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Bibliographic review

Algae and their uses in agriculture

Las algas y sus usos en la agricultura

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ABSTRACT: A sustainable agriculture without the inappropriate use of chemical products is a growing need worldwide that has been on the rise in recent years. That is why the increase in the use of biological products is one of modern agriculture challenges. The use of algae is one of the most viable alternatives to use for these purposes. Algae are photosynthesizing organisms with a simple organization live in water or in very humid environments. The application of seaweed extracts as biofertilizers to the soil, foliage and seeds has shown increases in the yield and harvest quality of various crops. They are also used as nutritional supplements, biostimulants or biofertilizers in agriculture. With this bibliographic review, it is proposed to give a general and updated vision of algae, their importance, characteristics, classification, as well as their uses and effects in agriculture.

Key words: plants, biological products, biostimulants, biofertilizers.

RESUMEN: Una agricultura sostenible sin la utilización inadecuada de productos químicos es una necesidad creciente a nivel mundial que ha ido en ascenso en los últimos años. Es por ello, que el incremento en el uso de productos biológicos es uno de los retos de la agricultura moderna. La utilización de las algas es una de las alternativas más viables a utilizar con estos fines. Las algas, son organismos fotosintetizadores de organización sencilla, que viven en el agua o en ambientes muy húmedos. La aplicación de extractos de algas marinas como biofertilizantes al suelo, follaje y semillas ha mostrado incrementos en rendimiento y calidad de la cosecha de diversos cultivos; además, se utilizan como suplementos nutricionales, bioestimulantes o biofertilizantes en la agricultura. Con esta revisión bibliográfica se propone dar una visión general y actualizada sobre las algas, su importancia, clasificación y características, además de sus usos y efectos en la agricultura.

Palabras clave: plantas, productos biológicos, bioestimulantes, biofertilizantes.

INTRODUCTION

The world's food supply depends, largely, on agriculture. At present, achieving this goal is a difficult task without the use of pesticides to manage crop pests. The widespread application of these synthetic products brings undesirable consequences, such as adverse effects on human health, soil and the environment in general, due to their toxicity and persistence. Another negative aspect is the emergence of resistance in pests, due to their evolution in the face of these applications and the survival of better adapted and possibly more aggressive individuals, which leads to an increase in applications, thus forming a closed spiral circle that worsens the conditions of the ecosystem in general (1).

The inadequate use of chemical products in agriculture has caused the loss of the fertile layer of soils, has diminished their biodiversity and has eliminated the natural enemies of pests (2). In order to conserve the agroecosystem and taking into account the growing demand for food, it is necessary to seek new technologies to increase crop production and quality, as well as to offer consumers products free of toxic residues (3,4).

Nowadays, the unquestionable need to protect the environment and fight against the adverse effects caused by climate change in agriculture, has brought about the

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resumption, with great acceptance, of the use of plant and algae extracts to increase agricultural yields and for the prevention and treatment of plant diseases. These extracts are biodegradable products with low or no toxicity for animals and humans (5).

Among the bioproducts that have been evaluated for use in agriculture are algae and derived products that have been used as human food, animal feed, fodder, in paper production and in other industries (6,7). Algae, mostly belonging to the protista kingdom, are photosynthesizing organisms of simple organization, living in water or in very humid environments. This group also includes prokaryotic cyanobacteria (8).

Since the 1950s, the use of algae has been replaced by extracts made from different macroalgae species. Currently, these extracts have gained acceptance as "plant biostimulators" (9). They induce physiological responses in plants, such as promoting plant growth, improving flowering and yield, stimulating the quality and nutritional content of the edible product, as well as prolonging shelf life. In addition, applications of different types of extracts have stimulated plant tolerance to a wide range of abiotic stresses (2).

DEVELOPMENT

Importance of seaweeds or sargassum

Seaweeds have been used as fertilizers since the beginning of agriculture in Japan, China, Greece, on the islands and coasts of northwestern Europe and in Chile. Agriculture and horticulture in temperate zones frequently use brown algae products such as *Ascophyllum nodosum*, *Ecklonia maxima* and *Fucus vesiculosus* as fertilizers. Laminaria and Sargassum species are used less frequently, although these two belong to the brown algae, their use has been determined mainly by their size and availability rather than by a specific convenient determination. In Chile, the red alga Gracilaria is used as a fertilizer in potato crops (10).

Biofertilizers based on seaweed extracts, which are natural bioactive materials soluble in water, are organic fertilizers that promote seed germination and increase crop development and yield (11). Seaweed extracts are used as nutritional are used as nutritional supplements, bio-stimulants or bio-fertilizers in agriculture biofertilizers in agriculture and horticulture (12).

In recent years, the use of seaweed extracts as biofertilizers has allowed the partial replacement of conventional mineral fertilizers (13-16). These can be used as liquid extracts applied in foliar form, to the soil, or in granular form (powder) as soil improvers and fertilizers (17,18).

Seaweed extracts contain a wide variety of plant growth promoting substances such as auxins, cytokinins, betaines, gibberellins and organic substances such as amino acids, macronutrients and trace elements that improve the yield and quality of crops (15).

The application of seaweed to the soil and foliage, nutrient absorption, chlorophyll content is increased; the plant size is chlorophyll content and leaf size, resulting in higher yields and crop quality (18).

Characteristics of seaweeds

Taxonomically, marine algae are classified into three groups based on their color: green (Chlorophyceae), brown (Phaeophyceae), and red (Rhodophyceae) as they present predominant pigments such as chlorophylls, carotenoids and phycobilins (19).

Marine algae are thallophyte plants (organisms lacking roots, stems, leaves), unicellular or multicellular plants that live preferentially in fresh or marine water and they are generally provided with chlorophyll, sometimes accompanied by other pigments of various colors that mask the chlorophyll. The thallus of multicellular algae has the form of a filament, ribbon or lamina and can be branched (20).

Algae are inhabitants of all environments, not only in bodies of stable water, but also in those that are stable water bodies but also in those exposed to desiccation: on bare rocks, hot springs (where they withstand high temperatures), snow, glaciers. It is common to find them in places with little light at great depths. This capacity is conditioned by the lack of requirements and their ability to adapt (19).

Classification of algae

There are some differences in the classification of algae; however, they can be generally divided into three large groups: microalgae, macroalgae and true vascular plants, which in turn are subdivided into different groups (Table 1) (9).

Uses and effects of algae in agriculture

Traditionally, coastal communities around the world have been using seaweed as a soil amendment. The effect of composted seaweed fertilizer is dependent on its composition, biochemical mineralization pattern, and the timing of nutrients with crop demand (21). Seaweeds are commercially available, and are considered as a resource for organic farming (22,23).

Seaweed extracts as biofertilizers, natural water-soluble bioactive materials, are natural organic fertilizers that promote seed germination and increase crop development and yield (24).

Effects achieved with seaweed extracts depend to a great extent on the synergic effect of the action of all the components, not being able to isolate the effect of each one of the active principles alone (24). These effects are achieved with low concentrations of the extracts, even using proportions of 1:1000 (25).

The increase in yields and the good quality of fruits as an effect of seaweed use and their derivatives in agriculture is because they contain all the major, minor elements and

Table 1. Different algae types

Type of algae	Features
	Microalgae
Phyllopyrophytes (dinoflagellates)	They are mostly unicellular, having two flagella of different lengths. The cell is naked or is provided with a more or less hard covering. They have a parasitic or predatory life form (8,22).
Phyllochrysophytes	Known as yellow algae, they are unicellular or multicellular organisms that gather in colonies. Their main characteristic is the presence of chromatophores with yellow pigments that give them a golden appearance. They are of variable morphology with and without flagella and in some cases they move by rhizopods. They always reproduce vegetatively (23,24).
Phyllo-euglenophytes	Algae with a very simple structure, whose most significant characteristic is the presence of a photosensitive pigment spot. They have one or two flagella, which allows them to change their shape, and they multiply by longitudinal division (8,23,24).
Phyllobacillariophytes (diatomaceae) Filo-bacilariofitas (diatomáceas)	These are the well-known diatoms. They are solitary forms that form stellate colonies (8,22). Known as blue-green algae (cyanobacteria), they are a type of photosynthesizing bacteria. They can withstand extreme conditions of salinity, temperature and pH, because they produce mucilaginous envelopes that isolate them from the external environment when sudden changes occur (23,24).
Cianofíceas Cyanophyceae	Known as blue-green algae (cyanobacteria), they are a type of photosynthesizing bacteria. They can resist extreme conditions of salinity, temperature and pH, because they produce mucilaginous envelopes that isolate them from the external environment when sudden changes occur (23,24).
	Macroalgae
Chlorophytes Clorófitas	Known as green algae, they are unicellular or multicellular organisms of highly variable shapes. Most of the microscopic species are native to fresh water, although there are numerous marine groups that reach large sizes. They multiply by cell division sexually or by the fusion of two gametes of different sizes (23,25).
Phaeophytes Feófitas	Algae that reach sizes of up to 100 m. Although they possess chlorophylls, brown pigments hide them, so they have brown or brownish coloration. These algae are typical of salt water, with very few living in fresh water (23,25). This group of algae is the most widely used in agriculture, with *Ascophyllum nodosum* being among the most widely used of the group for these purposes (19,25).
Rhodophytes Rodófitas	They are known as red algae, with lengths ranging from a few centimeters to about one meter and include species typical of deep-sea waters, areas where other species cannot survive due to lack of light. They are red in color, although they do not always present this color, sometimes they are purple, or even brownish red in color, in spite of this, they possess chlorophyll. They reproduce sexually and asexually and have complicated cycles of alternating generations (23,25).
	True vascular plants
	True vascular plants or charophytes are very complex algae, mostly green in color, frequent on the banks of rivers and lakes, which reproduce sexually or vegetatively (23,24).

trace elements present in plants. They also contain 27 natural substances reported so far whose effects are similar to those of plant growth regulators; vitamins, carbohydrates, proteins, biocidal substances that act against some pests and chelating agents such as organic acids and mannitol (26,27).

Among the effects of algae and their extracts are: stimulation of seed germination (25), plant growth (2,8), flowering and delaying senescence (5,8). On the other hand, they stimulate root growth, advance fruit ripening (8), increase plant tolerance to abiotic stresses such as salinity, drought, high temperatures and frost, and have fortifying effects (5,8).

Results in Cuba

Evaluating the effectiveness of seaweed use as a component of substrates for vegetable production in root ball systems, sargassum accumulated over the years was collected on Cayo Coco beaches, Ciego de Avila province. Substrates were made from a mixture of 25 % sargassum (S) with earthworm humus (H), sea sand (SS) and rice husks (R). The horticultural species used were chard (*Brassica rapa subs. chinensis* var. PK-7) and lettuce (*Lactuca sativa* L. var. BSS-13) and the management tasks during the seedling production process were carried out according to the recommended technical instructions (28).

The evaluations carried out were relative seed germination and behavior of physiological indicators in seedlings. The chard and lettuce seeds reached high germination values with respect to the control for all the study treatments and did not differ from the control, nor were differences observed between them. In both evaluations, the two species showed that the best treatment was (H50 + S25 + SS25), which consisted of the combination of mineral materials (sand) with organic materials (humus + sargassum) (28).

In Cuba, Spirulina has been widely used for pharmaceutical, cosmetic and nutritional purposes. This microalgae has not been practically used in agriculture, although their chemical composition and the influence that the application could exert on the growth and development of plants is known, as well as the benefit that it can cause in soils due to the quantity and quality of nutrients that it possesses. Some biofertilizers based on Spirulina have been elaborated, such as CBFERT, and more recently, Spirufert, being evaluated its foliar use in some crops (9).

CONCLUSIONS

One of the options to achieve a sustainable and more environmentally friendly agriculture is the use of algae, taking into account the great benefit they offer as natural products; they possess a diversity of substances that stimulate the growth and yield of crops; they favor soil microbial activity and improve the absorption of nutrients by the roots. In addition, they provide plants with an effective resistance to abiotic stress, since they contain substances with a high antioxidant power.

Taking into account all that has been stated in this review, it is necessary, in Cuba, to accelerate research related to the application of seaweeds in agriculture.

BIBLIOGRAPHY

1. Pérez OP. La resistencia inducida por productos derivados de plantas: alternativa para el manejo de plagas agrícolas. Rev Protección Veg [Internet]. 1 de enero de 2020 [citado 14 de mayo de 2024];35(3). Available in: https://www.academia.edu/101496565/La_resistencia_inducida_por_productos_derivados_de_plantas_alternativa_para_el_manejo_de_plagas_agr%C3%ADcolas
2. Battacharyya D, Babgohari MZ, Rathor P, Prithiviraj B. Seaweed extracts as biostimulants in horticulture. Sci Hortic [Internet]. 30 de noviembre de 2015 [citado 14 de mayo de 2024];196:39-48. Available in: https://www.sciencedirect.com/science/article/pii/S030442381530176X
3. Alfonso ET, Rodríguez ABF, Padrón JR, Sosa YC, Morales HM. Respuesta agronómica del cultivo de tomate al bioproducto QuitoMax®. Cultiv Trop [Internet]. 10 de abril de 2017 [citado 14 de mayo de 2024];38(1):147-54. Available in: https://ediciones.inca.edu.cu/index.php/ediciones/article/view/1348
4. Ronga D, Biazzi E, Parati K, Carminati D, Carminati E, Tava A. Microalgal biostimulants and biofertilisers in crop productions. Agronomy [Internet]. abril de 2019 [citado 14 de mayo de 2024];9(4):192. Disponible en: https://www.mdpi.com/2073-4395/9/4/192
5. Crouch IJ, van Staden J. Evidence for the presence of plant growth regulators in commercial seaweed products. Plant Growth Regul [Internet]. 1 de mayo de 1993 [citado 14 de mayo de 2024];13(1):21-9. Disponible en: https://doi.org/10.1007/BF00207588
6. Hamed SM, Abd El-Rhman AA, Abdel-Raouf N, Ibraheem IBM. Role of marine macroalgae in plant protection & improvement for sustainable agriculture technology. Beni-Suef Univ J Basic Appl Sci [Internet]. 1 de marzo de 2018 [citado 14 de mayo de 2024];7(1):104-10. Available in: https://www.sciencedirect.com/science/article/pii/S2314853517301294
7. Ansari AA, Ghanem SM, Naeem M. Brown Alga Padina: A review. Int J Bot Stud [Internet]. 2019;4(1):1-3. Available in: https://www.researchgate.net/profile/Abid-Ansari-5/publication/333879310_Brown_Alga_Padina_A_review/links/5d0a670ea6fdcc35c15b5c2d/Brown-Alga-Padinareview.pdf
8. Preston J, Inouchi Y, Shioya F. Acoustic classification of submerged aquatic vegetation. ECUA [Internet]. 1 de julio de 2006;12-5. Available in: https://www.researchgate.net/publication/228564120_Acoustic_classification_of_submerged_aquatic_vegetation
9. López-Padrón I, Martínez-González L, Pérez-Domínguez G, Reyes-Guerrero Y, Núñez-Vázquez M, Cabrera-Rodríguez JA. Las algas y sus usos en la agricultura. Una visión actualizada. Cultiv Trop [Internet]. 5 de agosto de 2020 [citado 14 de mayo de 2024];41(2):e10-e10. Available in: https://ediciones.inca.edu.cu/index.php/ediciones/article/view/1554
10. Las macroalgas marinas en la agronomía y el uso potencial del Sargassum flotante en la produccion de fertilizantes en el archipiélago de San Andrés y Providencia , Colombia | Intropica. 19 de abril de 2016 [citado 14 de mayo de 2024]; Available in: https://revistas.unimagdalena.edu.co/index.php/intropica/article/view/461
11. Norrie J, Keathley JP. Benefits of *Ascophyllum nodosum* marine-plant extract applications to «Thompson seedless» grape production. Acta Hortic [Internet]. 1 de noviembre de 2006;727:243-8. Available in: https://www.researchgate.net/publication/284250867_Benefits_of_Ascophyllum_nodosum_marine-plant_extract_applications_to_%27Thompson_seedless%27_grape_production
12. Hernández-Herrera RM, Santacruz-Ruvalcaba F, Ruiz-López MA, Norrie J, Hernández-Carmona G. Effect of liquid seaweed extracts on growth of tomato seedlings (*Solanum lycopersicum* L.). J Appl Phycol [Internet]. 1 de febrero de 2014 [citado 14 de mayo de 2024];26(1):619-28. Available in: https://doi.org/10.1007/s10811-013-0078-4
13. Dhargalkar VK, Pereira N. Seaweed: Promising Plant of the Millennium. Sci Cult [Internet]. 30 de noviembre de 2004;71. Available in: https://www.researchgate.net/publication/27667265_Seaweed_Promising_Plant_of_the_Millennium
14. Khan W, Rayirath UP, Subramanian S, Jithesh MN, Rayorath P, Hodges DM, *et al*. Seaweed extracts as biostimulants of plant growth and development. J Plant Growth Regul [Internet]. 1 de diciembre de 2009 [citado 14 de mayo de 2024];28(4):386-99. Disponible en: https://doi.org/10.1007/s00344-009-9103-x
15. Sathya1 B, Indu1 H, Geetha2 RS and S. Influence of seaweed liquid fertilizer on the growth and biochemical composition of legume crop, *Cajanus cajan* (L.) Mill sp. J Phytol [Internet]. 8 de septiembre de 2010 [citado 14 de mayo de 2024]; Available in: https://updatepublishing.com/journal/index.php/jp/article/view/2115
16. Zodape ST, Mukhopadhyay S, Eswaran K, Reddy M, Chikara J. Enhanced yield and nutritional quality in green gram (*Phaseolus radiata* L) treated with seaweed (*Kappaphycus alvarezii*) extract. J Sci Ind Res [Internet]. 1 de junio de 2010;69:468-71. Available in: https://www.researchgate.net/publication/286020475_Enhanced_yield_and_nutritional_quality_in_green_gram_Phaseolus_radiata_L_treated_with_seaweed_Kappaphycus_alvarezii_extract

17. Lingakumar K, Jeyaprakash R, Manimuthu C, Haribaskar A. Influence of *Sargassum* sp crude extract on vegetative growth and biochemical characteristics in *Zea mays* and *Phaseolus mungo*. Seaweed Res Utiln. 1 de enero de 2004;26:155-60.
18. Thirumaran, Arumugam M, Arumugam R, Anantharaman P. Effect of seaweed liquid fertilizer on growth and pigment concentration of *Abelmoschus esculentus* (l) medikus. Am-Eurasian J Agron [Internet]. 1 de enero de 2009; 2:57-66. Available in: https://www.researchgate.net/publication/237046173_Effect_of_Seaweed_Liquid_Fertilizer_ on _Growth_and_Pigment_Concentration_of_Abelmoschus_esculentus_l_medikus
19. Erulan V, P. S, Thirumaran G, Ananthan G. Studies on the effect of *Sargassum polycystum* (C.Agardh, 1824) extract on the growth and biochemical composition of *Cajanus cajan* (L.) Mill sp. Am Eur J Agric Env Sci [Internet]. 1 de enero de 2009;6. Available in: https://www.researchgate.net/publication/242558446_Studies_on_the_Effect_of_Sargassum_polycystum_CAgardh_1824_Extract_on_the_Growth_and_Biochemical_Composition_of_Cajanus_cajan_L_Mill_sp
20. Robledo D. Las algas y la biodiversidad. Biodiversidad [Internet]. 1997;13(1):1-4. Available in: https://jolbenm30.wordpress.com/wp-content/uploads/2012/05/biodiversidad dealgas.pdf
21. Craigie JS. Seaweed extract stimuli in plant science and agriculture. J Appl Phycol [Internet]. 1 de junio de 2011 [citado 14 de mayo de 2024];23(3):371-93. Available in: https://doi.org/10.1007/s10811-010-9560-4
22. Rebours C, Pedersen S, Roleda M, Ovsthus I. Seaweed - a resource for organic farming. Bioforsk Fokus. 2014;9(2).
23. Grzesik M, Romanowska-Duda Z, Kalaji HM. Effectiveness of cyanobacteria and green algae in enhancing the photosynthetic performance and growth of willow (*Salix viminalis* L.) plants under limited synthetic fertilizers application. Photosynthetica [Internet]. 1 de septiembre de 2017 [citado 14 de mayo de 2024]; 55(3):510-21. Available in: https://doi.org/10.1007/s11099-017-0716-1
24. Calvo P, Nelson L, Kloepper JW. Agricultural uses of plant biostimulants. Plant Soil [Internet]. 1 de octubre de 2014 [citado 14 de mayo de 2024];383(1):3-41. Available in: https://doi.org/10.1007/s11104-014-2131-8
25. Méndez G. Fertilización a base de extractos de algas marinas y su relación con la eficiencia del uso del agua y de la luz de una plantación de vid y su efecto en el rendimiento y calidad de frutos. [Internet] [Tesis de Maestría]. [México]; 2014. Available in: http://repositorio.uaaan.mx:8080/xmlui/handle/123456789/7549
26. van Staden J, Crouch IJ. Evidence for the presence of plant growth regulators in commercial seaweed products. Plant Growth Regul [Internet]. 1 de mayo de 1993 [citado 14 de mayo de 2024];13(1):21-9. Available in: https://doi.org/10.1007/BF00207588
27. López BC. Enzimas-algas: Posibilidades de su uso para estimular la producción agrícola y mejorar los suelos. Terra Latinoam [Internet]. 1999 [citado 14 de mayo de 2024];17(3):271-6. Available in: https://www.redalyc.org/articulo.oa?id=57317312
28. Rodríguez W, Orellana R. Utilización de algas marinas como componente de sustratos para la producción de plántulas de acelga y lechuga. 2008.