MedCrave Step into the World of Research
Horticulture International Journal

Research Article

A preliminary study on emergence and growth of carrot seedlings in response to varying proportions of vermicompost and copper

Abstract

Vermicompost is a nutrient-rich amendment commonly used to restore soil health such as restoration of trace element contamination of growing media. A pot study was carried out to determine vermin compost and copper (Cu) interaction on little finger carrot (*Daucus carota* cv. Nantes) seedlings emergence and plant growth. The treatments were varying rates of Cu (i.e., 0, 100, 200 and 300 mg Cu l^{-1}) and vermicompost (i.e., 0, 25, 50 and 75% w/w).At two weeks after sowing, the emergence rate of carrot seedlings in pots with no vermicompost (i.e., control) were 0.22, 0.25, and 0.32 folds higher than those that received the 25%, 50% and 75% vermicompost, respectively. Vermicompost, Cu and their interaction had significant ($p<0.05$) effects on leaf chlorophyll and anthocyanin contents. The 50% vermicompost combined with the 100 mg Cu l^{-1} resulted in greater leaf greenness and anthocyanin content. Plant height and number of leaves were significantly ($p<0.05$)increased by 0.07 and 0.16 folds following the application of the 25% and 50% vermin compost respectively, compared to the control. The 50% vermicompost had a strongly positive impact on the carrot shoot compared to the root. This preliminary study on little finger carrot cv. Nantes seedlings will require further detailed studies to explain vermicompost mitigation of Cu stress on carrot plants and productivity.

Keywords: trace element, soil contamination, nutrient toxicity, soil amendment, organic carrot

Volume 6 Issue 1 - 2022

Tongxin Ye, Mercy Ijenyo, Lord Abbey
Department of Plant, Food, and Environmental Sciences, Faculty of Agriculture, Dalhousie University, Nova Scotia, Canada

Correspondence: Mercy Ijenyo, Department of Plant, Food, and Environmental Sciences, Faculty of Agriculture, Dalhousie University, 50 Pictou Road, PO Box 550, Truro B2N 5E3, Nova Scotia, Canada, Email 2178mercy@gmail.com

Received: January 17, 2022 | **Published:** January 27, 2022

Introduction

Carrot (*Daucuscarota*) is an important horticultural crop that is widely grown in small and large production systems mainly for its edible roots. Carrot roots, like any other plant roots, is in close contact with growing media and can easily accumulate chemicals from the growing media.[1] Previous research revealed that exposure of plant roots to trace elements in the soil can adversely affect plant productivity depending on the concentration and management practices.[1,2]

Copper (Cu) is an essential trace element taken up plants through the root system as Cu^{+} by the actions of transporters and chelators.[3] However, excess accumulation of Cu in the plant cell can result in the production of reactive oxygen species.[3] Previous experiment reported toxic effect following application of 3 mM Cu to seeds of carrot and wheat (*Triticumaestivum L*). Further increase in Cu concentration to 6 mM reduced the wheat plant root growth by a significant amount compared to control.[4] In a pot experiment, Hou et al.[2] found that root and shoot dry weights of carrot were reduced by 0.14-fold when exposed to >400 mg Cu kg^{-1}.In another instance, carrot plants grown in soils contaminated with Cu from natural sources such as weathering of mineral deposits led to accumulation of excessive amount of Cu in the roots ranging from 14 to 109 mg kg^{-1}.[5,6]

As such, many countries have set safe limits for Cu in agricultural soils. For instance, the Canadian Council of Ministers of the Environment soil quality guideline for Cu in agricultural soils and residential parks is 63 mg kg^{-1}.[7] There are many options for Cu remediation in agri-environment, which may differ according to management practices and soil conditions. According to Abbey et al.[1] annual application of municipal solid waste compost increased Cu content of carrot roots by approximately, 0.15-foldcompared to biennial and unamended soil. In another study, Bolan et al.[8] reported that the addition of 50 g kg^{-1} of manure compost increased Cu toxicity (i.e., from 50 to 400 mg kg^{-1}) and reduced soil free Cu^{2+} between 0.19 and 0.43 folds compared to the control. These reductions were attributed to compost remediation of Cu contamination. However, information on the impact of vermicompost on Cu toxicity and carrot plant growth is scarce. Based on current information, it was hypothesized that Cu toxicity will be reduced by vermicompost application, while low to medium vermincompost rate will increase seedling emergence and seedling growth. Therefore, the objective of the present study was to determine vermicompost and Cu interaction effect on little finger carrot cv. Nantes seedlings emergence and plant growth.

Materials and methods

Location: A pot experiment was carried out in the Department of Plant, Food, and Environmental Sciences greenhouse between August and November 2020. The mean maximum daytime temperature and the mean minimum night time temperature during the study were 20°C and 9°C, respectively.

Materials: Seeds of carrot cv. Nantes and the potting mix (Promix BX™) general purpose (Premier Horticulture Inc., Quakertown, PA) was purchased from Halifax Seeds Inc., NS. The Promix BX™ was comprised of 75%-85% sphagnum peat moss, horticultural-grade per lite, vermiculite, limestone, and wetting agent. The vermicompost used was also purchased from Halifax Seeds. The vermicompost contained 23.2% organic carbon, calcium 7.24%, iron 0.76 mg kg^{-1} and Cu 0.07 mg kg^{-1}, 1.1% phosphorus, 4.2% potassium and at a pH of 5.97. The source of Cu used for the experiment was Cu (II) sulfate penta hydrate ($CuSO_4 \cdot 5H_2O$) (Acros Organic AR grade, 7758-99-8) purchased from Thermo Fisher scientific, Inc., Canada.

Planting and experimental design: Ten (10) carrot seeds were directly sown into 2.84-litreplastic pots containing Promix BX mixed with vermicompost at the rates of 25%, 50% and 75% (w/w) of a total growing media weight of 400 g. The control is 400 g of Promix BX alone. At the 2-3 true leave stage, five seedlings were thinned out for each pot to have five plants per treatment. The Cu levels were 0 (control), 100, 200 and 300 mgl^{-1}, respectively. The experiment was arranged in a two-factor randomized block design with three replications and the total number of experimental treatments was 48 (i.e. 4 Cu levels x 4 vermicompost rates x 3 replications). Distilled water was used to make the Cu solution from $CuSO_4{\cdot}5H_2O$ at concentrations100, 200 and 300 mg Cu l^{-1}.The control was distilled water alone i.e., no Cu treatment. Each potted plant received 50ml of the Cu solution, which was equivalent to 19.5, 39.1 and 58.6 mg $CuSO_4{\cdot}5H_2O$ kg^{-1}, respectively. The positions of the potted plants on the greenhouse bench were re-arranged weekly to minimize variations due to microclimate conditions. The carrot plants were watered with tap water every other day until the experiment was terminated at 11 weeks after sowing.

Data collection: The number of germinates that emerged from the growing media were counted in the first and second week after sowing.

The emergence rate per pot was calculated a:

$$\frac{\text{Number of emerged germinates)}}{10} x100\%$$

Leaf greenness and anthocyanin contents were collected from five plants per pot between five and 10weeks after sowing and the average value was computed. The leaf greenness was measured using SPAD-502 chlorophyll meter (Konica Minolta, Inc. USA).The anthocyanin content was measured using ACM-20 anthocyanin content meter (Opti-Sciences, Inc. USA).Changes in leaf length was recorded every three days between 26 to 46 days after sowing. Plant height and number of leaves were recorded every two weeks between six and 10 weeks after sowing. The immature carrot plants were harvested at 11 weeks after sowing and the shoot and root were partitioned, and their fresh weights were recorded.

Statistical analysis: Data was subjected to analysis of variance (ANOVA) using Minitab version 19.3 (Minitab Inc., USA).Treatment means were compared by the least significance method at $\alpha<0.05$ when the ANOVA indicated statistical difference between treatment means at $p\leq 0.05$. MS Excel was used to draw the tables and figures.

Results and discussion

There was a clear difference in percentage carrot seedlings (germinates) emergence between the control plants and the vermicompost treated plants (Figure 1). The percentage seedlings emergence for the control were 0.25- and 0.22-fold, 0.31- and 0.25-fold, and 0.77-and 0.29-foldgreaterthanthose for treatments 25%, 50% and 75% vermicompost rates at 1 and 2 weeks after sowing, respectively. The high percentage of emerged seedlings in the control medium could be attributed to low bulk density and favorable porosity of the media made up of the Promix BX alone.[9]

Vermicast by nature is rich in chemical elements and compounds[10] and therefore, the delay and trend of the seedlings emergence could also be attributed to increased growing media chemical composition as vermicompost rates was increased from 0 to 75%. However, previous study reported that 20% vermicompost rate enhanced seedling emergence that was attributed to favorable medium pH and electric conductivity.[11] In a similar work, He et al.[12] reported that higher concentration of carbonated water from seafood compost reduced seed germination and seedling growth components. These suggested that there is a threshold of application rate of vermicompost for the enhancement of seed germination and seedling emergence beyond which there may be adverse effect. In general, Cu did not significantly ($p> 0.05$) affect seedlings emergence.

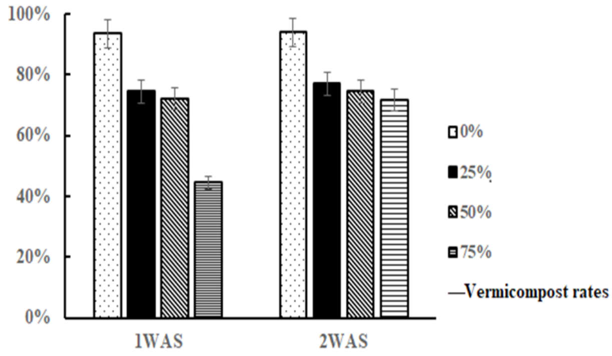

Figure 1 Effect of vermicompost application rate on percentage emergence of carrot (*Daucus carota cv.* Nantes) seedlings within the first two weeks after sowing.

Vermicompost significantly ($p< 0.05$) altered seedling growth parameters i.e., plant height, number of leaves, and shoot and root biomasses (Table 1). The 25% and 50% vermicompost rates significantly ($p< 0.05$) increased plant height by 0.16 and 0.06 folds, respectively; and a plant height reduction of0.2-foldwas observed following application of the 75%vermicompost rate compared to the control. The stunted plants observed in the control (i.e. negligible chemical composition) and the 75% vermicompost (i.e. excess chemical composition) treatments were presumed to be in response to media chemical imbalance (Table 1). The balance between various nutrients is key to their availability for plant use. In a previous study, Abbey and Appah[13] found that application of manure compost at a rate of 50% or more retarded plant growth due to increased nutrient toxicity. Another study indicated that excessive uptake of plant nutrients such as phosphorus from vermicompost antagonized iron uptake and its assimilation leading to reduced plant growth.[11] These reports can explain the observations made in the present study. The 50% vermicompost rate significantly ($p < 0.05$) increased the number of carrot plant leaves by approximately 0.14-foldcompared to the control (Table 1). According to the present result, moderate vermicompostrate supported more leaf production and this is in accordance with a recent study by Pryzwmienicki et al.[14] and a previous study by Abbey and Appah.[13]

ACI, anthocyanin content index; values are means of three replications; means with same alphabetical letters within columns are significant different ($p<0.05$);***significant at 1%; *significant at 5% and ns, not significant ($p>0.05$).

Differences in vermicompostrates had marginal effect oncarrot leaf length but Cu had no effect (Table 1). Overall, leaf length was increased by vermicompost application irrespective of the rate compared to the control. According to Przemieniecki et al.[14] and Abbey et al.[10] vermicompost contains plant growth compounds such as humic substances, amino acids, enzymes, and essential nutrients, which have positive effect on leaf production. Vermicompost and Cu applications had significant ($p<0.05$) effect on leaf greenness and anthocyanin content as shown in Table 1. The 100 mg Cu l^{-1} significantly ($p<0.05$) increased leaf greenness by 0.012-fold, which was observed as dark green leaves due to high chlorophyll content. Leaf greenness was highly increased by the 200 and 300 mg Cu l^{-1}treatments compared to the control (Table 1). According to Printz et al.,[3] cellular process such as photosynthetic electron transport is altered by Cu availability. The deficiency of Cu affects young leaves while excess impairs plant growth including oxidative damage and leaf discoloration. The 50% vermicompost rates followed by the 25% vermicompost rate were the most sustained effect on leaf greenness. The least effect was observed in the 75% vermicompost rate (Table 1).The 50% vermicompost rate in combination with the 100 mg Cu l^{-1} resulted in the greatest leaf greenness (Figure 2).

Table 1 Carrot (*Daucus carota* cv. Nantes) seedling growth parameters and leaf pigmentation as affected by varying rates of vermicompost and copper applications

Copper level (mg/l)	Change in leaf length (cm)	Plant height (cm)	Number of leaves	Leaf greenness (SPAD value)	ACI
0	2.31a	17.62a	3.87a	8.99 a	1.46 a
100	2.33a	17.71a	3.97a	10.03 a	1.49 a
200	2.63a	17.32a	3.98a	7.05 b	1.34 b
300	2.67a	17.13a	3.72a	6.89 b	1.37 b
Significance (α=0.05)					
Copper	ns	ns	ns	***	*
Compost Rate (%)					
0	2.17 b	17.19 b	3.90 b	7.25 b	1.33 b
25	2.56 ab	18.37 ab	4.22 ab	8.66 ab	1.45 ab
50	2.41 ab	20.03 a	4.32 a	9.51 a	1.50 a
75	2.79 a	14.19 c	3.10 c	7.54 b	1.38 ab
Significance level (α=0.05)					
Vermicompost	ns	***	***	***	*
Interaction	ns	ns	ns	*	***

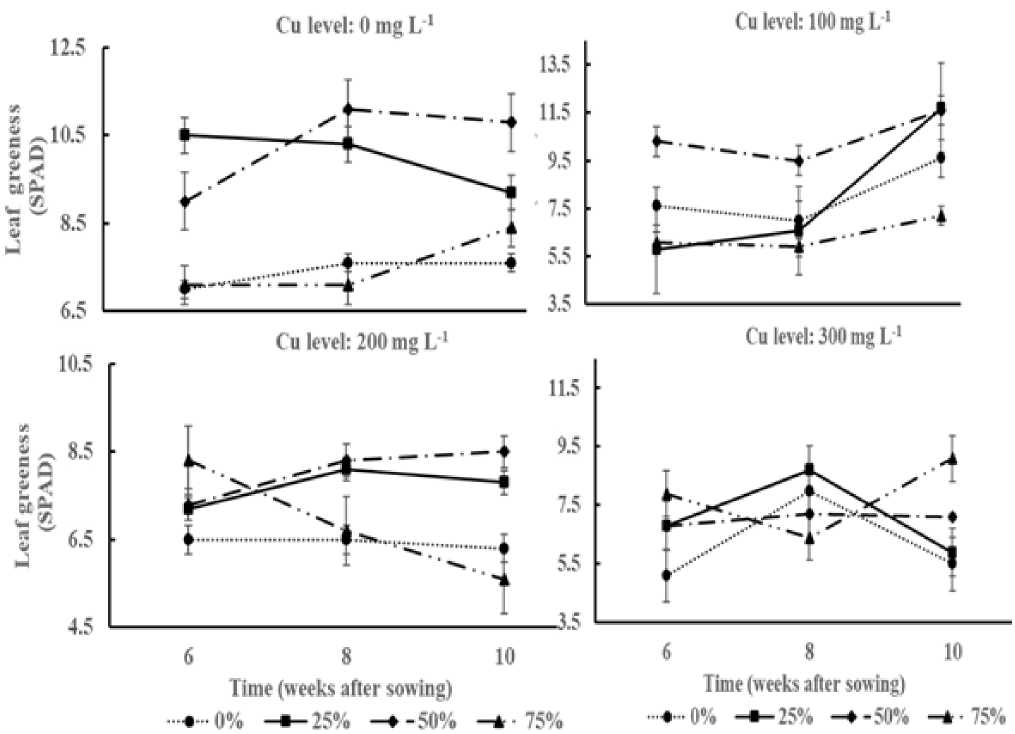

Figure 2 Effect of vermicompost and copper on carrot (*Daucus carota* cv. Nantes) leaf greenness.

Citation: Ye T, Ijenyo M, Abbey L. A preliminary study on emergence and growth of carrot seedlings in response to varying proportions of vermicompost and copper. *Horticult Int J.* 2022;6(1):11–15. DOI: 10.15406/hij.2022.06.00235

The results indicated that the addition of low to moderate vermicompost to a medium containing 100 mg Cu l^{-1}will enhance leaf greenness. The benefits of supplying adequate Cu to plants are attributed to its role in metabolic processes such as chlorophyll production.[2] The vermicompost also contained Cu, which may have influenced the concentration of the added Cu. The anthocyanin content of leaves from carrot plants treated with 100 mg Cu $l^{-1}$was higher than that for leaves from the control plants. However, the 200 and the 300 mg Cu l^{-1} had the least anthocyanin content suggesting that plant defense was lower due to Cu stress. Exposure to excess Cu results in the production of reactive oxygen scavenging activities and reduced plant physiological functions.[2] The 50% vermicompost under 100 mg Cu l^{-1} had a slightly higher anthocyanin content compared to the control at week 10 (Figure 3). This result indicated that moderate vermicompost and low Cu additions had a greater effect on anthocyanin production, which is a plant protective mechanism under stress conditions. Overall, the results indicated that Cu equilibration and vermicompost rates are important regulators of chlorophyll activities and plant defense.

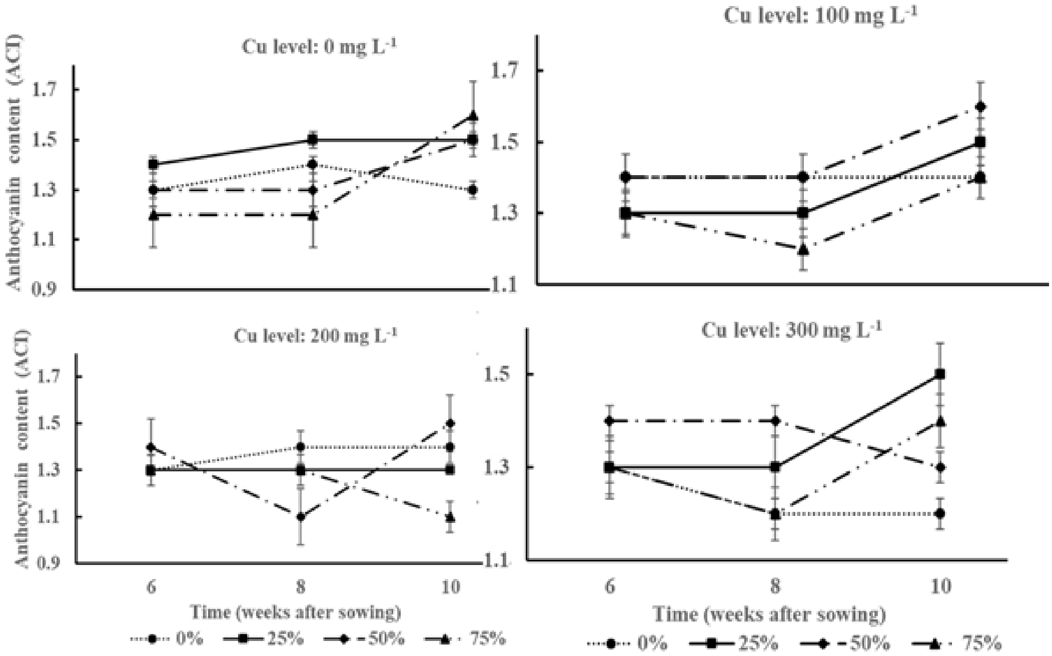

Figure 3 Effect of vermicompost and copper on carrot (*Daucus carota* cv. Nantes) leaf anthocyanin content measured between six and 10 weeks after sowing.

The differences in treatment effects on shoot and root fresh weights were significant ($p<0.05$), and the variability was higher in the shoot fresh weight following variations in vermicompost treatment (Figure 4). Distinctly, the 50% vermicompost increased shoot fresh weight by 0.65-foldcompared to the control, but the shoot fresh weight of the 75%vermicompost treated plants were greatly reduced. Based on the result, optimal conditions for shoot growth were established because of potting media improvement with the vermicompost. Vermicompost contains plant nutrients, beneficial microorganism, and organic compounds such as humic acids, which can improve the effectiveness of the grow media to promote plant growth.[10,11,14]

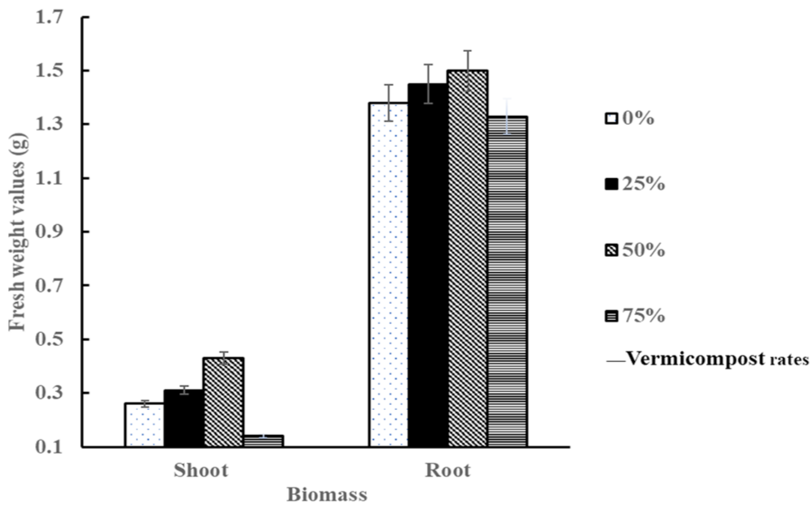

Figure 4 Effect of compost rate on carrot (*Daucus carota* cv. Nantes) fresh shoot and root weights.

The 25% and 50% vermicompost treatments had positive impacts on the roots of the carrot seedlings although not statistically significant ($p>0.05$).The highest reduction was observed in the 75% vermicompost treatment due to suboptimal media condition (Figure 4).

Conclusion

The present preliminary study demonstrates that carrot cv. Nantes seed germination and seedling (i.e., germinates) emergence are not dependent on growing medium amendment. Rather, high application rate of growing medium amendment like vermicompost can delay seedling emergence. It was also confirmed that vermicompost can mitigate Cu stress at certain threshold of application. For example, the interaction between 50% vermicompost and 100 mg Cu l^{-1}improved leaf greenness and anthocyanin contents. Higher vermicompost application with or without Cu imposes stress that reduces carrot seedling growth. In this study, carrot root did not develop to marketable stage as the study was focused on seedling emergence and seedling growth. The next step to this preliminary study will be to determine the interactive effect of vermicompost and Cu on carrot plant productivity and edible.

Acknowledgments

None.

Conflicts of interest

The author declares there is no conflict of interest.

References

1. Abbey L, Ijenyo MO, Amo Larbi V, et al. Bioaccumulation of chemical element and health risk assessment of vegetables with varying frequency of CQA-tested municipal solid waste compost. *Canadian Journal of Plant Science*. 2021;101(6):967–983.
2. Hou S, Zheng N, Tang L, et al. Effects of cadmium and copper mixtures to carrot and pak choi under greenhouse cultivation condition. *Ecotoxicology and environmental saf*ety. 2018;159:172–181.
3. Printz B, Lutts S, Hausman JF, et al. Copper trafficking in plants and its implication on cell wall dynamics. *Frontiers in Plant Science*. 2016;**7**:601.
4. Konieczna I, Rut G, Kliszcz A. Effect of copper and vanadium ions on morphology of carrot (*Daucus carota* L. subsp. *sativus* (Hoffm.) Schübl. & G. Martens) and wheat (*Triticum aestivum* L.) plants. *Annales Universitatis Paedagogicae Cracoviensis Studia Naturae.* 2018;3:55–69.
5. Gharbi F, Rejeb S, Ghorbal MH, et al. Plant response to copper toxicity as affected by plant species and soil type. *Journal of Plant Nutrition. 2005;*28(3):379–392.
6. Kabata Pendias A. *Trace elements in soils and plants*. 4th Ed. CRC press, Boca Raton: USA; 2010;16:253–266.
7. Canadian Council of Ministers of the Environment (CCME). *CCME Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health*. 2007.
8. Bolan N, Adriano D, Mani S, et al. Adsorption, complexation, and phytoavailability of copper as influenced by organic manure. *Environmental Toxicology and Chemistry.* 2003;22(2):450–456.
9. Pietola L. Effect of soil compactness on the growth and quality of carrot. *Agricultural and Food Science.* 1995;4(2):139–237.
10. Abbey L, Annan N, Asiedu SK, et al. Amino acids, mineral nutrients and efficacy of vermicompost and seafood and municipal solid wastes composts. *International Journal of Agronomy.* 2018;8:1–6.
11. Şimşek Erşahin Y, Ece E, Karnez E. Differential effects of a vermicompost Fertilizer on Emergence and seedling growth of tomato plants. *Turkish Journal of Agriculture.* 2017;5(11):1360–1364.
12. He Y, Pruski K, Abbey L**,** et al. Seed germination and seedling growth responses to different sources and application rates of hydrothermal carbonization processed liquid. *Sustainable Agricultural Res*earch. 2021;10(4),1–14.
13. Abbey L, Appah P. Effect of excessive application of manure compost on leaching of soluble chemicals and plant growth in pots. *Acta Horticulturae.* 2017;1164:241–248.
14. Przemieniecki SW, Zapałowska A, Skwiercz A, et al. An evaluation of selected chemical, biochemical, and biological parameters of soil enriched with vermicompost. *Environmental Science and Pollution Research.* 2021;28:8117–8127.