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Effects of seed rhizome size on growth and yield of ginger cultivated using fertigation system

M. Yaseer Suhaimi[1], A. M. Mohamad[2] and M.A. Adzemi[3]

[1]Technology Promotion and Business Development Centre, MARDI Headquarters, Persiaran MARDI-UPM, 43400 Serdang, Selangor, Malaysia
[2]Director General Office, MARDI Headquarters, Persiaran MARDI-UPM, 43400 Serdang, Selangor, Malaysia
[3]Food Crop Science Unit, School of Food Science and Technology, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia

Abstract
Ginger planting in Malaysia is usually carried out using shifting cultivation technique. This technique is practiced due to the infertile soils and the need to avoid soil-borne diseases that could infect the plant roots. Fertigation system could overcome the above problem and replaces the shifting cultivation technique, which is detrimental to the environment. Since the rhizome is the planting material, it is necessary to determine its suitable size and feasibility using this system. An experiment was conducted to study the influence of seed rhizome size on the growth and yield of ginger, thus determine an optimum seed rhizome size for the fertigation cultivation techniques. The study was conducted under rain shelter equipped with an irrigation system to supply fertiliser solution at a scheduled time. The study revealed that 1 g of rhizome seed yield fresh rhizome weight by 53 times after a nine-month cultivation period. It is concluded that the greater the seed rhizome size/weight, the larger is the fresh rhizome.

Keywords: ginger, seed rhizomes, fertigation system, soil nutrients, fertiliser

Introduction

The fertigation technology has been proven to improve plant growth and yields. The demands for this technique have increased significantly throughout the years. It increases the yields of chillies, rockmelons and tomatoes up to three to five times as compared to the conventional cultivation. This significant increase in yields leads to the studies on the potential of rhizome plant growth and yields using fertigation system.

Cultivating ginger using soilless culture techniques is one of the alternatives to overcome infertile soils and prevent soil-borne disease such as *Fusarium oxysporum*, *Pseudomonas solanacearum* and leaf spot diseases that can infect the plant root (Hayden et al. 2004). Shifting cultivation practices in Malaysia have caused land corrosion, mainly in the highlands. It takes about 6 years to overcome soil infertility problems before ginger could be replanted (Yaseer Suhaimi and Mohamad 2012). Cultivating ginger using fertigation system could overcome soil infertility, prevents soil-borne diseases and perhaps replaces the shifting cultivation techniques that is detrimental to the environment. Ginger (*Zingiber officinale* Rosc.) belongs to the tropical and sub-tropical family of Zingiberaceae. It originated from South-East Asia and is being introduced to many parts of the globe. It has been cultivated for thousands of years and used as spice and for medicinal purposes (Park and Pizzuto 2002).

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Authors' full names: Yaseer Suhaimi, Mohd Mohamad Abd Manas and Adzemi Mat Arshad
E-mail: ysuhaimi@mardi.gov.my

Zingiber officinale Roscoe or ginger, is a perennial plant with thick tuberous roots or rhizomes with an above-ground stem which is erect, oblique, round, annual and invested by the smooth sheaths of the leaves, 2 or 3 feet in height. The plant produces orchid like flowers, with petals that are greenish-yellow streaked. Ginger had been used as an ingredient in traditional medicines and cooking among the Malay, Indian and Chinese.

Ginger is cultivated in areas with abundant rainfall and 1,500m above sea level. It produces a pungent and aromatic rhizome that is valuable all over the world either as a spice or herbal medicine (Guo and Zhang 2005). In Malaysia, ginger is cultivated commercially in Pahang (Bentong), Sabah (Keningau and Tambunan), Sarawak, Selangor and Johor. The main ginger varieties cultivated are Bentong, Bara, China dan Indonesia. In spite of its immense importance, very little information is available on the agronomic aspects of the crop. Normally, ginger is propagated using a small portion of rhizomes known as seed rhizomes (Dupriez and De Leener 1992; Borget 1993; Ravindran et al. 2004). Rhizomes size and planting methods are the two important aspects of ginger production (Aiyadurai 1996). On the other hand, rhizome size is an important factor for good yield. The planting material or seed rhizomes effects both economic return of the grower and the establishment, growth and yield of the crop (Girma and Kindie 2008). The uses of large seed rhizome results in an increase in the planting material cost, whereas the use of small seed rhizome results in growth and yield reduction. Therefore, using the right size of planting material is a very important factor in rhizomatous and turmeric crops, and hence the objective of this study is to determine the optimum seed rhizome size of ginger for cultivation using fertigation system.

Materials and method

Plant materials and treatments

Bentong ginger was selected and used in the study. This variety can be harvested in 3 – 6 months as young ginger or 8 – 10 months as matured ginger. Bentong ginger has bigger rhizome than Tanjong Sepat, Chinese, and Indonesian gingers. The rhizome is pale and low in fibre. The ginger was vegetatively propagated through rhizome and the shoot appears after one to two weeks of sowing. Ginger rhizomes of 10-month old were bought from a ginger plantation in Bentong, Pahang. Each of the rhizomes was cut into smaller pieces as seed rhizomes according to treatments; 10 g, 50 g and 100 g. Each treatment contained 30 samples. The treatments were arranged in Randomized Complete Block Design (RCBD) with four replications. Each of the seed rhizomes contained 1 – 3 point buds. The seed rhizomes were treated with fungicide: previcur-N prior to planting. Then the seed rhizomes were sow in the coco peat as germination and rooting media according to treatments. After 21 days of sowing, the ginger seedlings were transferred into polybags containing coco peat and then arranged accordingly to the treatments.

Rain shelter structure

Field experiment was designed to evaluate the growth and yields of the ginger plant. A side-netted rain shelter of 30 m long × 10 m wide × 4.5 m high located in MARDI Station, Kluang, Johor was used in the study. The structures were made of galvanised steel frame with transparent polyethylene film (180 μm thick) roofing and insect repellent net (0.1 × 0.1 mm^2) side cladding. The front of the structure has a double door system to reduce entry of insect pests. Routine horticultural practices for pest, disease and weed were followed. Insecticide (*Malathion*) and fungicide (*Benlate*) were applied once every two weeks.

Nutrient concentrations and irrigation frequencies

The fertiliser formulation used was based on the needs of the plant rhizomes (Yaseer Suhaimi et al. 2009). *Table 1* shows the macro and micro nutrients used in the study. All of the fertiliser components were water soluble. Fertiliser stocks solutions were prepared according to Yaseer Suhaimi et al. (2011). The macro and micro nutrients were prepared as stock A and stock B nutrient solutions, in 100× dilution. Solution A contained calcium nitrate and iron, while solution B contained all others components. All components were added one by one to ensure they dissolved completely in the water. To prepare stock A solution, calcium nitrate was added into a container containing tap water (pH 5.5 – 6.5), stirred until it dissolved and the solution was poured into a 100litre vessel. Iron powder were added into another container that contained tap water, stirred until it dissolved completely, and then added into the vessel. The same procedure was also applied in preparing stock B solution.

The nutrient solution for irrigation was prepared in a 1,500-litre tank. Stock A and stock B were added into the tank at 1:1 ratio until the required electrical conductivity (EC) was achieved. The EC of the irrigation solution was between 1.8 μS and 2.3 μS. The irrigation scheduling was automatically implemented by digital timer, 3 times per day in the first 3 months (0800 h, 1200 h, and 1600 h), 6 times per day in the fourth to seventh months (0700 h, 0800 h, 1000 h, 1200 h, 1400 h, and 1600 h), and once a day in the last 2 months (1000 h). The duration of irrigation was 3 minutes and equal amount of the fertiliser solution was applied to all the polybags. The daily irrigation volume per plant was 675 ml in the first 3 months, 1,350 ml in the fourth to seventh months, and 275 ml in the last 2 months.

Table 1. The macro and micro nutrients used in preparing the stock solutions

Chemical components
Calcium nitrate
Iron (chelate)
Potassium nitrate
Monopotassium hydrogen phosphate
Magnesium sulphate
Mangan sulphate
Boric acid
Zinc sulphate
Cuprum sulphate
Ammonia molybdate

Parameter measurements

The growth of the ginger plants was done by measuring the height and weight of the combination of leaves/shoots and rhizomes. The ginger plants were randomly selected and the rhizomes harvested every 3 months until 9 month of sowing to determine the growth of rhizomes. The weight was measured immediately after harvesting to prevent desiccation and water loss from the rhizomes.

Statistical analysis and calculations

Data obtained were subjected to statistical analysis using analysis of variance procedures to test the significant effect of all the variables investigated using SAS version 9.1. Means were separated using the Duncan Multiple Range Test as the test of significance at $p \leq 0.005$.

Results and discussion

The growth of plant

Seed rhizome size significantly affected all of the growth parameters measured (*Table 2*). Plant height and number of tillers per plant were significantly affected by differences in seed rhizome size during the cultivation period. Plant height significantly increased with an increase in seed rhizome size. The mean shoot height was 120 cm with the range of 105 – 143 cm. The minimum plant height was recorded for 10 g rhizome seed (105 ± 7.5 cm) while the maximum plant height was achieved by 100 g rhizome seed (143 ± 25 cm). A weight of 100 g of seed rhizome size gave rise to the highest plant height, followed by 50 g and 10 g seed rhizome, respectively. Girma and Kindie (2008) revealed that big and cut transplanted seed rhizomes gave rise to taller ginger plants. The number of tillers per plant also increased significantly with an increase in seed rhizome size. The mean tiller was 12 with the range of 7 – 18 tillers between treatments. A weight of 100 g of seed rhizome size also showed the highest number of tillers compared to 50 g and 10 g of seed rhizomes. It is observed that rhizome size have significant influences on the ginger plant growth (Whiley 1990; Zaman et al. 2002). 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 rhizome to shoot ratio. The ratio of underground biomass to aboveground biomass was highest in plants cultivated with 100 g of seed rhizome size with a ratio of 4.09. The high ratio of underground biomass to aboveground biomass reflects the ability of the roots to supply the top of the plant with adequate water, nutrient, stored carbohydrates and certain growth regulators in soilless culture condition (Harris 1992). The moisture availablity of the media in the polybag enhanced the largest rhizomes size that allow earlier emergence and resulted in vigorous and rapid growth of plant.

The yield component of ginger

Fresh rhizome weight per rhizome was significantly affected by seed rhizome size in all treatments (*Table 3*). The largest seed rhizome treatment produced significantly heavier fresh rhizomes. The mean rhizome fresh weight was 2,856 g which ranged from 534 – 5,433 g. The highest rhizomes yield was obtained from 100 g seeds with an average of 5,433 ± 66.7 g per bag. The lowest rhizome weight (534 ± 9.7 g) was produced from 10 g of seed, while the average rhizomes weight produced by 50 g of seed was 2,600 ± 38.7 g per bag. Monnaf et al. (2010) claimed that big rhizome seed produced high yield compared to small rhizome seed that produced low yield. Large seed rhizome or mother rhizome showed vigorous and rapid growth using the initially more reserve food materials than the small seed rhizome, resulting in high yield. The highest fresh weight rhizome contributed to highest dry weight after been oven dry 48 h at 40 °C in the oven. Seed rhizome size significantly affected dry rhizome yield in all treatments.The highest dry rhizome weight was obtained from 100 g of seed rhizome is 3,708 g followed by 50 g (1,820 g) and 10 g (374 g) seed rhizome.Dry rhizome yield increased with an increase in seed rhizome size.The ratio of seed rhizomes to fresh rhizomes showed no significant differences among the treatments (*Table 3*). The ratio was 1:53 from 10 g of seed; 1:52 from 50 g of seed; and 1:54 from 100 g of seed. The study showed that 1 g seed rhizome produced 53 gof fresh rhizomes after 9 months of cultivation periods. There was no significant difference in term of seed to fresh rhizome ratio. Rhizome size also had showed a great influenced the ginger yield (Ahmed et al. 1988).

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 100 g seed rhizomes showed the highest growth compared to other treatments (*Figure 1*). Higher yield and profit were obtained from larger seed pieces (Nybe and Raj 2004).

These results were similar with the study conducted by Kratky (1998), who found that ginger rhizome yield increases 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.

Table 2. Plant height, number of tiller and rhizomes to shoot ratio after 9 months of cultivation periods

Rhizome size (g/piece)	No. of tillers per plant	Plant height (cm)	Rhizome to shoot ratio
10	7[c]	105 ± 7.5[c]	1.62
50	11[b]	112 ± 15[b]	3.96
100	18[a]	143 ± 25[a]	4.09

Table 3. Mean of fresh and dry weight and ratio of seed to rhizome yield of rhizome after 9 months of cultivation periods

Seed rhizome size (g)	Fresh weight (g/bag)	Dry rhizome weight (g)	Ratio of seed to fresh rhizome yield
10	534 ± 9.7[c]	374 ± 5.6[c]	1:53[a]
50	2,600 ± 38.7[b]	1,820 ± 28.5[b]	1:52[a]
100	5,433 ± 66.7[a]	3,708 ± 55.1[a]	1:54[a]

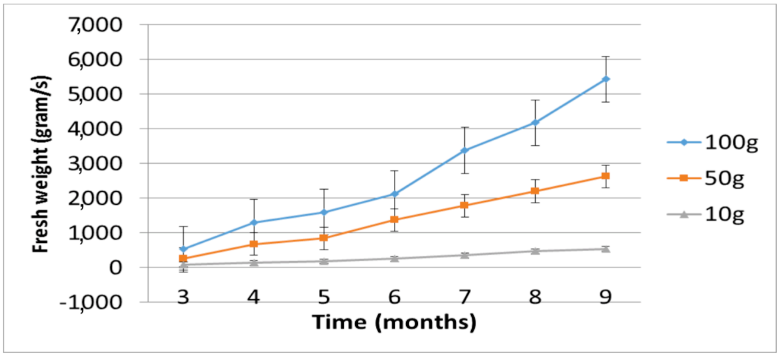

Figure 1. Growth of ginger rhizomes between third and ninth months of cultivation

Yield and income

The economic analysis of the effect of seed rhizome size on ginger production is presented in *Table 4*. The studies revealed that an increase in seed rhizome size increased the economic return of ginger production. The development cost for ginger farm per hectare using fertigation system is RM355,400. There were two major infrastructures required in ginger cultivation using fertigation are the fertigation irrigation system and the rain shelter structure. The production cost involved expenses that vary according to the scale of production such as the cost of labour, fertilisers, pesticides and utilities which amounts to RM49,700. The development and production cost remained the same for each treatment except for planting material expenses. The lowest seed cost is obtained from 10 g seed rhizome size, while 100 g seed rhizome resulted in highest seed expenses. Although, the 10 g seed rhizome size reduced the planting material expenses significantly, it gave the lowest yield compared to other treatments which resulted in losses of RM19,100 in average net profit. The expenses of 100 g seed rhizome size were 10 times higher compared to 10 g seed rhizome. The used of 100 g seed rhizome also resulted in significantly increased in yield and income compared to others treatments. Each cropping of ginger using 100 g seed rhizome was able to generate RM259,900 of average net profit.

Conclusion

The studies showed that an increased in seed rhizome size of ginger significantly improved most of the growth and yield components of ginger. There were significant differences in the number of tillers, plant height, and rhizome fresh weight after 9 months of planting periods between the rhizome seeds (10, 50 and 100 g). Rhizome seeds at 100 g produced the highest rhizome biomass, plant height and number of tillers. However, there was no significant difference between the treatments in terms of the ratio of seed to rhizome yield. Results showed that 1 g rhizome seed produced 54 g of fresh rhizomes after 9 months of cultivation periods using the fertigation system. Seed rhizome size of 100 g of also gave the highest average net profit compared to other treatments. It also significantly increased rhizome yield and provided an attractive investment return.

Table 4. Comparison of the costs of production using different seed rhizome size using fertigation system

Parameter	Seed rhizome size		
	10 g	50 g	100 g
Investment cost (RM/ha)	355,400	355,400	355,400
Production cost (RM/ha/year)	49,700	49,700	49,700
Seed cost (RM/ha/year)	1,440	7,200	14,400
Average yield (kg/ha)	6,408	31,200	64,800
Average gross income (RM5.00/kg)	32,040	156,000	324,000
Average net profit (RM/ha/year)	–19,100	99,100	259,900

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Abstrak
Penanaman halia di Malaysia biasanya dilakukan menggunakan sistem berpindah-randah. Kaedah ini diamalkan di negara ini kerana tahap kesuburan tanah yang rendah dan keperluan untuk mengelakkan penyakit bawaan tanah yang boleh menjangkiti akar tumbuhan. Sistem fertigasi boleh mengatasi masalah tersebut di atas dan menggantikan kaedah berpindah-randah yang boleh memudaratkan alam sekitar. Rizom merupakan bahan tanaman dan adalah perlu untuk menentukan saiz bahan tanaman yang sesuai dan boleh dilaksanakan dari segi ekonomi untuk penanaman menggunakan sistem fertigasi. Satu eksperimen telah dijalankan untuk mengkaji kesan saiz benih rizom terhadap pertumbuhan dan hasil halia untuk menentukan saiz benih rizom yang optimum untuk teknik penanaman fertigasi. Kajian ini telah dijalankan di bawah struktur pelindung hujan yang dilengkapi dengan sistem pengairan fertigasi untuk membekalkan larutan baja pada kekerapan masa yang telah dijadualkan. Kajian ini mendedahkan bahawa 1 g benih rizom menghasilkan berat rizom segar 53 kali ganda selepas sembilan bulan tempoh penanaman. Dapat disimpulkan bahawa lebih besar saiz benih rizom, lebih besar rizom segar dihasilkan.