GSC Advanced Research and Reviews

eISSN: 2582-4597 CODEN (USA): GARRC2

Cross Ref DOI: 10.30574/gscarr

Journal homepage: https://gsconlinepress.com/journals/gscarr/

(Research Article)

Check for updates

Sea minerals and marine recycled water use obtained through an innovative extraction process for the cultivation of *Impatiens glandulifera* and *Helianthus annuus*

Domenico Prisa *

CREA Research Centre for Vegetable and Ornamental Crops, Council for Agricultural Research and Economics, Via dei Fiori 8, 51012 Pescia, PT, Italy.

GSC Advanced Research and Reviews, 2023, 14(03), 141–148

Publication history: Received on 01 February 2023; revised on 07 March 2023; accepted on 10 March 2023

Article DOI: https://doi.org/10.30574/gscarr.2023.14.3.0077

Abstract

Research objective: The aim of this research was to evaluate the stimulating potential of (FertilTomix: product based on minerals and organic molecules from the sea) obtained from an innovative extraction process and to determine the possible use of the recycled sea water obtained from this process for the cultivation of *Impatiens glandulifera* and *Helianthus annuus*.

Materials and Methods: The experiments, which started in September 2022, were conducted in the CREA-OF greenhouses in Pescia, Italy. Two experiments were carried out for each species in cultivation. One test was performed to evaluate the biostimulant activity of FertilTomix compared with an algae-based biostimulant and a fertilised control. A second experiment was carried out to evaluate the possible use of water obtained from the extraction process of sea minerals as possible irrigation water for plants. On February 15, 2023, plant height, leaves number, leaves surface area, vegetative weight, roots weight and length, the number of germinated seeds, average germination time, the number of microorganisms in the substrate, plants dead number were determined. In addition, the SPAD index was measured on three leaves pinched from the bottom to the apex of the canopy of each plant (for a total of 90 measurements per treatment).

Results and Discussion: The first experiment showed that the use of FertilTomix, irrespective of the extraction process, was able to significantly increase seed germination, vegetative and root growth (Figures 2-3), root length and reduce mortality of *Impatiens glandulifera* plants (Tables 1-2). As found in the first experiment in the treated theses, a significant increase in microbial biomass was noted, which definitely influenced seed germination, vegetative and root development and significantly reduced plant mortality. With regard to the second part of the experiment carried out to test whether recycled water, obtained from the extraction process of sea minerals, was valid for plant irrigation, the data showed that it can indeed be used successfully on *Helianthus annuus*. There are as yet no cost-effective technologies and processes in the world capable of extracting minerals from seawater that are useful for fertilising plants and recycling process water that can be used for irrigation. The technology of the FertilTomix product itself could be regarded as innovations in this respect, which deserve great consideration and expanded knowledge.

Conclusions: The test demonstrated a significant effect on plant growth after the application of certain extracts obtained by an innovative mineral extraction process from seawater. Furthermore, the possibility of being able to use recycled seawater from this process to irrigate plants, which is very interesting and applicable in countries where this resource is scarce. New experiments are currently underway to test the product on new plant species in and out of soil and to assess whether the application of FertilTomix can increase the organoleptic and nutraceutical quality of treated fruits and vegetables.

Keywords: Seawater minerals; Microorganisms; Marine recycled water; Biofertilizers; Ormus

* Corresponding author: Domenico Prisa

1. Introduction

Increasing population growth, climate change, and agricultural demands are predicted to increase water scarcity [1,2,3]. During this century, Spain has invested a great deal of capital in increasing water availability. Desalination consumes high amounts of energy, and may cause deleterious effects on marine ecosystems [4,5]. Treating seawater can be used to water tree plantations near the sea due to the limited amount of water available for irrigation. Diluted seawater (DSW) is created by mixing seawater and fresh water at a ratio of 1:30 [6]. The concentration of soil ammonium in wetlands increases when saltwater incursion causes salinization. As intact soil is exposed to saltwater for a long time, an exchange of salt cations occurs, which increases the amount of reactive N released into the environment. It is becoming increasingly difficult to use inorganic fertilizers [7, 8]. Cover cropping and manure-based compost provide plant-available nitrogen economically in organic systems. Although dry organic fertilizers such as fishery waste and guano are widely used, their quantity is limited, and their nitrogen minerals can take between four and eight weeks to mineralize [9]. The use of sea salt as a source of sea mineral solids has been demonstrated for foliar and soil treatments [10, 11, 12]. As far as production costs are concerned, water costs are far more relevant to total replacement than fertilizer costs; the cost of water fluctuates from 2.6% for lettuce to 35.1% for lemons [13]. A 1% increase in fertilizer costs represents less than 1% of total production costs. When plants were watered with seawater that had been diluted, the length, weight, number of leaves per plant, and photosynthetic pigments all went down by a lot [14]. Bittern solution, made as a byproduct of making solar salt, can give plants Mg and other nutrients [15, 16]. As a great thermostat and heat reservoir, the sea has many functions for terrestrial life. It levels the temperature extremes that would otherwise exist on the planet without its moderating influence [10]. Finally, as a mineral source, the sea has been underutilized compared to its potential [11] despite its low cost as a transport method. The main reasons for this deficiency are the lack of knowledge of what is found in the ocean and the advantages of exploiting marine mineral deposits, the lack of technology for economically exploiting these deposits, and the lack of an economically and politically compelling need to exploit them at this point [12]. Marine beaches, seawater, continental shelves, surface sediments, and hard rock beneath the surface sediments of the seabed are the five areas where mineral resources are found. The first three regions of the ocean are currently being mined for a variety of minerals. As a result, there is a voluminous literature about these minerals and their recovery methods.

1.1. Experiments using minerals from the sea in agriculture

Hou Tian Zhen, head of the Department of Tree Physiology and Biochemistry at the Xinjiang Academy of Forestry Sciences in China, led a team of researchers who evaluated the use of sea minerals in three experiments [17]. First tested in 1989 at the A-ning Experiment Station, tomatoes treated with these minerals had nearly twice as many flowers per plant and 27% more fruit [18,19]. At the A-ning Experiment Station, a 1990 field experiment demonstrated that treated green beans increased yield by 81%, sweet beets by 67%, and soybeans by 29%. The A-ning Experiment Station conducted a large-scale experiment in 1991, where watermelon plots were 300 meters apart in a field [20]. The treated melons yielded 65% more than the control plots. The sea mineral extract was used by Harold Aungst, an alfalfa grower in Pennsylvania who achieved a 29% increase in protein with a significant increase in yield per acre and five cuts rather than three. In the first year, it produced 7.6 tons per acre, almost twice the average of 3.4 tons per acre in the state. In the second year, the production reached 10 tons per acre, three times the state average [21]. Milk production also increased by 30 percent due to treated hay. In Wisconsin, Wilson Mills has increased the fruit production on apple trees by using a marine extract since 1989. As a result of the studies, zinc absorption was 1200% increased, iron absorption was 400% increased, chromium absorption was 326% increased, and potassium absorption was 120% higher. The apples were giant and ripened two to three weeks earlier [22]. An Okinawa banana plantation experienced a 100% increase in yield and a 35% reduction in ripening time for the first eight years. The yield doubled every year, the fruit set tripled, and the sugar content increased significantly. The A-ning Experiment Station in 1990 found that treated green beans resulted in 81% more yield and treated sugar beets resulted in 67% more yield. While other neighboring farms experienced 80% empty pods due to environmental stress, treatment with marine mineral extracts increased coffee production by 50–100%, with better flavor, bigger beans, and 80% fancy and gourmet quality. There were fewer harvests needed because the young plants produced 1/3 earlier than expected [23,24]. In a trial carried out by Dr. Prisa in 2022 on Cichorium intybus and Carthamus tinctorius, it was shown that the use of Ormus (FertilTomix) increased seed germination, vegetative and root development and had significantly reduced plant mortality. Furthermore, a significant increase in beneficial microorganisms was observed in the theses treated with the product.

1.2. Research Objectives

The aim of this research was to evaluate the stimulating potential of (FertilTomix: product based on minerals and organic molecules from the sea) obtained from an innovative extraction process and to determine the possible use of the recycled sea water obtained from this process for the cultivation of *Impatiens glandulifera* and *Helianthus annuus.*

Figure 1 Detail of treatment with FertilTomix on *Impatiens glandulifera*. Use of a pipette to provide 3 ml of product every week

2. Material and methods

The experiments, which started in September 2022, were conducted in the CREA-OF greenhouses in Pescia (Pt), Tuscany, Italy (43°54′N 10°41′E) on *Impatiens grandulifera* and *Helianthus annuus* (Figure 1A,1B). Seeds were placed in ø 10 cm pots, 30 seeds per thesis, divided into three replications of 10 seeds each. Two experiments were carried out for each species in cultivation. One test was performed to evaluate the biostimulant activity of FertilTomix compared with an algae-based biostimulant and a fertilised control. A second experiment was carried out to evaluate the possible use of water obtained from the extraction process of sea minerals as possible irrigation water for plants.

In the first test concerning the stimulant evaluation of the product FertilTomix on *Impatiens grandulifera*, the experimental groups were:

- Control group (CTRL) (peat 80%+ pumice 20%), irrigated with water three times a week (5 ml per plant) and substrate fertilised once a week with Compo BIO (organic plant fertiliser; organic nitrogenous fertiliser; fluid borage), 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 three times a week (5 ml per plant) and substrate fertilised once a week with Compo BIO (organic plant fertiliser; organic nitrogenous fertiliser fluid borer), 5 ml in 1 L 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 with soda extraction procedure (FE0) (peat 80% + pumice 20%) irrigated with water three times a week (5 ml per plant) and substrate fertilised once a week with Compo BIO (organic plant fertiliser; organic nitrogenous fertiliser; fluid borer), 5 ml of product in 1 L of water and then 3 ml per plant of this dilution; watering with fertiltomix (3 ml per plant) once a week;
- The group with fertiltomix with soda extraction procedure (FE1) (peat 80% + pumice 20%) irrigated with water three times a week (5 ml per plant) and the substrate fertilised once a week with Compo BIO (organic plant fertiliser; organic nitrogenous fertiliser; fluid borage), 5 ml of product in 1 L of water and then 3 ml per plant of this dilution; wetting with fertiltomix (3 ml per plant) once a week;
- The group with fertiltomix with soda extraction procedure (FE2) with silver (peat 80% + pumice 20%) irrigated with water three times a week (5 ml per plant) and substrate fertilised once a week with Compo BIO (organic plant fertiliser; organic nitrogenous fertiliser; fluid borage), 5 ml of product in 1 L of water and then 3 ml per plant of this dilution; wetting with fertiltomix (3 ml per plant) once a week.

In the second test concerning the reuse of water produced by the marine mineral extraction process on *Helianthus annuus*, the experimental groups were:

- Control group (CTRL) (peat 80%+ pumice 20%), irrigated with water three times a week (5 ml per plant) without fertilisation;
- Control group1 (CTRL1) (peat 80%+ pumice 20%), irrigated with water three times a week (5 ml per plant) and fertilised with Compo BIO once a week (organic plant fertiliser; organic nitrogenous fertiliser), 5 ml of product in 1 L of water and then 3 ml per plant of this dilution;
- Water-wash group (WTL) (peat 80%+ pumice 20%), irrigated with water three times a week (5 ml per plant) and fertilised with Compo BIO once a week (organic plant fertiliser; organic nitrogenous fertiliser), 5 ml of product in 1 L of water and then 3 ml per plant of this dilution;

- Purified water group (WTP) (peat 80%+ pumice 20%), irrigated with water three times a week (5 ml per plant) and fertilised with Compo BIO once a week (organic plant fertiliser; organic nitrogenous fertiliser), 5 ml of product in 1 L of water and then 3 ml per plant of this dilution;
- Purified water enriched (WTPA) group (peat 80%+ pumice 20%), irrigated with water three times a week (5 ml per plant) and fertilised with Compo BIO once a week (organic plant fertiliser; organic nitrogenous fertiliser), 5 ml of product in 1 L of water and then 3 ml per plant of this dilution.

On February 15, 2023, plant height, leaves number, leaves surface area, vegetative weight, roots weight and length, the number of germinated seeds, average germination time, the number of microorganisms in the substrate, plants dead number were determined. In addition, the SPAD index was measured on three leaves pinched from the bottom to the apex of the canopy of each plant (for a total of 90 measurements per treatment).

2.1. Analysis methods

Microbial count: direct determination of total microbial count by microscopy of cells contained in a known sample volume using counting chambers (Thoma chamber). The surface of the slide is etched with a grid of squares, with the area of each square known. Determination of viable microbial load after serial decimal dilutions, spatula seeding (1 ml) and plate counting after incubation [25];

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, irrespective of the extraction process, was able to significantly increase seed germination, vegetative and root growth (Figures 2-3), root length and reduce mortality of *Impatiens glandulifera* plants (Tables 1-2). As found in the first experiment in the treated theses, a significant increase in microbial biomass was noted, which definitely influenced seed germination, vegetative and root development and significantly reduced plant mortality (Tables 1-2). Again, the FE2: minerals from the soda + silver extraction process proved to be the best thesis for all the treatments analysed. For the best application of the product FertilTomix, it was also noted that when the substrate is slightly moist, the product is more easily absorbed than when the substrate is dry, when the product remains on the surface and colours the soil white (Figure 1).

Table 1 Evaluation of the use of FertilTomix on the vegetative growth and substrate bacteria colonisation of *Impatiens glandulifera*

Groups	Plant height (cm)	Leaves number (n°)	Leaves surface area (cm²)	Vegetative Weight (g)	Substrate total bacteria (Log CFU/g soil)
CTRL	6.39 e	5.84 e	14.80 e	25.20 c	2.23 e
BIOAL	7.22 d	7.22 d	15.19 d	27.34 b	2.96 d
FE0	7.41 c	7.83 c	15.59 c	27.52 b	3.16 c
FE1	8.29 b	9.21 b	16.32 b	28.29 a	4.65 b
FE2	8.78 a	11.20 a	17.25 a	28.52 a	4.95 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 with lye extraction;(FE1) FertilTomix with soda extraction; (FE2) FertilTomix with soda extraction procedure with silver

With regard to the second part of the experiment carried out to test whether recycled water, obtained from the extraction process of sea minerals, was valid for plant irrigation, the data showed that it can indeed be used successfully on Helianthus annuus. The thesis with enriched purified water (WTPA) proved to be the best for all agronomic parameters analysed. The theses WTL: wash water and WTP: purified water were also generally better or with comparable results to the fertilised irrigation control water CTRL1. The most noticeable effects were an increase in vegetative and root development of plants irrigated with water from the FertilTomix extraction processes (Figure 4). An increase in substrate microbiology in the treated theses and a significant reduction in plant mortality were also observed in this trial (Tables 3-4).

Table 2 Evaluation of the use of FertilTomix on the germination seeds and root biomass of *Impatiens glandulifera*

Groups	Germinated seed (n°)	Average germination time (days)	Roots Weight (g)	Roots Length (cm)	Plants dead number (n°)
CTRL	17.20 c	13.00 a	13.32 e	5.07 e	1.80 a
BIOAL	20.80 b	13.20 a	14.92 c	5.95 d	1.00 b
FE0	21.40 b	13.20 a	14.62 d	6.24 c	0.20 c
FE1	23.40 a	12.40 a	15.27 b	6.93 b	0.00 c
FE2	23.80 a	11.40 b	16.04 a	7.22 a	0.00 c
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 with lye extraction;(FE1) FertilTomix with soda extraction; (FE2) FertilTomix with soda extraction procedure with silver

Table 3 Evaluation of the use of water obtained from the extraction process of sea minerals on the vegetative growth and substrate bacteria colonisation of *Helianthus annuus*

Groups	Plant height (cm)	Leaves number (n°)	Leaves surface area (cm²)	Vegetative Weight (g)	Substrate total bacteria (Log CFU/g soil)
CTRL	5.40 c	3.80 c	6.39 d	18.51 c	2.03 e
CTRL1	10.57 b	7.60 b	12.39 c	23.52 b	2.36 d
WTL	10.31 b	7.20 b	12.47 bc	23.59 b	2.55 c
WTP	10.43 b	7.20 b	12.67 b	23.56 b	2.69 b
WTPA	11.68 a	9.20 a	13.62 a	24.63 a	3.22 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 aqueduct water no fertilisation; (CTRL1) COMPO BIO + *aqueduct water* ;(WTL) COMPO BIO + water-wash group;(WTP) COMPO BIO + purified water; (WTPA) COMPO BIO + purified water enriched

Figure 2 Comparison of the control thesis (CTRL), the thesis with algal biofertiliser (BIOAL) and the theses treated with FertilTomix (FE1; FE2) on vegetative growth of *Impatiens glandulifera*

Table 4 Evaluation of the use of water obtained from the extraction process of sea minerals on the germination seeds and root biomass of *Helianthus annus*

Groups	Germinated seed (n°)	Average germination time (days)	Roots Weight (g)	Roots Length (cm)	Plants dead number (n°)
CTRL	21.80 c	12.81 a	13.51 d	5.30 c	2.20 a
CTRL1	23.00 b	12.63 a	15.14 c	6.94 b	1.80 a
WTL	22.80 b	12.00 a	15.36 bc	6.93 b	0.20 b
WTP	23.20 ab	12.21 a	15.43 b	6.93 b	0.20 b
WTPA	24.00 a	11.00 b	16.26 a	7.16 a	0.00 b
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 aqueduct water no fertilisation; (CTRL1) COMPO BIO + aqueduct water ;(WTL) COMPO BIO + water-wash group;(WTP) COMPO BIO + purified water; (WTPA) COMPO BIO + purified water enriched

Figure 3 Effect of the FertilTomix treatment (FE2 and FE1) on root growth of *Impatiens glandulifera* compared to the fertilising algae treatment (BIOAL) and the untreated control (CTRL)

Figure 4 Comparison of the control thesis treated with fertilised aqueduct water (CTRL1), the control thesis with purified sea mineral extraction (WTP), the control thesis with wash water (WTL) and the control thesis with purified and enriched water (WTPA) on *Helianthus annuus*

4. Discussion

The use of marine extracts in these experiments significantly influenced seed germination and plant development of all analysed plant species (*Impatiens glandulifera*, *Helianthus annuus*). In addition, it resulted in a noticeable increase in microfauna in the treated substrates, an effect probably influenced by all the mineral and organic substances present in the seawater. Also of interest was the increase in chlorophyll in the leaves, an effect probably influenced by the microbial activity in the soil, which not only increased root development but also resulted in increased nutrient uptake, as found in previous trials by the same author [26]. The presence of molecules such as silver significantly reduced the mortality of treated seedlings, probably acting on the intrinsic stimulation of plant defences and not directly on biotic stresses (in the treated theses, in fact, soil microbial biomass increased) [27,28]. Also with regard to the use of the wash water obtained from the FertilTomix extraction process, the experimentation showed that it is possible to use it to irrigate the plants, also obtaining benefits on plant development and defence. This is very interesting because in those locations where there is no water for irrigation, a fertiliser/biostimulant and water to irrigate plants could be obtained from the seawater extraction process through the same process. There are as yet no cost-effective technologies and processes in the world capable of extracting minerals from seawater that are useful for fertilising plants and recycling process water that can be used for irrigation [29,30,31,32]. The technology of the Aquatomix company and the FertilTomix product itself could be regarded as innovations in this respect, which deserve great consideration and expanded knowledge.

Precisely in this direction Further investigations will be carried out in the future to evaluate: 1) use of FertilTomix in case of biotic and abiotic stresses (water, salt, thermal); 2) analysis of the mineral and organic content present within FertilTomix and the wash water, which were partially analysed due to the considerable number of minerals present in the products and the sophisticated instrumentation and high costs required for the analysis; 3) effect of FertilTomix on the mineral and nutraceutical content of fruits and vegetables; 4) increase in the number of experiments on other plant species to confirm the results obtained, diversifying the protocols and application methods; 5) use of the wash water with other fertilisers, biostimulants and types of substrate. The results obtained, however, already lay the foundations for further studies and applications in the field and above ground of this technology.

5. Conclusion

The test demonstrated a significant effect on plant growth after the application of certain extracts obtained by an innovative mineral extraction process from seawater. Furthermore, the possibility of being able to use recycled seawater from this process to irrigate plants, which is very interesting and applicable in countries where this resource is scarce. In general, experimentation has shown how mineral and organic substances in seawater can have a significantly positive influence on soil microfauna, with direct and indirect effects on plant growth and defence. The results obtained are particularly interesting precisely for those who have to cultivate in arid environments or those without drinking water, as well as for those who want to start reducing the use of industrial fertilisers and use an inexhaustible source such as sea water. New experiments are currently underway to test the product on new plant species in and out of soil and to assess whether the application of FertilTomix can increase the organoleptic and nutraceutical quality of treated fruits and vegetables.

Compliance with ethical standards

Acknowledgments

The research is part of the WATERFERT project: Using minerals extracted from seawater to develop new biostimulants for the cultivation of ornamental plants. We thank the company AQUATOMIX LLC of San Diego, California, and in particular, Mr Nicola Ghelardi, for funding the project.

Disclosure of conflict of interest

The author declares no conflict of interest.

References

[1] Clark AL, Clark JC. 'Marine Metallic Mineral Resources of the Pacific Basin', Marine Resource Economies, 1986; 3, 45-62.

[2] Dubs, M. 'Minerals of the Deep Sea: Myth and Reality', in G. Pontecorvo, ed.,The New Order of the Oceans — The Advent of a Managed Environment. Columbia University Press, 1986: 85-125.

[3] Livernois J, Uhler R. 'Extraction Costs and The Economics of Nonrenewable Resources', Journal of Political Economy, 1987; 95: 195-203.

[4] Fairbridge RW.The encyclopedia of oceanology. Reinhold, New York, 1971.

[5] Amann, H. Marine raw material exploration with the Valdivia. Marine Technology. 1972; 3: 102–106.

[6] La Que FL. "Prospects for and from deep ocean mining." Marine Technology and Science Journal. 1971; 5(2): 5–15.

[7] Purrett L."Hot spots in the Red Sea." Science news. 1971; 99: 388–389.

[8] Hein JR, Conrad TA, Staudigel H. Seamount mineral deposits a source of rare metals for high-technology industries. Oceanography. 2010; 23: 184–189.

[9] Kato Y, Fujinaga K, Nakamura K, Takaya Y, Kitamura, K Ohta J, Toda R, Nakashima T, Iwamori H. Deep-sea mud in the Pacific Ocean as a potential resource for rare-earth elements. Nat. Geosci. 2011; 4: 535–539.

[10] Hein JR, Cherkashov GA. Preface for ore geology reviews special issue: Marine mineral deposits: New resources for base, precious, and critical metals. Ore Geol. Rev, 2017; 87: 1–2.

[11] Chakhmouradian, A.R.; Wall, F. Rare earth elements: Minerals, mines, magnets (and more). Elements. 2012; 8: 333–340.

[12] Deng Y, Ren J, Guo Q, Cao J, Wang H, Liu C. Rare earth element geochemistry characteristics of seawater and porewater from deep sea in western Pacific. Sci. Rep. 2017; 7: 16539.

[13] Pourret O, Tuduri J. Continental shelves as potential resource of rare earth elements. Sci. Rep. 2017; 7: 5857.

[14] Josso P, Pelleter E, Pourret O, Fouquet Y, Etoubleau J, Cheron S, Bollinger C. A new discrimination scheme for oceanic ferromanganese deposits using high field strength and rare earth elements. Ore Geol. Rev. 2017; 87: 3–15.

[15] Banerjee R. Manganese nodules as a possible source of precious metals. Curr. Sci. India. 2004; 87: 278–279.

[16] Kawamoto H. Japan's Policies to Be Adopted on Rare Metal Resources. Sci. Technol. Trends Q. Rev. 2008; 27: 57–76.

[17] https://lighthouseemporium.co.za/ormus-field-trials/

[18] www.diatomaceousearthonline.com.au

[19] www.ormus-water.com/science-behind

[20] www.life-enthusiast.com/articles

[21] www.subtleenergies.com/ormus

[22] www.liquidplasmafeeding.com/blogs

[23] https://vancouverislandormus.net/ormus-tests-and-reactions/

[24] https://africangoddess.co.za/category/ormus/

[25] Prisa D, Testa A. Use and evaluation of new organic fertilizers in the cultivation of Abelmoschus esculenthus (Okra). World Journal of Biology Pharmacy and Health Sciences. 2022; 11(03): 077–084.

[26] Prisa D. Bio stimulation activity of minerals obtained from an innovative seawater extraction process in the cultivation of vegetable plants. GSC Biological and Pharmaceutical Sciences, 2022; 21(02): 186–196.

[27] Prisa D, Benati A. Microbial bio stimulant obtained from cactus and succulent plants for rooting and growth of the castello hybrid rose (Attilio Ragionieri)World Journal of Biology Pharmacy and Health Sciences, 2022; 12(03): 054–062.

[28] Prisa D, Centomo G. Microbial processing of tannery waste for compost production in the growth and quality improvement of ornamental plants. GSC Advanced Research and Reviews, 2022; 12(01): 135–144.

[29] Taylor S. Abundance of chemical elements in the continental crust: A new table. Geochim. Cosmochim. Acta. 1964; 28: 1273–1285.

[30] Zhou BL, Li ZX, Chen CC. Global potential of rare earth resources and rare earth demand from clean technologies. Minerals. 2017; 7: 203.

[31] Pak S-J, Moon J-W, Lee K-Y, Chi S-B. Rare metal contents and their implications of seabed mineral resources explored by Korea. Econ. Environ. Geol. 2010; 43: 455–466.

[32] Hoshino M, Sanematsu K, Watanabe Y. REE mineralogy and resources. In Handbook on the Physics and Chemistry of Rare Earths; Elsevier: Amsterdam, The Netherlands. 2016; 49: 129–291.