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Review article

The Use and Importance of Nano Fertilizers in Medicinal Aromatic Plants[a]

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ABSTRACT

Medicinal and aromatic plants are widely used in the food, pharmaceutical and cosmetic industries around the world. The production of medicinal aromatic plants, which are subject to international trade, is increasing rapidly due to the increasing demand in recent years. The added value of medicinal and aromatic plants grown organic or with good agricultural practices is increasing in both domestic and foreign markets. New generation nano-fertilizers that are sensitive to human and environmental health may be a more effective application for nutrient management in good agricultural practices in medicinal aromatic plants, as they have more penetration capacity, surface area and efficiency. Although there are few studies investigating the effects of nanofertilizers on the yield and quality of medicinal and aromatic plants, these studies have determined that nanofertilizers have a positive effect on yield and quality. This approach opens a new avenue for investigating nanofertilizers as an alternative application to traditional fertilizers used in medicinal aromatic plant culture.

Keywords: Nano, fertilizer, medicinal aromatic plants

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Derleme makale

Nano Gübrelerin Tıbbi Aromatik Bitkilerde Kullanımı ve Önemi

ÖZ

Tıbbi ve aromatik bitkiler dünyada gıda, ilaç ve kozmetik sanayinde yaygın olarak kullanılan bitkilerdir. Uluslararası ticarete konu olan ve son yıllarda artan talepten dolayı tıbbi aromatik bitkilerin üretimi hızla artmaktadır. Organik ya da iyi tarım uygulamaları ile yetiştirilen tıbbi aromatik bitkilerin hem iç hem dış pazarda katma değerleri artmaktadır. Yeni nesil, insan ve çevre sağlığına duyarlı nano-gübreler daha fazla nüfuz etme kapasitesine, yüzey alanına ve verimliliğe sahip olmalarından tıbbi aromatik bitkilerde iyi tarım uygulamalarında besin yönetimi için daha etkili bir uygulama olabilir. Nano gübrelerin tıbbi ve aromatik bitkilerin verim ve kalitesine etkisini araştıran az sayıda çalışma bulunmakla birlikte yapılan bu çalışmalarda verim ve kalite üzerine nano gübrelerin pozitif etki yaptığı belirlenmiştir. Bu yaklaşım, tıbbi aromatik bitki kültüründe kullanılan geleneksel gübrelere alternatif bir uygulama olarak nano gübrelerin araştırılması için yeni bir yol açmaktadır.

Anahtar Kelimeler: Nano, gübre, tıbbi aromatik bitkiler

Introduction

When population growth is evaluated in a national, regional and global context, limited natural resources and climatic changes, the effects of which we are beginning to see, have become an important issue for future generations. Moreover, issues such as meeting the food needs of the increasing population, ensuring food security, decreasing natural resources and global climate change increase the importance of agriculture. Since the beginning of human history, agriculture has continued its existence sensitively in every period, as it is both a source of food and plays an important role in the development of economic disciplines by providing the raw material source of the industry.

One of the biggest challenges of global agriculture is the rapidly growing human population. It is estimated by the World Health Organization that the global population size will reach 10 billion in 2050 (United Nations, 2019). Factors such as misuse of agricultural land, increased food requirements and environmental pollution have reached levels that threaten human health. As a result, researchers have not only searched for ways to increase crop production, but also turned to alternative solutions to increase the yield per unit area. In plant production, it is very important to obtain a high level of product yield and increase economic profitability. This is achieved through proper fertilization methods in agricultural production. The income provided by farmers who use nutrients in crop production is also an indicator of the demand for fertilizer.

Soil, which is the first of the production factors, also constitutes the main source of agricultural activities. When fertilization is carried out using incorrect methods and in an uncontrolled manner, it can cause direct and indirect harm to the environment. As a result of applying chemical fertilizers to the soil more than necessary; It can cause negative effects such as deterioration in soil structure, heavy metal accumulation, increasing soil salinity and toxicity levels, negatively affecting the population and life of soil organisms, causing nitrate accumulation in underground and surface waters, and causing eutrophication (Karaca and Turgay, 2012). It can be said that the biggest factor of land destruction, desertification and the risks arising by these negativities arise as a result of human activities. Agricultural methods that have been widely used for many years have reduced the existing quality of the soil; caused it to lose its physical, chemical, and biological properties and decrease its efficiency (ÇMUSEP, 2019).

Global population growth has brought about the necessity of providing high productivity per unit area in agricultural areas in order to meet food and nutritional needs. For this reason, humankind has tried to find more efficient resources to meet this need in order to increase the efficiency of plant production, and in this direction, agricultural systems in which fertilizers are used for plants have been developed in agricultural areas. At the beginning of the 19th century, Carl Bosch first introduced fertilization in agricultural areas by adding organic and inorganic substances to the soil to provide the necessary plant nutrients to obtain more product per unit area. Approximately 10-20 years after the Haber-Bosch process (the method used to fix ammonia and nitrogen) was commercialized in 1913, a faster increase in the world population was observed and more fertilizer was needed (Tsuji, 2010). In Türkiye, synthetic fertilizer production started in 1939 with the production of ammonium sulfate as a by-product at the Karabük Iron and Steel Enterprises. The first fertilizer facility was established by the public in 1954. In order to meet the increasing need for fertilizer, public investments continued in the following years, and it took its place in the private sector in the 1970s (Aydoğan and Demiryürek, 2012).

Nanotechnology

The word nano is a word of Greek origin and the use of this word means very small. On the other hand, scientifically, the word nano means a unit of measurement that is one billionth of a meter. Nanotechnology field of study is in a wide variety of fields such as food industry, agriculture, electronics, medicine, textile, automobile, energy, improving water quality, sports equipment, improving air quality, space science; It examines substances whose size is less than 100 nm. The field of nanotechnology is concerned with producing and functionalizing biological or non-biological structures in the size of 0.1-100 nm. In order to achieve development in this field, multidisciplinary studies of biology, food, agriculture, medicine, physics, engineering and chemistry are needed (Kayır and Baççıl, 2010; Liu and Lal, 2014; Demirbilek, 2015; Dağhan, 2017).

Nanotechnology is recognized by the European Commission as one of six "Key Enabling Technologies" that contribute to sustainable competitiveness and growth in various areas of industrial application. Current situations regarding sustainability, food security and climate change are driving researchers to explore the field of nanotechnology as a new source of significant improvements for the agricultural sector (Parisi,Vigani,and Rodriguez-Cerezo, 2015).

Nano fertilizers

One of the highly effective and slow-dissolving fertilizer types is nanotechnology fertilizers. Nano-sized elements make it much easier for plants to absorb minerals. These are types of fertilizers that can be applied especially foliar. Much more effective results can be achieved by using less fertilizer. Nano fertilizers in agricultural production; They are known as nano materials that have an enhancing effect on the growth and development of the plant and provide nutrients to the plant. Nanofertilizers can be classified at two basic levels: those containing micro and macro nutrients (Chhipa and Joshi, 2016). Macro nano fertilizers, which are essential for the growth and development of the plant, contain elements such as nitrogen, potassium, phosphorus, sulfur, magnesium and calcium. These nano fertilizers are fertilizers that dissolve slowly in the soil and have high efficiency performance. Micro nano fertilizers, which make plants resistant to pathogens, are nano fertilizers that contain trace elements that the plant needs, even in small amounts (Dağhan, 2017).

Nanofertilizers deliver the nutrients necessary for plant development to the plant in three different ways. These are respectively; The plant nutrient element is encapsulated in the nano material in the form of nano tubes or nano porous materials. Secondly, the plant nutrient element necessary for the plant is covered with a thin protective polymer film. Thirdly, plant nutrients are transported to the plant in the form of nanoscale particles or emulsions. Thus, the efficiency of the use of nutrients can be increased by transporting nanofertilizers in nanoparticles to the plant (Valizadeh and Milic, 2016; Dağhan 2017). As a result of the research, nanomaterials in agriculture aim to reduce the amount of dispersed chemical products, while minimizing nutrient losses during fertilization thanks to the smart distribution of active ingredients, so the quality and quantity of the product obtained by applying nanofertilizers can be increased (Parisi, Vigani, and Rodriguez-Cerezo, 2015; Mukherjee, Sinha and Das, 2015). Increasing product yield in agriculture, reducing environmental pollution, and developing innovative and effective fertilizers by using new technologies for reliable and sustainable agriculture and the environment have become a need of recent years. As a result of the use of nanofertilizers in the form of nanoparticles, the healthy growth and development of the plant, its resistance to pathogens, and its productivity and quality characteristics increase, and another issue is that this issue will be examined more broadly in the future (Rameshaiah, Pallavi and Shabnam, 2015; Dağhan, 2017).

Nano fertilizer applications in medicinal and aromatic plants

Medicinal and aromatic plants cover a large area that is evaluated in many ways. It has a wide range of uses, both as raw drugs of plants, as well as active ingredients and as products with outputs in terms of various consumption areas. In this regard, although there is no standardized grouping today, they are generally grouped according to their families, the active substances they contain, their consumption and use, the organs used and their pharmacological effects (Ceylan, 2015). Cultivation of medicinal and aromatic plants has become widespread in recent years due to the inability to meet the commercial needs through collection from nature, the lack of standardization and the need for endangered species. Since medicinal and aromatic plants are widely used in the food, cosmetics and pharmaceutical industries, organic and good agricultural practices are preferred in their cultivation. In recent years, the added value of medicinal and aromatic plants grown with organic farming or good agricultural techniques has been increasing in both domestic and foreign markets in order to meet the demand for medicinal aromatic plants in the world market. Since the quality of the final product in medicinal aromatic plants is very important in determining their share in the market, correct fertilizer applications are essential in the cultivation of medicinal and aromatic plants for both human, environmental and soil health. Fertilizers with a size below 100 nm can be used as nano-fertilizers for more environmentally friendly and efficient nutrient management, reducing environmental pollution. Nanofertilizers may be a more effective application for nutrient management in good agricultural practices in medicinal and aromatic plants, as they have greater penetration capacity, surface area and efficiency (Morales-Díaz et al. 2017; Shang et al. 2019). Research is being carried out on nano-fertilizer applications to increase the yield and quality of some medicinal aromatic plants that are subject to the domestic and foreign markets.

Coriandrum sativum (coriander) is a medicinal herb used in the kitchen. Nowadays, it is widely grown all over the world. It is used both as food and medicine. It is one of the most famous spices all over the world and has an important place in international trade (Ulutaş et al. 2018). In the study, nano-fertilizer applications were carried out to examine the effect of *Coriandrum sativum* on its vegetative characteristics, mineral elements and essential oils. Nano-fertilizer was applied twice with a one-month interval during the development phase of the plant, at concentrations of 0.5 and 1 g/L. When the results were examined, it was determined that a significant and clear increase in the mineral elements and essential oil, as well as the vegetative properties of *Coriandrum sativum* was applied with 1g/L nano fertilizer concentration (Shakır, 2023).

Nigella sativa (black cumin) is an annual herbaceous medicinal plant belonging to the Ranunculaceae family. It is grown for its seeds. The composition of the seed contains 30-45% fixed oil, 0.01-0.5% essential oil, 20-30% protein, alkaloid bitter substances and saponins. *Nigella sativa* is an important medicinal plant with an economic role in various industries such as food, cosmetics, nutraceutical and pharmaceutical and in the agricultural sector. The effects of micronutrient application on seed yield and essential oil in *Nigella sativa* were investigated. A controlled application was made by applying Nano-Fe, Nano-Zn, Nano-Mn separately and their binary and triple combinations (Fe+Mn, Fe+Zn, Zn+Mn, Fe+Zn+Mn). The results showed that the application of micronutrients to the leaves had a significant effect on yield factors such as plant height, number of capsules per plant, number of shoots per capsule, 1000 grain weight, biological yield, seed yield, percentage of essential oil and yield components and essential oil compared to the control. It has been shown to increase productivity. In addition, the combined use of micronutrients (Nano-Fe, Nano-Zn, Nano-Mn) applied to the plant showed the highest increase in the examined properties compared to their individual use. The highest seed yield of 706.67 kg/ha and essential oil yield of 8.66% were obtained from Fe+Zn+Mn application. It has been demonstrated that increasing the quantitative and qualitative yield of *Nigella sativa*, a medicinal plant, by spraying nano-micro nutrients onto the leaves plays a remarkable role (Rezaei-Chiyaneh et al, 2018). The effect of applying different levels of humic acid and nano fertilizer (Farmks®) to the leaves during the development period of *Nigella sativa* L. plant on the yield and yield components was investigated. Application of nano fertilizer (Farmks®) significantly increased the yield and yield components of *Nigella sativa*. Nanofertilizer application had a significant effect on seed weight, seed yield, biological yield and harvest index. As a result of the study, it was observed that nanofertilizer and humic acid application increased *Nigella sativa* performance and reduced environmental pollution due to its nutritional content and different physiological effects, and could be used to increase and stabilize field crop production (Azizi and Safaei, 2014).

While the *Rosmarinus officinalis* L. (rosemary) plant is dried and used as a spice, it is also used in the production of essential oil. The products produced are marketed domestically and abroad. In order to increase the yield, hydroxyapatite, that is, calcium phosphate, as a new phosphorus nanofertilizer, was developed as nanoparticles (HAP NPs) and nanoparticles were applied to the plants through foliar application at different concentrations (0.25, 0.5 and 1 g/l) in *Rosmarinus officinalis*. The results showed that the application of HAP NP with different main components increased the growth parameters and essential oil yield compared to NPK. It also played an improving role on many physiological indexes of the rosemary plant (Elsayed et al, 2022).

Foeniculum vulgare, belonging to the Apiaceae family, is an annual spice and medicine plant cultivated in Türkiye (Kan et al. 2006). The effects of different drought stress and different doses of zinc nanofertilizer and salicylic acid on yield and yield components were investigated by applying them to the leaves of *Foeniculum vulgare* (fennel). In severe drought stress, the highest umbel number per umbel was obtained with the application of zinc nanofertilizer and salicylic acid at 4mM concentration. Grain yield increased by 14%, 5.3% and 4.5% in zinc nanofertilizer application under non-stress, moderate and severe drought conditions, respectively (Heydarnejadiyan et al, 2021).

Crocus sativus L. (saffron) is one of the most valuable and special agricultural plants in the world and is generally cultivated in regions with arid climate. Saffron plant, which belongs to the Iridaceae family, attracts attention as it is in the international market as the world's most expensive spice/agricultural product according to its weight. In order to investigate the effect of Nano-Fe chelate on saffron and compare it with EDDHSA chelate, in a study where two different doses of 0.5 and 10 kg/ha were applied, flower number, flower performance, fresh and dry stigma yield, chlorophyll (a, b, total). Research was conducted on its amount, leaf area index, dry leaf yield, leaf iron concentration and total iron. Additionally, secondary metabolites such as crocin, picrocrocin, and safranal were also examined. The findings showed that nano-based iron fertilizer was more effective than microfertilizer and had positive effects on the properties of the saffron plant. The most positive effect on saffron production was seen in the 5 kg application and the use of nano fertilizer was recommended (Farahani et al. 2015).

Cuminum cyminum L. (cumin) seeds are used in commerce and industry in the perfumery, food, beverage and pharmaceutical sectors. The highest cumin production in Türkiye takes place in Ankara and Konya provinces. Cumin has an extensive history dating back approximately 5000 years to the ancient Egyptian civilization, where it was used as a spice and a preservative in mummification (Chaudhry et al. 2020). In 2019, 20,245 tons of cumin were produced in

321,889 da production areas in Türkiye. The largest share of the amount of medicinal and aromatic plants produced with good agricultural practices belongs to cumin production, with 34,6% (TAB, 2021). Various productivity increasing studies are carried out on the Cuminum cyminum plant, which has economic value. Three different types of Fe fertilization were tested in order to increase the growth, yield and nutritional properties of the cumin plant during its development (higher Fe content is desired). These nano-Fe-chelated, Fe-chelated and Fe-siderophore were sprayed on the plants and applied twice with an interval of 10 days, before and after flowering. Application doses are 0 (control), 0.5 and 1 g/l. The 1g/l concentration of all three fertilization methods (nano, chelate and siderophore) was the most effective and significantly changing dose application. The results showed that the use of nanofertilization is an effective method for a significant increase in cumin growth and yield. While nano-Fe and Fe-chelated fertilizers are effective methods that increase cumin growth and yield, Fe-sidedrophore has been reported to be the most effective method in seed enrichment (Sabet et al. 2018).

Conclusion

Nowadays, it is seen that there is a significant increase in the use of medicinal and aromatic plants due to increase of people's interest in natural products instead of synthetic products containing chemicals. These plants have been used in every aspect of daily life from past to present. In order to meet the increasing demand, appropriate cultivation programs must be implemented for medicinal aromatic plants. Organic and good agricultural practices should be preferred for these plants used in health and food.

Agricultural production, since it is an area where natural resources such as water and soil are used directly, efficient resource use is very important in agricultural production. In modern agricultural practices, excessive use of synthetic fertilizers is used to provide the necessary nutrients to increase crop productivity. Although beneficial in the short term, long-term and permanent applications damage soil fertility and the nutrient dynamics of the rhizospheric microbium. The application of nanotechnology in the form of nanofertilizers appears to provide an innovative, efficient and environmentally friendly alternative to synthetic fertilizers. Nanofertilizers allow a slow and sustained release of nutrients that not only support plant growth but also maintain the diversity of the beneficial microbiome (Kalwani et al., 2022). In addition, although they have much higher efficiency and ease of application compared to synthetic fertilizers used in modern agricultural practices, research on the relationships between medicinal aromatic plants and nanofertilizers is important due to some limitations such as complex production processes and dose-sensitive efficiency related to nanofertilizers.

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