Growth, Yield and Quality of Ginger from Produced through Early Senescence

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Abstract

As so far, ginger seed rhizome used for planting is derived from 9 months or more after planting. Erratic climate change led to a long dry season. During the day, temperatures tend to higher up to 40℃, causing impaired growth and development of the ginger rhizome. Many ginger plant yellowed and senescense on 7 months after planting (MAP), make farmers difficult to get ginger seed rhizome. Rhizomes derived from 7th and 8th MAP have never been used for seed. Ginger for consumption purpose typically harvested at 5 MAP. This study aims to determine the effect of seed rhizome age on growth, yield and quality of rhizome. The results showed the seed rhizomes aged 8 MAP produce the best growing (plant height, number of tillers, stem diameter, number of leaves). Rhizome quality at the 5th months showed water content and starch, fibers were not significantly different between the ages of the seed. Production of ginger showed the highest yield at 8 MAP. Rhizome of early senescence can be used as seeds and the best results obtained at 8 MAP.

Keywords: Climate change, high temperature, senescence, rhizomes.

Introduction

Ginger is one of the medicinal plants needed in large quantities both for domestic industries and export. The large of ginger demand associated with health benefits that have been scientifically tested. The simplisia has many good uses as raw material for traditional medicine, warmers beverage, spices, and flavor enhancer. Ginger propagation is usually performed with rhizome but has a lot of obstacles. The obstacle among other is the availability of good-quality seed rhizome. Rhizome age, filled out, no wrinkles, bright shiny skin color, and free of pests attacks is characteristic of high-quality seed (Hasanah et al. 2004). As so far, aged rhizome of large white ginger set at the time when the plant has been shed and usually at 9th months after planting (MAP) .If the plant shed before 9th MAP, then the plant will be allowed to grow back, and the rhizome will be harvested at 14th MAP.

Erratic climate change led to a long dry season. During the day, temperatures tend to higher up to 40C, causing impaired growth and development of the ginger rhizome. Plants tend to shed at 7th MAP, while under normal climatic conditions ginger senescense at 9th MAP. Normally, rhizome harvested at 7 MAP is only used for consumption at a cheaper price. Rhizome at 7th MAP is never used for propagation material (seeds) due to lower quality. In undesirable climatic conditions, the availability of seed to at 9th MAP is difficult to obtain and it caused the price of 9th MAP seed rhizome becomes high and in turn increasing production costs. Postponed ginger harvesting is equal with storage in ground. Hirpa et al. (2010) in ground storage of potato is also associated with large losses. Losses of up to 50% have been reported caused by tuber moth and ants. Postponed ginger harvesting could reduce the quality of rhizome.

Because of storage and other post harvest problems loses 30 % of its yield rhizome (Sukarman and Seswita 2012). Rusmin et al. (2015) seed rhizome storage at room temperature with any harvesting time seed rhizome showed that the rhizomes were sprouted after 2 months after storage. Seeds will be deterioration during storage, increasing respiration, lossing weight, greening and budding (Pringle et al. 2009). Postponed harvesting is the most commonly used storage method for ware potatoes in the highland and northwestern areas of the country to extend piece-meal consumption and also to wait for a better price (Endale et al. 2008).

Ginger rhizome used as raw material for medicine, food and beverages comes from 5th MAP. This is first study that determines the effect of seed rhizomes derived from early senescence on 7th MAP and harvested with 3 different times, namely 7th, 8th, 9th MAP on growth, production and quality of the rhizomes at 5 MAP.

Materials and Methods

Study area : The study was conducted in Bogor (188 m above sea level) (West Java, Indonesia), located at 25^{0}03'N latitude and 21^{0}38'E longitude. Seed Technology Laboratory and Green house of Indonesian Spice and Medicinal Crops Research Institute (ISMCRI), from March 2014 to January 2015.

Plants material: Large white ginger, var. "Cimanggu 1" was used as plant material seed rhizome was derived from early senescenseat at 7^{th} month and harvested in 3 different time of rhizomes age namely 7, 8, and 9 MAP (month after planting) and stored for 3 months. The treatment was arranged in Randomized Complete Block Design (RCBD). Factors tested were harvesting time seeds rhizome (7, 8 and 9 MAP) with four replications.
Criteria of seed rhizomes used: firm, weight 7-20 g, have 2-3 buds and free of pests and seed born diseases. Furthermore, seed rhizomes were soaked in a solution of fungicide and bactericide prior to seeding. Seeding was carried out in a plastic box with cocopeat media for 1 month to get healthy seed and grow uniformly.

Seeds rhizome were planted with spacing 50 x 60 cm in the field. Manure is given as much as 1 kg / planting hole, SP 36 as much as 3.5 g per individual plant at planting time. N and K fertilizer are given at 1 MAP for 3.5 g. Watering is performed 3 times a week, while pest and disease control carried out if needed.

Observations : Initial observation was carried out for seed rhizome quality in accordance with the treatment of seed rhizome age such as starch content, fiber content, ABA and GA3 hormones. Observations were carried out on plant growth (plant height, number of tillers, number of leaves, and stem diameter), yield (wet weight rhizome) and quality of rhizomes (starch content, fiber content, gingerol content, water content).

Plant height was measured from the stem base to the tip of the highest leaf. The number of tillers was determined by counting all tillers with leaves and all non-leafy tillers. The number of leaves were counted from the stem tip (growing point) to the stem base, along the 30 cm. The sample being measured is the highest bud in clumps of plants. Observations were carried out monthly, from 1^{st} month until 9^{th} month. Observations on wet weight of shoots at 5^{th} month and 9^{th} month, yield at 5^{th} month and 9^{th} month , quality of rhizome and nutrient content of leaves and stems at the 5^{th} month. The data were analysed according to F test (ANOVA) and the significant difference between treatments were observed using Duncan's multiple range test at P < 0´05.

Results and Discussion

Growth (plant height, number of leaves, and number of tillers and stem diameter)

The best plant height found on the seed rhizomes age 8 MAP (Figure 1a). Plant height peaked at 7^{th} month on all of harvesting time seed rhizomes. Plant height declined sharply by an average of 43 cm in the 8^{th} month compared to 7^{th} with an average of 107 cm. The sharp decline occurred because at 7^{th} month ginger has entered in a period of aging; the leaves turn yellow and senescence. Subsequently observation uses new shoots, so that the plant height is reduced.

The number of tillers formed at the seed rhizome of 8 MAP dominant than other age from beginning to the end of observation (Figure 1b). The number of tillers reached the peak at 7^{th} month reached 42.3 tillers form seed rhizome age 8 MAP. In the following month, the number of tillers began to decrease in all of seed rhizome age. Tillers addition at 7^{th} month is very low in all of seed rhizome age. At 7^{th} MAP, tillers addition is almost nothing. It shows that vegetative growth at 6^{th} MAP started to slow. The highest tillers addition in early observations found at the seed rhizome age of 8 MAP. The highest increase in the number of tillers found from 4^{th} and 5^{th} months. At 7^{th} and 9^{th} MAP, plant growth is slower; it is also shown by the increase tillers peaked at 6^{th} month. There is reduction in the number of tillers when entering in 8^{th} month for all of seed rhizome.

The condition shows that after 5th and 6th months, following the slowing of vegetative growth, photosynthate used primarily for charging rhizomes. This is in conformity with the studies made by Melati *et al*. (2015) who observed growth of large white ginger grown in cocopeat media with and without fertilizers has the same pattern, increasing rapidly in the 4th and 5th month.

The highest number of leaves found at 8 MAP seed rhizome. The number of leaves increased with increasing age, peaked at 6th month (31.2 strands), and decreasing for the following month until the end of the observation (Figure 1c). Decrease in the number of leaves at 7th month 7 confirmed that the vegetative growth peaked at 4th and 5th month, followed with rhizome development phase. Li *et al*. (2010) found that the active phase of vegetative growth on the plant life is 110-130 days after planting, or around 4th month, a phase when most activities are allocated to plant vegetative growth. The next phase is the phase of charging the rhizome.

The tillers diameter of the seed rhizome 8 MAP is better and significantly different with 7th and 9th MAP (Figure 1d). Tillers diameter reaches the largest size at age 5th MAP and afterwards started to decrease. Seed rhizome of 8 MAP produce the best plant in all growth parameters (plant height, number of shoots, number of leaves and stem diameter) during the growth period in 1th – 9th months. The dominance of the growth from 8 MAP allegedly because of the low content of ABA ie 0.018% (Table 1) compared to the other seeds rhizome age, namely 0.025% for 7th MAP and 0.029% for 9th MAP. ABA is a growth retardants that will increase if the plants in a state of drought, so the plants become shed. ABA is pitohormon formed as influenced by environmental factors. Endogenous ABA increased in stress environmental conditions (Leung and Giraudat 1998). Availability of ABA is strongly influenced by environmental factors such as light and water stress (Cutler and Krochko 1999) as well as salinity and cold temperatures (Hanchock and Wilson 2011). Shinohara and Leslovar (2014) confirm that the content of ABA in arthicoke (*Helianthus tuberosus*) will increase in drought conditions.

Harvesting time seed rhizome also affects the ability of rhizome to germinate. Plants that senescence at 7th month and immediately harvested have dormancy rhizome period due to the high content of ABA compared with plant that senescence at 7th month and left in the soil, then harvested at 8th and 9th months. The content of ABA and GA in rhizome at 9th MAP is the highest compared to 7th and 8th MAP. Growth of plants from seed rhizome 9th MAP better than 7th MAP. High availability of GA (0.014%) at the seed rhizome of 9th MAP is able to break dormancy effects of ABA. Rhizome viability testing at seeds rhizome 7th and 8th MAP that harvested from the plant that not shedding yet has been reported by Rusmin *et al.* (2015). The result shows that insufficient seeds rhizome (7th and 8th MAP) has a degree of dormancy higher than 9th MAP. Seed rhizome harvested at 7th, 8th, and 9th MAP has high grown ability ($\geq$ 95%) after stored for three months. Dormancy period is also experienced by potato. Freshly harvested potato tuber experiencing dormancy and ABA will maintain the dormancy (Suttle 2004). Although the content of GA3 in rhizomes at 8th MAP lower than others, but the levels of GA3 is able to break dormancy induced by ABA and induce germination. GA has antagonist roles with the ABA, and the presence of GA is able to grow the rhizomes buds. Plant hormone functions largely in combination, therefore, hormone balance between ABA and GA will provide a different response. The antagonist role of ABA and GA has been found in the seeds of many plant species (Nambara *et al.* 2010).

Seed rhizome of 9 MAP has high starch content (47.15%) rather than 7 and 8 MAP (Table 1). The starch content of seed rhizomes affect buds initiated at the beginning of germination. High levels of ABA on the seed of 9th MAP offset by high levels of starch, so that the rhizomes can sprout and grow better than 7th MAP. Rhizome starch content is strongly influenced by the harvest age, the longer the life of the seed, the higher the levels of starch. The same thing happened in potato tubers. Bhattacharjee *et al*. (2014) states that early harvested potatoes on 80 and 90 days after planting, the tuber starch content lower than potatoes harvested in 100 days after planting.

Production and quality of the rhizome

Ginger rhizome production is strongly influenced by seed rhizome age (Table 2). Rhizome production from seed rhizome age of 8th MAP reached 953 g, significantly different from 7th MAP (310 g) and 9th MAP (605 g). It is alleged that seed rhizome age of 8th MAP have high vigor to with stand on biotic and abiotic environmental stress. Planting conditions in the field seem to be more green and stocky. Optimum growth makes better photosynthesis that produce photosynthate to support the rhizomes growth. Good vigor of rhizome harvesting at 8th MAP is indicated by the fiber content (18.21%), higher than 7th MAP dan 9th MAP. The higher the fiber content of rhizomes, the lower rhizomes softness (Sanewski 2002), the stronger the strength of the rhizomes cell wall (Sanyal and Dhar 2006). This is expected increase the durability of the rhizome to outbreaks of pests and diseases (Rahardjo et al. 2012).

Rhizome quality (water and starch content) were not significantly different between seeds rhizome ages (Table 2). The water content of the rhizome is affected by the moisture content of the growing media. Media with high porosity produces rhizomes with high hardness which indicates that the rhizome moisture content is low. Porous media does not hold water in a long time, the water will pass quickly. It affects the water content of the rhizome. The three seed age treatment was planted with by the same cultivation technique so that the rhizome has the same water content.

The highest fiber content is derived from the seed rhizome age of 9th MAP. The lowest gingerol content found at rhizomes with 7th MAP. Gingerol is a secondary metabolite produced from photosynthesis. High photosynthesis will affect the formation of primary metabolites (starch) and secondary metabolites (gingerol). The age seed of 7th MAP has lower photosynthesis than 8th and 9th MAP, as indicated by slower vegetative growth. Low photosynthesis will produce lower levels of gingerol. Ghasemzadeh and Jaafar (2011) stated that the increase in photosynthesis would increase the levels of starch and levels of young rhizomes gingerol of Malaysia ginger varieties. Rhizome fiber content is influenced by the plant age. The difference in the rhizome quality is suspected due to random sampling. In the development, rhizome will form parent rhizome, primary rhizome, secondary rhizomes, and tertiary rhizomes, but the development time is not differing among rhizomes, thus affecting the maturity of the rhizome. The older age of the rhizome, the higher content of secondary metabolites. The older age of ginger, the higher fiber content of rhizome. According to Parthasarathy et al. (2008), fiber content is more than 10%.

Wet weight of shoot from harvested seed rhizome of 7th MAP is 341 g, significantly different from 8th and 9th MAP (Table 3). Although the wet weight between 8th and 9th MAP were not significantly different but visually indicates that plants from seed rhizome 9th MAP have much yellowing leaves. Seed rhizome of 8th MAP grow with colored green and stockier stem. The ability of leaves to perform photosynthesis can be characterized by its color. Greener leaf color has higher photosynthesis ability that makes photosynthate capable to supply maximum rhizome development. Study of Sarma et al. (1994) in Sood and Dohro (2005) found that the yellow leaves can reduce the formation of rhizomes around 66%.

The nutrients content (N and P) of leaves and stems were not significantly different among seed age (Table 3). K content from 7th MAP is the highest, but visually not indicates that plant conditions are better than others. This shows that the seed nutrient content is not affected by age. Leaf nutrient content is influenced by the availability of nutrients in the soil. NPK nutrient absorption is not affected by seed age but by soil pH. According to soil analysis, the pH is 6.2, suitable for ginger cultivation. Ginger can grow well at pH 6 to 7.4 (Rostiana et al. 2005, Nishina et al. 2015). The higher uptake of K compared to N and P is confirmed by Xin-Sheng et al., (2010) which states that K nutrient is most absorbed by ginger compared to N and P, the uptake ratio of N: P: K was 2.5 : 1.0: 3.8.

Rhizome wet weight in the 5th month was positively correlated with the number of shoots, and give linear equation $x = -176 + 37.1\ y$ ($R2 = 65.1\%$) and ($P = 0.81$) as shown at Figure 2. It shows that the more the number of shoots, the higher the weight of produced rhizomes, so that the production of seed rhizomes can be predicted from the number of shoots. Shoots serves as photosynthesis site that will supply food for the development of rhizomes (sink). The more shoots will certainly increase the occurrence of photosynthesis. Abraham and Latha (2003) states that there are 12 characters that have a positive correlation with the production of rhizome among others tillers and number of leaves have a high correlation. Purwiyanti (2012) stated that rhizome of small white ginger is resultant of the stem length, number of tillers, leaf number, leaf length, and leaf width. Stem length and leaf thickness correlated positively and directly affect the weight of the rhizome, while the other has indirect effect.

The highest wet weight of rhizomes in the 9th month was found in harvest 8th MAP, namely 1.225 g (Table 4). Rhizome development increased to ± 30% from 5th month. It shows that high vigor seeds are able to grow and develop and produce high rhizome production. Seed rhizome of 7th and 9th MAP shows rhizome production that not differs significantly. The highest shoots wet weight derived from harvest age of 8th MAP. The low fresh weight of tillers caused by the plant had senescence.

Conclusions

Harvesting time seed rhizomes 8 MAP has the best growth, as indicated by the high all growth parameters (plant height, number of tillers, number of leaves and diameter of tillers) at almost any time of observation than harvesting time seed rhizomes 7 and 9 MAP. Harvesting time seed rhizome not affect nutrient content of leaves and stems of plants in the 5^{th} but affect the vigor shown by greener and stocky plant that comes from harvesting 8 MAP. Quality rhizome in the 5th month of seed rhizome 7,8,9 MAP were not significantly different. The best weight of rhizomes at 5^{th} month and 9^{th} months indicated by seed rhizome 8 MAP. The number of tillers at 5^{th} positively correlated with the weight of rhizomes. Ginger senescence at 7^{th} month, the rhizome can be used as seeds and the best results obtained at seed rhizome 8 MAP.

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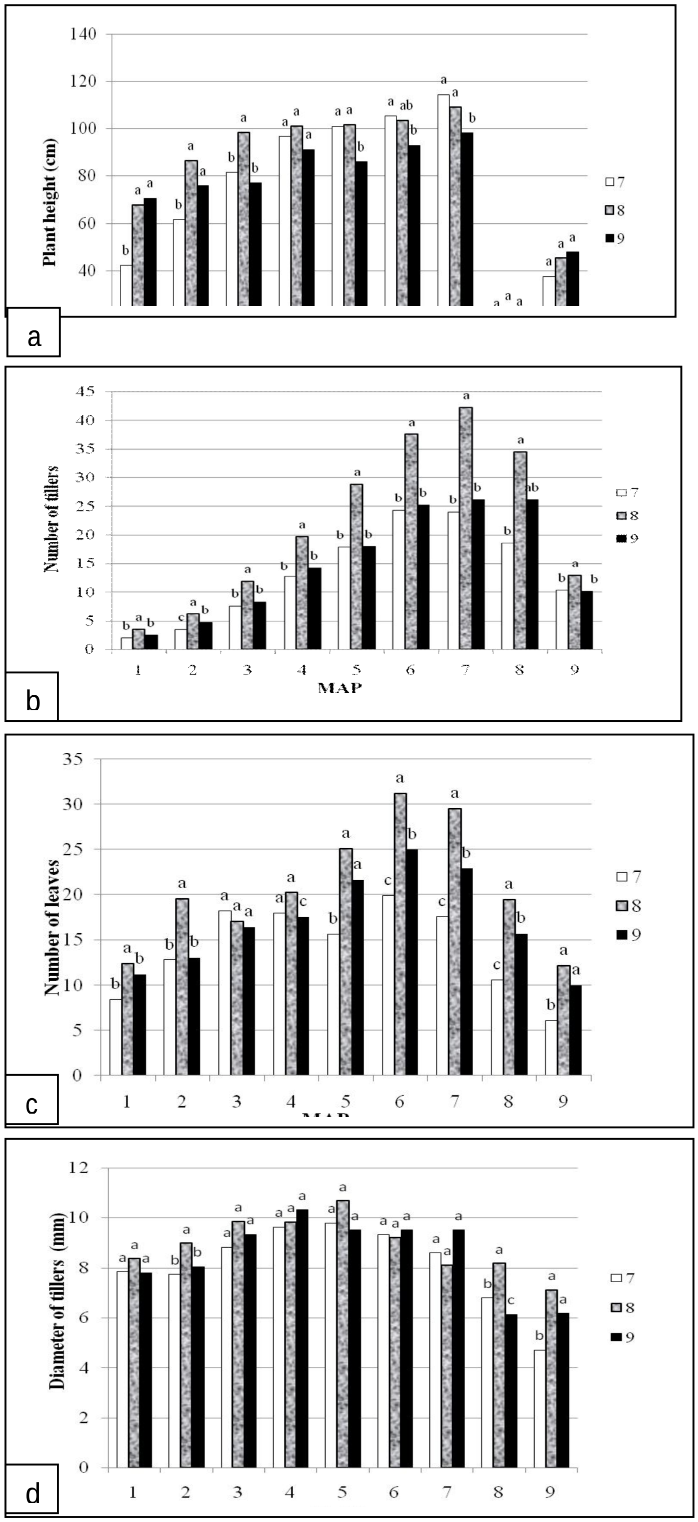

Figure 1. Effect of harvesting time seed rhizome on a) plants heigh, b) number of tillers, c) number leaves, d)diameters of tillers

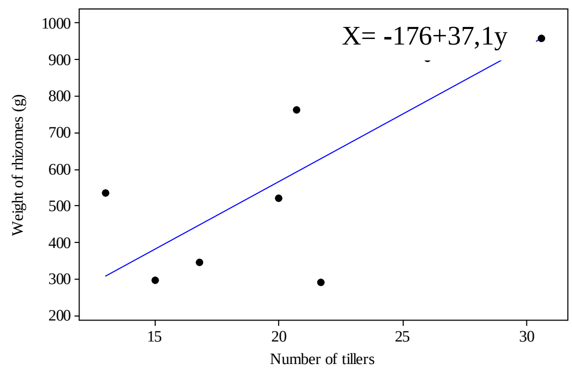

Figure 2: Relationship number of tillers (x) and yield of rhizomes (y) on 5 MAP.

Table 1: Quality of seed rhizome age.

Treatment	Quality of seed rhizome age. (%)			
	Starch content	Fiber content	ABA	GA3
7 MAP	31.92	16.09	0.025	0.008
8 MAP	41.54	18.21	0.018	0.007
9 MAP	47.15	10.30	0.029	0.014

Table 2. Effect of seed rhizome age on yield and quality of rhizomes at 5 th month

Treatment	Yield of rhizomes (g)	Quality of rhizomes (%)			
		Water content	Starch content	Fiber content	Gingerol content
7 MAP	310 c	90.7	41.6	16.40 b	1.07 b
8 MAP	953 a	91.2	43.6	15.94 b	1.51 a
9 MAP	605 b	92.7	42.7	22.5 a	1.71 a
CV (%)	14.36	2.06	5.21	5.21	11.57

Note: The same letters in each column are not significantly different at 5% level by DMRT

Table 3. Effect of harvesting time seed rhizome on fresh weigh of shoot and N,P, K content of stem and leaf on 5 th month.

Treatment	Fresh weigh of shoot (g)	N,P, K content of stem and leaf (%)		
		N	P	K
7 MAP	341 b	2.43	0.32	5.41 a
8 MAP	655 a	2.20	0.27	4.23 b
9 MAP	503 ab	2.20	0.26	4.06 b
CV (%)	22.57	6.21	10.07	9.12

Note: The same letters in each column are not significantly different at 5% level by DMRT

Table 4. Effect of harvesting time seed rhizome on weight of rhizomes/yield and fresh weight tillers at 9 th month

Treatment	Weight of rhizomes(g)	Fresh weight of tillers (g)
7 MAP	595 b	64 b
8 MAP	1225 a	135 a
9 MAP	685 b	122 a

Note: The same letters in each column are not significantly different at 5% level by DMRT