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UTILIZATION OF SPENT MUSHROOM WASTE AND PEAT AS SOILLESS GROWING MEDIUM FOR Brassica oleracea var. Alboglabra

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By

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Peat moss (PM) is the most widely used growing substrate for the pot culture. Due to diminishing availability and increasing price of PM, researchers are looking for viable alternatives for peat as a growth media component for potted plants. A pot study was conducted with a view to investigate the possibility of using spent mushroom waste (SMW) for kailan (*Brassica oleracea* var. Alboglabra) production replacing PM in growth media. The treatments evaluated were 100% SMW, 100% PM, and mixtures of SMW and PM in different ratios like 1:1, 1:2 and 2:1 (v/v) with or without NPK amendment. The experiment was arranged in a completely randomized design (CRD) with five replications per treatment. Chemical properties like pH and salinity level (EC) of SMW were within the acceptable range of crop production but, nutrient content, especially nitrogen content was not enough to provide sufficient nutrition to plant for normal growth. Only PM (100%) and SMW and PM mixture in 1:2 ratio with NPK amendment performed equally in terms of kailan growth. This study confirms the feasibility of replacing PM by SMW up to maximum 50% in the growth media, and suggests NPK supplementation from inorganic sources to ensure higher productivity of kailan.

Further testing was conducted to study the effects of various rates of SMW with virgin peat (VP) and non-virgin peat (NVP) at different location on the growth and yield of kailan. The peat sampling for VP and NVP was collected at Malaysian Agricultural Research and Development Institute (MARDI), Pontian Johor. The treatments evaluated were 100% SMW, 100% VP, 100% NVP and mixtures of SMW and VP or NVP in different ratios like 1:1, 1:2 and 2:1 (v/v) with NPK amendment. The experiment was arranged in a completely randomized design (CRD) with five replications per treatment. Result was obtained from peat soil in Peninsular Malaysia (Johor) indicated that no significant differences occurred between treatments that contained the portion of SMW with VP and SMW with NVP when amended with NPK. Plant height, leaf number, leaf fresh weights, leaf dry weight, total leaf area and chlorophyll content increased significantly when kailan were planted with amended NPK especially on NVP. The media with 100%

NVP also showed a better plant growth because of the existing of fertilizer in the soil which is came from previous agriculture activities.

For experiment three, the peat sampling was collected at Malaysian Agricultural Research and Development Institute (MARDI), Saratok Sarawak. Result obtained from observation in Sarawak also showed the media with amended NPK, fertilized soilless, there is not much differences among VP and NVP. This is due to the pH reading for all treatments gave almost similar result in between pH 3.63 to pH 5.04.

Plants grown in soilless media that contained portions of SMW and NVP gave better result compared to plants grown in media that contained SMW and VP. Further studies should be conducted under various conditions with plant species or other horticultural crops. Since imported PM is expensive and not economical to use as part of the soilless media, more studies need to be done to determine the modifications on soil fertility, and fertilizer requirements should be taken into account to enable SMW and peat compound to become a soilless media.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains Pertanian

PENGGUNAAN SISA BUANGAN CENDAWAN DAN GAMBUT SEBAGAI MEDIA PERTUMBUHAN KURANG TANAH UNTUK *Brassica oleracea* var. Alboglabra

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Peat moss (PM) adalah media tanaman yang paling meluas digunakan untuk kultur pot. Disebabkan ketersediaan pengurangan dan kenaikan harga PM, para penyelidik melihat gambut sebagai alternatif media pertumbuhan bagi tanaman berpasu. Kajian ini dilaksanakan untuk menilai kemungkinan menggunakan bahan buangan cendawan (SMW) untuk pengeluaran kailan (*Brassica oleracea* var. Alboglabra) menggantikan PM dalam media tanaman. Rawatan yang telah dibuat adalah 100% SMW, 100% PM pada nisbah berbeza seperti 1:1, 1:2, 2:1 dengan pengubahan NPK. Rekabentuk kajian yang digunakan ialah rekabentuk penuh rawak lengkap (CRD) dengan lima replikasi setiap rawatan. Sifat kimia seperti pH dan tahap kemasinan bahan buangan cendawan adalah di dalam lingkungan yang boleh diterima untuk pengeluaran tanaman tetapi kandungan nutrien khasnya kandungan nitrogen adalah tidak mencukupi untuk dijadikan zat makanan supaya tanaman ini tumbuh dalam keadaan biasa. Hanya PM (100%) dan campuran SMW dan PM pada nisbah 1:2 dengan NPK menunjukkan pertumbuhan sebenar kailan. Kajian ini mengesahkan SMW dapat menggantikan PM sehingga 50% dalam media tanaman dan mencadangkan gantian NPK dari sumber bukan organik untuk memastikan produktiviti kailan meningkat.

Kajian selanjutnya dijalankan untuk menilai keberkesanan kepelbagaian kadar SMW dengan tanah gambut dara (VP) dan bukan tanah gambut dara (NVP) di kawasan yang berbeza terhadap pertumbuhan dan hasilan kailan. Persampelan gambut untuk VP dan NVP telah diambil di Institut Penyelidikan dan Kemajuan Pertanian Malaysia (MARDI), Pontian Johor. Rawatan yang telah dinilai adalah 100% SMW, 100% VP dan 100% NVP pada nisbah berbeza seperti 1:1, 1:2, 2:1 dengan pengubahan NPK. Rekabentuk kajian yang digunakan ialah rekabentuk penuh rawak lengkap (CRD) dengan lima replikasi setiap kawatan. Keputusan yang diperolehi di Semenanjung Malaysia (Johor) menunjukkan perbezaan yang tidak ketara pada rawatan yang mengandungi SMW dengan VP dan SMW dengan NVP apabila adanya pengubahan NPK. Ketinggian tanaman, jumlah bilangan daun, berat basah pucuk, berat kering pucuk, jumlah keluasan daun dan

kandungan klorofil meningkat dengan ketara apabila di tanam dengan campuran baja NPK terutamanya pada media NVP. Media yang mengandungi 100% NVP juga menunjukkan pertumbuhan tanaman yang lebih baik berbanding dengan rawatan kawalan disebabkan oleh kewujudan baja di dalam kandungan tanah yang terhasil daripada aktiviti pertanian sebelum ini.

Untuk kajian ketiga, persampelan gambut untuk VP dan NVP telah diambil di Institut Penyelidikan dan Kemajuan Pertanian Malaysia (MARDI), Saratok Sarawak. Keputusan yang diperolehi daripada pemerhatian di Sarawak menunjukkan media yang dibaja NPK, ianya tidak menunjukkan perbezaan yang ketara di antara VP dan NVP. Ini berikutan bacaan pH tanah untuk kesemua rawatan memberikan keputusan yang hampir sama di antara pH 3.63 hinga pH 5.04.

Pertumbuhan pokok dalam media kurang tanah yang mengandungi SMW dan NVP memberikan keputusan yang baik berbanding dengan tanaman pada media yang mengandungi SMW dan VP. Kajian pada masa akan datang haruslah dibuat dengan mengambil kira pelbagai keadaan dengan spesis tanaman atau tanaman hortikultur yang lain. Memandangkan PM import adalah mahal dan tidak ekonomi untuk digunakan sebagai sebahagian daripada media kurang tanah, kajian lanjut haruslah dibuat untuk menentukan pengubahsuaian pada kesuburan tanah, dan keperluan pembajaan perlulah di ambil kira untuk membolehkan SMW dan kandungan gambut boleh menjadi media kurang tanah.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Agricultural Science. The members of the Supervisory Committee were as follows:

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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5.3 Effect of different ratios of spent mushroom waste (SMW) mixed with virgin peat (VP) or non-virgin peat (NVP) with NPK amended on plant height of *Brassica alboglabra* at 5 weeks after transplanting (WAT). Means with the same letter are not significantly different ($p<0.05$) according to least significant different (LSD) test. T_1=100% SMW; T_2=100% VP; T_3=100% NVP; T_4=1(SMW):1(VP) + NPK; T_5=1(SMW):1(NVP) + NPK; T_6=1(SMW):2(VP) + NPK; T_7=1(SMW):2(NVP) + NPK; T_8=2(SMW):1(VP) + NPK; T_9=2(SMW):1(NVP) + NPK. 56

5.4 Effect of different ratios of spent mushroom waste (SMW) mixed with virgin peat (VP) or non-virgin peat (NVP) with NPK amended on number of leaves of *Brassica alboglabra* at 5 weeks after transplanting (WAT). Means with the same letter are not significantly different ($p<0.05$) according to least significant different (LSD) test. T_1=100% SMW; T_2=100% VP; T_3=100% NVP; T_4=1(SMW):1(VP) + NPK; T_5=1(SMW):1(NVP) + NPK; T_6=1(SMW):2(VP) + NPK; T_7=1(SMW):2(NVP) + NPK; T_8=2(SMW):1(VP) + NPK; T_9=2(SMW):1(NVP) + NPK. 57

5.5 Effect of different ratios of spent mushroom waste (SMW) mixed with virgin peat (VP) or non-virgin peat (NVP) with NPK amended on shoot fresh weight of *Brassica alboglabra* at 5 weeks after transplanting (WAT). Means with the same letter are not significantly different ($p<0.05$) according to least significant different (LSD) test. T_1=100% SMW; T_2=100% VP; T_3=100% NVP; T_4=1(SMW):1(VP) + NPK; T_5=1(SMW):1(NVP) + NPK; T_6=1(SMW):2(VP) + NPK; T_7=1(SMW):2(NVP) + NPK; T_8=2(SMW):1(VP) + NPK; T_9=2(SMW):1(NVP) + NPK. 58

5.6 Effect of different ratios of spent mushroom waste (SMW) mixed with virgin peat (VP) or non-virgin peat (NVP) with NPK amended on shoot dry weight of *Brassica alboglabra* at 5 weeks after transplanting (WAT). Means with the same letter are not significantly different ($p<0.05$) according to least significant different (LSD) test. T_1=100% SMW; T_2=100% VP; T_3=100% NVP; T_4=1(SMW):1(VP) + NPK; T_5=1(SMW):1(NVP) + NPK; T_6=1(SMW):2(VP) + NPK; T_7=1(SMW):2(NVP) + NPK; T_8=2(SMW):1(VP) + NPK; T_9=2(SMW):1(NVP) + NPK. 59

5.7 Effect of different ratios of spent mushroom waste (SMW) mixed with virgin peat (VP) or non-virgin peat (NVP) with NPK amended on root length of *Brassica alboglabra* at 5 weeks after transplanting (WAT). Means with the same letter are not significantly different ($p<0.05$) according to least significant different (LSD) test. T_1=100% SMW; T_2=100% VP; T_3=100% NVP; T_4=1(SMW):1(VP) + NPK; T_5=1(SMW):1(NVP) + NPK; T_6=1(SMW):2(VP) + NPK; T_7=1(SMW):2(NVP) + NPK; T_8=2(SMW):1(VP) + NPK; T_9=2(SMW):1(NVP) + NPK. 60

5.8 Effect of different ratios of spent mushroom waste (SMW) mixed with virgin peat (VP) or non-virgin peat (NVP) with NPK amended on total leaf area of *Brassica alboglabra* at 5 weeks after transplanting (WAT). Means with the same letter are not significantly different ($p<0.05$) according to least significant different (LSD) test. T_1=100% SMW; T_2=100% VP; T_3=100% NVP; T_4=1(SMW):1(VP) + NPK; T_5=1(SMW):1(NVP) + NPK; T_6=1(SMW):2(VP) + NPK; T_7=1(SMW):2(NVP) + NPK; T_8=2(SMW):1(VP) + NPK; T_9=2(SMW):1(NVP) + NPK. 61

5.9 Effect of different ratios of spent mushroom waste (SMW) mixed with virgin peat (VP) or non-virgin peat (NVP) with NPK amended on chlorophyll contents of *Brassica alboglabra* at 5 weeks after transplanting (WAT). Means with the same letter are not significantly different ($p<0.05$) according to least significant different (LSD) test. T_1=100% SMW; T_2=100% VP; T_3=100% NVP; T_4=1(SMW):1(VP) + NPK; T_5=1(SMW):1(NVP) + NPK; T_6=1(SMW):2(VP) + NPK; T_7=1(SMW):2(NVP) + NPK; T_8=2(SMW):1(VP) + NPK; T_9=2(SMW):1(NVP) + NPK. 62

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
CRD	Completely randomized design
EC	Electrical conductivity
LSD	Least significant difference
NAP	National agrofood policy
NVP	Non-virgin peat
PM	Peat moss
SMC	Spent mushroom compost
SMS	Spent mushroom substrate
SMW	Spent mushroom waste
VP	Virgin peat
WAT	Week after transplanting

CHAPTER 1

INTRODUCTION

Mushroom cultivation is a profitable agribusiness. In 2007, global mushroom production amounted to 3.4 million tons (USITC, 2010). China, European Union and the United States were the largest global producers of mushrooms. Other important global producers in year 2007 included Canada, Japan, India, Australia and Indonesia. Global mushroom consumption amounted to 3.3 million tons and China, the European Union and the United States were the leading consumers of mushrooms. Other major consumers included Canada, Japan, Russia, Australia and India. All consumption in China, European Union and India was supplied from domestic production. Global exports of canned mushrooms amounted to 458 thousand tons with China accounting for 87% of total volume in 2008. However, global imports of canned mushroom amounted to 292 thousand tons with the United States and Russia accounting for the largest of total import volume in 2008 (USITC, 2010). For the global exports of fresh mushroom, Canada and the United States were the largest global exporters in 2008 together accounting almost 80% of the total volume. Other major exporters of fresh mushrooms in 2008 included Malaysia and Mexico. For the global imports of fresh mushroom, Russia and the United States together were the most important global import markets (USITC, 2010).

In Malaysia, the cultivation technique of the mushroom has been introduced into Malaysia from Canton and has been grown at Penang since 1934 (Baker, 1934). In 2008, there were 436 mushroom growers in Malaysia (Khairul *et al.*, 2012). In year 2007, total import for mushroom is 16,243 tonnes with a value of RM 50.40 million compared to total quantity of exported mushroom which was only 3,506 tonnes with a value of RM 25.1 million (DOSM, 2005). Among the types of mushrooms grown in Malaysia, grey oyster mushroom (*Pleurotus sojar-caju*) is widely cultivated. Oyster mushroom is harvested four to seven times from each production cycle. Normally, at the end of the mushroom fruiting cycle, “spent” (used) mushroom substrate is left abandoned or discarded (Danny and Seung, 2004). If not properly handled, these spent substrates may eventually cause environmental hazard.

Worldwide, mushrooms are produced on natural materials obtained from agriculture, woodlands, animal husbandry and manufacturing industries. Some of these wastes include banana leaves, peanut hull and corn leaves, mango fruits and seeds, sugarcane leaves, wheat and rice straw (Cangy and Peerally, 1995). The widely used substrate for cultivation of the oyster mushroom in Asia is rice straw (Thomas *et al.*, 1998). Rice straw considered as the best substrate in terms of yield and protein content of mushroom. In Europe, wheat straw is used as a growing medium for mushroom, while in the South East Asian countries sawdust is more common. Adding of soil, peat moss or both components to the media will increase the nutrient contents. Hence, growth of plants in media that was formulated with peat, soil or both amended with fertilizers is better than without amendment.

In recent years, plant growing in a soilless culture has a great importance worldwide. Lohr *et al*. (1984) and Maher (1991) reported that spent mushroom waste (SMW) also was used as plant growing medium. Mixtures of SMW with high quality growing medium such as peat, vermiculite and bark were given a significant result than used alone in studies on SMW (Calvin *et al.*, 1994). SMW from *Agaricus bisporus* production is used in horticulture as a component of potting soil mixes, soil amendment to improve turf-grass, in wetlands for remediation of contaminated water, in stabilizing severely disturbed soils, as bedding for animals and to control plant diseases (Danny, 2002). SMW from *Agaricus bisporus* has found acceptance as feed or animals, ingredients in the cultivation of other mushroom species, fuel, medium for vermiculture, in agriculture or landscape to enrich soils and as a matrix for bio-remediation of contaminated soils (Danny, 2002).

Shi *et al*. (2008) reported that the electronic conductivity value of SMW is high but low for peat. Thus, the pH value of SMW can be lowered by mixing with peat. If SMW is used in proper proportion, it can act as peat substitute in soilless culture (Shi *et al*., 2008). According to Wang *et al*. (1984) increased plant growth and yield were obtained with the addition of 20 to 30% of SMW with sandy loam. However, vegetables grown at 50% of SMW with sandy loam exhibited some stunting effect.

In Europe, farmers are using SMW, supplemented with other materials to cultivate plants but, in Malaysia there are not much scientific research done to use it in combination with other agricultural by-products. Study on the use of SMW as a part of soilless media is still scarce in Malaysia, thus this study was deemed necessary. This study was undertaken with an ultimate aim to determine the effects of SMW alone and in combination with peat moss (PM) and peat on growth and quality of kailan, *Brassica oleracea* var. Alboglabra. This variety is a popular variety, easy to grow and contain high nutritional value. The specific objectives were:

i. To evaluate the effects of spent mushroom waste and different ratios of spent mushroom waste and peat moss with and without fertilizer on growth and yield of *Brassica oleracea* var. Alboglabra at an open field.

ii. To evaluate the effects of different ratios of spent mushroom waste, virgin peat and non-virgin peat in soilless media on growth and yield of *Brassica oleracea* var. Alboglabra at an open field.

iii. To evaluate the effects of different ratios of spent mushroom waste, virgin peat and non-virgin peat in soilless media on growth and yield of *Brassica oleracea* var. Alboglabra at Sarawak, East Malaysia under netted structure.

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