Effect of vermicompost on vegetative growth and nutrient status of acclimatized Grand Naine banana plants

S.A.M. Hassan a,b, Rania A. Taha a,b,*, Nagwa S.M. Zaied a,b, Entsar M. Essa c, Abd El-Rheem Kh. M d

ARTICLE INFO
Keywords:
Acclimatization
Leaf mineral content
Vermicompost
Banana
Culture medium

ABSTRACT
Novel approach for introducing vermicompost as an acclimatization soil for banana plants was conducted. Different potting mixture of vermicompost, vermiculite, peatmoss and sand at different ratios were used to study the effect of different agricultural media on vegetative growth and leaf mineral content of banana tissue culture plantlets, after acclimatization stage. Two different trial periods were studied; 12 and 24 weeks in these agricultural media for two seasons. Results indicated that using vermicompost combined with vermiculite and sand (33.3% for each) recorded the best results for the most vegetative growth studied parameters (plant height, plants and roots length, stem diameter, leaf width and shoot and root fresh and dry weight). Moreover, vermicompost at 50% þ peat moss at 50% significantly increased total chlorophyll content in banana plants. Furthermore, N, P and K plant analysis has shown that vermicompost at 75% with peat moss gave the highest mineral content values at the two periods. Addition of vermicompost to the culture media improved in vitro-produced banana plants in greenhouse.

1. Introduction

Many scientific researches were conducted to improve the survival rate and growth parameters of the tissue cultured plants during acclimatization. Culture medium is an important factor to get these enhancements. Sand, perlite, vermiculite and peat moss were the most investigated substances as Ali et al. (2011) concluded that application of potting mixture containing soil: sand: farm yard manure (2:1:1 v/v/v) was superior treatment for increasing vegetative growth and survival of banana plantlets. Furthermore, survival rate (98%) of Atlanta cultivar was reported by Han and Goo (2003) using a growth substrate of vermiculite and perlite (1:1 v/v). In contrast, Parkhe et al. (2018) claimed that from different potting mixtures; garden soil, cocopeat, farm yard manure (FYM), vermicompost and sand with different combinations, 100% hardening success was conducted to banana plantlets of cv. Grand Naine when garden soil and FYM (3:1) were used. This combination gave maximum height and survival of plantlets and shows outstanding performances in field condition. The positive effects of vermicompost are also highlighted in other studies (Naiji and Souri, 2018; Souri and Hatamian, 2019; Najarian and Souri, 2020).

Vermicompost represents a very suitable medium for plant growth showing improved growth for many plant species (Ebrahimi et al., 2021; Serri et al., 2021), that can also be used as a growth substrate in different stages of micropropagation. It is rich in macro and micronutrients, vitamins, growth hormones, enzymes such as proteases, amylases, lipase, cellulase, and chitinase, and immobilised microflora created by earthworm activity. Even after the earthworms have ejected the enzymes, they continue to degrade organic matter (Barik et al., 2011). However, vermicompost as a culture medium for acclimatization are rarely investigated. Martin et al. (2003) assured that Anthurium andreanum was planted in vermicompost and sand (1:3), kept in the greenhouse for acclimatization, revived growth within two weeks then transferred to a net house. In contrast, Parkhe et al. (2018) claimed that from different potting mixtures; garden soil, cocopeat, farm yard manure (FYM), vermicompost and sand with different combinations, 100 % hardening success was conducted to banana plantlets of cv. Grand Naine when garden soil and FYM (3:1) were used. This combination gave maximum height and survival of plantlets and shows outstanding performances in field condition. The positive effects of vermicompost are also highlighted in other studies (Naiji and Souri, 2018; Souri and Hatamian, 2019; Najarian and Souri, 2020).

* Corresponding author.
E-mail address: rania_abdelghaffar@yahoo.com (R.A. Taha).

https://doi.org/10.1016/j.heliyon.2022.e10914
Received 16 December 2021; Received in revised form 17 March 2022; Accepted 28 September 2022
2405-8440/© 2022 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Banana (Musa spp.) is considered as one of the most important tropical fruit crops grown in the world. This crop plays an important role in the economy of tropical and subtropical countries. Micropropagation is a unique process for banana large numbers production. Acclimatization is the most crucial process during banana micropropagation (Ozdemir et al., 2020). This is for that the in vitro raised plantlets are not readily acclimatized for ex-vitro conditions due to the non-functional stomata, weak root system and poorly developed cuticle (Vasane and Kothari, 2006). Moreover, an effective acclimatization technique saved time, labour, and money, including the culture medium used, is really needed (Gantait et al., 2009).

The present investigation was carried out to study the effect of vermicompost, as a novel culture medium, combined with other agricultural media as sand, vermiculite and peat moss on vegetative growth and leaf mineral contents of ex-vitro Grand Naine banana plants acclimatization.

2. Materials and methods

This study was carried out during September to February for two seasons in the greenhouse of Pomology Dept., National Research Centre, Dokki, Giza Governorate, Egypt. Plantlet leaf contents were analyzed at Soils and Water Use Department and Plant Nutrition Department, National Research Centre, Dokki, Giza, Egypt.

2.1. Acclimatization process

Grand Naine banana (Musa spp.) plantlets derived from in vitro cultures of Tissue Culture Technique Lab., Central Laboratories Network, National Research Centre, Dokki, Giza Governorate, Egypt as described by Taha et al. (2020) were taken away from the jars and the basal portion of these plantlets were subjected to continuous flow of tap water to get rid of medium residues then rinsed carefully in sterile distilled water. The basal part of plantlets was dipped in antifungal solution (Benlate) at the rate of 0.1% for 10 min. Then, they were planted in suitable black pots filled with wetted peat moss: sand (1:1) without any water surplus to avoid decay of plantlets roots. The planted pots were covered with transparent polyethylene bags (0.2 mm thick) after spraying water inside the bag to raise up the relative humidity (RH) to 80–90% around the first new leaf (indicator of successful gradual acclimatization), then increased longitudinally by increasing their lengths and numbers until removing the whole bag.

2.2. Vermicompost description

The vermicompost used in this experiment was made of animal wastes (cow and horse manure), which were digested by species of earthworm such as Eisenia fetida and Eisenia fetida. Some chemical properties of vermicompost were determined in Table 1. Micronutrient content (Fe, Mn, Zn) were determined using atomic absorption spectrophotometer as described by Cotiente et al. (1982). Other chemical properties of vermicompost were measured according to the standard methods described by Cotiente (1980).

2.3. Effect of various culture media on banana vegetative growth

The gradual acclimatized Grand Naine banana plants were planted in bigger pots (20 × 20) filled with sand, peat moss, vermiculite and vermicompost in their combination as follows:

- T 1: Peat moss (50%) + sand (50%)
- T 2: Vermicompost (50%) + sand (50%)
- T 3: Peat moss (50%) + vermicompost (50%)
- T 4: Peat moss (75%) + vermicompost (25%)
- T 5: Peat moss (25%) + vermicompost (75%)
- T 6: Vermiculite (50%) + sand (50%)
- T 7: Vermiculite (50%) + vermicompost (50%)
- T 8: Vermiculite (33.3%) + vermicompost (33.3%) + sand (33.3%)
- T 9: Vermiculite (25%) + vermicompost (50%) + sand (25%)
- T 10: Vermiculite (25%) + vermicompost (25%) + sand (25%) + peat moss (25%)  

2.4. Fertilization

Crystalon (2.0 g/l) as a source of NPK (20% N, 20% P, 20% K) was used to fertilize the plants. It was applied to soil during growing season to different tested treatments, including control.

2.5. Data collection

Morphological parameters determination and chemical analysis were done for plants at two times; 12 and 24 weeks after transplanting for two seasons. Samples (three plants/treatment/time) were collected to take morphological data. Moreover, leaves were cut and dried for chemical analysis. The following morphological parameters were measured: Plant length (cm), number of leaves, root length (cm), leaf length (cm), stem diameter (cm), leaf width (cm), root and shoot fresh weight (g) were determined at two times; after 12 weeks and 24 weeks from transplanting.

2.6. Chemical analysis

Total nitrogen content was estimated by micro-Kjeldahl (Gerhardt, EV16) (Motsara and Roy, 2008). The percentages of phosphorus and potassium in the acid digested samples of banana dry leaves were determined. Phosphorus was determined colorimetrically with NH4-Metavanidate method by spectrophotometer (Unico, 2000UV). Potassium was flame-photometrical estimated in leaves samples (England, Jenway, 7PFF). Total chlorophyll content was determined in first leaves by Minolta meter (SPAD-502, Japan) and the data were expressed as SPAD units (Markwell et al., 1995).

3. Statistical analysis

Data for the two seasons were collected and average were counted. All data were subjected to statistical analysis using MStat software. The
4. Results

4.1. Vegetative growth characteristics

Data in Table 2 which collected after 12 weeks from transplanting, clearly showed that T8 (Vermiculite 33.3% + vermicompost 33.3% + sand 33.3%) surpassed other treatments in enhancing plant length, root length, stem diameter, leaf width, shoot dry weight and gave satisfactory root dry weight. Meanwhile, T3 (peat moss 50% + vermicompost 50%) gave the highest leaves number, stem diameter and leaf length. Furthermore, T9 (Vermiculite 25% + vermicompost 50% + sand 25%) gave the highest leaf width, shoot and root fresh weight (Figure 1).

Similarly, data in Table 3 which collected after 24 weeks from transplanting, clearly showed that T8 surpassed other treatments in enhancing plant length, root length, stem diameter, leaf width, shoot fresh weight and shoot and root dry weight. It gave satisfied leaves number, leaf length and root fresh weight.

4.2. Leaf chlorophyll and leaf mineral contents

Results in Table 4 show the effect of vermicompost combined with different agricultural media on total chlorophyll and Leaf mineral content in the leaves after 12 and 24 weeks from transplanting. The highest total chlorophyll was obtained from T3 (peat moss 50% + vermicompost 50%) after the 12 weeks from transplanting. Furthermore, after 24 weeks, the positive effect of planting in vermicompost combinations clearly appeared as most vermicompost treatments surpassed others and T10 (Vermiculite 25% + vermicompost 25% + sand 25% + peat moss 25%) gave the highest value.

Likewise, results in Table 5 indicated that leaf mineral content was affected significantly by different treatments under this investigation. The highest N%, P% and K% in leaves were recorded by plants grown in T3 (Peat moss 25% + vermicompost 75%) at 12 weeks as well as 24 weeks after transplanting.

5. Discussion

Many researchers indicated that culture medium affects significantly primary and secondary acclimatization success of banana plantlets (Ali et al., 2011; Vasana and Kothari, 2006) but few of them investigated vermicompost on banana plants. Our results indicated that vermicompost combined with other culture materials; specially vermiculite and sand recorded the best results in terms of most studied morphological measurements during greenhouse stage of in vitro-produced banana plants. Similarly, Kashyap et al. (2017) investigated the effect of vermicompost with different methods of extraction; vermicompost, eluant or vermicompost extract for B. monnieri plants. Results showed that 100% survival for the three methods. Moreover, vermicompost extract medium gave the higher root numbers and plantlets weight while, vermicompost alone gave the higher number of shoots. It might be due to the high quantities of nutrients, humic acids, and humates in vermicompost that cause the plant growth response to resemble hormone-induced activity (Atiyeh et al., 2000; Edwards and Burrows, 1988). Soil amendment with vermicompost and pistachio biochar increased plant growth and performance of eggplant as well as yield and water use efficiency (Ebrahimi et al., 2021). Otherwise, sugarcane bagasse compost was used at various concentrations (20%, 30%, 40%, 80% and 100%) into soil bedding medium mixture for Pelargonium × hortorum. Generally, application of sugarcane compost stimulated plant growth. In addition, low concentrations especially 20% resulted in the highest morphological parameters including leaves number, stem number, shoots originate flowers, flowers number, inflorescence diameter, main shoot diameter, shoot and root biomass (Najarian and Souri, 2020).

Generally, our results assured that addition of vermicompost to growth environments improved banana leaves content of chlorophyll, nitrogen, phosphorus and potassium. Similarly, chlorophyll a increased in plants grown in sugarcane compost at all concentrations used compared to control plants (Najarian and Souri, 2020).

It is clear that T5 had the highest rate of vermicompost used so that, it gave superior nutrient contents. It is evident that vermicompost

![Figure 1. Effect of vermicompost combined with different agricultural media on growth parameters of Grand Naine banana after 12 weeks.](image-url)

Table 2. Effect of vermicompost combined with different agricultural media on growth parameters of Grand Naine banana after 12 weeks.

| Treatments | Leaves no. | Plant length (cm) | Root length (cm) | Stem diameter (cm) | Leaf length (cm) | Leaf width (cm) | Shoot F.W (G) | Shoot D.W (G) | Root F.W (G) | Root D.W (G) |
|------------|------------|------------------|------------------|-------------------|-----------------|----------------|---------------|---------------|--------------|--------------|
| T1         | 4.333      | 47.0             | 29.67            | 16.33             | 23.67           | 10.97          | 44.0          | 3.643         | 17.4         | 2.193        |
| T2         | 4.667      | 49.33            | 22.33            | 17.33             | 24.63           | 11.40          | 39.97         | 4.390         | 22.93        | 2.930        |
| T3         | 5.333      | 58.33            | 30.67            | 22.33             | 28.67           | 12.93          | 77.0          | 6.510         | 32.03        | 3.387        |
| T4         | 5.00       | 47.0             | 25.33            | 17.0              | 20.60           | 10.33          | 45.23         | 3.833         | 19.3         | 1.947        |
| T5         | 3.667      | 48.33            | 18.0             | 14.0              | 20.93           | 10.27          | 29.53         | 3.377         | 19.43        | 2.277        |
| T6         | 4.333      | 59.0             | 28.0             | 19.0              | 24.83           | 11.50          | 70.17         | 7.667         | 32.90        | 4.933        |
| T7         | 3.667      | 49.67            | 25.67            | 16.67             | 23.5            | 11.87          | 46.43         | 7.583         | 33.60        | 2.550        |
| T8         | 4.333      | 59.67            | 36.67            | 21.33             | 23.67           | 13.30          | 70.20         | 8.787         | 35.30        | 5.097        |
| T9         | 4.00       | 54.67            | 18.0             | 20.0              | 27.17           | 13.57          | 82.63         | 7.987         | 41.33        | 3.723        |
| T10        | 5.00       | 57.33            | 27.0             | 20.67             | 27.9            | 12.37          | 64.63         | 7.847         | 38.30        | 5.213        |

LSD0.05 0.91 0.67 2.33 4.04 0.64 5.63 0.80 3.03 0.116
enhances uptake of nutrients by plants and this may be by providing all nutrients in readily available form. As, Mahmud et al. (2020) assured that the application of vermicompost reduced soil acidity and produced macro and micronutrients content (N, P, K, Mg, Ca, S, Fe, Zn, B and Al) in the soil and plants. In fact, the technology of vermicomposting was found to provide better phosphorus nutrition from different organic wastes (Ghosh et al., 1999). In that manner, highest phosphorus concentration content was occurred at 20% sugarcane bagasse compost substitution. Moreover, a large amount of nitrogen and potassium were observed at 40% sugarcane bagasse compost (Najarian and Souri, 2020).

Vermicompost proved to be a very suitable organic fertilizer or substrate with high porosity, aeration, drainage and good water holding capacity (Edwards and Arancon, 2005). It has also significant levels of growth promoting substances including minerals, enzymes, and phytohormones (Nalji and Souri, 2018; Souri and Hatamian, 2019; Najarian and Souri, 2020). It was found to include growth-promoting auxins, cytokinins, and gibberellins (Suhane, 2007).

Table 3. Effect of vermicompost combined with different agricultural media on growth parameters of Grand Naine banana after 24 weeks.

| Treatments | Leaves no. | Plant length cm | Root length | Stem diameter | Leaf length | Leaf width | Shoot F.W. | Shoot D.W. | Root F.W. | Root D.W. |
|------------|------------|-----------------|-------------|---------------|-------------|------------|------------|------------|-----------|-----------|
| T1         | 6.50       | 51.33           | 29.33       | 6.30          | 33.28       | 17.67      | 56.41      | 4.513      | 17.36     | 2.21      |
| T2         | 6.50       | 49.50           | 21.00       | 6.90          | 37.17       | 17.23      | 46.81      | 3.745      | 21.49     | 2.96      |
| T3         | 5.00       | 59.00           | 29.67       | 4.33          | 38.00       | 13.17      | 85.09      | 6.807      | 31.02     | 3.33      |
| T4         | 7.00       | 50.17           | 24.67       | 6.50          | 37.58       | 18.72      | 45.22      | 3.618      | 19.67     | 1.96      |
| T5         | 6.00       | 45.66           | 18.67       | 6.00          | 42.00       | 19.83      | 32.87      | 2.630      | 19.78     | 2.20      |
| T6         | 8.00       | 56.20           | 27.67       | 6.25          | 31.00       | 14.73      | 63.77      | 5.102      | 32.67     | 4.67      |
| T7         | 8.00       | 54.10           | 25.33       | 6.60          | 37.92       | 19.72      | 46.42      | 3.714      | 33.76     | 2.36      |
| T8         | 9.00       | 63.80           | 37.00       | 8.75          | 39.17       | 20.33      | 90.15      | 7.212      | 35.33     | 5.16      |
| T9         | 10.0       | 57.83           | 18.00       | 7.50          | 34.75       | 17.40      | 70.14      | 5.611      | 41.67     | 3.67      |
| T10        | 9.00       | 62.17           | 26.67       | 8.00          | 38.41       | 19.17      | 84.84      | 6.787      | 39.00     | 5.23      |
| LSD0.05    | 0.90       | 1.63            | 4.80        | 0.74          | 0.75        | 0.49       | 5.04       | 4.00       | 3.05      | 0.21      |

Table 4. Effect of vermicompost combined with different agricultural media on total chlorophyll and mineral content% of Grand Naine banana.

| Treatments | Total chlorophyll | Total Chlorophyll | N % | P % | K % | N % | P % | K % |
|------------|------------------|------------------|-----|-----|-----|-----|-----|-----|
|            | 12 weeks         | 24 weeks         | 12 weeks | 24 weeks | 12 weeks | 24 weeks | 12 weeks | 24 weeks | 12 weeks | 24 weeks | 12 weeks | 24 weeks |
| T1         | 31.33            | 21.0             | 2.25 | 0.21 | 3.15 | 2.24 | 0.22 | 3.14 |
| T2         | 23.27            | 23.0             | 2.25 | 0.20 | 3.34 | 2.24 | 0.21 | 3.33 |
| T3         | 35.90            | 27.0             | 2.56 | 0.23 | 3.45 | 2.55 | 0.24 | 3.44 |
| T4         | 30.77            | 26.95            | 2.30 | 0.24 | 3.23 | 2.30 | 0.25 | 3.24 |
| T5         | 27.83            | 22.60            | 2.63 | 0.25 | 3.55 | 2.62 | 0.26 | 3.54 |
| T6         | 33.33            | 24.85            | 2.31 | 0.12 | 3.27 | 2.32 | 0.13 | 3.28 |
| T7         | 26.23            | 33.05            | 2.52 | 0.17 | 3.41 | 2.53 | 0.17 | 3.42 |
| T8         | 30.57            | 33.10            | 2.48 | 0.14 | 3.38 | 2.49 | 0.14 | 3.39 |
| T9         | 25.17            | 31.70            | 2.51 | 0.21 | 3.41 | 2.52 | 0.21 | 3.42 |
| T10        | 30.47            | 39.45            | 2.61 | 0.22 | 3.50 | 2.62 | 0.23 | 3.51 |
| LSD0.05    | 2.57             | 6.33             | 0.01 | 0.008 | 0.04 | 0.01 | 0.008 | 0.04 |

Declarations

Author contribution statement

S.A.M. Hassan: Performed the experiments; Analyzed and interpreted the data.
Rania A. Taha, Nagwa S.M. Zaied: Conceived and designed the experiments; Wrote the paper.
Entsar M. Essa, Abd ElRheem Kh. M: Contributed reagents, materials, analysis tools or data.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.
Acknowledgements

Not applicable.

References

Ali, A., Sajid, A., Naveed, N.H., Majid, A., Saleem, A., Khan, U.A., Naz, S., 2011. Initiation, proliferation and development of micropropagation system for mass scale production of banana through meristem culture. Afr. J. Biotechnol. 10 (70), 15731–15738.

Atiyeh, R.M., Sablier, S., Edwards, C.A., Bachman, G., Metzger, J.D., Shuster, W., 2000. Effects of vermicomposts and composts on plant growth in horticultural container media and soil. Pedobiologia 44, 579–590.

Barik, T., Gulati, Garnayak, J.M.L., Bastia, D.K., 2011. Production of vermicompost from agricultural wastes- A Review. Agric. For. 31, 172–183.

Cottenie, A., 1980. Soil Management for Conservation and Production. New York, pp. 245–250.

Cottenie, A., Verloo, M., Kiekens, L., Velghe, G., Camerlynck, R., 1982. Chemical Analysis of Plant and Soil. Laboratory of Analytical and Agrochemistry, State Univ. Ghent. Belgium, pp. 100–129.

Duncan, D.B., 1955. Multiple range and multiple F-tests. Biometrics 11, 1–42.

Ebrahim, M., Souri, M.K., Moosavi, A., Sahebani, N., 2021. Biochar and vermicompost improve growth and physiological traits of eggplant (Solanum melongena L.) under deficit irrigation. Chemical and Biological Technologies in Agriculture 8 (1), 1–14.

Edwards, C.A., Burrows, I., 1988. The potential of earthworms composts as plant growth media. In: Edward, C.A., Neuhauser, E.F. (Eds.), Earthworms in Waste and Environmental Management. SPB Academic Publishing, The Hague, pp. 21–32.

Edwards, C.A., Arancón, N.Q., 2005. The use of earthworms in the breakdown of organic wastes to produce vermicomposts and animal feed protein. Earthworm Ecology 2, 345–380.

Gantait, S., Mandal, N., Bhattacharyya, S., Das, P.K., Nandy, S., 2009. Mass multiplication of Vanilla planifolia with pure genetic identity confirmed by ISSR. Int. J. Plant Dev. Biol. 3, 18–23.

Han, B.H., Goo, D.H., 2003. In vitro propagation of Anthurium andreanum ‘Atlanta’ developed for pot culture. Korean J. Plant Biotech. 2, 179–184.

Hassan, S.A.M., Taha, R.A., Mustafa, N.S., Nagwa, S.M. Zaied., 2021. Relation between culture medium, hormones combination and shoots proliferation of plum cv. ‘Santa Rosa’. Asian J. Plant Sci. 20 (1), 157–162.

Kashyap, S., Kapoor, N., Kale, R.D., 2017. Micropropogation using vermicompost, eluant and extracts of vermicompost in plant tissue culture media. Int. J. Adv. Res. Sci. Eng. 417–425.

Mahmud, M., Abdullah, R., Yasob, J.S., 2020. Effect of vermicompost on growth, plant nutrient uptake and bioactivity of ex vitro pineapple (Ananas comosus var. MD2). Agronomy 10 (9), 1233.

Markwell, J., Osterman, J.C., Mitchell, J.L.J.P., 1995. Calibration of the Minolta SPAD-502 leaf chlorophyll meter. Photosynth. Res. 46 (3), 467–472.

Martin, K.P., Joseph, D., Madassery, J., Philip, V.J., 2003. Direct shoot regeneration from lamina explants of two commercial cut flower cultivars of Anthurium andreanum Hort. vitro Cell Dev. Biol. Plant 39 (5), 500–504.

Motsara, M.R., Roy, R.N., 2008. Guide to Laboratory Establishment for Plant Nutrient Analysis. Food and Agriculture Organization of the United Nations FAO Fertilizer and Plant Nutrition Bulletin. Rome, p. 219.

Naiji, M., Souri, M.K., 2018. Nutritional value and mineral concentrations of sweet basil under organic compared to chemical fertilization. J. Hortorum Cultus 17 (2), 167175.

Najarian, A., Souri, M.K., 2020. Influence of sugar cane compost as potting media on vegetative growth, and some biochemical parameters of Pelargonium × hortorum. J. Plant Nutr. 43 (17), 2680–2684.

Ozdemir, S., Ozdemir, M., Yetilmezsoy, K., 2020. Effects of acclimatization soil prepared from hazelnut husk and gyttja on in vitro propagated ornamental plants. Propag. Ornam. Plants 20 (2), 63–71.

Purkhe, S., Megha, D., Ekta, N., Sveta, G., 2018. Study of different potting mixture on hardening of banana tissue culture plantlets: its field performance. Int. J. Curr. Microbiol. App. Sci. (Special Issue-6), 1941–1947.

Serri, F., Souri, M.K., Rezapunah, M., 2021. Growth, biochemical quality and antioxidant capacity of coriander leaves under organic and inorganic fertilization programs. Chemical and Biological Technologies in Agriculture 8 (1), 1–8.

Souri, M.K., Hatamian, M., 2019. Aminochelates in plant nutrition; a review. J. Plant Nutr. & Soil Science 182, 429–437.

Souri, M.K., Hatamian, M., 2019. Aminochelates in plant nutrition; a review. J. Plant Nutr. & Soil Science 182, 429–437.

Souri, M.K., Hatamian, M., 2019. Aminochelates in plant nutrition; a review. J. Plant Nutr. 42 (1), 67–78.

Suhane, R.K., 2007. Vermicompost. Publication of Rajendra Agriculture University, Pusa, Bihar, India, p. 88.

Taha, R.A., El-Nagdi, W.M.A., Kamel, H.A., 2020. Micropropagated banana plants induced by gamma irradiation and resistant to the root-knot nematode reproduction. Agric. Eng. Int.: CIGR J. 22 (2), 217–225.

Vasane, S.R., Kothari, R.M., 2006. Optimization of secondary hardening process of banana plantlets (Musa paradisiaca L. var. Grand Naine). Indian J. Biotechnol. 5, 394–395.