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Effect of plant growth hormones and plant nutrients on different plants: A detailed literature review

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Abstract

Micronutrients along with macronutrients play a vital role for the better growth and development of plants. Nutrient reduction in the soil has becomes major problem all over the world due to the over cultivations of the fields. Nutrients are leached out due to extensive cropping and require a constant and sustained supply of micronutrients and macronutrients to produce better-quality agriculture products. For the enhancement of global crop production, the development and application of various new types of fertilizers using nanotechnology are one of the potential and effective options. Optimized amount of soil micronutrients, macronutrients and growth hormones can be used for the better crop yields. The present review describes different macro and micronutrients along with growth hormones in detail in the perspective of increasing crop yields significantly.

Key words: Zinc, basil, growth hormones, nutrients, fertilizers

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1. Introduction

The demand for food from agriculture land per unit area has increased in the recent years [1]. It is well known that the nutrition of the plants is the one of the most important factors to control agricultural productivity and quality [2-3]. The rate of nutrients in the soil affects the quality and quantity of produced crops. Chemical fertilizers are reported to have many deleterious effects on human health owing to the presence of lethal and toxic heavy metals in it [4]. These heavy metals also have negative impact on land, soil, water and human beings [5]. Excessive use of chemical fertilizers has hazardous effects causing pollution and lead to many problems [6] including greenhouse effect. The increase in amount of nitrate (due to the use of nitrogen fertilizers) and phosphate (due to the phosphorus fertilizers) in rivers and drinking water are causing too many environmental and health problems [7]. The extreme use of nitrogen fertilizers contains many carcinogenic substances such as nitrosamines and their derivatives. Spinach and lettuce leaves are eaten which leads to the accumulation of harmful chemical constituents like NO_2 and NO_3 in animal and human bodies [8]. As a result of these increased concentrations, level of atmospheric nitrogen is increased and amount of nitrogen dioxide is also enhanced that acts as a potential greenhouse gas and disturbs the natural ecological balance [9]. Some of the radionuclides and heavy metals such as cadmium and chromium are present in chemical fertilizers in large proportions and cause number of environmental problems [10-11]. It is necessary to overcome the problem of uncontrolled fertilizer use to avoid the further environmental and health damages. In order to overcome these escalating environmental and health issues, globally researchers has put their efforts in synthesizing the nano fertilizers [12]. These nano fertilizers have thus reduced the shortcomings of commercial fertilizers and have long lasting impacts on atmosphere and human health [13]. The nano science and nano technology has vast applications in each and every field including agriculture productions [6-14-15]. The new strategies are introduced to synthesize the nano materials, nano pesticides and nano fertilizers that not only contributes in increasing the agricultural products but also reduces the risk of environmental pollution [16]. Nano materials are defined as an ingredient containing particles with atleast one dimension that approximately measures 1-100 nm. Nano fertilizers (an alternative of ordinary chemical fertilizers) have larger surface area that contributes to increased absorption of fertilizers and are helpful in overcoming the loss of nutrients due to the leaching effect [17-18]. The fertilizer loss caused by elution and evaporation in the soil system is minimized with the use of nano-sized materials [19-20]. The nano fertilizer nutrients retain their identity in soil due to their diversity [21-22]. In addition, nano fertilizers are cost effective and prevent water from toxic pesticides and insecticides.

The preferred use of nano-fertillizers is of extreme importance in modern agriculture as it helps to increase the yield of crops and quality parameters of plant growth such as increased nutrient efficiency, reduced fertilizer usage and total cultivation cost. Nano-fertillizers increase the surface area and provide space for number of metabolic reactions in plants to take place. These fertillizers increase the rate of photosynthesis and enhances the growth of biomass in plant. Nano-fertillizers enable the plants to bear the biotic and abiotic stresses. The nano-fertilizer is the nanomaterials that could serve as macro and micronutrient for plants [23]. It can also act as nanocarriers for efficient utilization of nutrients from conventional chemical fertilizers [24]. Nano particles are generally synthesized by precipitation method using micro and macronutrients in the fixed proportion. The process of formation of separable solids from solutions either by changing the chemical composition of solvent or through conversion of soluble materials into insoluble substances is called "precipitation".

2. Plant nutrients

2.1. Macro-nutrients

Macronutrients (redox-sensitive agents) play a significant role in the development of plants. These macronutrients enhance the growth, quality and yield of crops. Due to the effective behavior, the macronutrients contribute in various metabolic processes that occurs in plants [25-26]. Plants require various macronutrients (calcium, magnesium, nitrogen, phosphorous, potassium) in relatively larger amounts, as these are usually present in low concentration in the soil, for better growth of plants [27].

2.1.1. Primary nutrients

Role of Potassium: The potassium is one of the most significant primary nutrients of plants. It is required in large amount for the proper growth and development of plants. Potassium is the second most important plant nutrient after nitrogen, therefore it is considered as "quality nutrient". Potassium helps to regulate the opening and closing of stomata and activates the large number of enzymes essential for metabolic reactions of plants. It also promotes the efficiency of water usage.

Role of Nitrogen: Nitrogen is crucial to produce amino acids (building blocks of proteins) and is also necessary for the division of plant cell. It is also key component for the growth of plants.

Role of Phosphorus: Phosphorus is necessary for the respiration of plants and process of photosynthesis, energy transfer process, cell division and enlargement. It also improves the quality of fruits, grains, and vegetables by increasing the growth of plants.

2.1.2. Secondary nutrients

Role of Calcium: Plants utilizes calcium for the formation and continuous division of cells. It decreases the respiration in plants and helps in the translocation process of photosynthesis from leaves towards the other organs.

Role of Magnesium: Magnesium helps in mobility of phosphorus in plants and is a fundamental element for the chlorophyll production. It improves the consumption of iron in the plants.

Role of Sulphur: Sulphur aids in the development of vitamin and enzymes in plants. It is the fundamental part of amino acids. It stimulates the formation of nodes on the legumes. It also helps in the production of seeds and is necessary for chlorophyll formation in plants.

2.2. Micro-nutrients

Micronutrients (Zn, Fe, B, Mn, Cu and Mo) are essential for growth of plants. In addition, their inadequacy can interrupt the quality and yield of plant [28]. The deficiency of micronutrients in plants is the result of high pH, calcareous nature of soil and depleted organic substance etc. [29] [28].

Role of Nickel: Nickel and cobalt are required in very small amount for the proper growth of plant. Nickel is a component of some plant enzymes and helps to regulate urea levels in plants. Deficiency of nickel in plants results in urea toxicity.

Role of Molybdenum: Molybdenum produces reductase which reduces the conversion of nitrates into ammonium. It also aids in the node formation on the legumes and is essential for the production of organic phosphates [30]. It serves as the fundamental part of various enzymes systems. It helps in the production of chlorophyll and also improves the Ca and P availability [31].

Role of Iron: Iron facilitates the production of chlorophyll. It acts as oxygen carrier that is involved in the growth of plants. Iron is also part of reactions involved in cell division [32].

Role of Copper: The copper activates some essential plant hormones and enzymes involved in the synthesis of lignin. Copper helps in the regulation of large number of processes such as respiration, photosynthesis and metabolism of proteins and carbohydrates. The copper ion is toxic to all plant cells and must be used in discrete doses or relatively insoluble forms to prevent tissue damage [33].

Role of Chlorine: Chlorine is an essential micronutrient of plant. It is taken up by the plants in form of chloride ion (an electrically charged form of chlorine). The chlorine is most commonly found in form of chlorinated organic compounds [34].

Role of Boron: Boron is necessary for growth of pollen tubes and pollen grains germination. It is also involved in the formation of cell wall and seeds [35].

Role of Zinc: Zinc is vital for production of chlorophyll and helps in the system of enzymes and growth hormones. It also facilitates the formation of starch and carbohydrate and in seed formation. Plants also required oxygen, carbon and hydrogen, additionally to the above cited nutrients which are extracted from water and air to make up the bulk of plant weight [36].

3. Plant growth hormones

3.1. Role of oxalic acid

Oxalic acid and various other oxalate ions are found in seeds, fruits, stems, roots and leaves of plants. It is a dicarboxylic acid having acidic strength greater than the acetic acid. It is the strongest organic acid naturally found in plants. Oxalic acid acts as a strong reducing agent and its conjugate base is known as a potential chelating agent for large number of cations including iron, manganese, zinc, magnesium and calcium. Oxalic acid forms different oxalate ions upon reaction with cations. The solubility of oxalic acid is much higher in water as compared to the solubility of magnesium oxalates, potassium oxalates and sodium oxalates. On the other hand, solubility of calcium oxalate is very less among all other metallic oxalates. Due to the ion chelating properties of metallic oxalates, oxalic acid is used as a bleaching agent in dying industry for removal of rust stains. It is also helpful in restoration of old wood blocks [37].

3.2. Role of salicylic acid

Salicylic acid a universal plant phenolic compound, is acquiring great attention as a regulator for metabolism and physiological processes of plants. It is also involved in both systematic and local plant defense response. It plays a significant role in development, plant growth regulation and immune responses [38]. The deleterious effect of 10^{-2}M salicylic acid on counteracting of NaCl having different concentrations (50, 100 and 150 mM) was applied on maize (*Zea mays* L.). Different parameters (shoot and root lengths, fresh and dry weight, and leaf area) were determined to check the effect of SA on the salt tolerance capability of maize. Appliance of different test levels of NaCl to maize plant has influenced their growth parameters as compared to control plants. The plants treated with salicylic acid exhibited a greater tolerance to salt treatment. This increase in salt tolerance was reflected in measured growth parameters (leaf area, fresh and dry weight and length of roots and shoots) as compared with the plants that only received NaCl [38]. The effect of drought stress and spray of salicylic acid was studied at two different concentrations (10^{-4} and 10^{-5} mol/L) on *Zea mays* plants. These concentrations were applied to plants for about 10 days (30–35% field capacity). The SA has more distinct effect at 10^{-4} mol/L as compared to 10^{-5} mol/L. But the foliar spray at a concentration of 10^{-5} mol/L is more effective for adapting the effect of drought stress on maize [39]. The effect of salicylic acid was studied on basil (*Ocimum basilicum*) and marjoram (*Majorana hortensis*) at different concentrations in pot experiments. Salicylic acid increased the fresh weight and dry weight of herbs, amino acids, total carbohydrates, photosynthetic pigments as well as micro-element contents at concentration of 10^{-4} M. Percentage yield of oil was also increased at 10^{-4} M in basil plant while at 10^{-3} M in marjoram comparative to control treatment. Major, chemical components present in essential oils were analyzed by gas chromatography coupled to mass spectrometry (GC-MS) [40-41]. The results revealed that common components of essential oil of *Ocimum basilicum* under all treatments were α-cadinol (4.46-9.59%), linalool (43.32-46.63%), 1,8-cineol (4.43-13.20%), methyl eugenol (5.68-13.83%) and eugenol (7.16-12.64%). Salicylic acid at concentration of 10^{-4} M was found to increase the quantity and quality of basil oil. Marjoram essential oil contained cis-sabinene hydrate (14.27-37.50%), β-caryophyllene (1.76-3.82%), terpinen-4-ol (13.99-24.33%), α-terpinene (0.00-2.41%), p-cymene (2.29-18.21%), sabinene (4.11-17.69%), trans-sabinene hydrate (5.45-8.19%), γ-terpinene (4.77-10.64%) in addition to α-terpineol (3.96-5.52%). Moreover, SA at 10^{-5} M and 10^{-3} M improves the quality of oil by increasing the level of sabinene component accompanied by the decrease in the proportion of cis-sabinene hydrate comparative to controls. It was concluded that SA treatment at concentration of 10^{-4} M might have higher capability to reduce stress and better ability for osmotic adjustment in both species [42].

3.3. Role of triacontanol (TRIA)

The effect of TRIA was studied at different concentrations, on crop productivity and crop quality. Hyacinth bean plant was grown in pots and different concentrations (10^{-0} (control), 10^{-8}, 10^{-7}, 10^{-6} and 10^{-5} M) were applied at interval of 15 days. Different parameters like fresh and dry weights, chlorophyll contents and carotenoid contents, carbonic anhydrase contents, nitrate reductase activity, leghemoglobin contents and leaf contents were studied at interval of different days (60, 90 and 120 days) after sowing. At higher concentration of 10^{-5} M all the parameters were drastically decreased at all three stages. Seed yield and protein contents were increased at a concentration of 10^{-6} M. TRIA also promoted the activity of tyrosinase in comparison to control plants [43].

3.4. Role of gibberellic acid

Gibberellic acid is an important plant growth regulator that (i) influences the germination of seeds (ii) triggers the growth of shoot (iii) ensures the rejuvenation of adult leaves (iv) increases the number of flowers (v) determine the sex expression of plants and (vi) helps in the development of grains. It also improves the interactions of plants with environment by involving the moisture contents, temperature and light intensity. Stamens of the plants are the major bioactive sites of gibberellic acid that influence the pedicel growth and production of male flowers [44].

To check the effects of induction of gibberellic acid and salt tolerance on physio-chemical responses of wheat, three different concentrations (such as 100mg/L, 150mg/L and 200mg/L) were applied on the two varieties of plants. These two varieties include salt tolerant wheat (Inqlab-91) and salt intolerant wheat (MH-97). The results of this experimental study indicated that all the concentrations of gibberellic acid improved the yield of grains in both types of wheat. However, the concentration 150mg/L showed the most pronounced effects on salt tolerant species of wheat. This level of concentration decreased the uptake of sodium in both roots and shoots and increased the concentration of potassium and calcium in the roots of both verities [45].

3.5. Role of NATCA/AATC and forchlorfenuron

To increase the yield of apricot, eleven different treatments of two growth regulators including forchlorfenuron (CPPU) and N-acetyl thiazolidine 4-carboxylic acid (NATCA) were applied. The concentration of CPPU was taken as 5 and 10 ppm while that of NATCA was 50 and 100 ppm. The combinations of both hormones were also applied to the pink bud and the petal fall stage. After two times, the application of hormones in the form of spray significantly improved the petal fall stage. Foliar spray of CPPU at a concentration of 10 ppm increased the size of fruit (29.88 mm), breadth (30.51 mm), weight (16.20 g) and volume (14.93 cc). By keeping all the observations in consideration CPPU at a concentration of 10 ppm in petal fall stage found to be the best among all the treatments [46].

3.6. Role of indole acetic acid (IAA) and indole butyric acid (IBB)

The effect of IBA and IAA (Auxins) concentrations were studied on trees of *Terminalia arjuna* (Roxb.) vegetative reproduction through rooting of the stem cuttings. Different concentrations of 0, 500, 1000, 1500 and 2000 ppm of Indole 3-Butyric acid (IBA) and Indole 3-Acetic acid (IAA) were applied to the plants that were planted in the poly bags kept under controlled conditions. In comparison to two auxins applied, IBA was the most effective one. Out of different concentrations of IBA and IAA, 2000 ppm concentration of IBA was found to be the best and attained over 75% of rooting in cuttings. It also triggered greater number of roots, increased length of roots, enhanced shoot proliferation, and produced maximum shoot and root biomass [47]. The effect of Indole butyric acid (IBA) hormone on the plant of guava (Sufeda) was also studied previously. One-year old healthy branches of guava were grown and wounded by complete removal of 2 inches bark just below the bud for rooting. Wounds were covered with soil media having various concentrations of IBA hormone and were tied from both ends. After application of the treatment, it was concluded that plant treated with 150 ppm IBA produced the best results [48].

4. Effect of growth hormones

Plant hormones also referred as the photo-hormones and have the chief role in healthy development of plant parts and plant body. These hormones act as a functional unit of plants and carry out essential chemical reactions and metabolic processes as well. They have a dominant role in the healthy growth of leaves, stems, and flowering as well. These hormones also help plants to overcome the stress. Plant hormones effects the physiological development (growth, differentiation and stomata movement) at minute concentrations [49]-[50]. In addition, they participate as a controlling agent in plant reproduction [10]. Plant hormones normalize the augmentation of plants and take part in extremely minute proportions. Growth hormones are most effective for plants because they help to initiate the rooting in stem cutting, promote natural detachment of older leaves and fruits and promote flowering in plants.

5. Conclusion

Micronutrients along with macronutrients play a vital role for the better growth of plants and their reduced amounts in the soil becomes a major concern for the scientists all over the world. Micronutrients are always required in truly little amounts but play an especially important role in the physiological processes of the crop plants. Macronutrients play a particularly important role in plant growth and development. They are found to be helpful in structural development and acts as redox-sensitive agents. Plant hormones affect the (i) plant growth (ii) cell division (iii) transcription level and (iv) gene expression. In this regard, nanotechnology holds great potential to sustain the agricultural practices, to reduce the environmental concerns and to cause less harm to naturally existing biota. Nano-fertillizers encapsulate the plant growth hormones and essential plant nutrients at nano scale for efficient delivery and controlled release ensuring the cleaner surroundings.

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