size, high versatility, and low toxicity [57].

6. Conclusions

An extreme nutrient deficiency in agricultural soil has brought about remarkable diminishes in effectiveness of yield and tremendous agricultural economic losses. However, improvement in crop production could achieve by use of chemical fertilizers. Their use in excess is not a better option for extended time. Fertilizer bearer as nanostructured material can bring improvement in nutrient use efficiency and minimize the natural contamination expense. Precise release of their active ingredients in response to ecological triggers and natural demand can perform by nano-fertilizers. Different nanoparticles, for example metal nanoparticles, nano-iron oxide particles, multi-walled carbon nanotubes (MWCNTs), TiO_2 nanoparticles, ZnO nanoparticles fundamentally improved the distinctive development parameters of various plants under different concentrations and environmental conditions. An organized and precise quantitative examination concerning the possible impacts on health, environmental consent, and safe nanomaterial disposing could guide for enhancements in controlling advance utilization of nano-fertilizers. Throughout agriculture, viticulture, and horticulture different plant growth regulators are frequently used to enhanced plant growth and crop yield under non-perfect soil and natural conditions. Indolebutyric Acid (IBA), Gibberellic Acid (GA_3), Abscisic Acid (s-ABA), Salicylic Acid (SA), Indoleacetic Acid (IAA), N-Acetyl Thiazolidine 4-Carboxylic Acid (NATCA) amazingly increase different growth parameters and crop yield. Their utilization may continue remodel achievement by upgrading development of moderate developing nearby plants and transplanted seedlings and cuttings.

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