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EFFECTS OF ORGANIC SUBSTRATES ON GROWTH AND YIELD OF GINGER CULTIVATED USING SOILLESS CULTURE

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ABSTRACT

The effects of organic soilless substrates on growth and yield of ginger were studied. 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. Alternative substrates that are cheaper and locally available such as coconut fibres and burnt paddy husks should be used as alternative media. The main objective of the study was to determine the most suitable organic 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.

Key words: ginger, fertigation system, soilless substrate, coir dust, burnt paddy husk

INTRODUCTION

Fertigation technology is normally applied in soilless culture production system. Yields of chillies, rock melons and tomatoes cultivated in soilless system increased 3 to 5 times compared to those using conventional methods (Verdonck *et al*., 1983, De Rijck *et al*., 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; Bohme, 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).

Zingiber officinale Rosc. or ginger 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 to 4 months) or mature ginger (8 to 9 months). In Malaysia, ginger

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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 to prevent soil-borne diseases.

There is a 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 *et al*., 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 to 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 to 3 point buds. The seed rhizomes were treated with previcur-N prior to planting. Bentong ginger can be harvested at 3 to 6 months as young ginger or 8 to 10 months as mature ginger.

Experimental design

A side-netted rain shelter of 30 m long x10 m wide x 4.5 m high located in MARDI Station, Kluang, Johor was used in the study. 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.

Nutrient concentrations and irrigation frequencies

The fertiliser was formulated by MARDI based on the needs of the plant rhizomes (Yaseer *et al*., 2009). All the fertiliser components were water soluble. The fertiliser stocks were prepared according to Yaseer *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 S and 2.3 S. 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} to 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} to 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.

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

Ginger plant 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%. Similar reports had also shown 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 (Babu *et al*., 1992). Others studies 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 (Pandey *et al*., 1996).

Plant growth performance

There were significant differences in plant height between treatments (Table 1). 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 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 two 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 1), 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 $p \leq 0.05$. Other studies also revealed an increase in melon biomass when grown in coir dust (Fukuda and Anami, 2002).

Table 1. 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 ± 23^{a}	1,340 ± 235^{a}	5,480 ± 325^{a}	4.09^{a}
100% BPH	114 ± 15^{b}	1,210 ± 223^{b}	3,480 ± 150^{d}	2.87^{d}
70%CD+30%BPH	112 ± 12^{c}	1,130 ± 127^{b}	4,580 ± 170^{b}	4.05^{b}
30%CD+70%BPH	105±8^{d}	1,090 ± 115^{c}	2,570 ± 135^{e}	2.33^{e}
50%CD+50%BPH	115 ± 16^{b}	1,120 ± 120^{b}	4,400 ± 180^{c}	4.03^{c}

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

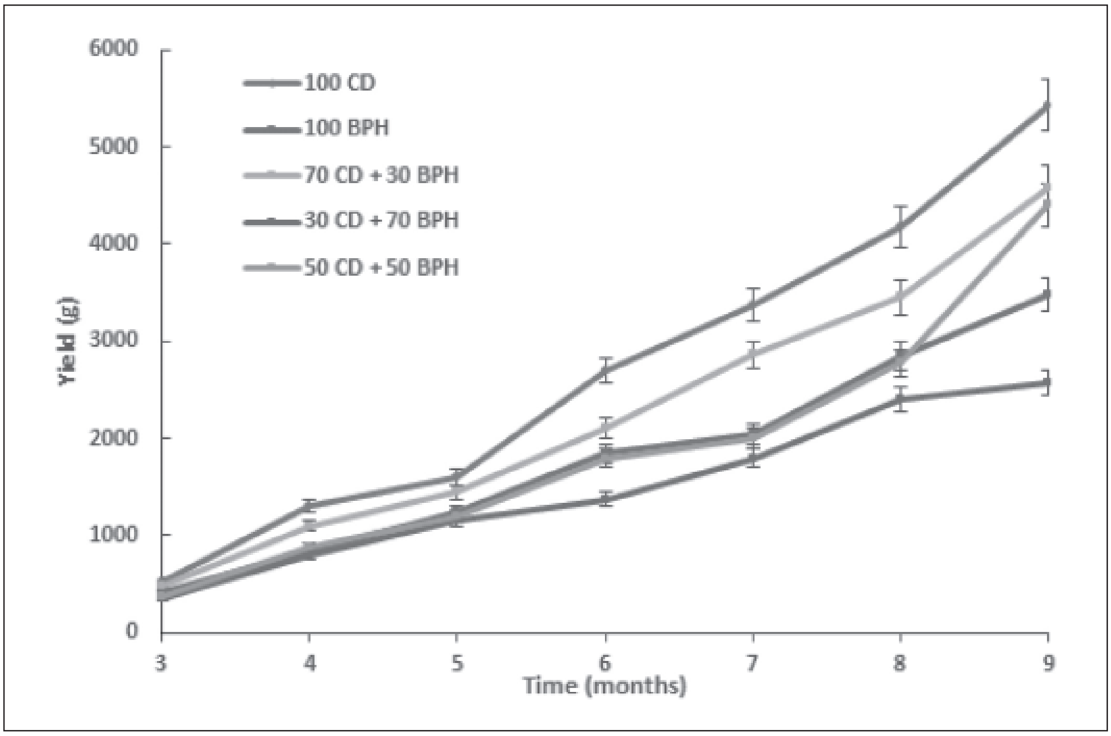

Fig. 1. Growth of ginger rhizomes between third and ninth month of cultivation

Ginger rhizome yield

For commercial purposes, ginger rhizomes are harvested 7 to 9 months after sowing (Wilson and Ovid, 1993). In this study, the rhizomes were harvested after 3 to 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 base mix that is suitable for root development and improved 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 also showed 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 (Hayden *et al*., 2008).

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 1). 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.

CONCLUSIONS

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 in soilless culture system.

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