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Improving plant nutrition and growth through the use of minerals extracted from the sea on Aubergine and cucumber plants

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Abstract

Research objective: The aim of this research was to evaluate the stimulating potential of a product (FertilTomix) obtained by an innovative extraction process from seawater with the addition of silver, copper and zinc on aubergine and cucumber plants. In addition, it was assessed whether the product improves the nutritional quality of the fruit.

Materials and Methods: The experiments, which started in May 2024, were conducted in the CREA-OF greenhouses in Pescia (Pt), on aubergine (*Solanum melongena* L.) and cucumber (*Cucumis sativus*). Plants were placed in pots of ø 14 cm, 30 plants per thesis, divided into three replications of 10 plants each. The experimental groups were: i) control group; ii) conmmercial biofertilizer; iii) FertilTomix; iv) FertilTomix with added silver, copper and zinc. On 10 September 2024, plant height (aubergine), length of the central branch (cucumber), number of leaves, leaf area, vegetative weight, root volume, number and weight of fruits were determined. The nutritional properties of the fruits were also assessed, for aubergine (iron, calcium, sodium, potassium, phosphorus, zinc, riboflavin thiamnine, vitamin C, niacin, vitamin B6, folate) and for cucumber (potassium, phosphorus, calcium, magnesium, sodium, iron, pantothenic acid, pyridoxine, zinc, manganese, vitamin C, niacin, riboflavin, vitamin E, thiamine, vitamin K, folate).

Results and Discussion: The experiment showed that the use of FertilTomix, can significantly increase the height, number of leaves, vegetative and root growth, and leaf area of aubergine and cucumber plants. The product FertilTomix with added silver, copper and zinc worked better than as such, stimulating plant growth more. The trial also showed an increase in the number and weight of fruits in both aubergine and cucumber, in the theses treated with FertilTomix compared to the control and the commercial control with algae. The leaves also appeared larger and more intensely green in the theses treated with minerals extracted from the sea. The analysis of the mineral and vitamin content of the fruits showed a significant increase in minerals and vitamins in the fruits treated with FertilTomix for most of the analysed parameters, to a greater extent with FertilTomix with added silver, copper and zinc

Conclusions: Various extracts obtained from seawater using an innovative mineral process were found to significantly increase plant growth. The test also showed an increase in the mineral and vitamin content of the fruit, probably influenced by the increased presence of bacteria in the soil, in the theses treated with marine extracts, as demonstrated in other tests with the same product. As well as for those wishing to reduce the use of industrial fertilisers, the results obtained are particularly interesting for those growing in arid environments or those without drinking water

Keywords: Seawater minerals; Microorganisms; Sustainable agriculture; Biofertilizers; Rhizosphere

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1. Introduction

The sea is generally viewed as the source of life on Earth. Life today would not be possible without the sea. It serves a number of functions related to life on earth. In addition to acting as a great thermostat and heat reservoir, it also reduces the extremes of temperature that would be experienced without its moderating influence [1]. It is the least costly form of transportation available to man to use the sea. Furthermore, the sea has not been explored to its fullest potential as a mineral source [2]. Among the primary reasons for this default are a lack of knowledge about marine mineral deposits, the lack of a technology for economically exploiting the deposits, and no pressing need for them at the moment, either economically or politically [3]. There are five regions of mineral resources in the sea: the beach, the sea water, the continental shelf, the surface sediments, and the hard rock beneath the surface sediments. Various minerals have been extracted from the first three regions of the ocean for some time [4,5]. Because of this, a large amount of literature exists on what is being recovered and how it is being recovered. A number of elements enter the ocean through biotic processes, but both plants and animals play a significant role in these processes in the open ocean. As an example, plants and animals extract calcium and silicon from seawater for shells and skeletons. In addition to copper, animals can concentrate other elements for use in their metabolic processes. Moreover, biota, such as manganese, can be absorbed by consumes the organic parts of complexes that maintain these elements in solution [6]. Afterward, the carried elements may either be deposited and concentrating in the animal or may be converted into an insoluble precipitate, which is then released into the ocean, slowly settling on its bottom. In consideration of economic mineral deposits, the residue from the dissolution of biogenous material can be classified as inorganic after diagenetic changes [7].

1.1. A seawater mineral source

Almost 71% of the Earth's surface is water, so whoever named it would have probably given it a name that meant water instead of Earth. About 330 million cubic miles of water are held in the sea, which covers an area of 139 million square miles and a depth of 2.46 miles. An average of 3.5% of various elements can be found in solution in sea water; thus, each cubic mile of seawater weighing 4.7 billion tons holds about 166 million tons of solids [8]. About 5.1016 tons of minerals are stored in the oceans. The concentration of 60 elements in seawater has been measured using sophisticated analytical procedures [9]. Given sophisticated analytical procedures, it is likely that each known, naturally occurring element can be found in seawater [9]. In Table 1, the elements are listed by their concentrations, their concentrations in one cubic mile of sea water, and their total amounts in the world's oceans [10]. The presence of other elements, such as ytterbium, beryllium, zirconium, platinum, etc., on the sea floor in marine organisms suggests that they are part of seawater. In the ocean surface, biological activity can significantly alter the concentration of various elements from place to place and over time [11]. Seawater isn't always a homogeneous medium when it comes to the concentration of less abundant elements. For some time, it has been known that marine organisms can affect the concentrations of certain elements in their bodies many times more than their concentrations in seawater [12]. Some tunicates, for example, take up vanadium in their mucus, which can be more than 280.000 times as concentrated in them as in seawater. Copper and zinc concentrations in marine organisms can be affected by another marine organism by a factor of one million. Lead concentrations in fish are increased by a factor of 20 million in parts of their skeletons. However, it is essential that these organisms have a mechanism by which they can concentrate. Developing artificial methods of extracting and concentrating elements from dilute solutions might be possible if these processes are understood [13].

1.2. Minerals extracted from the sea are used in experiments

A team of researchers from the Xinjiang Academy of Forestry Sciences in the People's Republic of China evaluated the use of sea minerals in three separate experiments [14] led by Professor Hou Tian Zhen, head of the Department of Tree Physiology and Biochemistry. It was reported in 1989 that tomatoes treated with these minerals produced almost twice as many flowers per plant and 27% more fruit than tomatoes untreated. At the A-ning Experiment Station, a field experiment conducted in 1990 showed that treated green beans increased yields by 81%, sweet beet yields by 67%, and soybean yields by 29 percent. Watermelon plots were planted 300 metres apart in a field in 1991 at the A-ning Experiment Station. The treated melons produced 65% more than those in the control group [15,16]. Alfalfa grower Harold Aungst's results from the use of sea minerals and the extract showed a 29% increase in protein, with a significant increase in yield and five cuts rather than three for the first year. The first year yielded 7.6 tonnes per acre, almost double the state average of 3.4 tonnes per acre. In the second year, the yield increased to 10 tonnes/acre, three times the state average [17]. Milk production also increased 30% when treated hay was used. Using a sea extract since 1989, Wilson Mills of Circle K Apple Orchard in Wisconsin has seen an increase in apple tree fruit production. During the first eight years, the apple yield doubled each year, the fruit set tripled, and the sugar content of the apples increased by 1200%. In addition, iron absorption increased 400%, chromium absorption increased 326%, and potassium absorption increased 120%. The apples were giant and ripened 2 to 3 weeks earlier [17]. In Okinawa, banana yields increased by 100% and ripening times decreased by 35%. According to a field experiment conducted in 1990 at the A-ning Experiment Station, treated green beans produced an 81% increase in yield and treated sweet beets produced a 67%

increase in yield. When environmental stress caused 80% empty pods on other neighbouring farms, the amount of coffee produced with marine mineral extracts increased 50-100%, with better flavour, more giant beans, and 80% Fancy or Gourmet quality. As a result of their young age, young plants produced 1/3 more than expected, ripening more evenly, and requiring fewer harvests. Experiments carried out at Crea Horticoltura e Florovivaismo in Pescia with extracts from the sea resulted in improved plant growth and quality on *Cichorium intybus*, *Carthamus tinctorius*, *Impatiens glandulifera*, *Helianthus annuus* and *Solanum lycopersicum* [18-20].

Table 1 Seawater concentrations and amounts of 60 elements

Element	Concentration (mg/l)	Amount of element in seawater (tons/mile^3)	The total amount in the oceans (tons)	Element	Concentration (mg/l)	Amount of element in seawater (tons/mile^3)	The total amount in the oceans (tons)
Chlorine	19.000,0	89,5 x 10^6	29,3 x 10^{15}	Manganese	0.002	9	3 x 10^9
Sodium	10.500,0	49,5 x 10^6	16,3 x 10^{15}	Titanium	0.001	5	1.5 x 10^9
Magnesium	1.350,0	6,4 x 10^6	2,1 x 10^{15}	Antimony	0.0005	2	0.8 x 10^9
Sulphur	885.0	4,2 x 10^6	1,4 x 10^{15}	Cobalt	0.0005	2	0.8 x 10^9
Calcium	400.0	1,9 x 10^6	0,6 x 10^{15}	Caesium	0.0005	2	0.8 x 10^9
Potassium	380.0	1,8 x 10^6	0,6 x 10^{15}	Cerium	0.0004	2	0.6 x 10^9
Bromine	65.0	306.000	0,1 x 10^{15}	Yttrium	0.0003	1	5 x 10^8
Carbon	28.0	132.000	0,04 x 10^{15}	Silver	0.0003	1	5 x 10^8
Strontium	8.0	38.000	12,000 x 10^9	Lanthanum	0.0003	1	5 x 10^8
Boron	4.6	23.000	7,100 x 10^9	Krypton	0.0003	1	5 x 10^8
Silicon	3.0	14.000	4,700 x 10^9	Neon	0.0001	0.5	150 x 10^6
Fluorine	1.3	6.100	2,000 x 10^9	Cadmium	0.0001	0.5	150 x 10^6
Argon	0.6	2.800	930 x 10^9	Tungsten	0.0001	0.5	150 x 10^6
Nitrogen	0.5	2.400	780 x 10^9	Xenon	0.0001	0.5	150 x 10^6
Lithium	0.17	800	260 x 10^9	Germanium	0.00007	0.3	110 x 10^6
Rubidium	0.12	570	190 x 10^9	Chromium	0.00005	0.2	78 x 10^6
Phosphorus	0.07	330	110 x 10^9	Thorium	0.00005	0.2	78 x 10^6
Iodine	0.06	280	93 x 10^9	Scandium	0.00004	0.2	62 x 10^6
Barium	0.03	140	47 x 10^9	Lead	0.00003	0.1	46 x 10^6
Indium	0.02	94	31 x 10^9	Mercury	0.00003	0.1	46 x 10^6
Zinc	0.01	47	16 x 10^9	Gallium	0.00003	0.1	46 x 10^6
Iron	0.01	47	16 x 10^9	Bismuth	0.00002	0.1	31 x 10^6
Aluminium	0.01	47	16 x 10^9	Niobium	0.00001	0.05	15 x 10^6
Molybdenum	0.01	47	16 x 10^9	Thallium	0.00001	0.05	15 x 10^6
Selenium	0.004	19	6 x 10^9	Helium	0.000005	0.03	8 x 10^6
Tin	0.003	14	5 x 10^9	Gold	0.000004	0.02	6 x 10^6

Copper	0.003	14	5×10^{9}	Protactinium	2×10^{-9}	1×10^{-5}	3,000
Arsenic	0.003	14	5×10^{9}	Radium	1×10^{-10}	5×10^{-7}	150
Uranium	0.003	14	5×10^{9}	Rodon	0.6×10^{-15}	3×10^{-12}	1×10^{-3}
Nickel	0.002	9	3×10^{9}				
Vanadium	0.002	9	3×10^{9}				

1.3. Research Objectives

The aim of this research was to evaluate the stimulating potential of a product (FertilTomix) obtained by an innovative extraction process from seawater with the addition of silver, copper and zinc on aubergine and cucumber plants (Figure 1A-1B). In addition, it was assessed whether the product improves the nutritional quality of the fruit.

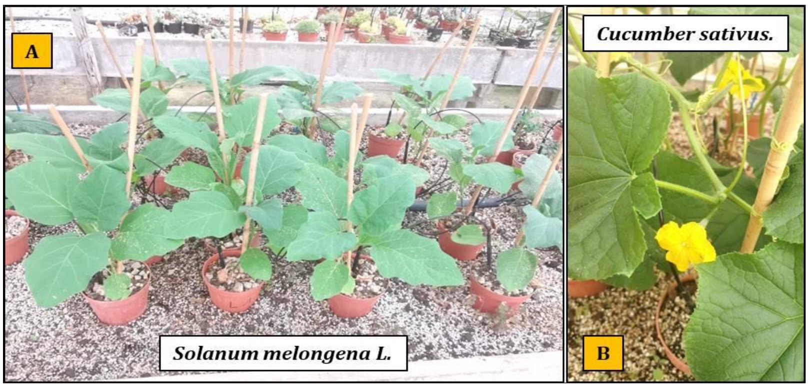

Figure 1 Detail of the aubergine (Figure A) and cucumber (Figure B) test

2. Materials and methods

The experiments, which started in May 2024, were conducted in the CREA-OF greenhouses in Pescia (Pt), Tuscany, Italy (43°54′N 10°41′E) on aubergine (*Solanum melongena* L.) and cucumber (*Cucumis sativus*). Plants were placed in pots of ø 14 cm, 30 plants per thesis, divided into three replications of 10 plants each. The experimental groups were:

- control group (CTRL) (peat 80%+ pumice 20%), irrigated with water and substrate fertilised once a week with Compo BIO (organic vegetable fertiliser; organic nitrogenous fertiliser; fluid borer), 5 ml of product in 1 L of water and then 3 ml per plant of this dilution;
- biofertiliser (BIOAL) group (peat 80%+ pumice 20%), irrigated with water and substrate fertilised once a week with Compo BIO (organic vegetable fertiliser; organic nitrogenous fertiliser; fluid borer), 5 ml of product in 1 L of water and then 3 ml per plant of this dilution; in addition, an algae-based biofertiliser (Kelpak biostimulant, Ecklonia maxima, Kelp products International) was used, dilution 1 1000, 3 ml of this dilution once a week;
- the group with FertilTomix (FE0) (peat 80% + pumice 20%) irrigated with water, 3 ml per plant once a week;
- the group with FertilTomix with added silver, copper and zinc (FE1) (peat 80% + pumice 20%) irrigated with water, 3 ml per plant once a week;

The plants were watered once a day and grew for five months. Irrigation was activated by a timer, the schedule of which was adjusted weekly according to the weather conditions and the leaching fraction. On 10 September 2024, plant height (aubergine), length of the central branch (cucumber), number of leaves, leaf area, vegetative weight, root volume, number and weight of fruits were determined. The nutritional properties of the fruits were also assessed, for aubergine (iron, calcium, sodium, potassium, phosphorus, zinc, riboflavin thiamnine, vitamin C, niacin, vitamin B6, folate) and for cucumber (potassium, phosphorus, calcium, magnesium, sodium, iron, pantothenic acid, pyridoxine, zinc, manganese, vitamin C, niacin, riboflavin, vitamin E, thiamine, vitamin K, folate).

2.1. Analysis methods

- VARIAN AA 10 Atomic Absorption Spectrophotometer was used for mineral analysis of the fruit.
- NanoElute2 was used for liquid mass analysis

2.2. Statistics

The experiment was carried out in a randomized complete block design. Collected data were analyzed by one-way ANOVA, using GLM univariate procedure, to assess significant ($P \leq 0.05$, 0.01 and 0.001) differences among treatments. Mean values were then separated by LSD multiple-range tests ($P = 0.05$). Statistics and graphics were supported by the programs Costat (version 6.451) and Excel (Office 2010).

3. Results

The experiment showed that the use of FertilTomix, , can significantly increase the height, number of leaves, vegetative and root growth, and leaf area of aubergine and cucumber plants (Tables 2-3). The product FertilTomix (F1) with added silver, copper and zinc worked better than as such, stimulating plant growth more. The trial also showed an increase in the number and weight of fruits in both aubergine and cucumber, in the theses treated with FertilTomix compared to the control and the commercial control with algae. The leaves also appeared larger and more intensely green in the theses treated with minerals extracted from the sea [Figure 2A and Figure 2B; Figure 3A and Figure 3B). The analysis of the mineral and vitamin content of the fruits showed a significant increase in minerals and vitamins in the fruits treated with FertilTomix for most of the analysed parameters, to a greater extent with FertilTomix with added silver, copper and zinc (FE1) (Table 4-5) (Figure 4A and Figure 4B). A longer production period was also noted in the theses treated with marine extracts.

Table 2 Evaluation of the use of FertilTomix on aubergine vegetative and root biomass

Groups	Plant height (cm)	Leaves number (n°)	Leaves surface area (cm^2)	Vegetative weight (g)	Roots volume (cm^3)	Fruits number (n°)	Fruits weight (g)
CTRL	10.33 c	22.33 d	56.23 c	64.22 d	41.11 d	7.13 c	25.12 d
BIOAL	10.41 b	24.68 c	58.32 b	65.13 c	44.54 c	9.24 b	27.33 c
FE0	10.66 a	32.11 b	64.66 a	67.36 b	48.99 b	13.11 a	28.14 b
FE1	10.68 a	32.44 a	64.55 a	69.12 a	50.16 a	13.66 a	29.16 a
ANOVA	**	***	**	***	***	**	***

One-way ANOVA; n.s. – non-significant; *,**,*** – significant at P ≤ 0.05, 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test (P = 0.05). Legend: (CTRL) control + COMPO BIO; (BIOAL) COMPO BIO + Ecklonia maxima; (FE0) FertilTomix; (FE1) FertilTomix with silver, copper and zinc;

Table 3 Evaluation of the use of FertilTomix on cucumber vegetative and root biomass

Groups	Central branch length (cm)	Leaves number (n°)	Leaves surface area (cm^2)	Vegetative Weight (g)	Roots Volume (cm^3)	Fruits number (n°)	Fruits weight (g)
CTRL	22.33 d	15.14 c	45.66 d	54.55. c	36.24 d	8.66 c	25.44 d
BIOAL	24.66 c	17.33 c	47.88 c	56.77 b	38.55 c	10.23 b	27.99 c
FE0	28.99 b	22.88 b	51.13 b	59.32 a	41.22 b	14.55 a	29.45 b
FE1	31.12 a	24.78 a	53.44 a	60.12 a	44.66 a	14.88 a	32.33 a
ANOVA	***	***	***	**	***	**	***

One-way ANOVA; n.s. – non-significant; *,**,*** – significant at P ≤ 0.05, 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test (P = 0.05). Legend: (CTRL) control + COMPO BIO; (BIOAL) COMPO BIO + Ecklonia maxima ; (FE0) FertilTomix; (FE1) FertilTomix with silver, copper and zinc

Table 4 Evaluation of the use of FertilTomix on the nutritional properties of aubergine fruits

Groups	CTRL	BIOAL	FE0	FE1	ANOVA
Iron (mg)	0.30 b	0.33 b	0.46 a	0.48 a	**
Calcium (mg)	14.00 c	14.11 c	14.88 b	15.12 a	***
Sodium (mg)	6.00 a	6.12 a	6.10 a	6.08 a	n.s.
Potassium (mg)	297.00 c	297.11 b	300.12 a	300.14 a	**
Phosphorus (mg)	33.00 c	33.24 b	35.66 a	35.68 a	**
Zinc (mg)	0.20 d	0.22 c	0.36 b	0.40 a	***
Thiamine (mg)	0.05 a	0.04 a	0.05 a	0.05 a	n.s.
Riboflavin (mg)	0.05 b	0.06 b	0.06 b	0.10 a	*
Vitamin C (mg)	11.00 d	11.10 c	11.36 b	11.45 a	***
Niacin (mg)	0.60 a	0.62 a	0.62 a	0.63 a	n.s.
Vitamin B6 (mg)	0.08 b	0.08 b	0.15 a	0.16 a	*
Folates (µg)	18.00 a	18.04 a	18.04 a	18.05 a	n.s.

One-way ANOVA; n.s. – non-significant; *,**,*** – significant at P ≤ 0.05, 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test (P = 0.05). Legend: (CTRL) control + COMPO BIO; (BIOAL) COMPO BIO + *Ecklonia maxima*; (FE0) FertilTomix; (FE1) FertilTomix with silver, copper and zinc

Table 5 Evaluation of the use of FertilTomix on the nutritional properties of cucumber fruits

Groups	CTRL	BIOAL	FE0	FE1	ANOVA
Vitamin C (mg)	2.80 d	2.82 c	2.84 b	2.86 a	***
Niacin (mg)	0.098 a	0.099 a	0.099 a	0.098 a	n.s.
Riboflavin (mg)	0.033 a	0.034 a	0.033 a	0.034 a	n.s.
Vitamin E (mg)	0.03 c	0.03 c	0.06 b	0.12 a	**
Thiamine (mg)	0.027 a	0.028 a	0.028 a	0.029 a	n.s.
Vitamin K (µg)	16.40 d	16.46 c	16.55 b	16.68 a	***
Folate (µg)	7.00 b	7.11 a	7.12 a	7.12 a	*
Potassium (mg)	147.00 b	147.03 b	147.44 a	147.45 a	*
Phosphorus (mg)	24.00 c	24.12 c	24.66 b	24.88 a	**
Calcium (mg)	16.00 c	16.22 b	16.44 a	16.45 a	**
Magnesium (mg)	13.00 b	13.02 b	13.88 a	13.92 a	*
Sodium (mg)	2.00 a	2.00 a	2.01 a	2.00 a	*
Iron (mg)	0.28 c	0.34 b	0.46 a	0.48 a	**
Pantothenic acid (mg)	0.259 a	0.258 a	0.259 a	0.260 a	n.s.
Pyridoxine (mg)	0.040 a	0.040 a	0.041 a	0.040 a	n.s.
Zinc (mg)	0.20 c	0.26 b	0.40 a	0.42 a	**
Manganese (mg)	0.079 b	0.080 b	0.092 a	0.093 a	*

One-way ANOVA; n.s. – non-significant; *,**,*** – significant at P ≤ 0.05, 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test (P = 0.05). Legend: (CTRL) control + COMPO BIO; (BIOAL) COMPO BIO + *Ecklonia maxima* ; (FE0) FertilTomix; (FE1) FertilTomix with silver, copper and zinc

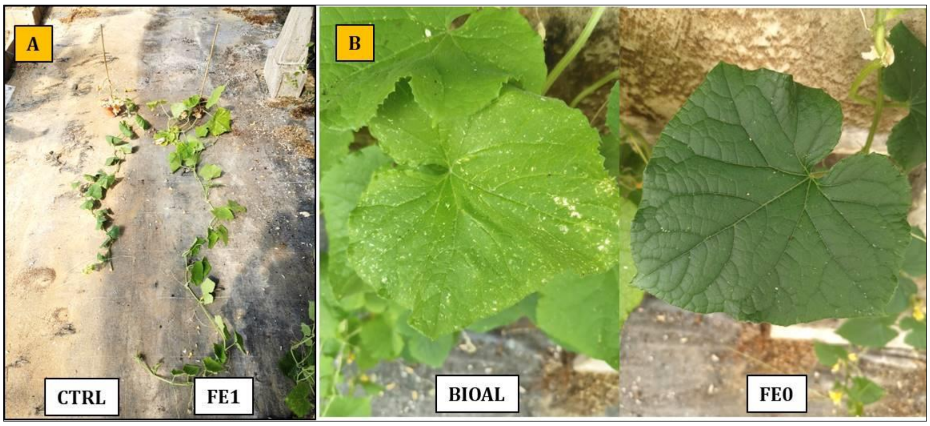

Figure 2 Comparison of the control thesis (CTRL) and Fertiltomix with added silver copper and zinc (FE1) (Figure A) and effect of Fertiltomix treatment (FE0) and algae biostimulant (BIOAL) on leaf colour (Figure B)

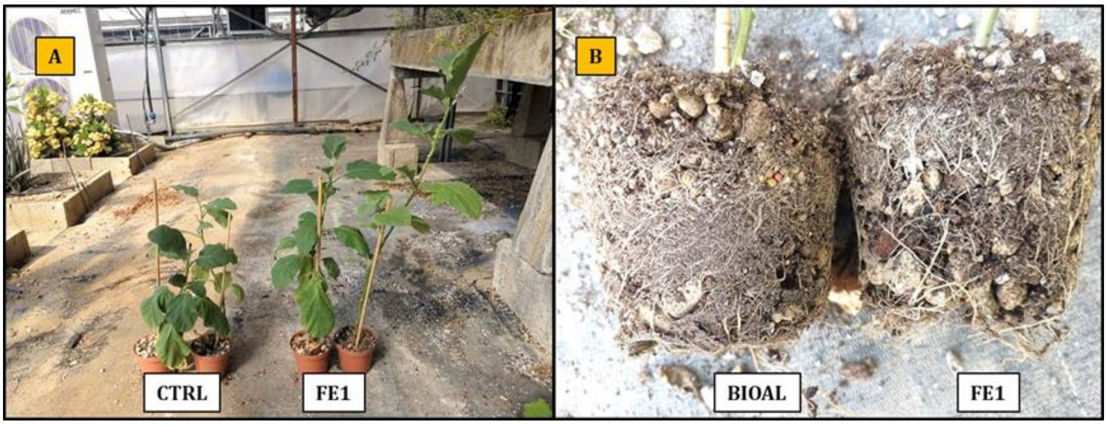

Figure 3 Comparison between the control thesis (CTRL) and Fertiltomix with added copper silver and zinc (FE1) on the vegetative (Figure A) and root (Figure B) part of aubergine.

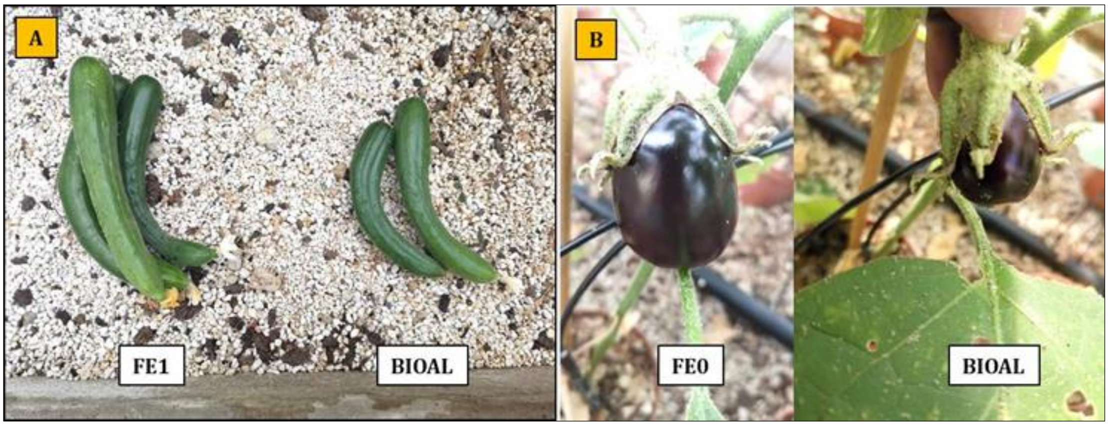

Figure 4 Comparison of commercial biostimulant (BIOAL) and Fertiltomix with added copper silver and zinc (FE1) on cucumber fruit (Figure A) and FertilTomix (FE0) and commercial biostimulant (BIOAL) on aubergine fruit (Figure B)

4. Discussion

There are 70 percent of planet's surface covered in salt water [21-25]. The seas and oceans are the largest reservoirs of healing remedies on earth. Seawater contains all the elements of Mendeleev's periodic table as well as a wide range of organic molecules like amino acids, vitamins, fatty acids, polysaccharides and enzymes [26-28]. There is more to the sea than a breeding ground: it is an essential element. The current biochemical understanding of seawater still needs to be improved in order to comprehend its therapeutic potential [29]. Seawater proves to be a true modern ally much more than a source of minerals and trace elements [30]. In seawater, virtually all known elements are present, sometimes in considerable quantities (e.g. gold), sometimes in minute amounts (e.g. hydrogen). Seawater is a complex solution, a ‘mineral’ water. Salts dissociate into positive (cations) and negative (anions) ions in water. Sodium chloride (NaCl) breaks down into Na+ and Cl-. Magnesium sulphate (MgSO4) breaks down into Mg++ and SO4--. Among the sixty or so salts present in seawater, six account for more than 99% of the salt composition [31]. Over millions of years, the runoff water that washed away the soil from the continents carried the marine salts over millions of years. Sulfur, nitrogen, boron, and other volatile elements come from the primordial atmosphere. Other minerals come from hot submarine hydrothermal springs [32]. In passing through the oceanic crust, the cold sea water was subjected to high pressures and high temperatures. By dissolving many elements, the water poured them into the underwater source. Seawater has one of the most significant characteristics: no matter how salty it is, the proportions of its main components remain the same regardless of its degree of salinity [33,34]. In addition to chemical characteristics, physical phenomena like ionisation and radioactivity play a crucial role in seawater's great activity [35,36]. Because seawater is rich in organic compounds, it resembles a fertile broth containing amino acids and microorganisms, such as mucosin and plankton, as well as flora and fauna. Assimilation of minerals suspended in water is carried out by these microorganisms, but they also fight foreign microbes, hence the antibacterial and antibiotic properties. Any animal or plant species can produce and release chemical messages in seawater and these substances can act remotely on their behavior or biological processes [37,38]. These chemical messages are also 'populated' in marine life. Observations of biochemical mechanisms in different organisms (bacteria, plankton, metazoans, vertebrates) have gone from hypotheses to widely accepted scientific facts since 1962 [39-41]. The term telemediators was first introduced in 1970 by Maurice Aubert, founder of INSERM and the International University of the Sea (formerly Cerbom). It is also very fragile to handle chemicals of such a diverse nature (repellent, sexual, toxic, antibiotic, etc.). Due to the multiplicity of signals detected, this system of relationships, where the biochemical message is the pivot around which the ocean's biological balance is organised, constitutes a new approach to marine biology [42-44]. In this experiment, sea extracts significantly influenced cucumber and aubergine vegetative and root growth. The number and size of fruits increased, as did the amount of nutrients in the fruit. A particularly interesting aspect of FertilTomix was that during the cultivation cycle, theses were not fertilized with essential nutrients as the control and biostimulant treated with algae, so the increase in plant growth was completely attributed to the marine mineral product. Other studies on horticulture and fruit plants from China and the United States have confirmed the results of this trial.

5. Conclusion

Various extracts obtained from seawater using an innovative mineral process were found to significantly increase plant growth. The test also showed an increase in the mineral and vitamin content of the fruit, probably influenced by the increased presence of bacteria in the soil, in the theses treated with marine extracts, as demonstrated in other tests with the same product. As well as for those wishing to reduce the use of industrial fertilisers, the results obtained are particularly interesting for those growing in arid environments or those without drinking water. An interesting aspect is the fact that in addition to the use of marine extracts for plant biostimulation, it is also possible to use the recycled water obtained from the process to irrigate the plants, so that all resources can be utilised in the process.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The author declares no conflict of interest.

Statement of ethical approval

The present research work does not contain any studies performed on animal/human subjects.

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