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# Effects of substrates on growth and yield of ginger cultivated using soilless culture

(Kesan substrat terhadap pertumbuhan dan hasil halia yang ditanam menggunakan kultur tanpa tanah)

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Keywords: ginger, fertigation system, soilless substrate, coir dust, burnt paddy husks

**Abstract**

The effects of soilless substrates on growth and yield of ginger were studied. The main objective of the study was to determine the most suitable growth substrate for cultivation of ginger using fertigation technique. The study was conducted under the side-netted rain shelter equipped with an irrigation system to supply fertiliser solution at a regulated time schedule. Five combinations of growth substrates were evaluated: 100% coir dust; 100% burnt paddy husks; 70% coir dust + 30% burnt paddy husks; 30% coir dust + 70% burnt paddy husks; and 50% coir dust + 50% burnt paddy husks. The ginger plants were selected randomly and the rhizomes were harvested 3 – 9 months after sowing. Plants grown in 100% coir dust gave the best growth performance and yield compared to the other treatments. They produced the highest shoot height (123 ± 23 cm), shoot fresh weight (1,340 ± 235 g) and rhizome yield (5,480 ± 325 g per plant). The lowest rhizome yield (2,570 ± 135 g) was obtained from plants planted in 30% coir dust + 70% burnt paddy husks. Hence, it can be concluded that the ginger plants cultivated in 100% coir dust substrate using fertigation technique gave the best plant growth and yields.

## Introduction

Fertigation technology is normally applied in soilless culture production system. Yields of chillies, rock melons and tomatoes cultivated in soilless system increased 3 – 5 times compared to those using conventional method (Verdonck et al. 1983; De Rijck and Schrevens 1998). In soilless production system, many types of growing media or substrates such as rockwool, perlite, vermiculite and peat have been used to grow many kinds of crops (Raja Harun et al. 1991; Jarvis 1992; Böhme 1995; Komada et al. 1997).

Media such as rockwool, perlite and vermiculite are expensive because they have to be imported. Hence, alternative substrates that are cheaper and locally available such as coconut fibres and burnt paddy husks should be used as alternative media (Ortega et al. 1996).

One of the most important factors influencing plant fertility, besides water and nutrient content, is soil aeration (Glinski and Stepniewski 1985; Hillel 1998). Different plant species have different rooting systems which enable them to grow under different oxygen requirement (Laan et al. 1987).

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Several studies have been conducted to analyse the physical properties of growth media including available water capacity (AWC) and air-filled porosity (AFP) (De Boodt and Verdonck 1972; Verdonck et al. 1973; Prasad 1979; Abad et al. 2001).

AWC indicates the water content of substrates and AFP gives the estimation of oxygen availability or level of aeration in the substrates (Wall and Heiskenen 2003). According to Humara et al. (2002), high water content in the growing substrates can reduce both AFP and aeration, which can lead to logging and hypoxia which are detrimental to most plant species. Sufficient amount of water in growing substrates is one of the most critical factors for plant growth and development (Beardsell et al. 1979).

Ginger (*Zingiber officinale* Rosc.) belongs to a tropical and sub-tropical *Zingiberaceae* family, which originated from Southeast Asia. This perennial plant with thick tuberous pungent aromatic roots or rhizomes has been cultivated for thousands of years for use as a spice and for herbal medicinal purposes (Park and Pizzuto 2002; Guo and Zhang 2005; Akram et al. 2011). In Malaysia, ginger is cultivated commercially in Bentong, Pahang; Banting, Selangor; Pontian, Johor; Keningau and Tambunan, Sabah; and Bakun, Sarawak. The main ginger varieties cultivated are Bentong, Bara, China and Indonesia.

Domestic demand for ginger is high. Ginger can be harvested as young ginger (3 – 4 months) or mature ginger (8 – 9 months). In Malaysia, ginger is cultivated using shifting cultivation technique. This is done to avoid infertile soil problems and soil-borne diseases caused by *Fusarium oxysporum* and *Pseudomonas solanacearum* that can infect plant roots and also to avoid leaf spot disease (Burrage 1992; Whipps 1992).

Shifting cultivation practice in Malaysia has caused land corrosion mainly in the highlands and it takes 6 years to overcome the soil infertility problem before replanting can be done. Therefore, cultivating ginger using soilless culture system could be an alternative method to overcome this problem as well as the soil-borne diseases.

There is potential to increase the growth and yield of ginger rhizomes using soilless system based on significant increase in yields of chillies, rock melons, tomatoes, and other leafy and fruity vegetables grown on various media (Verdonck et al. 1983; De Rijck and Schrevens 1998). Thus, this study was conducted to determine the effects of soilless substrates such as coir dust and burnt paddy husks on growth and yield of ginger. The main objective was to determine the optimum growth substrate for ginger cultivation using fertigation technique.

## Materials and methods

### *Plant materials*

Bentong ginger was selected and used in this study. This variety is easy to grow with proper cultural, insect and disease management practices. The plants have bigger rhizomes than Tanjong Sepat, Chinese and Indonesian gingers. The rhizomes are pale in colour and low in fibre. The ginger is vegetatively propagated through rhizomes and the shoot appears 1 – 2 weeks after sowing. Prior to sowing, 10-month-old ginger rhizomes were bought from a ginger plantation in Bentong, Pahang. Each of the rhizomes was cut into smaller pieces of about 4 cm long and 40 g in weight. Each of the seed rhizomes contained 2 – 3 point buds. The seed rhizomes were treated with previcur-N prior to planting. Bentong ginger can be harvested at 3 – 6 months as young ginger or 8 – 10 months as mature ginger.

### *Rain shelter structure*

A side-netted rain shelter of 30 m long x 10 m wide x 4.5 m high located in MARDI Station, Kluang, Johor was used in the study. All structures were made of galvanised steel frame with transparent polyethylene film (180 μm thick) roofing and insect repellent net (0.1 x 0.1 $mm^2$) side cladding. Entrance into the shelter must be through double doors to reduce the chance of insect entry.

***Experimental design and growth media***

The treatments were arranged in a randomised complete block design (RCBD) with five levels of treatment with three replicates and 30 plants per treatment. Coir dust was supplied by Fertitech Enterprise from Bagan Datoh, Perak. Burnt paddy husks were obtained from a paddy plantation in Alor Setar, Kedah. The coir dust and burnt paddy husks were weighed in accordance to the quantity required for each treatment. There were five coir dusts and burnt paddy husks mixtures used as treatments in this study. These treatments were as follows: T1 = 100% coir dust; T2 = 100% burnt paddy husks; T3 = 70% coir dust and 30% burnt paddy husks; T4 = 30% coir dust and 70% burnt paddy husks; and T5 = 50% coir dust and 50% burnt paddy husks.

Each mixture was thoroughly mixed in a 10-litre pail before filling into 60 cm x 60 cm black polyethylene bags. The seed rhizomes were sown into the media according to the treatments. Each polyethylene bag was placed randomly on four irrigation lines under the side-netted rain shelter and individually irrigated with nutrient solution via a dripper on the surface of the medium.

***Irrigation system***

The irrigation system, which was built in the side-netted rain shelter, consisted of a 1,500-litre tank, 1.5 Hp water pump, water filter, pressure meter and four lateral lines (28 m each) which looped to each other. Each of the lateral lines was equipped with 100 drippers that were placed into 100 polyethylene bags, side by side. The distance between each line was 1.5 m and the distance between each dripper point in the lateral line was 0.3 m. A valve was attached to an inlet to control the amount of the irrigated solution to be pumped in. A small valve was also attached to each lateral line to maintain the flow through the drip line. The nutrient solutions were supplied through 0.3 m micro tubes and arrow drippers.

***Nutrient concentrations and irrigation frequencies***

The fertiliser was formulated by MARDI based on the needs of the plant rhizomes (Yaseer Suhaimi et al. 2009). All the fertiliser components were water soluble. The fertiliser stocks were prepared according to Yaseer Suhaimi et al. (2011). The macro and micro nutrients were prepared separately as A and B stock solutions respectively, at 100x dilution. Solution A contained calcium nitrate and iron, while solution B contained all other components. All components were added one by one to ensure that they dissolved completely in the water. In preparing stock A solution, calcium nitrate was added into the container containing tap water (pH 5.5 – 6.5) and stirred until it dissolved, then the solution was poured into a 100-litre vessel. Iron powder was added into another container that contained tap water, stirred until it dissolved completely, and then added into the vessel. The same procedure was applied in preparing stock B solution.

The irrigation solutions were prepared in a 1,500-litre tank. Stock A and stock B were added into the tank at 1:1 ratio until the needed electricity conductivity (EC) was achieved. The EC of the fertigation solution was between 1.8 µS and 2.3 µS. The irrigation scheduling was automatically implemented by a digital timer, three times per day in the first 3 months (0800 h, 1200 h and 1600 h), six times per day in the $4^{th}$ – $7^{th}$ months (0700 h, 0800 h, 1000 h, 1200 h, 1400 h and 1600 h), and once per day in the last 2 months (1000 h).

The duration of irrigation was 3 min and an identical amount of fertiliser solution was applied to all polyethylene bags. The daily irrigation volumes per plant were 675 ml in the first 3 months, 1,350 ml in the $4^{th}$ – $7^{th}$ months, and 75 ml in the last 2 months. Routine horticultural practices for pest, disease and weed control were followed. Insecticide (*Malathion*) and fungicide (*Benlate*) were applied once every 2 weeks.

***Parameter measurements***

The growth of the ginger plants was measured monthly by measuring the height and weight of leaves/shoot and rhizomes. The ginger plants were randomly selected and the rhizomes were harvested after 3 – 9 months of sowing to determine the yield and growth of rhizomes. The weight was measured immediately after harvest to prevent desiccation and water loss from the rhizomes.

***Air-filled porosity (AFP) and container moisture capacity (CMC)***

The container moisture capacity (CMC) is the amount of water present after the medium has been saturated and allowed to drain. The CMC of the five different media mixtures were taken at two different time intervals and calculated using the formula: (saturated mass – dry mass)/dry volume. The measurement was taken by weighing the container at 1 h and 5 h after watering one month after planting. Air-filled porosity (AFP) or air capacity can be defined as the proportion of the volume that contains air after it has been saturated with water and allowed to drain. The AFP measurement was done according to Bunt (1988).

***Statistical analysis***

Data obtained were subjected to statistical analysis using analysis of variance (ANOVA) procedures to test the significant effect of all the variables investigated using SAS version 9.1. Means were separated using Duncan Multiple Range Test (DMRT) as the test of significance at $p \leq 0.05$.

**Results and discussion**

***Sprouting and establishment***

Although the seed rhizomes were already sprouted before planting, sprouting in the field was observed after 14 days of planting. There was 100% sprouting of rhizomes in all treatments. The establishment of ginger plants from the seed rhizomes in each treatment was also 100%. Babu et al. (1992) reported that transplanted plantlets in the soil (top soil and sand in 1:1 ratio) showed survival or establishment of the plants of more than 80% when high humidity was maintained for the first 2 weeks after transfer to soil. Similarly, Pandey et al. (1996) also reported that survival rate was more than 90% when ginger was transplanted in medium containing an equal volume of sand, burnt rice husk and coconut fibre.

***Air-filled porosity (AFP) and container moisture capacity (CMC)***

The treatment with 100% coir dust had the highest porosity after 1 h and 5 h of irrigation (*Table 1*). Meanwhile, there were no significant differences in the AFP value between 50% coir dust and 50% burnt paddy husks mixture and 70% coir dust and 30% burnt paddy husks mixture. 100% burnt paddy husks (initial: 6.44%/final: 8%) had the second lowest initial and final porosity at both times after irrigation, followed by 30% coir dust and 70% burnt paddy husks mixture (initial: 5.5%/final: 7.4%). The AFP value from 100% coir dust and mixture with higher coir dust (up to 70%) increased compared to 100% burnt paddy husks and mixture with higher burnt paddy husk (up to 70%).

Mixtures with high content of burnt paddy husks had lower AFP values due to its compaction and high water retention properties. The volume of air increased when coir dust was mixed into burnt paddy husks. The addition of coconut coir increased the air capacity and decreased the water contents of the mixtures. The availability of air in the substrate is an important factor affecting the success of growing plants in containers (Aendekerk 1994).

The container moisture capacity (CMC) measures the water availability or content in the growth substrate. The CMC values decreased 5 h after irrigation (*Table 1*). There were no significant differences between 100% burnt paddy husks substrate and mixture of 30% coir dust and 70% burnt paddy husks. The highest initial and final CMC values were obtained from the mixture of 30% coir dust and 70% burnt paddy husks, followed by 100% burnt paddy husks, mixture of 50% coir dust and 50% burnt paddy husks, mixture of 70% coir dust and 30% burnt paddy husks and the lowest CMC was observed in the 100% coir dust substrates. The differences in CMC values between 100% burnt paddy husks and 100% coir dust were 26% and 25% respectively in both times after irrigation. These results showed that addition of burnt paddy husk into coir dust increased the moisture content while lowering the AFP of the substrates. The air retention and moisture in the substrate play important roles for successful plant growth in containers (Aendekerk 1994).

***Effects on plant growth***

There were significant differences in plant height between treatments (*Table 2*). The tallest plants were produced by ginger cultivated in 100% coir dust with an average height of 123 ± 23 cm and the lowest were those cultivated in mixture of 30% coir dust and 70% burnt paddy husks (average height 105 ± 8 cm). Treatment containing 100% coir dust produced the tallest plants compared to burnt paddy husks and mixtures of both substrates. This could be due to the higher porosity of coir dust compared to

Table 1. Physical properties of 5 growing substrates at 2 different times after irrigation

| Treatment | Air-filled porosity (%) | | Container moisture capacity (%) | |
|---|---|---|---|---|
| | 1 h | 5 h | 1 h | 5 h |
| 100% CD | 9.4a | 13.4a | 39.5d | 35.0d |
| 100% BPH | 6.4c | 8.0c | 65.0a | 60.0a |
| 70% CD + 30% BPH | 8.0b | 9.9b | 48.6c | 45.0c |
| 30% CD + 70% BPH | 5.5d | 7.4d | 68.0a | 64.4a |
| 50% CD + 50% BPH | 8.4b | 9.8b | 52.9b | 50.0b |

Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$
CD = Coir dust; BPH = Burnt paddy husks

Table 2. Plant growth and rhizome yield after 9 months of cultivation

| Treatment | Plant height (cm) | Shoot fresh weight (g) | Average rhizome yield per plant (g) | Rhizome to shoot ratio |
|---|---|---|---|---|
| 100% CD | 123 ± 23a | 1,340 ± 235a | 5,480 ± 325a | 4.09a |
| 100% BPH | 114 ± 15b | 1,210 ± 223b | 3,480 ± 150d | 2.87d |
| 70% CD + 30% BPH | 112 ± 12c | 1,130 ± 127b | 4,580 ± 170b | 4.05b |
| 30% CD + 70% BPH | 105 ± 8d | 1,090 ± 115c | 2,570 ± 135e | 2.33e |
| 50% CD + 50% BPH | 115 ± 16b | 1,120 ± 120b | 4,400 ± 180c | 4.03c |

Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$
CD = Coir dust; BPH = Burnt paddy husks

the other treatments. This higher porosity property drained out the excess fertiliser solution between the irrigation schedules more quickly.

The mixtures between coir dust and burnt paddy husks could have increased the water holding capacity and subsequently decreased the dissolved oxygen availability in the growing medium. Plant height grown in mixture of 30% coir dust and 70% burnt paddy husks was significantly affected. The higher content of burnt paddy husks in the medium added more moisture content that lowered dissolved oxygen in the media, which consequently reduced height of the ginger plant compared to 100% coir dust. Similar studies also showed that high water holding capacity reduces the growth and yield of tomato and cucumber (Mahamud and Manisah 2007; Peyvast et al. 2010).

The shoots were cut and trimmed 2 weeks before harvesting. This allowed the rhizomes to harden in the media (Paul et al. 2004). There were significant differences in shoot fresh weight between treatments. The highest shoot fresh weight was recorded from plants cultivated in 100% coir dust with an average weight of 1,340 ± 235 g (*Table 2*), while the lowest weight was obtained from plants cultivated in mixture of 30% coir dust and 70% burnt paddy husks. The shoot fresh weights were higher with higher content of coir dust in the growing media. However, there was no significant difference between 100% burnt paddy husks, mixture of 70% coir dust and 30% burnt paddy husks, and mixture of 50% coir dust and 50% burnt paddy husks at $p \leq 0.05$. A study by Fukuda and Anami (2002) also revealed an increase in melon biomass when grown in coir dust.

***Effects on rhizome yield***

For commercial purposes, ginger rhizomes are harvested 7 – 9 months after sowing (Wilson and Ovid 1993). In this study, the rhizomes were harvested after 3 – 9 months and the fresh weight of the rhizomes were measured. The interior flesh and epidermis were lighter in colour than the mother seed piece. There was also fibre development in the interior flesh. The rhizomes also produced a pungent odour with a distinctive ginger flavour. They were marketable as fresh young ginger between 3 and 6 months of cultivation and mature ginger between 8 and 9 months.

There were significant differences in rhizome yield between treatments after 9 months of cultivation. The highest average fresh rhizome yield was obtained from plants cultivated in 100% coir dust, followed by mixtures of 70% coir dust and 30% burnt paddy husks, 50% coir dust and 50% burnt paddy husks, 100% burnt paddy husks, and 30% coir dust and 70% burnt paddy husks. These results showed that ginger cultivated in higher amount of coir dust media increased the rhizome yield up to 36% compared to those grown in media containing higher amount of burnt paddy husks. High oxygen availability in the coir dust media supported the underground rhizomes requirement for high oxygen for growth.

For crops grown in containers, it is important to consider the tendency of most root systems to grow gravitropically to form a dense layer at the bottom of the containers (Raviv et al. 2001). Coir dust has a strong capillarity that provides more uniform moisture conditions for roots. These conditions are able to increase aeration in the base mix and reduce drying of the surface by lifting the moisture higher up in the polyethylene bags. This increases the volume of the mix that is suitable for root development and improve access to moisture and fertiliser. This redistribution of moisture is perhaps one of the reasons for plants grown in pure coir dust to have higher rhizome yield. Aeration in the growing medium is positively related to AFP and negatively to water content (Raviv and Lieth 2008). The coir dust is less acidic with a pH suitable to facilitate ginger to grow and consequently allows the plant roots to absorb nutrient efficiently.

In the early cultivation period between 1 and 3 months, the growth of rhizomes between treatments was similar. The exponential growth of the rhizomes began in the fifth month and the rhizomes in 100% coir dust treatment showed the highest growth compared to other treatments (*Figure 1*). Media with high content of burnt paddy husks gave lower rhizome yield throughout the cultivation period with a mixture of 30% coir dust and 70% burnt paddy husks exhibited the lowest rhizome yield.

These results were similar with the study conducted by Kratky (1998), who found that ginger rhizome yield increased significantly when grown using soilless system under rain shelter. Previous study done by Hayden et al. (2004) found that the growth of rhizomes is dependent on the type of medium. The growing medium acts as heat insulator and provides heat that enhances the growth of rhizomes.

***Rhizomes and shoot ratio***

Overall biomass of ginger plants can be divided into two parts: aboveground biomass consisting of leaves and stem (shoots), and underground biomass consisting of rhizomes and roots. In this study, there were significant differences between treatments in rhizomes to shoot ratio. The ratio of underground biomass to aboveground biomass was highest in plants cultivated in 100% coir dust with a ratio of 4.09 (*Table 2*). There was higher underground biomass compared to aboveground biomass in plant grown in the 100% coir dust. The high ratio of underground biomass to aboveground biomass reflects that the roots were well able to supply the top of the plant with water, nutrient, stored carbohydrates and certain growth regulators (Harris 1992). The rhizome to shoot ratio in plants cultivated in high coir dust media was 4 to 1, while that in plants cultivated in high burnt paddy husks was 2 to 1.

**Conclusion**

The mixture of coir dust and burnt paddy husks significantly affected plant height, shoot biomass, rhizome yield, and rhizome to shoot ratio. Media containing high amount of coir dust (70 – 100%) showed good growth and increased the rhizome yield up to 36% compared to those containing high amount of burnt paddy husks. It can be concluded that 100% coir dust or any combinations with high amount of coir dust are the best substrates for growing ginger

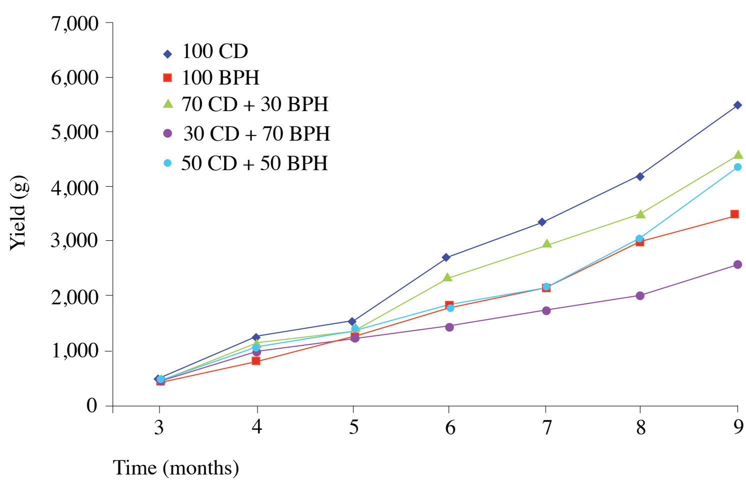


*Figure 1. Growth of ginger rhizomes between third and ninth months of cultivation*

in soilless culture system. However, studies on burnt paddy husks in combination with other agricultural wastes like sago waste, industrial by-products like polystyrene beads or any other cheaper media such as coarse sand should be continued to increase the use of burnt paddy husks as growing medium for growing ginger or any suitable crop in soilless culture production system.

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**References**
Abad, M., Noguera, P. and Bures, S. (2001). National inventory of organic wastes for use of growing media for ornamental potted plant production: Case study in Spain. *Bioresource Technology* 77(2): 197 – 200

Aendekerk, T.G.L. (1994). Standard of physical properties for substrate used in ebb and flow systems. Annual Report 1994, p. 38 – 38. Research Station for Nursery Stock

Akram, M., Ibrahim Shah, M., Khan Usmanghan, Mohiuddin, E., Abdul Sami, A.M., Ali Shah, S.M., Khalil, A. and Ghazala, S. (2011). *Zingiber officinale* Roscoe (A Medicinal Plant). *Pakistan Journal of Nutrition* 10 (4): 399 – 400

Babu, K.N., Shamsudeen, K. and Ratnambal, M.J. (1992). *In vitro* plant regeneration from leaf derived callus in ginger *(Zingiber officinale* Roscoe*). Plant cell, Tissue and Organ Culture* 29: 71 – 74

Beardsell, D.V., Nicholas, D.G. and Jones, D.L. (1979). Physical properties of nursery potting mixture. *Scientia Horticulturae* 11(1): 1 – 8

Böhme, M. (1995). Evaluation of organic, synthetic and mineral substrates for hydroponically grown cucumber. *Acta Horticulturae* 401: 209 – 217

Bunt, A.C. (1988). *Media and mixes for container grown plants*, 2nd Edition, 309 p. London: Unwin Hyman

Burrage, S.W. (1992). Nutrient film technique in protected cultivation. *Acta Horticulturae* 323: 23 – 38

De Boodt, M. and Verdonck, O. (1972). The physical properties of the substrates in horticulture. *Acta Horticulturae* 26: 37 – 44

De Rijck, G. and Schrevens, E. (1998). Distribution of nutrient and water in rockwool slabs. *Scientia Horticulturae* 72: 277 – 285

Fukuda, N. and Anami, Y. (2002). Substrate and nutrient level: Effects on the growth and yield of melon '*Cucumis melo'* in soilless culture. *Acta Horticulturae* 588: 111 – 117

Glinski, J. and Stepniewski, W. (1985). *Soil aeration and its role for plants*. 229 p. Boca Raton, Fla: CRC Press

Guo, Y.H. and Zhang, Z.X. (2005). Establishment and plant regeneration of somatic embryogenic cell suspension cultures of the *Zingiber officinale* Rosc. *Scientia Horticulturae* 107: 90 – 96

Harris, R.W. (1992). Root-shoot ratios. *Journal of Arboriculture* 18(1): 39 – 42

Hayden, A.L., Brigham, L.A. and Giacomelli, G.A. (2004). Aeroponic cultivation of ginger (*Zingiber officinale*) Rhizomes. *Acta Horticulturae* 659: 397 – 402

Hillel, D. (1998). *Environmental Soil Physics*. San Diego, CA: Academic Press

Humara, I.M., Casares, A. and Majada, I. (2002). Effect of seed size and growing media water availability on early seedling growth in *Eucalyptus globules*. *Forest Ecology and Management* 167: 1 – 11

Jarvis, W.R. (1992). *Managing diseases in greenhouse crops*. St Paul, MN, USA: American Phytopathological Society Press

Komada, H., Yokoyama, H., Yamamoto, M., Terada, T. and Matsui, Y. (1997). Sugi (*Cryptomeria japonica* D. Don) bark, a potential growth substrate for soilless culture with bioactivity against some soilborne diseases. *J. Hort. Science* 72: 989 – 996

Kratky, B.A. (1998). Experimental non-circulating hydroponic methods for growing edible ginger. *Proc. Nat. Agr. Plastics Congress* 27: 133 – 137

Laan, P., Smolders, A., Blom, C.W. and Armstrong, W. (1987). The anatomical characteristics of roots and plant response to soil flooding. *New Phytol*. 106: 465 – 495

Mahamud, S. and Manisah, M.D. (2007). Preliminary studies on sago waste as growing medium for tomato. *Acta Horticulturae* 742: 163 – 168

Ortega, M.C., Monero, M.T., Ordovas, J. and Aguado, M.T. (1996). Behaviour of different horticultural species in phytotoxicity bioassay of bark substrate. *Sci. Hort*. 66: 125 – 132

Pandey, Y.R., Sagwansupyakorn, C., Sahavacharin, O. and Thaveechai, N. (1996). Influence of photoperiods on dormancy and rhizome formation of ginger (*Zingiber officinale* Roscoe). *Kasetsart J. (Nat. Sci.)* 30: 386 – 391

Park, E.J. and Pizzuto, J.M., (2002). Botanicals in cancer chemoprevention. *Cancer Metastasis Review* 21: 231 – 255

Paul, H., Francis, Z., Russell, K., Claire, A., Mark, M., Bernard, K., Kert, H. and Dwight, S. (2004). Producing bacterial wilt-free ginger in greenhouse culture. *Soil and Crop Management, Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa* 8: 1 – 6

Peyvast, G., Olfati, J.A., Ramezani Kharazi, P. and Noori Roudsari, O. (2010). Effect of substrate on the greenhouse cucumber production in soilless culture. *Acta Horticulturae* 871: 429 – 436

Prasad, M. (1979). Physical properties of media for container grown crops. II peat mixes. *Scientia Horticultural* 10: 325 – 300

Raja Harun, R.M., Hall, D.A. and Szmidt, R.A.K. (1991). Melon cultivation in organic and inorganic substrates. *Acta Horticulturae* 294: 105 – 108

Raviv, M. and Lieth, J.H. (2008). *Soilless Culture: Theory and Practice*. p 45 – 80. United States of America: Elsevier

Raviv, M., Lieth, J.H., Burger, D.W. and Wallach, R. (2001). Optimization of transpiration and potential growth rates of Kardinal Rose with respect to root-zone physical properties. *J. Amer. Soc. Hort. Science* 126: 638 – 645

Verdonck, O., Carpenter, I. and De Boodt, M. (1973). The rooting of azalea cuttings in inert substrates, *Proc. 3rd Int. Congr. on Soilless Culture*, Sassiri. Italy, p. 143 – 148. IWOSC

Verdonck, O., Penninck, R. and De Boodt, M. (1983). The physical properties of horticultural substrates. *Acta Horticulturae* 150: 155 – 160

Wall, A. and Heiskenen, J. (2003). Effect of air-filled porosity and organic matter concentration of soil on growth of *Picea abies* seedlings after transplanting. *Scandinavian Journal of Forest Research* 18(4): 344 – 350

Whipps, J.M. (1992). Status of biological disease control in horticulture. *Biocontrol Science and Technology* 2: 3 – 24

Wilson, H. and Ovid, A. (1993). Growth and yield responses of ginger (*Zingiber officinale* Roscoe) as affected by shade and fertilizer applications. *J. Plant Nutrition* 16(8): 1539 – 1545

Yaseer Suhaimi, M., Mohamad, A.M. and Mahamud, S. (2009). Planting containerized ginger (*Zingiber officinale* Roscoe) using fertigation. *Proceeding of 20th Malaysian Society of Plant Physiology conference*, p 10 – 11. Kuala Lumpur: MSPP

Yaseer Suhaimi, M., Mohamad, A.M., Mahamud, S., Rezuwan, K., Fadlilah Annaim Huda, H. and Azman, J. (2011). Effects of temperature gradient generated by fan-pad cooling system on yield of cabbage grown using fertigation technique under side netted rain shelter. *J. Trop. Agric. and Fd. Sc.* 39(1): 93 – 101

**Abstrak**
Kesan substrat tanpa tanah pada pertumbuhan dan hasil halia telah dikaji. Objektif utama kajian adalah untuk menentukan substrat pertumbuhan paling sesuai untuk penanaman halia menggunakan teknik fertigasi. Kajian ini dijalankan di bawah rumah pelindung hujan lengkap dengan jaring kalis serangga yang dilengkapi dengan sistem pengairan untuk membekalkan air baja mengikut jadual masa. Lima gabungan substrat pertumbuhan telah diuji; sabut kelapa 100%; sekam padi bakar 100%; sabut kelapa 70% + sekam padi bakar 30%; sabut kelapa 30% + sekam padi bakar 70%; dan sabut kelapa 50% + sekam padi bakar 50%. Pokok halia dipilih secara rawak dan rizom dituai selepas 3 – 9 bulan disemai. Pokok yang ditanam di dalam 100% sabut kelapa menghasilkan prestasi pertumbuhan dan kadar hasil yang terbaik berbanding dengan rawatan lain. Tumbuhan menghasilkan pucuk paling tinggi (123 ± 23 cm) dengan berat pucuk segar (1.340 ± 235 g) dan hasil rizom (5480 ± 325 g) per pokok juga yang tertinggi. Berat rizom terendah (2570 ± 135 g) per pokok dihasilkan daripada penanaman dalam campuran 30% sabut kelapa + 70% sekam padi bakar. Oleh itu, dapat dirumuskan bahawa tanaman halia yang ditanam di dalam substrat sabut kelapa menggunakan teknik fertigasi dapat memberikan pertumbuhan pokok dan hasil terbaik.

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