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Research Article:

Evaluation of spent button mushroom compost as a nursery potting material for betel (*Piper betle* L.)

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Abstract

Spent Button Mushroom Compost (SBMC), a nutrient-rich by-product of mushroom cultivation, has potential for agricultural use but remains largely underutilized. This study evaluated the suitability of SBMC as a component of nursery potting mixtures for betel (*Piper betle* L.) cultivation. The experiment was conducted at the Intercropping and Betel Research Station, Narammala. The Department of Export Agriculture (DEA) recommended potting mixture [T1: topsoil:sand:coir dust: cattle manure (1:1:1:1)] was used as the control. Four SBMC-incorporated potting mixtures were tested: T2 [SBMC:topsoil:coir dust: sand (1:1:1:1)], T3 [SBMC:topsoil:sand (1:1:1)], T4 [SBMC:topsoil:coir dust:sand:poultry manure (1:1:1:1:1)] and T5 [SBMC:topsoil:sand:poultry manure (1:1:1:1)]. The experiment was arranged in a Completely Randomized Design (CRD) with five replicates using single node 'Ratadalu' stem cuttings. The initial pH, electrical conductivity (EC), and nutrient composition (N, P and K) of the potting mixtures were analyzed. Growth parameters, including number of leaves, shoot length, shoot diameter, were recorded at two-week intervals, while fresh and dry weights of roots and shoots, and root volume were measured at the final harvest. Results revealed no significant differences between the SBMC incorporated media and the DEA recommended potting mixture for most growth parameters. Among the SBMC-based treatments, T3 did not differ significantly from the DEA-recommended potting mixture (T1) in number of leaves (T1 6.6±1.81, T3 6±1.41), shoot length (T1 37.60±7.16 cm, T3 29.84±7.12 cm), shoot diameter (T1 1.78±0.41 cm, T3 1.78±0.41 cm), root dry weight (T1 0.19±0.06 g plant^{-1}, T3 0.15±0.11 g plant^{-1}) and root volume (T1 2.49±0.78 cm^3, T3 2.19±1.7 cm^3). These findings suggest that T3 [SBMC:topsoil:sand (1:1:1)] is a promising SBMC-based potting mixture for betel nursery production under the tested conditions. However, further evaluation across different SBMC batches, growing seasons and production environments is required to validate these findings. The study also indicates the potential for incorporating SBMC into betel nursery potting mixtures and highlights the opportunity for productive utilization of mushroom cultivation residues.

Keywords: Betel; Growth parameters; Nursery potting mixture; Spent button mushroom compost

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1. Introduction

Betel (*Piper betle* L.) is a perennial climbing vine belonging to the family Piperaceae. Its leaves are the economically important component of the crop and are widely used for chewing, cultural and religious practices, and traditional medicinal applications (Arambewela et al., 2011; Guha, 2006). The crop thrives under warm and humid tropical conditions and grows best in fertile, well-drained soils with adequate moisture availability (Guha, 2006). In Sri Lanka, betel is cultivated for both domestic consumption and export, with commercial production of export-quality betel mainly concentrated in the Kurunegala, Gampaha, Kegalle, Kalutara, and Colombo districts. Pakistan remains a major export market for Sri Lankan betel leaves (Department of Export Agriculture, 2016). Among the locally cultivated betel types, 'Maneru' and 'Ratadalu' are widely grown for commercial purposes, while 'Narammali' and 'Naramrathi' have been released as improved varieties by the Department of Export Agriculture (Department of Export Agriculture, 2016).

Even though the climatic conditions of Sri Lanka are usually suitable for betel cultivation, the production of a healthy and vigorous nursery plant depends on the selection of suitable planting materials and growing media (Lakshi et al., 2021). Betel is mainly propagated by stem cuttings. To increase the success rate, cuttings should be taken from healthy, high-yielding mother plants (better to have bigger, thick, dark-green leaves), and should be supplied with optimum nutrients and organic matter needed. For a strong and healthy plant establishment, maintaining a healthy nursery stage is essential. Optimum amount of nutrients and organic matter should be supplied during this period, which is mainly given from the nursery potting media. Therefore, the growing media plays a vital role in improving the vegetative growth in betel stem cuttings (Usendi et al., 2022). The Department of Export Agriculture recommended potting media for betel nursery is a mixture of topsoil, sand, coir dust and cattle manure (1:1:1:1) (Department of Export Agriculture, 2016). However, the commercial use of this medium is often constrained by the limited availability and increasing cost of key components, particularly cattle manure and sand. In addition, variability in compost quality and the time required for compost production may affect the consistency and availability of potting media. An ideal nursery medium should provide good drainage, adequate nutrient availability, and a suitable pH for plant growth while remaining readily available and economically viable.

Spent button mushroom compost (SBMC) is an organic by-product remaining after the cultivation of button mushrooms (Agaricus bisporus). The growing medium used for button mushroom production generally consists of composted agricultural materials, mainly straw and animal manure, together with gypsum and other supplements, although its composition may vary depending on the production system (Noble et al., 2024). Unlike the sawdust-based substrates commonly used for oyster mushroom cultivation, button mushrooms are grown on a specially prepared composted medium (Thai et al., 2022). After mushroom harvesting, the remaining compost contains residual organic matter and plant nutrients, which may be beneficial for plant growth (Muchena et al., 2021; Mwangi et al., 2024). However, their suitability depends on the physical and chemical properties of the substrate, including nutrient availability, pH, electrical conductivity, and water-holding capacity (Medina et al., 2009). The reuse of this SBMC in agricultural production also provides a great opportunity for the sustainable utilization of waste by-products generated by the mushroom industry (Mwangi et al., 2024). Therefore, the present study aimed to evaluate the suitability of different SBMC-incorporated potting mixtures for betel nursery production by assessing their effects on plant growth parameters and comparing their performances with the Department of Export Agriculture (DEA) recommended potting mixture.

2. Materials and Methods

This study was conducted under a shade house at the Intercropping and Betel Research Station, Department of Export Agriculture, Dampalassa, Narammala, Sri Lanka, located at Low Country Intermediate Zone (IL1) of the country, from February to June 2022. The experiment was conducted using a Completely Randomized Design (CRD). A total of 15 betel cuttings were established for each treatment. At the beginning of the experiment, five cuttings per treatment were randomly selected and designated as experimental replicates for data collection and statistical analysis. Each replicate consisted of a single betel cutting planted in an individual polybag; therefore, each polybag was considered an experimental unit. Treatments were assigned randomly to the experimental units. The same replicate plants were used for growth measurements and were subsequently subjected to destructive sampling at the final harvest.

Five potting mixtures were used with different proportions of topsoil, coir dust, sand, cattle manure, poultry manure, and spent button mushroom compost (SBMC) as treatments. The spent button mushroom compost used in this study was obtained from Globle Green Agro (Pvt) Ltd in Narammala, Kurunegala, following the final harvest of button mushrooms (*Agaricus bisporus*). A single batch of SBMC was used for the experiment to ensure uniformity among treatments. The DEA-recommended potting mixture (Department of Export Agriculture, 2016) was used as the control (T1) treatment. (Table 1). Healthy, vigorous single nodal cuttings of the 'Ratadalu' betel (*Piper betle* L.) variety were selected for propagation. The basal cut ends of the cuttings were surface sterilized by dipping in a 0.2% (w/v) solution of Captan 50 WP (20 g of formulated product dissolved in 10 L of water) for five minutes to minimize fungal infections. The growing media components, including topsoil, spent button mushroom compost (SBMC), coir dust, sand, poultry manure, and cattle manure, were solarized separately by covering them with transparent polyethylene sheets and exposing them to direct sunlight for 14 days. Poultry manure, cattle manure and SBMC were used only after reaching maturity, as indicated by a dark brown colour, friable texture, earthy odour, and the absence of recognizable undecomposed materials. Following solarization, the media components were mixed according to the proportions presented in Table 1 and filled into black polyethylene bags (20.3 × 12.7 cm; 150 gauge) provided with drainage holes. The treated stem cuttings were planted in the labelled polybags and maintained in a sealed propagator for 21 days to promote rooting. Thereafter, the rooted cuttings were transferred to a shade house providing approximately 45% shade for further growth and establishment. Irrigation and other routine nursery management practices were carried out as required following standard betel nursery management procedures.

2.1. Evaluation of Physicochemical Parameters and Growth Parameters

Before planting, the chemical properties of each potting mixture were analysed at the Central Research Station, Matale, Department of Export Agriculture. The pH and electrical conductivity (EC) were determined using a glass-electrode pH meter and an EC meter using a 1:5 (w/v) medium-to-water extract. Total nitrogen (%) was determined using the Kjeldahl method (Bremner, 1960), and available phosphorus (ppm) was determined by the Olsen extraction method using 0.5 M $NaHCO_3$ (Olsen et al., 1954),

Table 1: Treatment combinations of potting mixtures and their proportions

Treatment	Treatment Combination	Proportion (V/V)
T1 (Control)	Topsoil, coir dust, sand, cattle manure	1:1:1:1
T2	SBMC, topsoil, coir dust, sand	1:1:1:1
T3	SBMC, topsoil, sand	1:1:1
T4	SBMC, topsoil, coir dust, sand and poultry manure	1:1:1: 1:1
T5	SBMC, topsoil, sand and poultry manure	1:1:1:1

and extractable potassium (ppm) by atomic absorption spectrophotometry following ammonium acetate extraction (Isaac and Kerber, 1971).

Growth assessments commenced immediately after the rooted cuttings were removed from the propagator following the 21-day propagation period. The first assessment was conducted at the 3rd week after planting, and subsequent measurements were recorded at two-week intervals until the 9th week after planting. The parameters measured were number of leaves per plant, shoot length (cm), and stem diameter (cm). At the 9th week after planting, destructive sampling was conducted to determine shoot fresh weight (g plant^{-1}), shoot dry weight (g plant^{-1}), root fresh weight (g plant^{-1}), root dry weight (g plant^{-1}), and root volume (cm^3). Root volume was measured using the water displacement method (Harrington et al., 1994) and expressed as cubic centimetres (cm^3).

2.2. Data Analysis

Data from each assessment week were analyzed separately using one-way analysis of variance (ANOVA) in Minitab 17 Statistical Software, with treatment considered as the fixed effect. Each treatment consisted of five replicates (n = 5), and each polybag containing a single betel cutting was considered an experimental unit. The ANOVA model had treatment degrees of freedom = 4 and error degrees of freedom = 20. Separate ANOVAs were performed to compare treatment effects within each assessment week and were not intended to evaluate growth trajectories over time. Destructive measurements recorded at the final harvest were analyzed using the same statistical procedure. When treatment effects were significant ($p < 0.05$), means were separated using Tukey's test at the 95% confidence level.

3. Results and Discussion

3.1 Physicochemical Parameters of Different Nursery Mixtures

A composite sample was prepared from each potting mixture and analyzed to characterize the initial chemical properties of the media. As a single composite sample was analyzed for each treatment, the results were used descriptively and were not subjected to statistical comparison. pH and Electrical Conductivity (EC) are important chemical properties influencing the suitability of nursery growing media. In the present study, the pH of the potting mixtures ranged from 5.88 to 7.84, while EC ranged from 0.12 to 0.65 dS m^{-1} (Table 2). These values fall within ranges generally reported for betel-growing environments (Guha, 2006; Herath, 2015). However, the suitability of a nursery medium cannot be determined based solely on pH or EC, as plant growth is also influenced by other physical and chemical properties, including nutrient availability, aeration, drainage, texture, and water-holding capacity. The relatively low EC values observed among the treatments suggest the absence of excessive soluble salt accumulation that could adversely affect the establishment of betel cuttings. Therefore, the pH and EC values reported in this study should be interpreted as part of the overall characteristics of the potting media under the tested conditions rather than as independent indicators of media suitability (Kalaivanan et al., 2019).

The highest nitrogen content (0.17%) was observed in treatments T3 and T4, while the lowest was in T2 (0.13%). Nitrogen is crucial for betel cultivation, especially since the green leaves are the economically important part of the plant. Continuous, limited nitrogen supply results in optimal leaf yield and quality (Herath, 2015). According to Basnayake et al. (2005), betel requires a high nitrogen supply.

Treatment T4 recorded the highest available phosphorus (P) content (0.02 ppm), while the other treatments showed 0.01 ppm. This indicates a comparatively higher available P content in the T4 potting mixture. However, the phosphorus availability depends on factors such as the chemical forms of P, pH, and the composition of the growing medium (Zhang et al., 2004). Previous studies have reported improved betel leaf yields with the application of phosphorus fertilizers together

with appropriate amounts of nitrogen and potassium, indicating the importance of balanced nutrient management in betel cultivation (Indian Council of Agricultural Research [ICAR], 2007). However, these findings are based on fertilizer applications under field conditions and cannot be directly compared with the P contents measured in nursery potting mixtures.

The highest reported extractable potassium (0.28 ppm) was observed in T3, while the lowest content (0.07 ppm) was recorded in T1. Potassium is an essential macronutrient involved in enzyme activation, osmoregulation, stomatal regulation, photosynthesis, and the translocation of assimilates within the plant (Wang et al., 2013). However, the present study did not evaluate the relationship between potassium content in the potting media and plant growth parameters. The potassium values reported in this study are presented primarily as characteristics of the potting media.

Table 2. Results of the physicochemical parameters of the different treatments before planting

Media	pH	EC (dS m^{-1})	Total N (%)	Available P (ppm)	Extractable K (ppm)
T1	6.65	0.12	0.14	0.01	0.07
T2	5.88	0.35	0.13	0.01	0.09
T3	6.37	0.35	0.17	0.01	0.28
T4	7.84	0.65	0.17	0.02	0.19
T5	7.71	0.62	0.14	0.01	0.18

3.2 Growth Performance of Nursery Betel Plants Grown in Different Potting Mixtures

The growth parameters of betel plants grown in different potting mixtures were assessed at weeks 3, 5, 7 and 9 after planting; Table 3 presents the results for weeks 5 and 9.

The highest mean leaf number was recorded in T1, followed by T3; however, the treatment effect was not statistically significant. As the leaves of this plant are the most economically important part, this parameter is relevant when determining an effective potting mixture for betel nursery production. Treatments T1 and T3 recorded the highest and second-highest mean shoot lengths, respectively, with no statistically significant difference between the two treatments ($p > 0.05$). Similarly, T1 recorded the highest shoot diameter at the fifth week after planting. However, by the ninth week, both T1 and T3 recorded the same mean shoot diameter, which was the highest among all treatments.

Table 3: Growth parameters of nursery betel plants at 5th and 9th week after planting

T	No. of leaves/plant		Shoot length (cm)		Shoot diameter (cm)	
	5th WAP	9th WAP	5th WAP	9th WAP	5th WAP	9th WAP
T1	2.6±0.55	6.6±1.81	12.14±1.75	37.60±7.16^{a}	1.44±0.25	1.78±0.41
T2	1.6±0.55	5.4±1.14	11.64±2.64	26.50±7.76^{ab}	1.30±0.12	1.44±0.08
T3	2±0.71	6±1.41	12.28±2.62	29.84±7.12^{ab}	1.38±0.19	1.78±0.41
T4	1.6±0.55	4.8±2.16	9.82±2.38	24.24±8.90^{ab}	1.34±0.17	1.80±0.30
T5	1.8±0.45	4.6±1.34	10.38±2.29	19.44±7.37^{b}	1.40±0.37	1.74±0.36
F value	2.69	1.32	1.08	3.89	0.26	0.99
P value	0.061	0.296	0.393	0.017	0.898	0.437

Values are presented as mean ± SD (n = 5). Means followed by different letters within a column are significantly different according to Tukey's HSD test at p< 0.05. Mean separation was performed only when the overall ANOVA was significant. T- treatments

No statistically significant difference ($p > 0.05$) was observed between T1 and T3 for shoot diameter. At the 9th week after planting, T1 recorded the highest mean shoot length (37.60 ± 7.16 cm), while T5 recorded the lowest mean value (19.44 ± 7.37 cm). Analysis of variance indicated a significant treatment effect on shoot length (F = 3.89, P = 0.017). According to Tukey's HSD test, T1 differed significantly from T5, whereas T2, T3, and T4 showed intermediate values and were not significantly different from either treatment. For shoot diameter, no significant treatment effects were detected at either the 5th week (F = 0.26, $p = 0.898$) or the 9th week after planting (F = 0.99, $p = 0.437$). These results indicate that T3 produced growth responses that were not statistically distinguishable from those of the DEA-recommended potting mixture (T1) for the measured parameters under the conditions of this study

The average values of shoot and root dry weights, as well as root volume, were recorded through destructive sampling at the ninth week after planting, following the completion of the nursery establishment period. The results are presented in Table 4.

Table 4: Shoot and root parameters of betel stem cuttings at destructive sampling at the 9th week after planting

Treatment	Shoot FW (g plant^{-1})	Shoot DW (g plant^{-1})	Root FW (g plant^{-1})	Root DW (g plant^{-1})	Root Volume (cm^3)
T1	14.93±4.85^{a}	1.19±0.41	2.77±0.81	0.19±0.06	2.49±0.78
T2	8.54±1.90^{b}	0.63±0.21	1.71±0.88	0.11±0.06	1.39±0.86
T3	10.46±3.99^{ab}	0.70±0.30	2.37±1.50	0.15±0.11	2.19±1.71
T4	8.48±2.70^{b}	0.50±0.36	1.79±1.17	0.09±0.06	1.60±1.19
T5	5.78±1.45^{b}	0.53±0.34	1.03±0.64	0.05±0.02	0.98±0.37
F value	5.49	2.62	2.02	2.78	1.57
p-value	0.004	0.066	0.130	0.055	0.222

Values are presented as mean ± SD (n = 5). Means followed by different letters within a column are significantly different according to Tukey's HSD test at P < 0.05. Mean separation was performed only when the overall ANOVA was significant

Treatment T1 recorded the highest mean shoot fresh weight (14.93 ± 4.85 g), followed by T3 (10.46 ± 3.99 g). Analysis of variance indicated a significant treatment effect on shoot fresh weight (F = 5.49, P = 0.004). According to Tukey's HSD test, T1 differed significantly from T2, T4 and T5, while T3 showed an intermediate response and was not significantly different from either T1 or the lower-performing treatments.

Although T1 recorded the highest mean shoot dry weight (1.19 ± 0.41 g), followed by T3 (0.70 ± 0.30 g), the treatment effect was not significant (F = 2.62, P = 0.066). Similarly, no significant treatment effects were observed for root fresh weight (F = 2.02, P = 0.130), root dry weight (F = 2.78, P = 0.055), or root volume (F = 1.57, P = 0.222). Therefore, while T1 and T3 generally recorded higher numerical mean values for these parameters, the present results do not provide sufficient statistical evidence to conclude that these treatments performed better than the other treatments for shoot dry weight, root fresh weight, root dry weight, or root volume under the conditions of this study.

The composition of the nursery potting medium plays an important role in the production of healthy and vigorous betel nursery plants. In the present study, the incorporation of spent button mushroom compost (SBMC) influenced the chemical properties of the potting media, particularly nutrient content, pH, and EC. Among the tested treatments, T3,

which contained SBMC, generally produced higher numerical values for several growth parameters compared with some of the other treatments. The favourable response observed in SBMC-containing media may be associated with the nutrient contribution and physical characteristics of the compost, including its potential effects on moisture retention and aeration, as reported in previous studies (Medina et al., 2009; Mwangi et al., 2024). However, plant growth is influenced by the combined effects of several physical and chemical properties of the growing medium rather than any single factor. Therefore, further studies are required to better understand the mechanisms underlying the observed responses.

Sand is commonly included in nursery potting mixtures to improve drainage and aeration within the root zone. These physical properties may contribute to favourable conditions for root growth and plant establishment. In contrast, coir dust is also used for potting mixtures, which would increase the water-holding capacity of the soil, also by giving good aeration conditions for the plant. The proportions of these components may influence the physical properties of the nursery medium. It was reported that coir dust has the ability to absorb optimum amounts of water and then release them to the soil slowly by maintaining the optimum moisture requirement which would result in higher growth performances in betel (Shantha et al., 2018).

Previous studies have reported that spent button mushroom compost (SBMC) can be used as a component of growing media for horticultural crops. Collela et al. (2019) evaluated spent *Agaricus bisporus* substrate for tomato seedling production and reported satisfactory seedling growth compared with commercial growing media. Similarly, Medina et al. (2009) found that spent mushroom substrate particularly *Agaricus bisporus* could be incorporated into nursery growing media for tomato, pepper, and courgette seedlings. However, the incorporation of spent mushroom substrates was generally associated with increased pH, electrical conductivity, and nutrient concentrations, while reducing water holding capacity compared with peat-based growing media. More recently, da Silva Alves et al. (2024) reported that composted spent white button mushroom substrate could be used for cherry tomato seedling production without significant differences in seedling growth compared with the peat-based control. However, the use of fresh spent substrate was limited by its high salinity. These findings indicate that the suitability of SBMC as a nursery growing medium component depends on its nutrient content, pH, salinity, and physical properties, including porosity and water-holding capacity.

In the present study, the T3 potting mixture, consisting of spent button mushroom compost, topsoil, and sand at a 1:1:1 ratio, showed comparatively better growth performance among the SBMC-incorporated treatments. No statistically significant differences were observed between the SBMC-incorporated potting mixture (T3) and the DEA-recommended potting mixture (T1) in terms of shoot and root fresh weights, shoot and root dry weights, and root volume ($P > 0.05$). The comparatively good growth performance observed in T3 may be associated with the nutrient supply and favorable physicochemical properties of the potting mixture, as suggested by previous studies (Medina et al., 2009; Collela et al., 2019). However, the effects of individual factors, particularly porosity and water-holding capacity, were not directly evaluated in the present study. These findings indicate that the T3 potting mixture supported betel nursery growth responses that were not statistically distinguishable from those observed in the DEA-recommended potting mixture under the conditions of this study. In addition, the use of SBMC in nursery media may provide opportunities for the utilization of mushroom cultivation residues; however, its economic feasibility, environmental implications, and suitability for commercial-scale nursery production require further investigation.

4. Conclusions

In conclusion, the findings of this study indicate that spent button mushroom compost (SBMC) has potential as a component of nursery potting mixtures for betel (*P. betle*

L.). Among the SBMC-incorporated treatments, the T3 mixture generally produced the most favourable growth responses among the SBMC-containing media under the conditions of this study. Although the DEA-recommended potting mixture (T1) recorded higher numerical values for several growth parameters, the pairwise comparisons did not detect significant differences between T1 and T3 for the reported biomass and root traits; this does not establish equivalence. These findings suggest that T3 [SBMC: topsoil: sand (1:1:1)] is a promising SBMC-based potting mixture for betel nursery production under the tested conditions. However, additional studies across different growing seasons, locations, and SBMC batches are required to validate these findings, as the physicochemical properties of SBMC may vary depending on its source and composition. Further studies with increased replication are also recommended to strengthen the reliability of the findings. Further research is needed to evaluate the economic feasibility and practical applicability of SBMC-based nursery media under commercial production conditions.

Author contributions

W.V.D. Wansekara: methodology, data curation, formal analysis, writing – original draft, D.M.P.V. Dissanayaka: conceptualization, methodology, supervision, writing – review & editing. G.P.A.N. Weerasuriya: data analysis, writing – original draft. U.G.A.T Premathilake: conceptualization, methodology, supervision, writing – review & editing.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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Data availability

The data are available from the corresponding author upon reasonable request.

References

Arambewela, L. S., Arawwawala, L. D., Kumaratunga, K. G., Dissanayake, D. S., Ratnasooriya, W. D., & Kumarasingha, S. P. (2011). Investigations on Piper betle grown in Sri Lanka. Pharmacognosy Reviews, 5(10), 159–163. https://doi.org/10.4103/0973-7847.91111

Basnayake, B. M. S., Fernandopulle, M. N. D., & Sumanasena, H. A. (2005). Effect of type of fertilizer on growth and yield of betel (*Piper betle* L.) vines. In Proceedings of the 5th Agricultural Research Symposium (Part II, pp. 67–69). Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka.

Bremner, J. M. (1960). Determination of nitrogen in soil by the Kjeldahl method. The Journal of Agricultural Science, 55(1), 11–33. https://doi.org/10.1017/S0021859600021572

Collela, C. F., Costa, L. M. A. S., de Moraes, T. S. J., Zied, D. C., Rinker, D. L., & Dias, E. S. (2019). Potential utilization of spent *Agaricus bisporus* mushroom substrate for seedling production and organic fertilizer in tomato cultivation. Ciência e Agrotecnologia, 43, e017119. https://doi.org/10.1590/1413-7054201943017 119

da Silva Alves, L., Tolardo, G., Caitano, C. E. C., Vieira Júnior, W. G., Gomes Freitas, P. N., & Cunha Zied, D. (2024). Use of spent mushroom substrate for cherry tomato seedlings; a potential alternative to peat in horticulture. Biological Agriculture & Horticulture, 40(2), 127–140. https://doi.org/10.1080/01448765.2024.2308301

Department of Export Agriculture. (2016). බුලත් වගාව සහ අස්වනු සැකසීම [Betel cultivation and post-harvest processing].

Guha, P. (2006). Betel leaf: The neglected green gold of India. Journal of Human Ecology, 19(2), 87–93. https://doi.org/10.1080/09709274.2006.11905861

Harrington, J. T., Mexal, J. G., & Fisher, J. T. (1994). Volume displacement provides a quick and accurate way to quantify new root production. Tree Planters' Notes, 45(4), 121–124. https://rngr.net/publications/tpn/45-4/volume-displacement-provides-a-quick-and-accurate-way-to-quantify-new-root-production

Herath, H. M. J. K. (2015). Production and marketing of betel (Research Report No. 189). Hector Kobbekaduwa Agrarian Research and Training Institute. https://www.harti.gov.lk/assets/pdf/publications/1/report_189.pdf

Indian Council of Agricultural Research. (2007). DARE/ICAR annual report 2006–2007. https://icar.org.in/sites/default/files/inline-files/Horticulture-02.pdf

Isaac, R. A., & Kerber, J. D. (1971). Atomic absorption and flame photometry: Techniques and uses in soil, plant, and water analysis. In L. M. Walsh (Ed.), Instrumental methods for analysis of soils and plant tissue (pp. 17–37). Soil Science Society of America. https://doi.org/10.2136/1971.instrumentalmethods.c2

Kalaivanan, D., Ramesh, P. R., & Suryanarayana, M. A. (2019). Assessment of soil fertility status in major betel vine growing soils of Tumkur District of Southern Karnataka for sustainable production. International Journal of Current Microbiology and Applied Sciences, 8(10), 1751–1765. https://doi.org/10.20546/ijcmas.2019.810.204

Lakshi, M., Vithusan, K., Chandrasiri, W. K. S., Perera, R. G. J., & Kirthisinghe, J. P. (2021). Impact of potting mixture and size of cutting on propagation of betel (*Piper betle* L.). In Proceedings of the International Conference on Applied and Pure Sciences 2021 (Vol. 1, p. 108). Faculty of Science, University of Kelaniya.https://conf.kln.ac.lk/icaps/images/res/docs/ProceedingsICAPS2021.pdf

Medina, E., Paredes, C., Pérez-Murcia, M. D., Bustamante, M. A., & Moral, R. (2009). Spent mushroom substrates as component of growing media for germination and growth of horticultural plants. Bioresource Technology, 100(18), 4227–4232. https://doi.org/10.1016/j.biortech.2009.03.055

Muchena, F. B., Pisa, C., Mutetwa, M., Govera, C., & Ngezimana, W. (2021). Effect of spent button mushroom substrate on yield and quality of baby spinach (*Spinacia oleracea*). International Journal of Agronomy, 2021, Article 6671647. https://doi.org/10.1155/2021/6671647

Mwangi, R. W., Mustafa, M., Kappel, N., Csambalik, L., & Szabó, A. (2024). Practical applications of spent mushroom compost in cultivation and disease control of selected vegetables species. Journal of Material Cycles and Waste Management, 26, 1918–1933. https://doi.org/10.1007/s10163-024-01969-9

Noble, R., Thai, M., & Kertesz, M. A. (2024). Nitrogen balance and supply in Australasian mushroom composts. Applied Microbiology and Biotechnology, 108, Article 151. https://doi.org/10.1007/s00253-023-12933-2

Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L. A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate (USDA Circular No. 939). U.S. Department of Agriculture.

Shantha, K. G. P., Samaraweera, D. N., Silva, S. I. C., & Chandrarathna, W. M. (2018). Evaluation of different potting mixtures for nursery production of betel (*Piper betle* L.) stem cuttings. In B. Marambe (Ed.), Proceedings of the Annual Symposium on Export Agricultural Crops (Vol. 5, pp. 28–35). Department of Export Agriculture.

Thai, M., Safianowicz, K., Bell, T. L., & Kertesz, M. A. (2022). Dynamics of microbial community and enzyme activities during preparation of Agaricus bisporus compost substrate. ISME Communications, 2, Article 88. https://doi.org/10.1038/s43705-022-00174-9

Usendi, P., Asati, B. S., & Sahu, T. L. (2022). Effect of different growing media on vegetative propagation in betel vine (*Piper betle* L.). The Pharma Innovation Journal, 11(1), 84–89. https://www.thepharmajournal.com/archives/2022/vol11issue1/PartB/10-12-272-767.pdf

Wang, M., Zheng, Q., Shen, Q., & Guo, S. (2013). The critical role of potassium in plant stress response. International Journal of Molecular Sciences, 14(4), 7370–7390. https://doi.org/10.3390/ijms14047370

Zhang, M. K., He, Z. L., Stoffella, P. J., Calvert, D. V., Yang, X. E., Xia, Y. P., & Wilson, S. B. (2004). Solubility of phosphorus and heavy metals in potting media amended with yard waste–biosolids compost. Journal of Environmental Quality, 33(1), 373–379. https://doi.org/10.2134/jeq2004.3730