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Optimization of the microorganism performance in compost tea to control African violet powdery mildew

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Abstract

The African violet (*Saintpaulia ionantha*) is one of the most important commercial plants with a unique variety in color and shape, which has made this potted plant popular. African violet powdery mildew (*Erysiphe cichoracearum*) is a common disease of this plant that covers the leaves like white felt. Despite the heavy use of chemical pesticides in commercial greenhouses, this disease still causes significant damage to this plant. Using a different kind of compost in integrated pest management is a suitable solution for obtaining high-quality products with minimal environmental impacts due to the high population of microorganisms. Using the Taguchi design experiments method, this research used compost tea and vermicompost tea to control African violet powdery mildew in a healthy ecosystem. To achieve this, the effect of compost types was studied at four levels, and the consumption dosage and application intervals at two levels on two varieties of African violets. The results demonstrated that compost tea had a significant impact on the control of powdery mildew in African violet. After analyzing the main effects of the variables, it was found that the application interval did not show a significant effect, but three other variables (compost tea type, host plant variety, and dosage) significantly impacted the control of this disease. The result showed that the optimal conditions to control powdery mildew on the miniature cultivar involved using a dose of 20 cc of aerated compost tea.

1. Introduction

Integrated crop management (ICM) involves employing all possible solutions to achieve high-quality agricultural products with minimal environmental impact. This approach includes the use of a variety of strategies and techniques, such as optimizing soil health, choosing appropriate crop varieties, implementing sustainable pest management practices, and utilizing efficient irrigation and fertilizer application methods (Repetto, et al., 1996).

Composting is a process by which microorganisms rapidly break down a substrate containing raw materials such as dry and wet organic materials and animal manure. Effective microorganisms in the composting process include three groups, bacteria, actinomycetes, and fungi, which can be classified into three types of microorganisms based on their temperature response: psychrophilic microorganisms (15-20°C), mesophilic microorganisms (20-40°C), and thermophilic microorganisms (45-55°C) (Zhou, et al., 2022).

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At the beginning activation stage of the aerated composting process, psychrophilic and mesophilic microorganisms, which have the highest population, become active and grow well.

With increasing temperature, these bacteria die off, and thermophilic bacteria, which can tolerate temperatures up to 48°C, become dominant and active inside the compost pile (Biyada, et al., 2021). If the temperature is not controlled and exceeds 60°C, the activity of thermophilic bacteria will stop. However, if the compost temperature does not rise sufficiently, psychrophilic and mesophilic microorganisms will remain active, resulting in the loss of a significant amount of organic matter (da Silva Vilela, et al., 2022).

The main activity of microorganisms in the composting process is the decomposition of dead organic matter into simpler organic materials and mineral components, commonly referred to as mineralization. In the mineralization process, the activity of thermophilic microorganisms eliminates insects, pathogens, and other competing microorganisms present in the compost pile. Typically, the most persistent microorganisms throughout the compost production process are those that are most resistant to temperature. Regardless, to obtain high-quality compost, the temperature of the substrate must be adjusted to maintain the optimal performance of effective microorganisms (Chang, et al., 2021). Additionally, the ratio of carbon to nitrogen in the substrate must be appropriate to provide the best conditions for microorganism activity. Moreover, since microorganism activity in the composting process generates heat, the substrate temperature should be monitored and maintained to ensure it does not exceed 60°C (Salangsang, et al., 2022). Therefore, at each stage of the composting process, it is very important to control the temperature of the compost to preserve the effective microorganisms.

One of the most valuable solutions in integrated crop management (ICM) is using compost, vermicompost, and their products. Vermicompost is an organic and very valuable biological fertilizer that is obtained as a result of the continuous and slow passage of decaying organic matter through the digestive system of earthworm species and the removal of these materials from the worm's body (Rehman, et al., 2023). Compost tea is a nutrient-rich liquid fertilizer made by immersing mature compost in water, which can then be applied directly to plant roots or sprayed onto leaves as a foliar spray (Eudoxie, et al., 2019). When we spray compost tea on the leaves, the leaf's surface is covered with several microorganisms, and their activity in a competitive environment with pathogenic agents makes the plant resistant to those pathogenic agents (Morales-Corts, et al., 2018). The components of compost tea include soluble nutrients such as humic substances, bacteria (such as Serratia, Pseudomonas, and Bacillus), fungi, yeasts, nematodes, protozoa, microbial metabolites, and chemical antagonisms (such as phenols and amino acids) (St. Martin, et al., 2014).

Microorganisms play a critical role in the production of compost tea. During this process, the bacteria in the compost become active and multiply rapidly in the water, resulting in a diverse and thriving population of microorganisms [Eudoxie, et al., 2019; Morales-Corts, et al., 2018; St. Martin, et al., 2014]. This includes both aerated and non-aerated bacterial species that work in synergy to break down the organic matter in the compost and release nutrients into the water. The microorganisms in compost tea also exhibit pathogen-suppressing properties that prevent plant diseases (St. Martin, et al., 2012; St. Shaban, et al., 2015). The beneficial microorganisms in compost tea can colonize the root zone of plants and effectively outcompete harmful microorganisms for resources, inhibiting their growth and proliferation.

Furthermore, the microorganisms in compost tea can enhance plant growth and improve soil fertility by fixing nitrogen and solubilizing nutrients. Compost tea also creates a film over the leaves, occupying sites that could be attacked by pathogens (Matsuda, et al., 2001). Compost tea spraying is complementary to other disease management methods, such as crop rotation, the use of resistant plants, proper aeration and ventilation, seed disinfection, and soil sunning (Koné, et al., 2010). Compost tea is used both to control disease in the aerial parts of the plant and to increase soil microflora (Leroux, 2007). Research has shown that compost tea is effective in controlling *Phytophthora* diseases of potatoes (Dong, et al., 2022) and tomatoes (Al-Dahmani, et al., 2003), gray rot of beans, tomatoes, and berries (Scheuerell, et al., 2006), fusarium rot (Segarra, et al., 2009), powdery and false powdery mildew of grapes (Litterick, et al., 2004), powdery mildew of roses (Seddigh, et al., 2018; Seddigh, et al., 2014) and potato scab disease (Axel, et al., 2012). Research has also demonstrated that *Phytophthora* was completely controlled in the cucumber seedling cultivation stage by using compost as a culture medium (Kamalpour, et al., 2008). Lewis et al. managed to control the Phytophthora in cotton fields. In that experiment, they believed that compost prevents the sprouting of the disease-causing fungus by releasing substances and stopping its progress (Lewis, et al., 1992). Noble and Coventry revealed that plant diseases, including *Phytophthora* and *Pythium ultimum*, as well as root rot caused by *Rhizoctonia* solani and *Verticillium dahliae*, can be effectively managed through the application of compost tea (Noble, et al., 2005).

African violet powdery mildew (*Erysiphe cichoracearum*) is one of the most prevalent diseases of this plant that covers the leaves like white felt. It is necessary to use frequent chemical spraying to control this pest in the greenhouse (Van Raaij, et al., 1994). Therefore, with the aim of integrated management of this disease in a healthy ecosystem, the effect of compost tea and vermicompost tea on African violet powdery mildew was investigated.

2- Materials and methods

2-1- Compost production

The pile method (Kamalpour, et al., 2007) used to produce compost tea in this research is the most common method of producing compost. First, an area with dimensions of at least 1.5×1.5 meters was selected on the ground. Then, to facilitate airflow in the mound, the soil surface was covered with dry materials such as straw and dry wood to a height of 15-25 cm. The first layer of compost consisted of fresh or pulverized green plant materials such as weeds, cut grass, and other disposable green plant materials to a thickness of about 20-25 cm. The second layer, which included dry plant material such as dry leaves, was also 20-25 cm thick. The third layer was an animal manure (fresh or dried cow manure) that can be mixed with old compost, with a thickness of about 10-15 cm.

After placing each layer, the required moisture for the heap was provided by spraying (especially the layers of dry plant material and the layer of animal manure) (Tafaghodinia, et al., 2012). A deeper pile results in higher temperatures and more even heat distribution. Continue to add these three layers until the compost pile reaches a height of one meter. A layer of peat and clay solution was sprinkled on top as a covering to protect and prevent the compost pile from drying out. A thermometer was used to check the heap's heat production process daily. Once the temperature dropped below 50°C, the compost pile was turned upside down to mix layers of the pile.

2-2- Production of vermicompost

To produce vermicompost, earthworms of the species *Eisenia fetida* were prepared by the Behkam company. This species is capable of feeding on partially decomposed materials such as cow manure, horse manure, straw, cereal stubble, and plant residues. The semi-rotted cow manure was shaped in the form of a dome with a width and length of 150 cm and a height of 40 cm, which was washed with plenty of water to remove the manure leachate. Plastic baskets (width 50, length 70, and height 15 cm) were prepared and filled two-thirds of the way with cow manure. A groove was created in the basket, and the earthworms were released inside it. Then, the remaining space up to the surface of the basket was filled with cow manure. Depending on the weather conditions, the baskets were irrigated every 2 to 7 days. To improve aeration in the cultivation bed. The earthworms inside the bed were checked weekly, and the bed materials were turned upside down. The temperature of the culture bed should be maintained between 12 and 25 degrees Celsius, and the pH level should be in the range of 6 to 8. After three months, the worms and compost were separated using a sieve (Kamalpour, et al., 2007).

2-3- Production of compost tea

The compost tea production device used in this research was based on the method developed by Tafaghodinia and Kamalpour (Tafaghodinia, et al., 2012). Compost and water were blended at a 1:8 ratio to prepare aerated compost tea. Similarly, mix vermicompost and water in a 1:8 ratio for vermicompost tea. The compost tea was Aerated and stirred using an air pump and kept for 10 days at a temperature of 22 °C away from light. Then, the solution was filtered through a 200 mesh net and stored at 4°C. To produce non-aerated compost, all the stages above were carried out without mixing and aeration.

2-4- Preparation of African violet (*S. ionantha*)

The rooted plantlets produced through tissue culture were transferred to pots during the adaptation stage and kept until the 10th leaf stage; subsequently, with increased humidity and contamination with infected leaves, a relatively uniform layer of powdery mildew formed on the leaves (Yari, et al., 2019). (Fig 1) shows healthy African violet flowers and those infected with powdery mildew.

Figure 1: A view of produced African violet flowers (S. ionantha): left) healthy plants, right) powdery mildew-infected plant.

2-5- Design experiment and execution method

Four factors were investigated as independent variables (Table 1): (1) Type of compost tea at four levels (aerated compost tea, non-aerated compost tea, aerated vermicompost tea, and Non-aerated vermicompost tea) (2) Host plant variety at Two levels (Bozorg and miniature number) (3) Number of spraying at two levels (once a week and twice a week) and (4) Dosage at two levels (10 and 20cc per plant).

Table 1: Factors and their levels in the African violet whitefly control experiment design using the Taguchi method.

Factors	Type of factors	Level 1	Level 2	Level 3	Level 4
(1)	Types of compost tea	Aerated compost	Non-aerated compost	Aerated vermicompost	Non-aerated vermicompost
(2)	African violet cultivar	Bozorg	Miniature	-	-
(3)	Application intervals	Twice a week	Once a week	-	-
(4)	Dosage	10cc	20cc	-	-

The number of infected leaves was considered as the response variable.

The frequency of the healthy number and infected leaves was counted and recorded, and in the statistical comparison, the average number of

treatments (L_8 orthogonal array) to determine the optimal conditions for controlling powdery mildew in African violets (Table 2). The experiment was designed, and the data were analyzed using the Qualitek-4 software.

Table 2: Distribution of factor levels in eight experiments (8L) by Taguchi method

Test number	Type of compost tea	Cultivar	Number of applications per week	Dosage (cc)
1	Aerated vermicompost tea	Miniature	Once	10
2	Aerated vermicompost tea	Bozorg	Twice	20
3	Non-aerated vermicompost tea	Miniature	Once	10
4	Non-aerated vermicompost tea	Bozorg	Twice	20
5	Aerated compost tea	Miniature	Once	20
6	Aerated compost tea	Bozorg	Twice	10
7	Non-aerated compost tea	Miniature	Once	20
8	Non-aerated compost tea	Bozorg	twice	10

leaves was evaluated after applying the factors. Experiments were carried out in three replications using a Taguchi design, consisting of eight

3- Results and Discussion

(Table 3) shows the results of the variance analysis. According to the obtained results, the greatest effect was related to the factors of dosage, cultivar, and compost type, respectively. The number of applications had no significant effect on powdery mildew control (Fig. 2).

Table 3: Variance analysis of the effect of treatments, quantity, and dosage of compost on the control of surface whiteflies in two types of African violets.

Changing sources	Degrees of freedom	Sum of squares	(F)	Percent (%)
Compost types	3	15.375	1.64	7.069
Usage number	1	1.125	0.36	0
Dosage	1	55.125	17.64	61.266
Cultivar	1	10.125	3.24	8.247

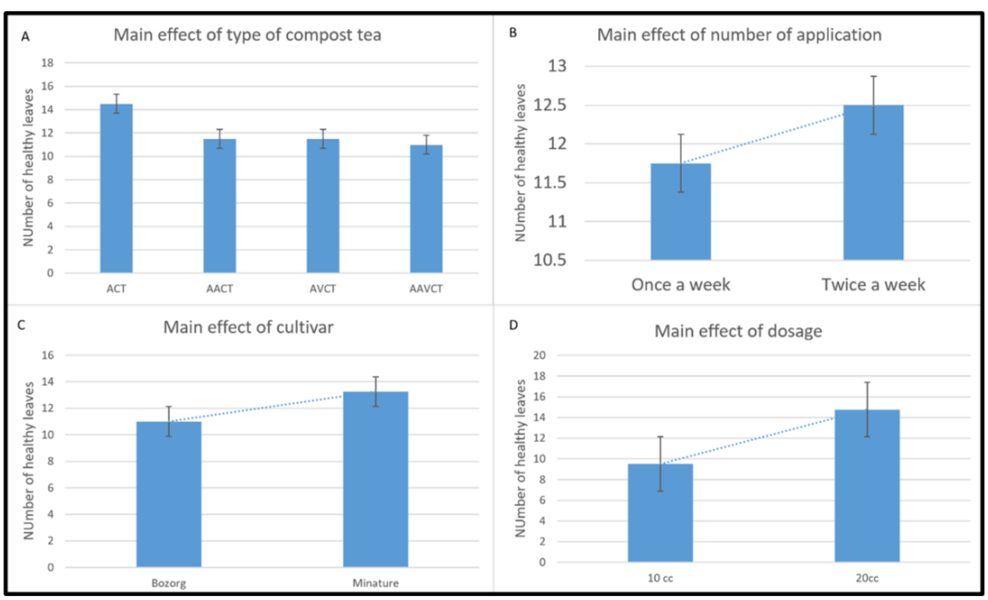

Figure 2: Main effects of independent variables, A) Type of compost tea, B) Number of applications, C) Cultivar, and D) Dosage, on the dependent variable (Healthy leaves). **ACT (Aerated compost tea,) AACT (Non-aerated compost tea,) AVCT (Aerated vermicompost tea), AAVCT (Non-aerated* vermicompost tea)

Considering that the target type was "more is better", to calculate the main effect of each factor, the difference between the average effects of two levels in each factor was calculated (Table 4). The dose factor in the second level (20cc) and the cultivar factor in the first level (Miniature) had the greatest effect in reducing powdery mildew.

Table 4: The main effect of investigated factors in controlling surface powdery mildew in two types of African violets.

Factors	Level 1	Level 2	Level 3	Level 4
Compost type	11.5	11.5	14.5	11
Usage number	11.75	12.5	-	-
Dosage	9.5	14.75	-	-
Cultivar	11	13.25	-	-

African violet powdery mildew is one of the most common pathogens in greenhouse cultivation of this flower. Due to the importance of sustainable development of agriculture and the production of healthy products, non-chemical control methods are of interest. Hence, it is imperative to develop a management approach for the organic production of diverse products that not only supply the required essential nutrients to the plant but also effectively manage pests and diseases (Stephens, et al., 1997). Recent research has shown the high potential of compost tea as an alternative to synthetic fungicides. A study conducted in 2003 revealed that pumpkin powdery mildew was reduced by 80% using compost tea (SARE, 2003). It was also found that the frequent use of compost tea in grapes resulted in a 50% decrease in disease incidence (Mostafa, et al., 2011). During a 2-year investigation in 2006, an institute in Pennsylvania studied the effectiveness of aerated compost tea in controlling various foliar diseases in field-grown pumpkins, grapes, and potatoes. The study's results indicated that compost tea effectively controlled plant diseases (Lanthier, et al., 2007). A group of researchers from the U.S. Department of Agriculture in Oregon reported in 2004 that a drenching application of compost tea effectively suppressed the damping-off of cucumber, which is caused by *Pythium ultimum*, in greenhouse media without soil (Scheuerell, et al., 2004). The ability of compost tea to control plant diseases occurred when it was used as a spray on the leaves or as a liquid in the soil (Bourbos, et al., 1998). Based on studies conducted in 2013, it was found that the ideal mineral nutrient level (half-strength fertilizing nutrients) along with weekly foliar spraying of compost tea enriched with microbes could be utilized as a biofertilizer and bio-protector for melon cultivation (Naidu, et al., 2013). A study in 2015 showed that applying aerated compost tea derived from organic compost-based MOVR (a mixture of rice straw compost, vermicompost, and Hinoki cypress bark compost) to the root zone resulted in increased plant shoot and root growth, as well as yield for red leaf lettuce, sweet corn, and soybean crops (Yadav, et al., 2023). Therefore, compost tea should be considered an effective agent for promoting plant growth in organic crop cultivation (Ramírez-Gottfried, et al., 2023).

Based on the results of 24 experiments, the optimal conditions for the control of African violet powdery mildew are presented in (Table 5). According to Table 5, the optimal conditions for powdery mildew control on the Miniature cultivar involve using a 20 cc dose of aerated compost tea twice a week.

Table 5: Suggested optimal conditions resulting from the control of African violet whitefly.

Factors	Level	Types
Compost type	4	Aerated compost tea
Cultiver	2	Miniature
Usage number	2	Twice a week
Dosage	2	20 cc

The data results of this research indicate the helpful efficiency of the Taguchi experiment design in determining the optimal control point of African violet powdery mildew with compost tea. The comparison of the performance of different types of compost tea shows the controlling performance of aerated compost tea as a fungicide because the aerated compost tea solution contains a significant amount of antibiotics against plant pathogens due to their richness of microflora. This ability of composting tea has turned it into one of the key tools in plant disease management.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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References

[1] Repetto, R., & Baliga, S. S. (1996). Pesticides and the immune system: the public health risks (p. 100). Washington, DC: World Resources Institute.
[2] Zhou, Y., Xiao, R., Klammsteiner, T., Kong, X., Yan, B., Mihai, F. C., Liu, T., Zhang, Z., & Awasthi, M. K. (2022). Recent trends and advances in composting and vermicomposting technologies: A review. Bioresource Technology, 127591. https://doi.org/10.1016/j.biortech.2022.127591
[3] Biyada, S., Merzouki, M., Dėmčėnko, T., Vasiliauskienė, D., Ivanec-Goranina, R., Urbonavičius, J., Marčiulaitienė, E., Vasarevičius, S., & Benlemlih, M. (2021). Microbial community dynamics in the mesophilic and thermophilic phases of textile waste composting identified through next-generation sequencing. Scientific Reports, 11(1), 23624. doi: 10.1038/s41598-021-03191-1
[4] da Silva Vilela, R. N., Orrico, A. C. A., Junior, M. A. P. O., Borquis, R. R. A., Tomazi, M., de Oliveira, J. D., de Ávila, M.R., dos Santos, F.T. & Leite, B. K. V. (2022). Effects of aeration and season on the composting of slaughterhouse waste. Environmental Technology & Innovation, 27, 102505. https://doi.org/10.1016/j.eti.2022.102505
[5] Chang, H. Q., Zhu, X. H., Jie, W. U., Guo, D. Y., Zhang, L. H., & Yao, F. E. N. G. (2021). Dynamics of microbial diversity during the composting of agricultural straw. Journal of Integrative Agriculture, 20(5), 1121-1136. https://doi.org/10.1016/S2095-3119(20)63341-X
[6] Salangsang, M. C. D., Sekine, M., Akizuki, S., Sakai, H. D., Kurosawa, N., & Toda, T. (2022). Effect of carbon to nitrogen ratio of food waste and short resting period on microbial accumulation during anaerobic digestion. Biomass and Bioenergy, 162, 106481. https://doi.org/10.1016/j.biombioe.2022.106481
[7] Rehman, S. U., De Castro, F., Aprile, A., Benedetti, M., & Fanizzi, F. P. (2023). Vermicompost: Enhancing plant growth and combating abiotic and biotic stress. Agronomy, 13(4), 1134. DOI:10.3390/agronomy13041134
[8] Eudoxie, G., & Martin, M. (2019). Compost tea quality and fertility. Organic fertilizers-history, production and applications. DOI:10.5772/intechopen.86877
[9] Morales-Corts, M. R., Pérez-Sánchez, R., & Gómez-Sánhez, M. Á. (2018). Efficiency of garden waste compost teas on tomato growth and its suppressiveness against soilborne pathogens. Scientia Agricola, 75, 400-409. https://doi.org/10.1590/1678-992X-2016-0439
[10] St. Martin, C. C. G. (2015). Potential of compost tea for suppressing plant diseases. CABI Reviews, (2014), 1-38. DOI:10.1079/PAVSNNR20149032
[11] St. Martin, C. C. G., & Brathwaite, R. A. I. (2012). Compost and compost tea: Principles and prospects as substrates and soil-borne disease management strategies in soil-less vegetable production. Biological Agriculture & Horticulture, 28(1), 1-33. DOI:10.1080/01448765.2012.671516
[12] Shaban, H., Fazeli-Nasab, B., Alahyari, H., Alizadeh, G., & Shahpesandi, S. (2015). An Overview of the Benefits of Compost tea on Plant and Soil Structure. Advances in Bioresearch, 6(1). DOI:10.15515/abr.0976-4585.6.1.154158
[13] Matsuda, Y., Kashimoto, K., Takikawa, Y., Aikami, R., Nonomura, T., & Toyoda, H. (2001). Occurrence of new powdery mildew on greenhouse tomato cultivars. Journal of

General Plant Pathology, 67, 294-298. https://doi.org/10.1007/PL00013034

[14] Koné, S. B., Dionne, A., Tweddell, R. J., Antoun, H., & Avis, T. J. (2010). Suppressive effect of non-aerated compost teas on foliar fungal pathogens of tomato. Biological control, 52(2), 167-173. https://doi.org/10.1016/j.biocontrol.2009.10.018

[15] Leroux, P. (2007). Chemical control of Botrytis and its resistance to chemical fungicides. In Botrytis: Biology, pathology and control (pp. 195-222). Dordrecht: Springer Netherlands. DOI:10.1007/978-1-4020-2626-3_12

[16] Dong, S. M., & Zhou, S. Q. (2022). Potato late blight caused by Phytophthora infestans: From molecular interactions to integrated management strategies. Journal of Integrative Agriculture, 21(12), 3456.https://doi.org/10.1016/j.jia.2022.08.060

[17] Al-Dahmani, J. H., Abbasi, P. A., Miller, S. A., & Hoitink, H. A. (2003). Suppression of bacterial spot of tomato with foliar sprays of compost extracts under greenhouse and field conditions. Plant Disease, 87(8), 913-919. DOI: 10.1094/PDIS.2003.87.8.913

[18] Scheuerell, S. J., & Mahaffee, W. F. (2006). Variability associated with suppression of gray mold (Botrytis cinerea) on geranium by foliar applications of nonaerated and aerated compost teas. Plant Disease, 90(9), 1201-1208. https://doi.org/10.1094/PD-90-1201

[19] Segarra, G., Reis, M., Casanova, E., & Trillas, M. I. (2009). Control of powdery mildew (*Erysiphe polygoni*) in tomato by foliar applications of compost tea. Journal of Plant Pathology, 683-689. DOI:10.4454/JPP.V91I3.561

[20] Litterick, A. M., Harrier, L., Wallace, P., Watson, C. A., & Wood, M. (2004). The role of uncomposted materials, composts, manures, and compost extracts in reducing pest and disease incidence and severity in sustainable temperate agricultural and horticultural crop production—a review. Critical Reviews in Plant Sciences, 23(6), 453-479. DOI:10.1080/07352680490886815

[21] Seddigh, S., & Kiani, L. (2018). Evaluation of different types of compost tea to control rose powdery mildew (*Sphaerotheca pannosa* var. rosae). International Journal of Pest Management, 64(2), 178-184. DOI:10.1080/09670874.2017.1361050

[22] Seddigh, S., Kiani, L., Tafaghodinia, B., & Hashemi, B. (2014). Using aerated compost tea in comparison with a chemical pesticide for controlling rose powdery mildew. Archives of Phytopathology and Plant Protection, 47(6), 658-664. https://doi.org/10.1080/03235408.2013.817075

[23] Axel, C., Zannini, E., Coffey, A., Guo, J., Waters, D. M., & Arendt, E. K. (2012). Ecofriendly control of potato late blight causative agent and the potential role of lactic acid bacteria: a review. Applied Microbiology and Biotechnology, 96, 37-48. doi: 10.1007/s00253-012-4282

[24] Kamalpour, M., & Tafaghodinia, B. (2008). Evaluation of the effect of compost as soil bed for cucumber seedling production. Proceedings of the International Congress CODIS 2008, (pp. 251-252)., Solothurn, Switzerland.

[25] Lewis, J. A., Lumsden, R. D., Millner, P. D., & Keinath, A. P. (1992). Suppression of damping-off of peas and cotton in the field with composted sewage sludge. Crop Protection, 11(3), 260-266. https://doi.org/10.1016/0261-2194(92)90047-9

[26] Noble, R., & Coventry, E. (2005). Suppression of soil-borne plant diseases with composts: a review. Biocontrol Science and Technology, 15(1), 3-20. https://doi.org/10.1080/09583150400015904

[27] Van Raaij, J. A. G. M., Frijters, C. M. G., Kong, L. W. Y., Van den Berg, K. J., & Notten, W. R. F. (1994). Reduction of thyroxine uptake into cerebrospinal fluid and rat brain by hexachlorobenzene and pentachlorophenol. Toxicology, 94(1-3), 197-208. https://doi.org/10.1016/0300-483X(94)90038-8

[28] Kamalpour M. (2007) Crop integrated management of cucumber, MS Thesis, Azad university, Arak, 95pp.

[29] Tafaghodinia B. and Kamalpour M., (2012) Compost Tea, 2nd ed., Sepehr, Tehran, 72pp.

[30] Yari F., Tafaghodinia B., Ghaemmaghami A. (2019) Investigating the possibility of gene transferring in order to increase the longevity of African violet flowers and evaluation of powdery mildew sensitivity, Research report of Iranian Research Organization for Science and Technology, 108 pp.

[31] Stephens, R., Spurgeon, A., & Berry, H. (1997). Organophosphates: The relationship between chronic and acute exposure effects. Occupational Health and Industrial Medicine, 1(36), 27-28. https://doi.org/10.1016/0892-0362(96)00028-1

[32] SARE (Sustainable Agriculture Research & Education) Compost tea for disease management in horticultural crops. 2023 URL https://projects.sare.org/project-reports/lne03-181/. Accessed 22.04.15.

[33] Mostafa, M. F. M., El-Baz, E., El-Wahab, A., & Omar, A. S. (2011). Using different sources of compost tea on grapes. Journal of Plant Production, *2*(7), 935-947. DOI:10.21608/jpp.2011.85627

[34] Lanthier, M. (2007). Compost tea and its impact on plant diseases. BC Organic Grower, 10(2), 8-11.

[35] Scheuerell, S. J., & Mahaffee, W. F. (2004). Compost tea as a container medium drench for suppressing seedling damping-off caused by Pythium ultimum. Phytopathology, 94(11), 1156-1163. doi:10.1094/PHYTO.2004.94.11.1156

[36] Bourbos, V. A., Skoudridakis, M. T., & Barbopoulou, E. (1998, May). Sodium bicarbonate for the control of Erysiphe polygoni in greenhouse tomato. In VI International Symposium on Processing Tomato & Workshop on Irrigation & Fertigation of Processing Tomato 487 (pp. 275-278). DOI:10.17660/ActaHortic.1999.487.41

[37] Naidu, Y., Meon, S., & Siddiqui, Y. (2013). Foliar application of microbial-enriched compost tea enhances growth, yield and quality of muskmelon (*Cucumis melo* L.) cultivated under fertigation system. Scientia Horticulturae, 159, 33-40. https://doi.org/10.1016/j.scienta.2013.04.024

[38] Yadav, N., Garg, V. K., Chhillar, A. K., & Rana, J. S. (2023). Recent advances in nanotechnology for the improvement of conventional agricultural systems: A Review. Plant Nano Biology, 100032. https://doi.org/10.1016/j.plana.2023.100032
[39] Ramírez-Gottfried, R. I., Preciado-Rangel, P., Carrillo, M. G., García, A. B., González-Rodríguez, G., & Espinosa-Palomeque, B. (2023). Compost Tea as Organic Fertilizer and Plant Disease Control: Bibliometric Analysis. Agronomy, 13(9), 2340. https://doi.org/10.3390/agronomy13092340.