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Innovative fertilizers with added plant extracts in the cultivation of *Valeriana officinalis* and *Raphanus sativus* and in the control of *Botrytis* and powdery mildew

Domenico Prisa [1,*] and Giordano Menci [2]

[1] CREA Research Centre for Vegetable and Ornamental Crops, Council for Agricultural Research and Economics, Via dei Fiori 8, 51012 Pescia, PT, Italy.
[2] Agrogen, Viale delle Fosse 16, Anagni (FR) 03012, Italy.

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Abstract

Research objective: The main objective of this article is to report the results obtained from the use of innovative fertilisers with added plant extracts in agriculture. In particular, this article will deal with two important topics: i) study of the effect of innovative fertilisers on the biomass of vegetable plants; ii) possible control on mortality due to diseases such as *Botrytis* and powdery mildew. The information reported in this research work can support the design of cultivation systems in which agricultural sustainability is fundamental due to the presence of plant extracts as an alternative to synthetic plant protection products.

Materials and Methods: The plants were grown in pots under controlled conditions; 30 seedlings per thesis, divided into 3 replications of 10 plants each, were planted in early January 2024. The plants used in the trial were *Valeriana officinalis* L. and *Raphanus sativus*. The five experimental groups in cultivation were: i) group control, irrigated with water and previously fertilised substrate; ii) group with Aktigen, irrigated with water and previously fertilised substrate, (3 ml per plant once a week); iii) group with Lifegen, irrigated with water and previously fertilised substrate, (3 ml per plant once a week); iv) group with QI-gen, irrigated with water and previously fertilised substrate, (3 ml per plant once a week); v) Group with *Ecklonia maxima* (EK): (peat 70% + pumice 20%), irrigated with water and previously fertilised substrate, (3 ml per plant once a week). On 5 May 2024, plant height, number of leaves, primary root length (mm), biomass of the aerial and root system, and number of dead plants (*Botrytis* and powdery mildew) were recorded.

Results and Discussion: The experiment showed that the use of innovative fertilisers enriched with plant extracts can indeed significantly improve the vegetative and root growth of *Valeriana officinalis* L. and *Raphanus sativus*. All treatments showed a significant improvement over the untreated control and the commercial *Ecklonia maxima* treatment for the agronomic parameters analysed, but the Qi-gen treatment was significantly the best for increasing vegetative and root biomass. Improvements were also found in plant height, leaf number and root length. The trial also revealed the significant effect on *Botrytis* control of the product Aktigen and on powdery mildew of the product Lifegen, in fact they reduced the mortality of *Valeriana officinalis* and *Raphanus sativus* seedlings.

Conclusions: A number of scientific studies have shown that the application of biofertilizers can improve plant growth, productivity, quality, and tolerance to biotic and abiotic stresses. Because of their multiple properties, they have become increasingly important as advanced agricultural techniques in global agriculture. This type of product, which includes natural substances, will contribute significantly to ecologically and economically sustainable agricultural production systems in the coming years, as well as serving as the foundation for large-scale sustainable agriculture in the future.

Keywords: Resistance inductors; Sustainable applications; Plant extract; Rhizosphere; Biofertilizers

* Corresponding author: Domenico Prisa

1. Introduction

1.1. Fertilizers: essential elements for plants and soil life

The growing demand for agricultural products to meet the demand for food for humans and animals, which has also increased in recent years for energy uses, with a steadily growing world population, cannot be met, as was the case in the recent past with the Green Revolution by exploiting genetic improvement and cultivating new land with increased use of irrigation water, simply because these are resources whose availability is limited [1-3]. Among the possible ways to maintain and if possible increase the productivity of cultivated fields, limiting ourselves to the field of mineral plant nutrition, it is reasonable to focus on:

- New types of fertilisers;
- Increasing the fertiliser unit (uf) efficiency of existing and of course new products;
- Increasing the bioavailability of certain elements already present in soils in a form not available for plant nutrition.

This means that we must aim for fertilisation that is even more targeted to the real needs of the plant and the characteristics of the soil-plant system, with fertiliser products that are able to follow the needs in relation to the different phenological phases that dictate the evolution of requirements. Increasing the efficiency of fertiliser units (NUE, Nutrient Use Efficiency) of products is not a choice, but a compulsory step to reach production objectives in terms of quantity (food security) and quality (food safety), always bearing in mind the sustainability of resources [4-7]. The strategy of increasing NUE is theoretically applicable to all fertility elements, but may find greater application in nitrogen (N) and phosphate (P) fertilisers. In this scenario, however, the technology and development of new fertilisers, especially from renewable resources, through the use of agro-industrial by-products from other production processes, must find more space [8]. The production of fertilisers from renewable resources, for example, is not only possible, but today it is necessary, as the new lines outlined in the Circular Economy issued by the European Union in 2014 also dictate [9,10]. The concept of the Circular Economy is based on the need to reuse and recycle resources, which, in this way, would remain in the economic cycle for a longer time than in the current, so-called linear model, in which resources are placed along the unidirectional line of extraction-production-consumption-disposal (*take-make-use-dispose*). In the circular economy model, on the other hand, resources are more appropriately placed in the extraction-production-consumption-reuse (*take-make-use-reuse*) type cycle [11]. Globally, it is estimated that the economic system consumes around 65 billion tonnes of raw materials per year, many of which are finite and whose extraction and processing comes at an environmental cost to the planet. In the same way, the production of fertilisers from the recovery from organic-based by-products of nutrients is theoretically possible on all fertility elements, although today the tendency is to favour nitrogen, phosphorus and certain trace elements [12].

1.2. Raw materials and environmental friendliness

In recent years, the protection of production quality and the environment has become increasingly important. On the one hand, this is the logical consequence of the end consumer's increased demand for environmentally friendly foodstuffs, on the other hand, one has to deal with the not entirely renewable resources that are used as raw materials for the production of a large part of mineral fertilisers [13]. In a broader perspective involving concepts of sustainability and recycling/recovery, organic by-products can also play a significant role, albeit a secondary role and certainly not on the assumption that self-sufficiency can be achieved with such products [14]. Products of plant and animal origin have two particularities from an economic-commercial point of view: their availability is infinite, just as their production has no geographical constraints since there can be plant and/or animal residues from which fertilisers can be obtained anywhere in the world. Organic fertilisers of plant origin, in most cases, are a source of nitrogen and, in the case of boron, also potassium; animal fertilisers often contain phosphorus and, in some cases, potassium in addition to nitrogen [15]. Considering the types of organic fertilisers most commonly used in Italy, and leaving aside plant extracts mostly used as biostimulants, usually products of plant origin have a low nutrient content while animal derivatives reach contents comparable to some mineral fertilisers [16,17].

1.3. Alternatives to conventional fertilisers

In order to decrease the depletion of resources and the degradation of the ecosystems, more sustainable management of agricultural land areas is required. It is imperative to reduce input costs, as well as reliance on chemical fertilizers and pesticides, which can pose multiple risks to human health and the environment if misused [18-24]. Farmers and researchers are therefore urged to find alternative solutions in order to increase agricultural productivity while preserving natural resources and reducing land use in particular. The use of alternative and sustainable approaches to address these issues is therefore of great interest [19,20,23,25].The most investigated and promising products to make agriculture more sustainable are organic products called biostimulants, which have been proposed several times. Plant-derived biostimulants (PDBs) are an efficient, eco-friendly alternative to synthetic biostimulants [20,21,25,26,27,28]. Currently, farmers and researchers are focusing on biostimulants to improve agricultural sustainability, but there are other natural products that need to be considered, studied, and assessed as well. In this review, we will discuss how plant extracts can be used to improve agricultural sustainability, particularly crop quality and production. Plant metabolites influence phenotype and physiological responses of plants [29]. The effects of plant extracts on hormones [30], organic acids [31], polyphenols [30], and sugars [31] have been reported in several previous studies. Quality traits (fruit size, colour, firmness, macro- and micronutrient contents, vitamins, polyphenols) and quantity traits (yield per square meter) are influenced by both biotic and abiotic stresses [32]. To cope with stress, crops shift from the first metabolism to the second metabolism, utilizing their energy reserves instead of concentrating on yielding. Following the recommendations of the European Union, synthetic plant protection products should be replaced by natural ones to improve agricultural sustainability in order to prevent this reduction of yield. Plant extracts have been extensively investigated as a practical approach to improving crop production sustainability, including producing biostimulants for specific crops. Plant extracts are still poorly understood even though they are often used to replace synthetic products such as fungicides, pesticides, and herbicides, despite their economic relevance. It is still largely unknown whether plant extracts can be used to overcome both biotic and abiotic stresses.

The main objective of this article is to report the results obtained from the use of innovative fertilisers with added plant extracts in agriculture. In particular, this article will deal with two important topics:

- Study of the effect of innovative fertilisers on the biomass of vegetable plants;
- Possible control on mortality due to diseases such as *Botrytis* and powdery mildew. The information reported in this research work can support the design of cultivation systems in which agricultural sustainability is fundamental due to the presence of plant extracts as an alternative to synthetic plant protection products.

Figure 1 Details of the plants used in the trial

2. Materials and methods

The plants were grown in pots under controlled conditions; 30 seedlings per thesis, divided into 3 replications of 10 plants each, were planted in early January 2024. The plants used in the trial were *Valeriana officinalis L.* (Figure 1) and *Raphanus sativus*. All plants were fertilised with a slow-release fertiliser (1 kg m^{-3} of Osmocote Pro® for 6 months) introduced into the growing medium at the time of transplanting.

The five experimental groups in cultivation were:

- Group control (CTRL): (peat 70% + pumice 20%), irrigated with water and previously fertilised substrate;
- Group with Aktigen (AT): (peat 70% + pumice 20%), irrigated with water and previously fertilised substrate, (3 ml per plant once a week); Aktigen is a formulation based on boron (2%) ethanolamine + plant

extracts. It prevents boron deficiency; facilitates the transport of sugars across membranes; stimulates the growth of apical meristems; stimulates pollen tube elongation; regulates cell multiplication; promotes fructification and increased resistance to physiopathologies;

- Group with Lifegen (LI): (peat 70% + pumice 20%), irrigated with water and previously fertilised substrate, (3 ml per plant once a week); Lifegen is a fertiliser based on zinc (2%) + plant extracts; promotes chlorophyll formation and stabilises ribosomes; improves cell relaxation; increases fruit production and colouration; prevents fruit drop;
- Group with QI-gen (QI): (peat 70% + pumice 20%), irrigated with water and previously fertilised substrate, (3 ml per plant once a week); Qi-gen is a fertiliser based on iron (EDTA) (2%) + plant extracts. It reactivates root growth; promotes root uptake; stimulates the plant to thicken root cortical tissue.
- Group with *Ecklonia maxima* (EK): (peat 70% + pumice 20%), irrigated with water and previously fertilised substrate, (3 ml per plant once a week).

The plants were watered once a day and cultivated for 5 months. The plants were drip-irrigated. Irrigation was activated by a timer whose schedule was adjusted weekly according to weather conditions and leaching fraction. On 5 May 2024, plant height, number of leaves, primary root length (mm), biomass of the aerial and root system, and number of dead plants (*Botrytis* and powdery mildew) were recorded.

2.1. Statistics

The experiment was carried out in a randomized complete block design. Collected data were analysed 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 test ($P = 0.05$). Statistics and graphics were supported by the programs Costat (version 6.451) and Excel (Office 2010).

3. Results and Discussion

The experiment showed that the use of innovative fertilisers enriched with plant extracts can indeed significantly improve the vegetative and root growth of *Valeriana officinalis* L. and *Raphanus sativus* (**Table 1** and **Table 2**). All treatments showed a significant improvement over the untreated control and the commercial *Ecklonia maxima* treatment for the agronomic parameters analysed, but the Qi-gen treatment was significantly the best for increasing vegetative and root biomass (**Figure 4** and **Figure 5**).

Improvements were also found in plant height, leaf number and root length. The trial also revealed the significant effect on *Botrytis* control of the product Aktigen and on powdery mildew of the product Lifegen, in fact they reduced the mortality of *Valeriana officinalis* and *Raphanus sativus* seedlings (Figures 2, Figures 3 and Figures 6).

A plant-derived biostimulant improves plant growth, quality, photosynthesis, tolerance to both biotic and abiotic stresses, as well as efficiency in using resources (nutrients, fertilizers, and water) by modulating plant biochemical, molecular, and physiological processes [18,26] Understanding the mechanism of action of biostimulants is crucial to improving their effectiveness and optimizing industrial processes. In addition to being rich in bioactive compounds, these bio-products are easily absorbed by plants at low dosages [22,24,27]. It is important to note that the effects of PDBs depend on the crop species, cultivar, development stage, environmental conditions, as well as the dose, time, and application method [22,24]. In response to consumer expectations for healthy food, European agricultural and food safety policies encourage more environmentally friendly and safe agricultural practices [18,22]. In order to produce potential biostimulants, moringa (*Moringa oleifera*) is one of the most commonly used higher plants. Many crops have been tested for its impact, including cherry tomatoes [33], coriander [34], plum trees [35], wheat [36], pea plants [37], and rocket [38]. Research confirmed the positive effects of their use, observing an increase in yields, the content of photosynthetic pigments, oils, elements, proteins, total sugars, phenols, ascorbic acid, anthocyanins, growth-promoting hormones, and antioxidant activity. For the production of biostimulants of plant growth, vegetables are often used as raw materials. In Pretorius (2007) [39], seeds of *Lupinus albus* were studied and found to be biostimulatory for coleoptile and root growth, both in the field and in the glasshouse. Furthermore, the author studied the effects of combing extracts from *Lupinus albus* seeds with extracts of seeds or plant parts from the Pink family and Alfalfa species. This suggests that synergism is involved in the biological processes involved, as the extracts or preparations of the single species have a higher biostimulatory efficacy. Licorice (*Glycyrrhiza glabra*) is the second most commonly used raw material. As a result of its application (improved growth, development, and chemical composition), common bean [40], onion [41], almond [42], and fennel [43] were found to benefit. Additionally, foliar spraying with garlic extracts (*Allium sativum*) was shown to increase yields and quality in the cultivation of faba beans [44], eggplant (improved growth and development, antioxidant enzymes, photosynthesis) [45], and snap beans (enhanced growth, leaf and pod chemical compositions) [46]. The biological properties of aromatic plants and medicinal plants rich in essential oils include biostimulant properties [47]. In particular, rosemary [47,48], eucalyptus [48], thyme [49,50] and tansy [50] are the most popular herbs. Among the essential oils extracted from rosemary and eucalyptus are 1,8-cineole, which has antibacterial, antifungal, herbicidal, and insecticidal properties [48]. Plant organs, genetics, growth conditions, soil composition, harvest stage, and microorganism colonization of roots may affect oil composition [51,52,53,54]. Abiotic stress tolerance is essential for both crop productivity and environmental sustainability (less water and fertilizer usage) [55]. Even though significant progress has been made in genetic transformation over the last few years, abiotic stress tolerance remains one of the most difficult problems to solve [56]. Plants performing better under terminal heat and drought stress include accumulating compatible solutes, reducing stomatal conductance, and activating antioxidant systems [57]. In order to combat the adverse impact of abiotic stress, a variety of strategies are used, including choosing the right cultivar, growing period, sowing density, water, and fertilizer, as well as controlling temperature, radiation, and atmospheric conditions. Bulgari et al. [58] also recommend soilless cultivation, grafting, and genetic improvement. Furthermore, exogenous application of osmoprotectants, stress signaling molecules, and plant extracts can be considered as a means of improving the aforementioned mechanisms. The use of plant extracts appears, however, to be the most eco-friendly and cheapest option [57,59]. In this research paper, the application of innovative fertilisers with added plant extracts resulted in a significant improvement in plant growth and increased protection against pathogens such as botrytis and powdery mildew, confirming results obtained in other research by other authors.

Table 1 Evaluation of innovative fertilisers on agronomic characters on plants of *Valeriana officinalis* L.

***Valeriana officinalis* L.**	**PH (cm)**	**LN (n°)**	**VW (g)**	**RW (g)**	**RL (cm)**
CTRL	6.26 d	8.00 d	16.24 e	12.33 d	3.75 d
AT	8.25 b	11.80 b	18.36 c	14.42 b	5.33 b
LI	8.31 b	11.83 b	18.57 b	14.68 b	5.36 b
QI	10.27 a	14.60 a	20.36 a	15.62 a	6.54 a
EK	7.37 c	9.44 c	17.39 d	13.51 c	4.63 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).

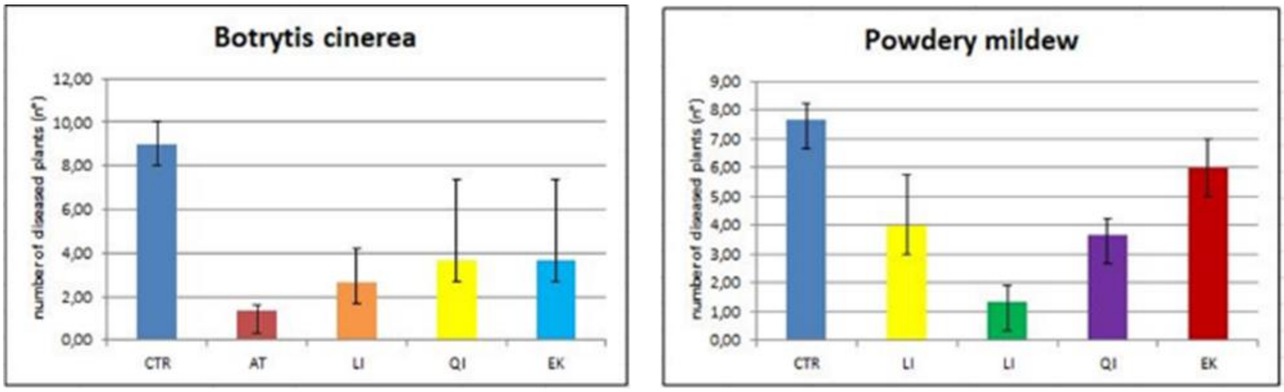
Parameters: PH = plant height (cm); LN = leaves number (cm); TLA = total leaves area (mm^2); VW = vegetative weight (g); RW = roots weight (g); RL = roots length (cm). Treatments: CTRL=control; AT= Aktigen; LI= Lifegen; QI= Qi-gen; EK= *Ecklonia maxima.*

Table 2 Evaluation of innovative fertilisers on agronomic characters on plants of *Raphanus sativus*

Raphanus sativus	**PH (cm)**	**LN (n°)**	**VW (g)**	**RW (g)**	**RL (cm)**
CTRL	8.38 e	7.23 d	17.39 d	12.26 d	3.27 d
AT	10.46 c	9.23 c	19.36 b	14.72 b	5.23 b
LI	10.77 b	11.64 b	19.34 b	14.84 b	5.22 b
QI	12.75 a	14.81 a	20.87 a	15.52 a	6.36 a
EK	9.37 d	7.84 d	18.35 c	13.59 c	4.38 c
ANOVA	***	***	***	***	***

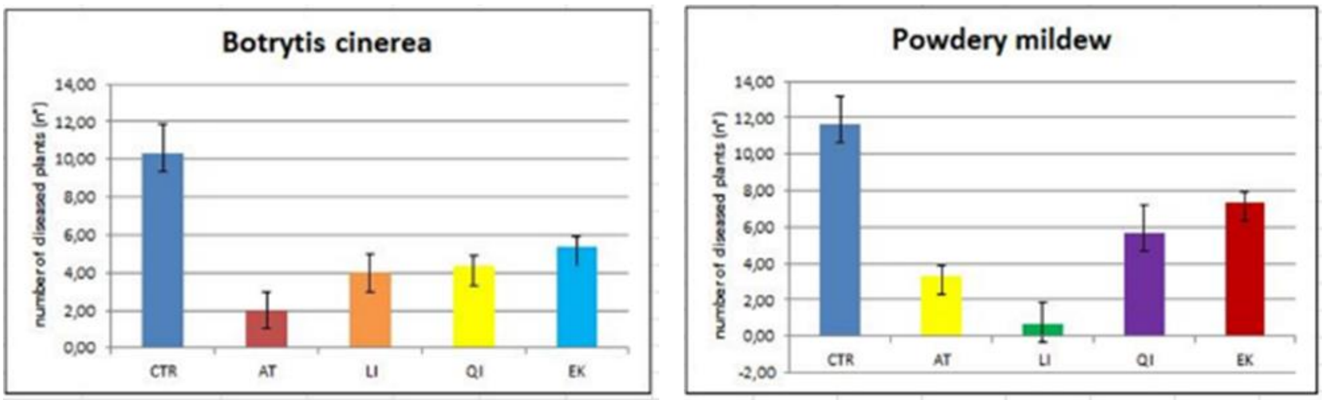
One-way ANOVA; n.s. – non significant; *,**,*** – significant at P ≤ 0.05, 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test (P = 0.05).

Parameters: PH = plant height (cm); LN = leaves number (cm); TLA = total leaves area (mm^2); VW = vegetative weight (g); RW = roots weight (g); RL = roots length (cm). Treatments: CTRL=control; AT= Aktigen; LI= Lifegen; QI= Qi-gen; EK= *Ecklonia maxima.*



Legend: QI: Qi-gen; LI: Lifegen; AT: Aktigen; EK: *Ecklonia maxima*; CT: control

Figure 2 Effect of innovative fertilisers with added plant extracts on the control of *Botrytis cinerea* and Powdery mildew in*Valeriana officinalis* L.



Legend: QI: Qi-gen; LI: Lifegen; AT: Aktigen; EK: *Ecklonia maxima*; CT: control

Figure 3 Effect of innovative fertilisers with added plant extracts on the control of *Botrytis cinerea* and Powdery mildew in *Raphanus sativus*

Figure 4 Effect of innovative fertilisers on vegetative biomass of *Valeriana officinalis* L. compared with fertilised control. Legend: QI: Qi-gen; LI: Lifegen; AT: Aktigen; EK: *Ecklonia maxima*; CT: control

Figure 5 Effect of Qi-gen (QI) on vegetative and radical biomass of *Valeriana officinalis* L. compared with fertilised control (CT)

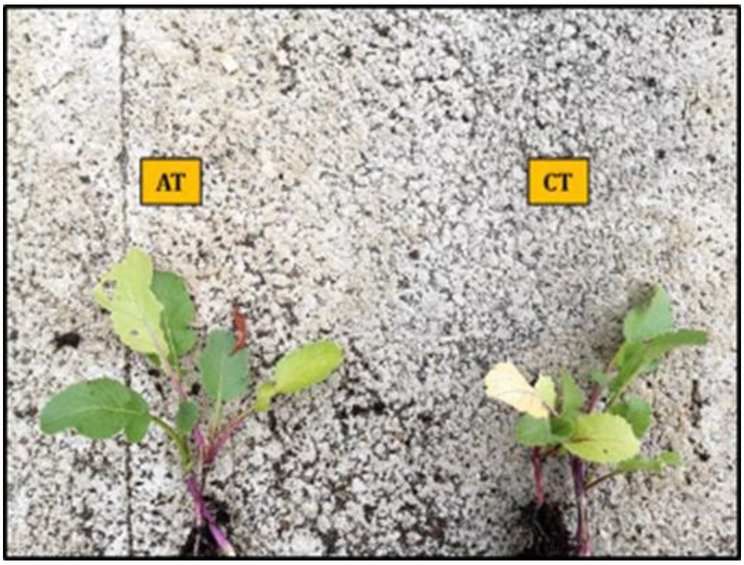


Figure 6 Effect of Aktigen (AT) on *Botrytis* control compared to untreated control (CT)

4. Conclusion

Increasing the production of high quality food for an ever-growing global population is one of the most important objectives of modern agriculture: reducing environmental impact and increasing food production. As part of this research, we examined whether fertilisers with plant extracts would be able to support both of these objectives. A number of scientific studies have shown that the application of these products can improve plant growth, productivity, quality, and tolerance to biotic and abiotic stresses. Because of their multiple properties, they have become increasingly important as advanced agricultural techniques in global agriculture. This type of product, which includes natural substances, will contribute significantly to ecologically and economically sustainable agricultural production systems in the coming years, as well as serving as the foundation for large-scale sustainable agriculture in the future.

Compliance with ethical standards

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Disclosure of conflict of interest

The author declares no conflict of interest.

References

[1] Clapp CE, Hayes MHB, Ciavatta C. Organic wastes in soils: Biogeochemical and environmental aspects. Soil Biol. Biochem. 2007, 39(6), 1239–1243.

[2] Shaviv A, Improvement of fertiliser efficiency-product processing, positioning and application methods. Proceedings of the International Fertiliser Society (UK). 2001, 469, 24.

[3] Ladd JN, Amato M, Jackson RB, Butler JHA. Utilisation by wheat crops of nitrogen from legume residues decomposing in the field. Soil Biology and Biochemistry. 1983, 15, 231–238.

[4] Nash D, Halliwell D, Hannah M. Phosphorus and selected metals mobilized from two commercial fertilizers into overland flow during border irrigation. Nutrient Cycling in Agroecosystems. 2003, 67, 255–264.

[5] Said-Pullicino D, Cucu MA, Sodano M, Birk JJ, Glaser B, Celi L. Nitrogen immobilization in paddy soils as affected by redox conditions and rice straw incorporation. Geoderma. 2014, 228-229, 44–53.

[6] Watt M, kirkegaard JA, Rebetzke GJ. A wheat genotype developed for rapid leaf growth copes well with the physical and biological constraints of unploughed soil. Functional Plant Biol. 2005, 32, 695–706.

[7] Sardare MMD, Admane MSV. A review on plant without soil-hydroponics. International Journal of Research in Engineering and Technology. 2013, 2, 299–303.

[8] Sengupta A, Banerjee H. Soil-less culture in modern agriculture. World Journal of Science Technology and Sustainable Development. 2012, 2(7), 103–108.

[9] Hunter Frame W, Alley MN, Whitehurst GB, Whitehurst BM, Campbell R. In vitro evaluation of coatings to control ammonia volatilization from surface applied urea. Agron. J. 2012, 104(5), 1201–1207.

[10] Sodhi GPS, Beri V, Benbi DK. Soil aggregation and distribution of carbon and nitrogen in different fractions under long-term application of compost in rice-wheat system. Soil Till. Res. 2009, 103(2), 412–418.

[11] Sullivan DM, Bary AI, Nartea TJ, Myrhe EA, Cogger CG, Fransen SC. Nitrogen availability seven years after a high-rate food waste compost application. Compost Sci. Util. 2003, 11, 265–275.

[12] Tejeda M, Gonzalez JL. Effects of application of a by-product of the two-step olive oil mill process on maize yield. Agronomy journal. 2004, 96, 692–699.

[13] Tejeda M, Hernandez MT, Garcia C. Soil restoration using composted plant residues: Effects on soil properties. Soil Till. Res. 2009, 102, 109–117.

[14] Habteselassie MY, Miller BE, Thacker SG, Stak JM, Norton JM. Soil nitrogen and nutrient dynamics asfter repeated application of treated dairy-waste. Soil Sci. Soc. Am. J. 2006, 70, 1328–1337.

[15] Prisa D. Possible use of Spirulina and Klamath algae as biostimulant in Portulaca grandiflora (Moss Rose). World Journal of Advanced Research and Reviews, 2019, 3(2), 1–6.

[16] Prisa D. Ascophyllum nodosum extract on growth plants in Rebutia heliosa and Sulcorebutia canigueralli. GSC Biological and Pharmaceutical Sciences, 2020, 10(01), 039–045

[17] Prisa D. Improving Quality of Crocus Sativus Through the Use of Bacillus Subtilis," International Journal of Scientific Research in Multidisciplinary Studies. 2020,6(2), 9–15.

[18] Bulgari R, Cocetta G, Trivellini A, Vernieri P, Ferrante A. Biostimulants and crop responses: A review. Biol. Agric. Hortic. 2015, 31, 1–17.

[19] Colla G, Hoagland L, Ruzzi M, Cardarelli M, Bonini P, Canaguier R, Rouphael Y. Biostimulant action of protein hydrolysates: Unraveling their effects on plant physiology and microbiome. Front. Plant Sci. 2017, 8, 1–14.

[20] Parađiković N, Teklić T, Zeljković S, Lisjak M, Špoljarević M. Biostimulants research in some horticultural plant species - A review. Food Energy Secur. 2018, 8,1–17.

[21] Rouphael Y, Colla G. Synergistic biostimulatory action: Designing the next generation of plant biostimulants for sustainable agriculture. Front. Plant Sci. 2018, 871, 1–7.

[22] Di Mola I, Ottaiano L, Cozzolino E, Senatore M, Giordano M, Elnakhel C, Sacco A, Rouphael Y, Colla G. Plant-Based biostimulants influence the agronomical, physiological, and qualitative responses of baby rocket leaves under diverse nitrogen conditions. Plants 2019, 8, 1–15.

[23] Zulfiqar F, Casadesús A, Brockman H, Munné-Bosch S. An overview of plant-based natural biostimulants for sustainable horticulture with a particular focus on moringa leaf extracts. Plant Sci. 2019, 295, 1–48.

[24] Dipak Kumar H, Aloke P. Role of biostimulant formulations in crop production: An overview. Int. J. Agric. Sci. Vet. Med. 2020, 8, 38–46.

[25] Rouphael Y, Colla G. Toward a sustainable agriculture through plant biostimulants: From experimental data to practical applications. Agronomy 2020, 10, 1–10.

[26] Ertani A, Sambo P, Nicoletto C, Santagata S, Schiavon M, Nardi S. The use of organic biostimulants in hot pepper plants to help low input sustainable agriculture. Chem. Biol. Technol. Agric. 2015, 2, 1–10.

[27] Ertani A, Pizzeghello D, Francioso O, Tinti A, Nardi S. Biological activity of vegetal extracts containing phenols on plant metabolism. Molecules 2016, 21, 1–14.

[28] De Pascale S, Rouphael Y, Colla G. Plant biostimulants: Innovative tool for enhancing plant nutrition in organic farming. Eur. J. Hortic. Sci. 2017, 82, 277–285.

[29] Barrajón-Catalán E, Herranz-López M, Joven J, Segura-Carretero A, Alonso-Villaverde C, Menéndez JA, Micol V. Molecular promiscuity of plant polyphenols in the management of age-related diseases: far beyond their antioxidant properties. Adv. Exp. Med. Biol. 2014, 824, 141–159.

[30] Lucini L, Rouphael Y, Cardarelli M, Bonini P, Baffi C, Colla G. A vegetal biopolymer-based biostimulant promoted root growth in melon while triggering brassinosteroids and stressrelated compounds. Front. Plant Sci. 2018, 9, 472.

[31] Abou Chehade L, Al Chami Z, De Pascali SA, Cavoski I, Fanizzi FP. Biostimulants from food processing by products: agronomic, quality and metabolic impacts on organic tomato (Solanum lycopersicum L.). J. Sci. Food Agric. 2018, 98, 1426–1436.

[32] Di Vittori L, Mazzoni L, Battino, M, Mezzetti B. Pre-harvest factors influencing the quality of berries. Sci. Hortic. 2018, 233, 310–322.

[33] Basra SMA, Lovatt C. Exogenous applications of Moringa oleifera leaf extract and cytokinins improve plant growth, yield and fruit quality of cherry tomato (Solanum lycopersicum). HortTechnol. 2016, 26, 327–337.

[34] Mazrou RM. Moringa leaf extract application as a natural biostimulant improves the volatile oil content, radical scavenging activity and total phenolics of coriander. J. Med. Plants Stud. 2019, 7, 45–51.

[35] Thanaa S, Kassim N, AbouRayya M, Abdalla A. Influence of foliar application with moringa (Moringa oleifera L.) leaf extract on yield and fruit quality of Hollywood plum cultivar. J. Hortic. 2017, 4, 1–7.

[36] Khan S, Basra SMA, Afzal I, Wahid A. Screening of moringa landraces for leaf extract as biostimulant in wheat. Int. J. Agric. Biol. 2017, 19, 999–1006.

[37] Merwad ARMA. Using Moringa oleifera extract as biostimulant enhancing the growth, yield and nutrients accumulation of pea plants. J. Plant Nutr. 2018, 41, 425–431.

[38] Mona MA. The potential of Moringa oleifera extract as a biostimulant in enhancing the growth, biochemical and hormonal contents in rocket (Eruca vesicaria subsp. sativa) plants. Int. J. Plant Physiol. Biochem. 2013, 5, 42–49.

[39] Pretorius JC. Seed suspensions from 'Lupinus albus', isolated compounds thereof and use as biological plant strengthening agent. Patent No. WO2007090438 A1, 2007, 59.

[40] Rady MM, Desoky ES, Elrys AS, Boghdady MS. Can licorice root extract be used as an effective natural biostimulant for salt-stressed common bean plants?. S. Afr. J. Bot. 2019, 121, 294–305.

[41] Babilie R, Jbour M, Trabi BA. Effect of foliar spraying with licorice root and seaweed extractson growth and seed production of onion (Allium cepa L.). Int. J. ChemTech Res. 2015, 8, 557–563.

[42] Thanaa SM, Nabila EK, Abou Rayya MS, Eisa RA. Response of nonpareil seedlings almond to foliar application of licorice root extract and bread yeast suspend under South Sinai conditions. J. Innov. Pharm. Biol. Sci. 2016, 3, 123–132.

[43] El-Azim A, Khater WM, And Badawy RMR. Effect of biofertilization and different licorice extracts on growth and productivity of Foeniculum vulgare, Mill. Plant. Middle East J. Agric. Res. 2017, 6, 1–12.

[44] Mohamed MH, Badr EA, Sadak MSh, Khedr HH. Effect of garlic extract, ascorbic acid and nicotinamide on growth, some biochemical aspects, yield and its components of three faba bean (Vicia faba L.) cultivars under sandy soil conditions. Bull. Nat. Res. Cent. 2020, 44,100.

[45] Ali M, Cheng ZH, Hayat S, Ahmad H, Ghani MI, Liu T. Foliar spraying of aqueous garlic bulb extract stimulates growth and antioxidant enzyme activity in eggplant (Solanum melongena L.). J. Integr. Agr. 2019, 18, 1001–1013.

[46] Elzaawely AA, Ahmed ME, Maswada HF, Al-Araby AA, Xuan TD. Growth traits, physiological parameters and hormonal status of snap bean (Phaseolus vulgaris L.) sprayed with garlic cloves extract. Arch. Agron. Soil Sci. 2018, 64, 1068–1082.

[47] Souri MK, Bakhtiarizade M. Biostimulation effects of rosemary essential oil on growth and nutrient uptake of tomato seedlings. Sci. Hort. 2019, 243, 472–476.

[48] Chrysargyris A, Charalambous S, Xylia P, Litskas V, Stavrinides M, Tzortzakis N. Assessing the biostimulant effects of a novel plant-based formulation on tomato crop. Sustainability. 2020, 12, 8432.

[49] Ben-Jabeur M, Vicente R, Lopez-Cristoffanini C, Alesami N, Djebali N, Gracia-Romero A, Serret MD, Lopez-Carbonell M, Araus JL, Hamada, W. A novel aspect of essential oils: coating seeds with thyme essential oil induces drought resistance in wheat. Plants-Basel. 2019, 8, 371.

[50] Beni C, Casorri L, Masciarelli E, Ficociello B, Masetti O, Neri U, Aromolo R, Rinaldi S, Papetti P, Cichelli A. Characterization of thyme and tansy extracts used as basic substances in zucchini crop protection. J. Agricult. Stud. 2020, 8, 95–110.

[51] Bajpai VK, Kang S, Xu H, Lee SG, Baek KH, Kang SC. Potential roles of essential oils on controlling plant pathogenic bacteria Xanthomonas species: a review. Plant Pathol. J. 2011, 27, 207–224.

[52] Nikolova M, Berkov S. Use of essential oils as natural herbicides. Ecol. Balk.2018, 10, 259–265.

[53] Karalija E, Dahija S, Parić A, Ćavar Zeljković S. Phytotoxic potential of selected essential oils against Ailanthus altissima (Mill.) Swingle, an invasive tree. Sustain. Chem. Pharm. 2020, 15, 1–8.

[54] Raveau R, Fontaine J, Lounès-Hadj Sahraoui A. Essential oils as potential alternative biocontrol products against plant pathogens and weeds: a review. Foods. 2020, 9, 1–31.

[55] Zhu JK. Abiotic stress signaling and responses in plants. Cell. 2016, 167, 313–324.

[56] Vinocur B, Altman A. Recent advances in engineering plant tolerance to abiotic stress: Achievements and limitations. Curr. Opin. Biotechnol. 2005,16, 123–132.

[57] Farooq M, Rizwan M, Nawaz A, Rehman A, Ahmad R. Application of natural plant extracts improves the tolerance against combined terminal heat and drought stresses in bread wheat. J. Agro. Crop Sci. 2017, 203, 528–538.

[58] Bulgari R, Franzoni G, Ferrante A. Biostimulants application in horticultural crops under abiotic stress conditions. Agronomy. 2019, 9,1–30.

[59] Desoky ESM, EL-Maghraby LMM, Awad AE, Abdo AI, Rady MM, Semida WM. Fennel and ammi seed extracts modulate antioxidant defence system and alleviate salinity stress in cowpea (Vigna unguiculata). Sci. Hortic. 2020, 272, 1–11.