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ALGAE (NORMAL AND NANO): CHARACTERISTICS, ECONOMIC IMPORTANCE, AND ROLE IN PLANT RESISTANCE OF DISEASE: A REVIEW

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Abstract

This study aimed to know the algae in terms of its spread, distribution and classification as well as its economic and environmental importance. Also, it clarified its great role in promoting plant growth, as studies have shown that the application of algae to the soil improved its retention of moisture, provided it with nutrients and substances stimulating for plant growth, increased the plant's ability to resist stress, reduced the destruction of chlorophyll and improving of yield. Also, the spraying of some types of algae extracts increases the plants' tolerance to stress and thus increases weight and yield. Algae are a source of many bio-organic substances, growth-regulating hormones, vitamins, carbohydrates and antioxidants, thus improving plant growth parameters, as well as its role in inhibiting the growth of pathogens and reducing the incidence and severity of disease for many pathogens.

Keywords: Algae, Nanotechnology, plant growth.

الطحالب (العادية والنانوية): خصائصها واهميتها الاقتصادية ودورها في مقاومة امراض النبات: مراجعة مقال

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الخلاصة

هدفت هذه الدراسة الى تسليط الضوء على الطحالب من حيث تواجدها وتصنيفها والاهمية التي تتميز بها من الناحية الاقتصادية والبيئية كما وضحت دورها الكبير في تعزيز نمو النبات اذ اثبتت الدراسات ان إضافة الطحالب الى التربة تعمل على تحسين احتفاظها بالرطوبة وتجهيزها بالمغذيات والمواد المحفزة لنمو النبات وزيادة قابلية النبات في مقاومة الاجهاد وتقليل هدم الكلوروفيل وتحسين الحاصل وزيادته ورش النباتات بمستخلصات بعض أنواع الطحالب تعمل على زيادة تحمل النباتات للإجهادات وبالتالي زيادة الوزن والحاصل وهي مصدر للعديد من المواد العضوية الحيوية والهرمونات المنظمة للنمو والفيتامينات والكربوهيدرات والمواد المضادة للأكسدة وبذلك تحسن مؤشرات نمو النباتات، وللطحالب تأثير كبير في تثبيط نمو المسببات المرضية وتقليل نسبة وشدة المرض للعديد من المسببات المرضية.

كلمات مفتاحية: الطحالب، علم النانوتكنلوجيا، نمو النبات.

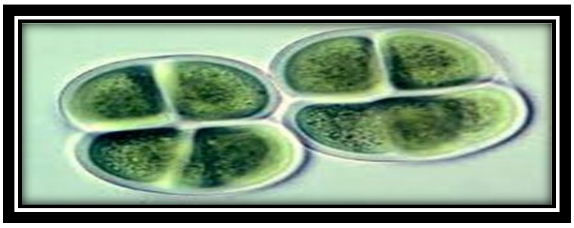
Introduction

Algae are eukaryotic and autotrophic organisms that contain the chlorophyll through which they can absorb light energy and convert it into chemical energy that they use in manufacture of organic compounds from simple inorganic compounds. Algae lack roots, stems, and leaves (63). Algae live in different environments (33) and its spread and distribution in each region is affected by many influences, including the type of vegetation cover, soil condition, suitability or unsuitability for cultivation, physical and chemical properties of the soil and climatic conditions (11).

Algae is a name derived from the Latin origin "Alga" or from the Greek term "Phykos", which mean sea weed, and the term of algae refers to both types, macroalgae and microalgae, and they have an important role in ecosystems as they produce a group of compounds such as: vitamins, amino acids, toxins and growth regulators.

Algae spread: Algae are spread in various environments around the world. They are found in fresh and salt water, soil, between rocks and on the bark of trees. Also, they are found in Polar Regions, hot regions and on soil surfaces and it lives for several centimeters below the soil surface (18). When algae are present in the aquatic environment, they are called aquatic algae, and when algae are present in land they are called terrestrial algae, whereas if they are airborne, they are called algae born air (algae aerial), which represents algae that have the ability to live in the air with a moisture percentage in the air (53).

Structure vegetative of Algae: Algae have a wide range of sizes; they can be as small (5.1 Microns) or up to more than 200 m, as in the case of marine algae (34). Algae have different unicellular forms, and they are eitherF.U motile such as Euglena, or non-motile, F.U non-motile such as in Chlorella diatoms.

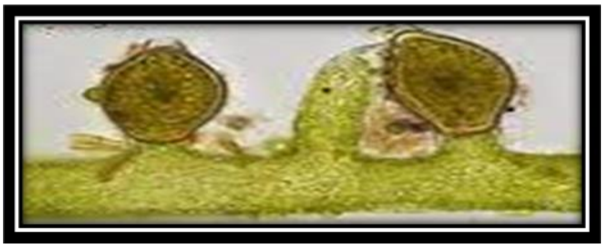


Unicellular alga (Chroococcus).

Anabaena Nostoc: Algae may be multicellular. Several main forms of the vegetative body can be observed in multicellular algae, which are form colonies: (60)

1. Filamentous form
2. Siphoneous form
3. Parenchymatous from
4. Erect thallus form

Nemalion. **Vaucheria.**



Chara.

Algae classification: Algae are classified according to several bases, as they have many characteristics that differ from each other, including the presence of two types of cells:

1. Prokaryotic: This type lacks nuclear material in the nuclear membrane as well as plastids, mitochondria, Colgi bodies, true vacuoles and flagella. This type of cell is represented by the blue-green algae (Cyanophyta).

2. Eukaryotic: It is represented by the other of algal groups, whose cells contain the true nucleus and other organelles.

Among the bases that which it depends is the structure of the cell wall and its components, composition of the plastids, types of pigments, composition and type of food and presence of flagella, their number, location and composition as well as the cellular structure of the other contents of the algae when they are classified into groups. Accordingly, the algae were classified into the following divisions:
A. Prokaryotic algae: It is placed within the Monera kingdom. This group is characterized by the organelles that are contained in the cell that aren't covered by a cell membrane, haven't flagella, sexual reproduction doesn't occur, sensitive to antibiotics and it includes the blue-green algae (Cyanophyta).

B. Eukaryotic algae: It is placed within the Protista kingdom. This group is characterized by the intracellular organelles are covered by cytoplasmic membrane, have flagella, sexually and asexuallyreproduction, insensitive to antibiotics. They include: Chlorophyta, Euglenophyta, Chrysophyta, Cryptophyta, Pyrrophyta, Phaeophyta, Rhodophyta (42).

The ecological and economic importance of algae: There are many positive effects of algae on the environmental and economic aspects, including: Algae as food for humans, as many types of marine algae as well as micro-algae are directly used for feed humans, so Chlorella is used as food because it approximately contains 50% of its dry weight protein. Some types of algae are dried and packed in bags and sold for use in making soups and added to some types of salads. Also, algae play an indirect role as a major link in the food chain of marine organisms, especially fish eaten by humans, as algae are a source of carbohydrates, vitamins E, D, C, A, inorganic materials (such as iodine), protein and fats (22 and 32). Algae are used in medicine, as some marine algae such as Sargasum and Laminaria contain high levels of iodine, which is extracted and used in the treatment of the thyroid gland. Minarin sodium sulfate is also extracted from the same algae, a substance that works against coagulation and it effects is similar to heparin. Carrageenin from brown algae is used in the preparation of cough drugs, and it relieves the bitter taste of drugs and is placed under bandages to treat burns. Some types of Chara contain properties that enable them to be used as an insecticide, and the chlorellan antibiotic is extracted from the Chlorella. Algae of the genus Gelledium, red algae, are used in the treatment of stomach disorders and diseases caused by high temperature, and this genus of algae is an important source for the production of agar, which is used in the preparation of solid food media for both fungi and bacteria, as well as it is used in medicine as a laxative and is included in some types of diet. On the other hand, Algae play a major role in agriculture, when some algae grow in the soil, especially blue-green algae, they can increase the soil fertility by fixing atmospheric nitrogen, as they convert nitrogen to ammonium, which the plant needs for growth, or by adding organic materials to improve soil properties and then increase production of various crops. Also, algae are considered a bio-fertilizer, as it transforms insoluble sources of phosphorous in the soil to a form that can be absorbed by the plant. In addition to, it improves the physical properties of the soil through the gel material that collects the soil granules and improves its physical properties and neutralizes the blue-green algae excess alkalinity in the soil. Some types of algae contribute to the aeration of the soil with oxygen resulting from the photosynthesis process. Otherwise, algae are used as fodder for animals such as Fucus, which leads to an increase the content of iodine and carotene in young, as well as It was proven to increase milk production for some livestock. In addition to, algae are used as a source of oil and gas formation, as they transform solar energy to organic matter, an important food source for marine animal organisms and other phytoplankton. When organic matter accumulates in the silt of the bottom of water bodies, it becomes isolated from free oxygen, thus is exposed to decomposition by anaerobic bacteria, which leads to formation of methane gas by bacteria producing methane and petroleum oil.

Finally, algae are used in industry, as algae species contain a large amounts of chlorophyll and carotene, as well as xanthophylls (41). These pigments can be extracted and have many industrial and scientific uses, as they are used as alternatives to industrial colors. Also, algae are good sources of commercial products, and there are four important products that are commercially produced and marketed from algae. These materials are agar, carrageenine, ligin acid and diatomaceous soil (63).

Nanotechnology: Nanotechnology is one of the modern applied sciences that work to change the properties of any material by rearranging its atoms through which distinct and completely different properties from their original properties before restructuring through the relationship between the structure of the material and its properties (9 and 24). A nano is equal to one billionth of a substance, i.e. the size of nanoparticles is 10 nanometers, while physically, the size of nanoparticles must range between 1-100 nanometers (13). Nanoparticles are characterized by possessing a large surface area and more number of atoms compared with traditional materials, and this gives them several physical, chemical and biological properties such as thermal, electrical and magnetic conductivity, resistance to stress, toxicity to microorganisms, penetration across cell membranes, fusiontemperature, binding energy, electronic structure, melting temperature and hardness strength (7 and 18). Nanoparticles are important in controlling fungal pathogens, many studies have indicated the effectiveness of nanoparticles against microbes, as they work to an increase the surface area relative to their size thus increase the contact area with pathogens and increase their ability to penetrate cells (10 and 38). However, many materials have proven their effectiveness when they are in nano sizes (29), (5 and 6) There are a number of methods for converting materials into nanoparticles, including the chemical, physical and biological methods. The use of the chemical and physical methods requires reducing and inhibitors agents as well as protective agents, which are often toxic and flammable, in addition to their low production and being unsafe for the environment and costly (7), and their sizes are often larger than particle sizes manufactured in a biological method. Therefore, studies have tended to use the biological method that relies on microorganisms (fungi, bacteria, viruses and algae) and plants (47), whose active materials such as enzymes, proteins, amino acids, sugars and vitamins act as reducing agents, anti-aggregating agents, and stabilizers for nanoparticles in production of inorganic nanoparticles such as gold, silver, calcium, silicon, iron oxides, zinc and titanium because of their distinctive properties and the possibility of producing nanoparticles in vitro and in vivo the cell (37).

Manufacture of nanoparticles using algae: Algae are an important source of the nanoparticles production, as many species have been used in the manufacture of nanoparticles (Table 1). More than 100 different types of algae are capable of nanoparticles producing in vitro and in vivoof cell (52). Algae have the ability to enhance the properties of nanoparticles (31), as well as they doesn't producing chemicals or toxic materials, and doesn't need to use chemicals as stabilizing agents because the bio-particles produce materials that provide higher stability, but it takes several days to a few weeks, as nanoparticles are produced by reacting algae extract with metal ions (27). (16) produced silver nanoparticles using 5 ml of *Botryococcus braunii* extract with 45 ml of 1 mM aqueous silver nitrate and placed on a magnetic stirrer at a room temperature for 3 h, then centrifuged the mixture and washed with deionized water three times, thereafter the particles were dried at a 55 °C for 5 hours. Silver nanoparticles were produced by *Chlamydomonas reinhardtii* extract (19). (26) reported the possibility of producing silver and gold nanoparticles using *Chlorella crispus* and *Sargassum insignis*. (17) were able to produce nanoparticles of zinc oxide by *Sargassum muticum*. Silver nanoparticles at a size of 2-20 nm were produced by one of the blue-green algae strains *Leptolyngbya valderianum* (52). The production of nanoparticles by algae is easy, as algae cell cultures are exposed to mineral salt solutions, and then the bioactive compounds reduce cations to form nanoparticles, and it depends on temperature, pH, time, ion concentration, light and algae concentration (27). However, it was found that some algae produce nanoparticles in an acidic or alkaline medium. The production time of nanoparticles varies, as it took 3 hours to produce silver nanoparticles when using *S.cinereum*, while the brown algae (*P. gymnospora* and *Sargassum wightii*) and the freshwater green alga (*Prasiolacrispa*) took 12 hours, while *S.longifolium* and *R. fontinale* took 64 and 72 hours respectively (46 and 49).The concentration of ions affects the shape of the nanoparticles as well as the quantity and color when different concentrations of ions are used. Regarding the light, it acts as a catalyst for nanoparticle biosynthesis reactions by algae. However, algae were found to enhance nanoparticle biosynthesis during the dark. Also, the concentration of algae biomass has an important role in the biosynthesis of nanoparticles by algae (48).

Table 1: Some types of algae used in the production of nanoparticles.

No.	Algae	Nanoparticles	Reference
1	*Klebsormidium flaccidum*	Au	(58)
2	*Turbinaria conoides*	Au	(62)
3	*Sargassummuticum*	ZnO	(17)
4	*Ulva lactuca*	Ag	Sangeetha et al., 2014
5	*Turbinaria conoides*	Ag and Au	(62)
6	*Sargassum plagiophyllum*	AgCl	(28)
7	*Bifurcaria bifurcate*	Cu_2O and CuO	(3)
8	*Spirulina platensis*	Ag	(56)
9	*Turbinaria conoides*	Au	(50)
10	*Acanthophora specifera*	Ag	(39)
11	*Cladophora glomerata*	ZnO	(8)

The role of algae in promoting plant growth: (1) noted that the spraying of some types of algae extracts led to an increase the plants' tolerance to stresses and increasing the plant dry weight and grain yield. (59) reported that the algae is a good source of many organic substances, growth regulating hormones, vitamins, carbohydrates, antioxidants and other active substances that improve plant growth indicators. The extract of nano-algae leads to the enhancement of the activity of various enzymes and proteins related with diseases, including polyphenol oxidase, peroxidase, β-1,3-glucanase and chitinase by activating the genes responsible for the production of these proteins (40). (23) showed a significant increasing in the fresh and dry weight as well as the shoot length when treated with algae. Several studies have clarified the role of algae in enhancing the production of plant hormones such as salicylic acid, jasmonic acid, ethylene, auxins, gibberellins and cytokinins (20 and 56). (51) noted that the algae contain a high percentage of salicylic acid, cytokinin, organic compounds, growth-promoting hormones and humic acid, and the spraying of nano-algae extract on plants led to an increase the resistance of plant, roots and branches growth, photosynthesis, carbohydrates and proteins, and reducing disease incidence by preventing the oxidation of vitamin C and E. (55) mentioned that the spraying of the marine algae Bulitem short cycle extract led to an increase the growth, number of spikes, grain weight, grain yield and seed strength of wheat. (43) found a significant increase in the grain yield of wheat when using *Ascophyllum nodosum*. The extracts of *Ascophyllum nodosum* promoted the growth of spinach and lettuce leaves and increased enzymes that have an important role in reducing environmental stress, and it was observed that the soaking spinach roots before harvest led to an increase in the antioxidant activity after harvest (25). *Ascophyllum nodosum* achieved an increase in the fresh weight 1.86 and 1.80 g ans dry weight 0.46 and 0.53 g of the traditional and nano algae treatments respectively compared with control treatment 0.46 and 0.13 g for the fresh and dry weight respectively, whereas the plant height was 18.66 and 17.33 and 8.33 cm for the nano and traditional algae as well as fungus treatment alone treatments respectively (14).

The role of algae in inhibiting plant pathogens: Several studies showed the effectiveness of algae in inhibiting plant pathogens as well as promoting plant growth due to its content of organic materials, vitamins and antimicrobials, saccharides, laminarin and fucans, which stimulate resistance in plants (54). (44) reported that marine algae were effective in inhibiting the growth of *Aspergillus flavus*, *A. fumigatus* and *A. niger*. (12) indicated that *Ascophyllum nodosum* extract inhibited the growth of *Fusarium oxysporum* f. sp. *Lycopersici* of 100% compared with control treatment 0%. (4) showed that the *Ascophyllum nodosum* reduced the severity of infection when treated alone with a concentration of 1 ml L^{-1} or with pathogenic fungus *Alternaria solani*, which reached 18.05 and 15.68% respectively. (2) observed the efficacy of algae extracts *Oscillatoriairrigua*, *Scenedesmus quadricauda* and a mixture of *Anabaena* sp. + *Stigo* sp. in resistance to potato tubers dry rot. Marmarine compound extracted from *Ascophyllum nodosum* was used against the fungi *Phytophthora melonis* and *Phytophthora capsica* in cucumber and tomato, respectively, which enhanced the activity of disease-controlling enzymes (45). (21)

reported the efficacy of *Chara schweinitzii* in inhibiting the *Pythium* sp., *Penicillium* sp., *Microsporum canis*, *Fusarium solani*, *Aspergillus niger*, *Aspergillus flaves* and *Trachoderma harzianum*, where the rate inhibition reached 65.62, 59.25, 53.12, 46.88, 37.50, 34.38 and 34.38% respectively. (61) revealed the efficacy of the *Ulvalactuca*, *Chlorella vulgaris*, *Chlorella minutissima* and *Chlorella protothecoides* against the apple pathogens (*Aspergillus niger*, *Alternaria alternata* and *Penicillium expansum*). (30) demonstrated the efficacy of marine algae extracts in inhibiting the *Fusarium oxysporum* and improving plant growth parameters.

Also, the research mentioned the effectiveness of algae in the manufacture of nanoparticles and their use in inhibiting plant pathogens. (34) noted that the zinc oxide from *Azadirachta indica* was more effective in inhibiting *Aspergillus fumigatus*, *Candida albicans* and *Penicillum varians*. (36) proved the effectiveness of traditional and nano-algae *Ascophyllum nodosum* in inhibiting *Sclerotinia sclerotiorum* that causes white mold on eggplant, the results of the greenhouse experiment showed that the traditional and nano-algae extract had a positive effect on the controlling the pathogenic fungus, as it provided best protection for eggplant plants through a significant reduction of the rate and severity of infection compared with fungus treatment alone, as the rate and severity of infection reached 91.67 and 54.21% respectively, while the treatment of nano algae reached 41.67 and 31.25% respectively followed by the treatment of traditional algae which gave the rate and severity of infection 58.33 and 43.75% respectively. The nano algae *Ascophyllum nodosum* achieved a highest rate of inhibition of the *Fusarium culmorum* 92.0% when using at a concentration of 3%, while the concentration of 0.5% of traditional algae was more effective in inhibiting the fungus 28.3%, whereas it was 5.33% at a concentration 3%, and the infection rate was 16.3 and 10.2% when using traditional and nano algae respectively, and it was 93.0% when the treatment with fungus alone (14 and 15).

Conclusions

This article explains the environmental and economic importance of algae and its great role in promoting plant growth and resisting fungal pathogens, whether in traditional or nano sizes, and shows its potential to manufacture nanoparticles by environmentally safe, cheap and easy method.

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