Influence of CMS as a biostimulant on cabbage production *(Brassica oleracea var .capitata)* under surface irrigation system

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Abstract. At a private farm, Sayed Ramadan in Ayat, Giza governorate, Egypt, two field experiments were conducted in the winter of 2021-2022 and 2022–2023 to investigate the influence of CMS compound on the growth and yield characteristics of cabbage. The nutritional balance attained by spraying CMS compound often resulted in a physiological improvement in the cabbage crop *(Brassica oleracea var .capitata).,* as evidenced by the crop's features when compared to the control on clay soil. The application of CMS, as a yeast by product, at a rate of 15 ml/l produced the greatest, head circumference (26.61%) and (22.88%), head weight (119.23%) and (126.45%), SPAD (45.72%) and (12.80%), yield ton/ feddan (39.36%) and (43.10%), N (99.87%) and (21.52%), P (43.33%) and (74.79%), K (81.14%) and (14.55%), Fe (7.19%) and (4.72%), Mn (14.81%) and (32.88%), Zn (25.93%) and (23.93%), in cabbage compared with control in both seasons, respectively. Economically, CMS compound at rate gave the net returns (45439 L.E. /fed) and (56864 L.E. /fed) in the both season respectively compared with control and other treatments.

1 Introduction

The health benefits of cabbage (Brassica oleracea var. capitata) are attributed to its high content of polyphenols, flavonoids, and glucosinolates [33]. In order to prevent and repair damage caused by free radicals, a balanced diet should include antioxidant phytochemicals such as flavonoids and polyphenols [34].
In the human body, glucosesinolates and their brokendown forms have physiological effects [35].

Myrosinase breaks down one of the glucosinolates, glucoraphanin, when digesting cabbage. The pharmaceutical compound sulforaphane, which has anti-inflammatory, antioxidant, and anticancer effects, can be obtained by degrading produced glucosinolates [36].

An important microbe, yeast is mostly employed in industrial food fermentation [37].

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The immune-modulatory substances beta glucan and mannan oligosaccharides are found in yeast cell walls [38].

Yeast beta-glucans stimulate the synthesis of cytokines [38], while mannan oligosaccharides modify the immune system [39].

Yeast is therefore interesting as a possible immunological modulator. In this investigation, we investigated the physicochemical characteristics of fermented cabbage, discovered yeast that works well for fermenting cabbage, and verified that fermentation causes an increase in sulforaphane in addition to antioxidant and anti-inflammatory benefits.

It was found that the crop growth rate, leaf area, and NRA were all enhanced by the treatment through the leaves [29]. Studies have demonstrated that the use of amino acid biostimulant through leaves is a useful tool for plant growth, allowing inorganic fertilizer to be reduced without compromising crop yields. In addition to regulating the resistance of plants to stress conditions from both biotic and abiotic sources, boosting soil enzymes and microbiology root zone activity, and enhancing the mechanism of photosynthesis to improve crop production using small application doses, biostimulants are substances that contain one or more compounds or organisms designed to stimulate plant growth, according to [30]. According to reports [31, 32], the application of biostimulants can boost the activity of essential enzymes involved in the metabolism of carbon and nitrogen, hormone activity, as well as biochemical and physiological modifications throughout plant tissues. Due to a shortage of water and the farmed soil's deterioration, small holding areas present significant obstacles to global farming. The highest yield per unit area ought to be attained in Egypt [2, 3]. The population of Egypt has grown quickly to over 109 million, which has led to a loss of water resources, a buildup of toxic substances in the soil, a reduction in the amount of land available for food crop cultivation, and a decline in the fertility and quality of the soil [24]. In order to attain the highest yield that would provide financial gains, it was vital to consider utilizing a few strategies to enhance the intercropping system's advantages and boost its effectiveness [18]. It is possible to interplant short-season crops like lettuce with cabbage, a very mid-season crop that requires a lot of mineral fertilizer, particularly nitrogen, and grows slowly during the early growth stage [23]. As a result, yield and quality will not change. A common leaf vegetable in the Asteraceae family is lettuce, or Lactuca sativa L. Furthermore, lettuce's requirements for water and minerals do not clash with those of cabbage, the principal crop, because it is a short-season crop. Green vegetables are quickly produced and have a low rate of return on investment, which is why Egyptian farmers historically preferred them. Using intercropping systems in conjunction with a biofertilizer technique could be a successful soil conservation strategy to improve sustainable agriculture. It is also a good replacement for mineral nutrients, which accumulate in plants and soil and cause adverse effects on the environment, population, and global warming danger. In the search for more sustainable and ecologically friendly strategies to boost crop output, microalgae and mycorrhiza are gaining popularity as crop production resources due to their potential for biostimulation. Cabbage requires surface-available nutrients and water for its shallow root systems. Consequently, mycorrhiza application improves soil's chemical and physical properties while reducing the buildup of nutrients in leaves [10]. Arbuscular mycorrhizal fungus (AMF) hyphae are essential for promoting soil aggregates and plant growth, according to [26, 27]. The soil's total dissolved solids (TDS) and pH are regulated by AMF because it boosts the biological activities of the soil, including the dehydrogenase, phosphatase, and nitrogen activities, as well as the availability of nitrogen, phosphorus, and potassium [6, 9, 10]. In general, research has suggested that mycorrhiza might be exploited to release compounds that promote growth, solubilize insoluble phosphates, enhance the quality of the crop, and improve the physicochemical properties of the soil. Biofertilizers are therefore inexpensive, safe for the environment, and improve soil fertility and features since they supply antioxidants, enzymes, and the essential macronutrient elements for plant growth and yield production [22]. Integrating biofertilization with intercropping may improve plant yield and soil fertility [13, 15, 20]. Intercropping strategies for cabbage were shown in the past to maximize soil nutrient uptake and yield, depending on the combination of treatments utilized [15]. The majority of growth parameters, including plant height, shoot weight, root weight, root length, and yield, are improved by monoculture cabbage cultivation [15]. Cabbage (Brassica oleracea var. capitata L.) is one of the most important and popular cruciferous vegetables throughout the winter months in temperate countries. A member of the Brassicaceae family, cabbage is cultivated for its medium-sized levels of calcium, niacin, vitamin C, minerals, and fiber in its leaves. Phytochemicals found in cruciferous vegetables, such as cabbage, have been shown to be important food sources. From a total planted area of about 38,892 faddan, 485,739 tons of cabbage were produced in Egypt in 2017 at an average yield of 12,489 tons per fad [5]. Biostimulants include microorganisms, natural sources, and nonorganic compounds [40]. In addition to enhancing soil fertility and structure, biofertilizers protect plants from pathogens and release plant growth regulators that advance plant development, increase yield, and enhance quality. Furthermore, biofertilizers are less expensive and better for the environment than synthetic fertilizer inputs [21, 25]. The current study aims to evaluate cabbage crops and employ CMS, a foliar spray of biostimulants, to boost the production of cabbage plants.

2 Material and Methods

Analysis of soil Calculating Some Physical and Chemical Parameters the features of the soil utilized in the experiment at Sayed Ramadan Farm in Ayat City, Giza Governorate, Egypt, are described by [8] Table (1).

Table 1. Some Physical and Chemical properties of soil samples.

Seasons	Particle size distribution (%)			Texture class	pH (1: 2.5)	EC (dS m-1)	CaCO3 (%)
	Sand	Silt	Clay				
2022/2023	28.9	25.13	43.71	Clay	8.4	1.8	4.28
	Macronutrient contents (mg/100g soil)						
	N	P			K		
2022/2023	27.6	13.7			11.2		

2.1 Experimental Work

On September 5, 2022–2023, cabbage seedlings were planted in clay soil using the agricultural management techniques necessary to produce cabbage seedlings. In addition to the control, two levels of concentration were applied topically: 5–10 and 15 ml/l CMS. Every treatment was set up in a randomized block design with three duplicates. The Ministry of Agriculture's recommendations for all necessary agricultural management were followed in order to promote growth and productivity. Cabbage Production Following a period of 130 days following transplantation, cabbage plants were harvested, and yield metrics, including head circumference (cm), head weight (g), stem diameter (cm), root weight (g), SPAD, and yield ton/feddan, were measured in accordance with AOAC (1980) procedures [1]. The macronutrients (N, P, and K) and nutritional status of cabbage were assessed in accordance with [11]. Fe, Mn, Zn and Cu was determined using Atomic Absorption Apparatus [11]. Statistical Analysis (SAS 1996) computer program's approach was followed for statistical analysis of all the data, and the LSD method was used to compare the means. After 45 and 60 days following planting, there are three levels of foliar CMS compound (condensed molasses soluble), which is a byproduct of yeast production produced by Angle Yeast Egypt Company at a rate of 5.0, 10.0, and 15.0 ml/L at two equal doses.

2.2 Plant constituents and cultivation methodologies

On the same side of the ridge as the cabbage plants, seedlings for the cabbage crop were planted in a row with a 20-cm plant spacing and 40 cm between plants. Every plot had five ridges that were each five meters long and six meters wide, and each plot had an area of fifteen square meters. Three treatments—5.0, 10, and 15 ml/l for cabbage—were employed, along with a control. All treatments were agriculturally feasible and followed the Egyptian Agricultural Ministry's standards.

2.3 Economic analysis

Net returns: The cost of cultivation for each feddan was subtracted from the gross income for each feddan to arrive at the net returns per feddan.

$$\text{Benefit cost ratio} = \frac{\text{Gross return (L.E fed-1)}}{\text{Total cost of cultivation (L.E fed - 1)}}$$

3 Result and discussion

The effect of CMS compound on maximizing the yield and quality of the cabbage crop planted at the Farm of Sayed Ramadan, Ayat Region, Giza, Egypt, was investigated through field trials carried out over the winter seasons of 2022–2023.

3.1 Effect of CMS rates on root weight (g), root length (cm) and stem diameter (cm)

Table (2) illustrates the implications of applying different rates of CMS through foliar application on the crop's root weight (g), root length (cm), and stem diameter (cm) in both seasons with regard to the influence of CMS compound on the cabbage crop's root weight (g), root length (cm), and stem diameter (cm).Foliar CMS administration at a rate of 15.0 ml/L was found to increase root weight (g), root length (cm), and stem diameter (cm) relative to the control for cabbage in both seasons by about 74.39%(59.54%; 16.13% (25.40%; and 118.52% (16.67%), respectively. Since some physical characteristics, such as head weight, head length, and head diameter, showsuperiority in monoculture, the results presented above are consistent with those obtained by the intercropped production approach, which has a significant impact on both crops [16]. The data that was gathered showed that while the intercropped cropping method affected several physical properties, it had no negative effects on growth or yield qualities [17, 18]. Although the quality of crops, soil, and water is improved by cover crop systems, special tactics are needed to increase yields in terms of both quality and quantity. One of the cropping system's amplifiers is biofertilization, which improves development and productivity. The outcomes demonstrate the advantages of biofertilization in conjunction with intercropping lettuce and cabbage [16, 26-29].

Table 2. Effect of CMS on root weight (g), root length (cm) and Stem diameter (cm) of cabbage crop in two seasons

Treatments	Root Weight(g)	Root Length (cm)	Stem Diameter(cm)
First season			
Control	75.5	20.7	9.0
CMS 5.0 ml /L	108.3	21.3	9.7
CMS 10.0 ml /L	109.7	21.0	15.3
CMS 15.0 ml /L	131.7	24.0	19.7
mean	106.3	21.8	13.4
LSD 0.05	17.333	4.279	3.646
Second season			
Control	87.3	21.0	10.0
CMS 5.0 ml /L	120.0	23.0	12.0
CMS 10.0 ml /L	126.3	23.0	16.7
CMS 15.0 ml /L	139.3	26.3	21.7
mean	118.3	23.3	15.1
LSD 0.05	10.483	2.549	2.606
CMS: Condeused Molassed Solution.			

3.2 Effect of CMS rates on head circumference (cm) and head weight (g)

In addition, cabbage plants treated with CMS foliar spraying showed a substantial increase in head circumference (cm) and head weight (g) when compared to control plants. When compared to the control of the tested varieties of cabbage, the maximum improvement in head circumference (cm) and head weight (g) was achieved by using CMS at a rate of 15.0 ml/L. This resulted in a significant increase in head circumference (cm) and head weight (g) of 26.61, 22.88%, and 119.23, 126.45%, respectively. These results are consistent with those where AMF is utilized as part of fertilization treatments that raise soil fertility, adjust soil pH and TDS, and sequester soil microbial and mineral levels because it helps to boost the quantity and quality of cabbage [7].

Table 3. Effect of CMS on Head circumference (cm) and Head Weight (g) of cabbage crop in two seasons.

Treatments	Head circumference (cm)	Head Weight (g)
First season		
Control	41.3	910.0
CMS 5.0 ml /L	41.7	966.7
CMS 10.0 ml /L	43.3	1336.7
CMS 15.0 ml /L	52.3	1995.0
mean	44.7	1302.1
LSD 0.05	5.752	279.05
Second season		
Control	39.3	934.0
CMS 5.0 ml /L	41.3	960.0
CMS 10.0 ml /L	42.0	1320.3
CMS 15.0 ml /L	48.3	2115.0
mean	42.8	1332.3
LSD 0.05	3.522	118.73
CMS: Condeused Molassed Solution.		

3.3 Effect of CMS rates on SPAD read and yield ton/feddan

When CMS compound was applied foliarly to the cabbage crop, the highest values of the SPAD read and yield ton/feddan were noted; the lowest values were noted when no foliar fertilizer was used as a control. According to data, the application of CMS compound at a rate of 15.0 ml/L resulted in the biggest increases in SPAD read and yield ton/feddan in cabbage in both seasons, at approximately 45.72, 12.80%, and 39.36, 43.10%, respectively, as compared to the control.

Table 4. Effect of CMS on SPAD read and yield ton/feddan of cabbage crop in two seasons

Treatments	SPAD	yield ton/feddan
First season		
Control	54.9	13.6
CMS 5.0 ml /L	58.6	15.0
CMS 10.0 ml /L	63.5	16.7
CMS 15.0 ml /L	80.0	19.0
mean	64.3	16.1
LSD 0.05	27.32	0.8225
Second season		
Control	54.2	13.8
CMS 5.0 ml /L	56.5	15.8
CMS 10.0 ml /L	60.4	17.3
CMS 15.0 ml /L	61.1	19.7
mean	58.0	16.6
LSD 0.05	4.8227	1.0269
CMS: Condeused Molassed Solution.		

3.4 Macronutrient contents

In this regard, Table (5) shows the influence of various CMS foliar treatment rates on the percentages of N, P, and K in the cabbage crop throughout the 2022–2023 growing season. In comparison to the control for the cabbage crop in both seasons, it was found that foliar CMS application at a rate of 15.0 ml/L raised the N%, P%, and k% by approximately 99.87, 21.52%; 43.33, 74.79%; and 81.14, 14.55%, respectively. These results are consistent with research by [4], who revealed that yeast extract includes vitamins and amino acids that boost metabolism and may even stimulate growth, both of which improve plant quality. Moreover, [4, 12] observed that applying yeast extract topically to flax enhanced the enzymes involved in the photosynthetic process, which improved the plant's absorption of iron, magnesium, and other elements crucial for the production of chlorophyll. The results appear to agree with the research results of [4]. Additionally, these results might be the result of spraying two different varieties growing in sandy soil that was deficient in all nutrients, particularly K. The CMS compound, which is rich in potassium, allowed for a quick correction of the deficiency, which was reflected in the two varieties. These absorption differences between the varieties occurred because of the variations in the varieties' responses. Furthermore, it was observed by [14] that treatments with yeast extract had a substantial impact on NPK in flax seeds. The maximum N%, P%, and K% were obtained in the two seasons, respectively, from the foliar application of yeast extract.

Table 5. Effect of CMS on N (%), P (%) and K (%) of cabbage crop in two seasons.

Treatments	N	P	K
First season			
Control	0.743	0.457	0.859
CMS 5.0 ml /L	0.947	0.589	0.888
CMS 10.0 ml /L	0.984	0.664	0.988
CMS 15.0 ml /L	1.485	0.655	1.556
mean	1.040	0.591	1.073
LSD 0.05	0.0542	0.0471	0.0412
Second season			
Control	0.381	0.234	0.488
CMS 5.0 ml /L	0.397	0.317	0.534
CMS 10.0 ml /L	0.457	0.39	0.55
CMS 15.0 ml /L	0.463	0.409	0.559
mean	0.425	0.338	0.533
LSD 0.05	0.0051	0.0739	0.0117
CMS: Condeused Molassed Solution.			

Data regarding the levels of Fe, Mn, and Zn in plant samples indicated that CMS was effective as a biofertilizer. Application of 15.0 ml/L of CMS compound increased the levels of Fe, Mn, and Zn in cabbage plants by approximately 7.19, 4.72%; 14.81, 32.88%; and 25.93, 23.93% in comparison to the control plants in both seasons. Ultimately, the data demonstrated that, in comparison to the control in both seasons, cabbage treated with CMS compound at a rate of 10.0 ml/L had the best values for Fe (ppm), Mn (ppm), and Zn (ppm). These findings are consistent with those of [4, 12, 19].

Table 6. Effect of CMS on Fe (ppm), Mn (ppm) and Zn (ppm) of cabbage crop in two seasons.

Treatments	**Fe**	**Mn**	**Zn**
First season			
Control	110.24	20.93	15.27
CMS 5.0 ml /L	134.3	26.3	18.7
CMS 10.0 ml /L	160	29.4	22.87
CMS 15.0 ml /L	118.17	24.03	19.23
mean	130.678	25.165	19.018
LSD 0.05	**3.753**	**1.088**	1.202
Second season			
Control	122.77	22.93	16.3
CMS 5.0 ml /L	131	26.13	19.5
CMS 10.0 ml /L	135.47	27.4	22.9
CMS 15.0 ml /L	128.57	30.47	20.2
mean	129.453	26.733	19.725
LSD 0.05	**2.517**	**0.793**	**0.739**
***CMS**: Condeused Molassed Solution.*			

3.5 Economic Analysis

Table (7) presents the statistics regarding the economics of the cabbage crop as improved by the CMS compound. When comparing CMS as foliar application at a rate of 15 ml/L to other treatments, the data regarding the economic analysis of cabbage showed that the first season's gross returns (L.E. 66500), net returns (L.E. 45439.0), and benefit-cost ratio (3.157) were higher than the second season's gross returns (L.E. 66502.0), net returns (L.E. 56864.0), and benefit-cost ratio (6.900).

Table 7. Effect of CMS on Fe (ppm), Mn (ppm) and Zn (ppm) of cabbage crop in two seasons

Treatments	Cabbage yield (kg/fed)	Total cost invested (L.E/fed)	Gross returns (L.E/fed)	Net returns (L.E/fed)	Benefit Cost ratio	TNI*
First season						
Control	13000.6	21025	45502	24477	2.164	0.000
CMS 5.0 ml /L	15000	21037	52500	31463	2.496	6986
CMS 10.0 ml /L	16000.7	21049	56002	34953	2.661	10476
CMS 15.0 ml /L	19000	21061	66500	45439	3.157	20962
Second season						
Control	13000.8	9620	45503	35883	4.730	0.000
CMS 5.0 ml /L	15000.8	9620.5	600032	42882	5.457	7000
CMS 10.0 ml /L	17000.3	9632	680012	49869	6.177	13986
CMS 15.0 ml /L	19000.7	9638	760028	56864	6.900	20982
CMS: Condeused Molassed Solution.						

4 Conclusion

Economically and under experimental conditions, it can be inferred that the CMS compound at a rate of 15.0 ml/l had the best effects. It was deemed to have the best growth characteristics, including root weight (g), root length (cm), stem diameter (cm), SPAD, and head circumference (cm), in cabbage compared with control in both seasons, respectively. Economically, CMS compound at rate gave the net returns (L.E./fed) compared with control and other treatments. & yield characteristics, including head weight (g), yield ton/feddan, and nutritional status such as macro and micronutrients of the cabbage plant.

References

1. A.O.A.C. Official Methods of Analysis of the Association of Official Agricultural Chemist 20th Ed. (Washington DC. USA, 1980)
2. M.A. Abdrabbo, F.A. Hashem, M.A. Abul-Soud, S.H. Abd-Elrahman, Int. J. Pl. Soil Sci., **8**, 1-13 (2015) https://doi.org/10.9734/IJPSS/2015/17590
3. A.A. Addo-Quaye, A.A. Darkwa, M.K. Ampiah, ARPN Journal of Agricultural and Biological Science, **6**, 34-42 (2011)
4. A.A. Ahmed, M.M.H. Abd El-Baky, M.F. Zaki and F.S.A. El-Aal, J. Appl. Sci. Res., **7**, 2479-2488 (2011)
5. Anonymous, *Central Administration for Economics and Statistics of Agriculture Ministry of Egypt*, 117 (2017)
6. V. Artursson, R.D. Finlay, J.K. Jansson, Environ Microbiol., **8(1),** 1-10 (2005) 10.1111/j.1462- 2920.2005.00942.x
7. S.F. Bender, C. Wagg, M.G.A. van der Heijden, Trends Ecol. Evol., **31**, 440–452 (2016) https://doi.org/10.1016/j.tree.2016.02.016

8. A.D. Blackmore, T.D. Davis Jolly and R.H. Walser, Soil Dureau.P A2.1, Dep., **10**, 522-530 (1972)
9. R.W. Brooker, A.E. Bennett, W. Cong, T.J. Daniell, T.S. George, P.D. Hallett, C. Hawes, P.M. Iannetta, H.G. Jones, A.J. Karley, L. Li, B.M. Mckenzie, R.J. Pakeman, E. Paterson, C. Schöb, J. Shen, G. Squire, C.A. Watson, C. Zhang, F. Zhang, J. Zhang, P.J. White, New Phytologist, **206**, 107–117 (2015) doi:10.1111/nph.13132 DOI: 10.1111/nph.13132.
10. P. Chiaiese, G. Corrado, G. Colla, M.C. Kyriacou, Y. Rouphael, Front. Plant Sci., **9**, 1782 (2018) https://doi.org/10.3389/fpls.2018.01782
11. A. Cottenie, M. Verloo, L. Kiekens, G. Velghe and R. Camerlynck, Chemical analysis of plant and soil. In: Laboratory of Analytical and Agro Chemistry State Univ (Ghent Press, Ghent, Belguim, 1982)
12. M.M. El-Hawary, K.I. Gad and A.O.A. Ismail, Biosci. Res., **16**, 1009-1027 (2019)
13. N.S. El-Mougy, M.M. Abdel-Kader, F. AbdelKareem, E.I. Embaby, R. El-Mohamady and H. Abd El-Khair, Res. J. Agric. and Biol. Sci., **7 (2),** 203–221 (2011)
14. Amina El-Shafey, I.M. Sallam and M.M. El-Hawary, Asian J. Plant Sci., **21 (4),** 582-596 (2022)
15. H. Gebru, Journal of Bi-ology, Agriculture and Healthcare, **5 (9),** 1-13 (2015)
16. S. Gianinazzi, A. Gollotte, M.N. Binet, D. van Tuinen, D. Redecker, D. Wipf, Mycorrhiza, **20**, 519–530 (2010) https://doi.org/10.1007/s00572-010-0333-3.
17. I. Guvenc, E. Yildirim, *Multiple cropping systems in vegetable production* (Turkey I. Organic Agriculture Symposium, 21-23 June, Izmir-Turkey, 1999) 288-296
18. I. Guvenc, E. Yildirim, Journal of Sustainable Agriculture, **28 (4),** 29-44 (2006) DOI: 10.1300/J064v28n04_04.
19. S.A.R. Hammad and A.M.A. Osama, Annal of Agricultural Science (2014) http://dx.doi.org/10.1016/j.aoas.2014.06.018.
20. H. Hauggaard-Nielsen, E.S. Jensen, Plant Soil, **274**, 237–250 (2005) doi:10.1007/1-4020- 4099-7_13
21. J.U. Itelima, W.J. Bang and I.A. Onyimba, J. Microbiol. Biotechnol. Rep., **2 (1),** 22-28 (2018)
22. A. Kusvuran, S. Kusvuran, Int. Lett. Nat. Sci. **76**, 147–157 (2019) https://doi.org/10.18052/www.scipress.com/I LNS.76.147
23. M. Nosek, E. Surowka, S. Cebula, A. Libik, S. Goraj, A.K.Z. Miszalski, Acta Physiologiae Plantarum, **33**, 2125–2134 (2011)
24. J. Pathak, Rajneesh, P.K. Maurya, S.P. Singh, D.P. Häder, R.P. Sinha, Front. Environ. Sci., **6**, 7–19 (2018) https://doi.org/10.3389/fenvs.2018.00007.
25. D. Ronga, E. Biazzi, K. Parati, D. Carminati, E. Carminati, A. Tava, Agronomy, **9**, 192 (2019) https://doi.org/10.3390/agronomy9040192.
26. K. Saharan, L. Schütz, A. Kahmen, A. Wiemken, T. Boller, N. Mathimaran, Front. Environ. Sci. **6**, 46, Agronomy **10**, 121 (2018) https://doi.org/10.3389/fenvs.2018.00046
27. K. Saharan, L. Schütz, A. Kahmen, A. Wiemken, T. Boller, N. Mathimaran, Front. Environ. Sci. **6**, 46, Agronomy **10**, 121 (2018) https://doi.org/10.3389/fenvs.2018.00046
28. E. Yildirim, I. Guvenc, European Journal of Agronomy, **22(1),** 11–18 (2005) 10.1016/j.eja.2003.11.003.

29. Sri Devi Octavia, Endang Sulistyaningsih, Valentina Dwi Suci Handayani and Rudi Hari Murti, J. Trop. Agri. Sci., **47 (1),** 103 - 121 (2024)
30. O. I. Yakhin, A. A. Lubyanov, I. A. Yakhin & P. H. Brown, Frontiers in Plant Science, 7, 2049 (2017) https://doi.org/10.3389/ fpls.2016.02049
31. M. Alfosea-Simón, E. A. Zavala-Gonzalez, J. M. CamaraZapata, J. J. Martínez-Nicolás, I. Simón, S. Simón-Grao & F. García-Sánchez, Scientia Horticulturae, **272**, 109509 (2020) https://doi. org/10.1016/j.scienta.2020.109509
32. Y. Sheng, H. Cheng, L. Wang, J. Shen, M. Tang, M. Liang, K. Zhang, H. Zhang, Q. Kong, M. Yu & Z. Song, BioMed Research International, **2020**, 2854795 (2020) https://doi. org/10.1155/2020/2854795
33. Y.Y. Xu, Y.D. Xiao, C. Lagnika, D.J. Li, C.Q. Liu, N. Jiang, Food Chem., **309**, 124935 (2020)
34. H. Nawaz, M.A. Shad, A Rauf. Food Chem, **242**, 182-187 (2018)
35. M.S. Jeong, S.J. Cho, Korean Soc. Food Sci. Nutr. **51**, 1166-1170 (2022)
36. X Men, X Han, SJ Lee, G Oh, KT Park, JK Han, Nutrients, **14**, 3814 (2022)
37. S.O. Seo, S.K. Park, S.C. Jung, C.M. Ryu, J.S. Kim, Microorganisms, **8**, 274 (2020)
38. G. Jensen, K. Patterson, I. Yoon, Comp. Immunol. Microbiol. Inf. Dis. **31**, 487-500 (2008)
39. A. Djeraba, P. Quéré, Int. J. Immunopharmacol., **22,** 365-372 (2000)
40. Y. Rouphael, G. Colla, Front. Plant Sci., **9**, 1–24 (2018)