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Research Article

The Effects of Fertilizer Treatment, Rhizome Seed Size, and Day of Harvest in Java Turmeric (*Curcuma xanthorrhiza* Roxb.)

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ABSTRACT

Java turmeric (Curcuma xanthorrhiza Roxb.) is cultivated as a secondary crop, resulting in variable rhizome quality which can be increased by suitable cultivation methods. This study investigated the effect of different cultivation methods on the rhizome yield of Java turmeric. Different fertilizer treatments(none, organic, inorganic, and semi-organic fertilizer), three groups of rhizome seed size (small (50–80 g), medium (100–150 g), and large (200–250 g)) and three groups of harvesting age (eight, ten, and twelve months after planting) were evaluated in a split plot design experiment. Results show that large rhizome seed size together with organic fertilizer treatment increased secondary rhizome production, yielding the highest number, weight and diameter. As high levels of starch in the primary rhizome are crucial for growth of the plant, the use of large rhizomes for propagation is indicated in Java turmeric cultivation. The highest weight and number of primary rhizomes were yielded when plants were harvested twelve months after planting.

Keywords: Curcuma xanthorrhiza; Organic fertilizer; Rhizome.

1. Introduction

Java turmeric (*Curcuma xanthorrhiza* Roxb.) originates from Indonesia and grows in tropical rain forest conditions. It is currently cultivated as a secondary plant under perennial crops such as fruit plants (Djakamihardja *et al*. 1985); however, the production and quality vary with different crops. Rhizome increases when Java turmeric is grown in loose soil (Djamhari 2010). The rhizomes of Java turmeric contain curcumin; the active ingredient used in traditional medicine for inducing the secretion of bile and pancreatic enzymes. The rhizomes also contain antioxidants, such as phenols, flavonoids and curcumins, which function as chelating agents of free radicals in the human body (Bintari *et al*. 2014). Soil nutrient quality affects the growth and yield of Java turmeric, and can be improved with the addition of organic (compost) and inorganic fertilizer (Hadipoentyanti & Syahid, 2007).

Turmeric, including Java turmeric, need high levels of nutrient absorption to produce rhizomes, and often require additional nutrients for maintaining productivity. The use of inorganic and organic fertilizer in plant cultivation increases available nutrients in the soil. Long-term use of inorganic fertilizer degrades physical and chemical soil properties and destroys soil microbes (Boud *et al*. 2013). It has long been established that organic fertilizer improves soil nutrient levels and physical structure. Organic fertilizers are made from plant matter and animal manure that has been decomposed by microbes (Samanhudi *et al*. 2014). Organic material increases nutrient supply, rhizome yield, and rhizome quality of Java turmeric (Somasundaran & Shanthi 2014). The organic farming system offers food production at a low cost and is safe for the environment due to minimum use of synthetic substances (Rahardjo *et al*. 2007). Organic farming is based on conservation principles with a practical, sustainable agricultural approach, creating improvement in soil structure, water

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infiltration and water retention, and maintaining soil microbial biodiversity (Duruigbo *et al*. 2013).

A part from the agricultural system used, another factor influencing successful cultivation is the use of a good rhizome seed, with up to 40% of the success of Java turmeric cultivation being dependent on rhizome seed quality. Java turmeric requires a seeding rate of 1.5–2 tons of rhizomes per hectare. Small primary rhizomes can be used as rhizome seeds for efficient cultivation (Sukarman *et al*. 2011).

The aim of this study was to evaluate the influence of different fertilization treatments (organic, inorganic, and semi-organic), different rhizome seed sizes used for propagation, and different harvesting ages on various agronomic characteristics of Java turmeric rhizomes.

2. Material and Method

Environmental conditions and materials used

The study was conducted from January 2015 to January 2016 at the plant germplasm collection garden managed by the Biotechnology Research Center of the Indonesian Institute of Science. The study site was a Kemang (*Mangifera kamanga* L.) tree grove (planted in 1980) with 60% light intensity and a latosol soil type with a pH value of 6.4. Primary rhizomes of Java turmeric plants (collected from the Yogyakarta province in 2014) were used as seedlings.

The experiment used a split plot design. The main plot factor was the use of fertilizer, with four groups: no fertilizer (control group), inorganic fertilizer, semi-organic fertilizer, and organic fertilizer. The organic fertilizer was produced by the germplasm collection garden from soil with the following composition: pH: 7.6, Nitrogen (N): 2.4%, Phosphorus (P): 3%, Carbon (C)-organic: 31.2, Copper (Cu): 51.3 ppm, Zinc (Zn): 55.7 ppm, Calcium (Ca): 0.27 ppm and Magnesium (Mg): 0.2 ppm. The second factor in the split plot design was the rhizome seed size used for propagation, with three groups: small (50–80 g), medium (100–150g), and large (200–250 g). The third factor in the split plot design was the harvesting age, with three groups: eight, ten, and twelve months after planting. In total, there were 36 combinations of factors used in the study, and each combination replicated three time.

Java turmeric cultivation

Fertilizer was applied twice at two and eighteen weeks after planting. The first application of fertilizer at two weeks after planting was given at the following rates: inorganic (100kg/hectare phosphate 36%), semi-organic (50 kg/hectare phosphate 36% and 35 ton/hectare compost) and organic (70 ton/hectare compost). The second application of fertilizer at eighteen weeks after planting was given at the following rates: inorganic (10 ton/hectare compost, 95kg/hectare urea, and 85 kg/hectare Potassium chloride (KCl)), semi-organic (40 ton/hectare compost,45.5kg/hectare urea, and 42.5 kg/hectare KCl) and organic (70 ton/hectare compost). The fertilizer was applied by digging up a circle surrounding the plant (radius of 10 cm), applying the fertilizer, and watering liberally to ensure adequate moisture. Plots were 1×5 m and spaced 0.5 m within rows and 0.6 m between rows. Rhizome dormancy was broken before planting (Adi *et al*. 2015).

Data collection and analysis

The following measurements were taken at the different harvesting ages: number of primary rhizomes (NPR), number of secondary rhizomes (NSR),number of tertiary rhizomes (NTR), weight of fresh primary rhizomes (WPR) (g), weight of secondary rhizomes (WSR) (g), weight of tertiary rhizomes (WTR) (g), total rhizome weight (RTW) (g), diameter of primary rhizomes (DPR) (mm), diameter of secondary rhizomes (DSR) (mm),and diameter of tertiary rhizomes (DTR) (mm) (Figure 1). These measurements were evaluated from three clump samples of Java turmeric from each treatment plot.

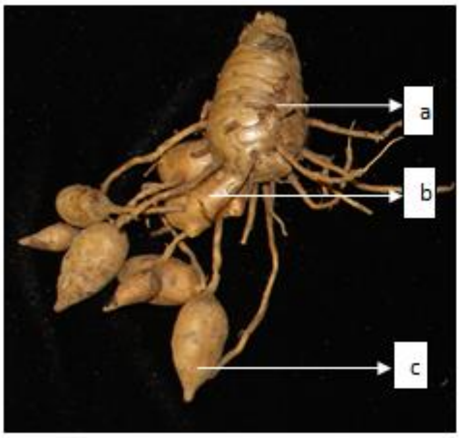

Figure 1. The Java turmeric rhizome showing a) primary, b) secondary, and c) tertiary rhizomes.

NPR was determined by counting the rhizomes attached to a lapsed plant, NSR by counting the side rhizome branches of the primary rhizomes (i.e. without the presence of a lapsed plant), and NTR by counting the number of tubers at the end of the root. The weight of the primary, secondary, and tertiary rhizomes was determined by weighing each rhizome in the clump sample; these were summed for total rhizome weight. The diameter of each rhizome was determined from its cut surface. Means were derived from measurements of three samples.

Data were analyzed by ANOVA to determine significant differences between treatment groups, and following by Duncan's Multiple Range Test by 5% error threshold if there is significant.

3. Result

Rhizome characteristics and analysis of variance

During the study period, the highest rainfall was recorded in January 2016 (765mm) and the lowest was recorded in July 2015 (0mm) (Figure 2). The early planting in January ensured a sufficient supply of water for the growth of the Java turmeric plants due to high rainfall (January–April 2015). The dry season started early (May–June 2015) with the leaves of the plants turning yellow and then going into a state of dormancy (July–October 2015) (Prana 1985). The dormancy state of plants in tropical areas such as Indonesia is an escape mechanism to survive drought stress in the dry season. In subtropical regions, *Curcuma* species develop a dormancy state in winter (Kristina *et al*., 2010).

When the Java turmeric plants were harvested eight months after planting (in September 2015), they had a tendency to be in the dormant phase and showed rhizomes without shoots. When harvested ten months after planting (in November 2015), they were in the vegetative phase and showed rhizomes with shoots. When harvested twelve months after planting, plants had leaves but some samples had rotten rhizomes.

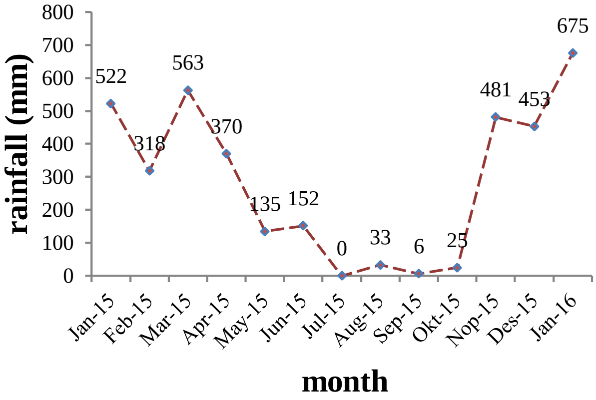

Figure 2. Monthly rainfall during the period January 2015 to January 2016 (Meteorology regency Bogor 2016).

Table 1 shows the effect of all factors and factor interactions on rhizome characteristics. The day of harvest significantly influenced the NPR, WTR, DPR, DSR, DTR, and RTW values. These results support Ferry *et al*. (2009)'s research showing that age of harvest in Java turmeric influences the weight of rhizomes.

Table 1. Analysis of variance of rhizome characteristics in the Java turmeric plants

Source of variation	NPR	NSR	NTR	WPR	WSR	WTR	DPR	DSR	DTR	RTW
Day of harvest (DH)	$252.5^{0.000}$	$4.7^{0.090}$	$8.1^{0.039}$	$42.9^{0.002}$	$5.6^{0.069}$	$13.8^{0.016}$	$11.9^{0.021}$	$17.4^{0.011}$	$19.9^{0.008}$	$2.7^{0.184}$
Fertilizer	$2.1^{0.142}$	$4.5^{0.016}$	$5.7^{0.006}$	$5.7^{0.006}$	$7.8^{0.001}$	$7.8^{0.002}$	$0.9^{0.480}$	$3.2^{0.048}$	$1.0^{0.432}$	$20.2^{0.000}$
DH×fertilizer	$1.4^{0.276}$	$0.7^{0.632}$	$1.7^{0.181}$	$1.0^{0.454}$	$0.4^{0.893}$	$1.5^{0.221}$	$0.6^{0.716}$	$1.4^{0.287}$	$0.7^{0.689}$	$1.9^{0.133}$
Rhizome seed size (RS)	$4.0^{0.024}$	$0.5^{0.584}$	$0.4^{0.702}$	$13.4^{0.000}$	$3.5^{0.040}$	$0.3^{0.745}$	$24.7^{0.000}$	$0.3^{0.722}$	$0.9^{0.403}$	$5.8^{0.006}$
DH×RS	$0.5^{0.707}$	$2.1^{0.102}$	$0.3^{0.857}$	$2.1^{0.097}$	$1.4^{0.237}$	$0.4^{0.775}$	$3.1^{0.025}$	$2.3^{0.075}$	$1.4^{0.261}$	$0.9^{0.458}$
Fertilizer× RS	$1.4^{0.240}$	$2.7^{0.023}$	$1.6^{0.170}$	$1.9^{0.094}$	$4.4^{0.001}$	$1.0^{0.409}$	$1.8^{0.117}$	$4.8^{0.001}$	$0.9^{0.474}$	$2.7^{0.025}$
DH × fertilizer×RS	$0.8^{0.603}$	$1.0^{0.443}$	$1.0^{0.442}$	$0.3^{0.979}$	$1.2^{0.294}$	$0.9^{0.571}$	$0.9^{0.546}$	$1.9^{0.060}$	$1.1^{0.360}$	$1.0^{0.471}$

Superscript values show the p-value; p-values less than 0.05 were considered significant. NPR= number of primary rhizomes, NSR= number of secondary rhizomes (transformed: log (x+2)), NTR= number of tertiary rhizomes (transformed: log (x+5)), WPR=weight of primary rhizomes (transformed: log (x+1)), WSR=weight of secondary rhizome (transformed: log (x+2)), WTR=weight of tertiary rhizomes (transformed: log (x+5)), DPR=diameter of primary rhizomes, DSR=diameter of secondary rhizomes (transformed: log (x+3)), DTR=diameter of tertiary rhizomes (transformed: log (x+4)), RTW=weight of

The fertilizer treatments showed significant effects on the NTR, WPR, WTR, and RTW values. Rhizome seed size showed significant effects on the NPR and RTW values; Hossain *et al*. (2005) reported similar findings, showing that rhizome seed size affected the size of primary and secondary rhizomes. There was a significant interaction effect of day of harvest and rhizome seed size on DPR value, and of fertilizer and rhizome seed size on number, weight, and diameter of the secondary rhizomes.

Day of harvest

Different harvesting ages (DH) influenced agronomic characteristics of Java turmeric such as the WPR and NPR (Table 2). The largest WPR value (124.1±45.7 g) and NPR value (3.3±0.3) were seen twelve months after planting, followed by the eight-month values (NPR 1.9±0.1,WPR 76.5±2.7 g); the lowest values were ten months after planting (NPR 1.4±0.3, WPR 45.1±28.5 g

Table 2. The effect of day of harvest on NPR, NTR, WPR, WTR, DTR, and RTW values of Java turmeric rhizomes

NPR	NTR	WPR (g)	WTR (g)	DTR (mm)	RTW (g)
1.9±0.1 b	7.3±0.2 b	76.5±34.8 b	31.2±2.7 b	11.6±1.9 b	150.6±21.8 b
1.4±0.3 a	3.3±0.7 a	45.1±28.5 a	13.1±4.9 a	4.9±0.7 a	74.4±41.4 a
3.3±0.3 c	5.5±0.8 ab	124.1±45.7 c	10.3±1.9 a	6.5±0.7 ab	156.3±35.8 b

Entries within a column followed by the same letter were not significantly different (Duncan's test, p = 0.05)

The highest tertiary rhizome values were seen eight months after planting with 7.2±0.2 NTR, 31.2±2.7 g WTR, and 11.6±1.9 mm DTR. Differences in number and weight of rhizomes in seem to occur during the plant growth phase. Plants were in the dormant phase eight months after planting and in the vegetative phase ten months after planting.

Rhizome size, rhizome weight, and number of rhizomes decreased ten months after planting; the same phenomenon was found in the lempuyang (*Zingiber zerumbet* (L.) J.E.Smith) (Yuliani *et al*., 1999).

The highest values for WPR (124.1±45.7 g) and NPR (3.3±0.3) were seen twelve months after planting. The large size of the primary rhizome is due to the storage of starch from the previous growth phase, providing energy for the following vegetative phase and affecting plant growth and yield.

Inorganic, organic, and semi-organic fertilizer treatment

The effect of the fertilizer treatments on rhizome characteristics is shown in Table 3. The highest NTR values were seen with the use of organic fertilizer (8.1±2.9) and inorganic fertilizer (5.4±3.7). Organic fertilizer produced the highest values for WPR (110.3±49.3 g), WTR (33.3±18.7 g), and RTW (188.8±65.3 g), it indicating that organic treatment resulted in increased production compared to inorganic, semi-organic and no fertilizer treatments. Differences in rhizome seed size did not influence the WPR value when treated with organic fertilizer. The same result was reported in temu ireng (*Curcuma aeruginosa*), where small (5–10 g) and large rhizome seeds (20–25 g) provided the same yield when using organic manure fertilizer (Rosita *et al*. 2001).

Table 3.The effect of fertilizer on NTR, WPR, WTR, and RTW values of Java turmeric rhizomes

Fertilizer	NTR	WPR (g)	WTR (g)	RTW (g)
Without fertilizer	3.4 ±1.3 a	62.8±33.2 a	10.5±5.9 a	93.7±33.1 a
Inorganic	5.4 ±3.7 ab	87.8±47.9 a	17.1±15.9 a	130.7±56.4 a
Semi-organic	4.5±0.7 a	66.3±31.5 a	11.6±5.2 a	95.1±34.9 a
Organic	8.1± 2.9 b	110.3± 49.3b	33.3±18.7 b	188.8±65.3 b

Entries within a column followed by the same letter were not significantly different (Duncan's test, p = 0.05)

Rhizome seed size

The effect on NPR values of use of large (2.4±1.1), medium (2.1±1.0), and small (2.1±0.9) rhizome seeds for propagation is shown in Table 4. Large rhizome seeds resulted in the highest WPR (110.1±43.3 g) and TRW (163.2±38.2 g) values. (A'yun *et al*. 2015) similarly reported that the largest Java turmeric rhizome seeds (15–20 g) produced the heaviest total rhizome weight (up to 380.7 g). The larger weight of the rhizomes ensures a larger stock of energy (starch stored in the rhizome is a source of glucose), improving plant production (Rosita *et al*. 2001).

Table 4. The effect of rhizome seed size on NPR, WPR, and RTW values of Java turmeric rhizomes

Rhizome seed size	NPR	WPR (g)	TRW (g)
Small	2.1±0.9a	65.7±38.4 a	105.9±55.9 a
Medium	2.1±1.0a	69.1±39.3 a	111.8±46.4 a
Large	2.4±1.1b	110.1±43.3 b	163.5±38.2 b

Entries within a column followed by the same letter were not significantly different (Duncan's test, p = 0.05)

Rhizome seed size and day of harvest

The largest rhizomes resulted from large rhizome seeds when harvested ten months after planting (39.4±3.1 mm) (Table 5). Rhizome seed size is an indicator of rhizome propagation quality, and large and heavy rhizomes show improved growth in the early vegetative phase (due to high levels of starch) (Rosita *et al*. 2001). This fast growth in the early vegetative phase likely causes the Java turmeric plant to start the generative phase earlier, producing larger rhizomes when harvested ten months after planting.

Table 5. The effect of rhizome seed size and day of harvest on DPR (mm) values of Java turmeric rhizomes

Day of harvest (month)	Rhizome seed size		
	small (50–80g)	medium (100–150g)	large (200–250g)
8	31.4±1.6 d	32.7±3.4 c	36.4±1.0 b
10	27.7±2.6 g	32.9±3.4 c	39.4±3.1 a
12	28.9±2.6 f	30.3±2.0 e	32.8±3.0 c

Entries within a column followed by the same letter were not significantly different (Duncan's test, p = 0.05).

Rhizome seed size and fertilizer treatment

The interaction between rhizome seed size and fertilizer treatme3.5.nt is shown in Table 6. Theuse of large rhizome seeds together with organic fertilizer showed the largest DSR (17.9±2.9 mm). The largest WSR was seen when using big rhizome seeds together with organic and inorganic fertilizer (56.6±13.6 g and 37.2±15.4 g respectively). The highest NSR was yielded when using organic fertilizer on any seed size (large: 4.3±0.1 g, medium: 3.1±1.3 g, small: 3.2±1.2 g). Kamal & Yousuf (2012) noted that turmeric plants produce more secondary rhizomes (16.2 on average) when using cow manure compared to not using any fertilizer.

Table 6. The effect of fertilizer treatment and rhizome seed size on NSR, WSR, and DSR values of Java turmeric rhizomes.

Rhizome seed size	Fertilizer	NSR	WSR (g)	DSR (mm)
Small	Without fertilizer	2.3±0.8 ab	15.3± 8.2 abcd	14.2±0.6 bcd
	Inorganic	2.5±1.3 ab	13.7±10.2 abcd	11.2±4.7 ab
	Semi-organic	1.7±0.7 ab	11.7± 6.7 ab	9.4±1.8 a
	Organic	3.2±1.2 cd	33.2±21.7 efg	14.9±5.0 bcd
Medium	Without fertilizer	2.4±0.5 bc	17.2± 2.0 cdef	15.0±0.4 cd
	Inorganic	1.7±1.3 ab	13.8± 9.0 abc	8.9±6.2 a
	Semi-organic	2.6±0.5 bc	15.2± 5.8 bcde	14.7±2.1 bcd
	Organic	3.1±1.3 cd	26.1±10.9 def	14.2±0.4 bcd
Large	Without fertilizer	1.5±0.6 a	9.0± 4.5 a	9.8±1.5 a
	Inorganic	2.8±0.9 c	37.2±15.4 fg	15.2±3.7 cd
	Semi-organic	2.3±1.4 ab	18.7±14.6 cde	11.5±4.2 abc
	Organic	4.3±0.1 d	56.6±13.6 g	17.9±2.9 d

Entries within a column followed by the same letter were not significantly different (Duncan's test, p = 0.05)

4. Discussion

The differences between the number and weight of the Java turmeric rhizomes during the growth phase (when harvested eight months after planting in the dormant phase) compared to during the early vegetative phase (when harvested ten months after planting) are likely due to rainfall (Muhartini & Kurniasih 2000). The decreasing size, weight and number of rhizomes recorded when harvested at ten months is caused by the starch content of the rhizomes being utilized for growing shoots, as recorded in lempuyang (Kristina, *et al*. 2010). In plants that produce rhizomes, environmental conditions determine the occurrence of initiation of cell division in the bud eye, which is followed by a growing shoot (Yuliani *et al*. 1999).

The use of organic fertilizer affected the number and weight of the tertiary rhizomes as well as the weight of the primary and total rhizomes. This effect is likely due to the nature of the organic compound. The fertilizer increases the soil nutrient levels so that using different rhizome seed sizes for propagation did not significantly affect the growth and production of Java turmeric rhizomes. Allison (1973), reports that using organic fertilizer improves soil condition and increases the soil microbe population, thereby increasing the available nutrients for the plant.

The effect of rhizome seed size was seen in the NPR, WPR, DPR, and WTR values, showing that large rhizome seeds are the best size rhizomes for propagation. This effect could be driven by the presence of starch stored in the rhizomes as a source of energy for new growth when used for vegetative propagation of rhizome plants (Addai & Scott 2011). Starch is metabolized by enzymes (amylase) to produce energy, which is transferred to the shoot for growth of the plant (Hopkin & Norman 2004). Larger rhizomes contain more starch, providing more energy for improved growth during the early growing phase (vegetative phase) compared to smaller rhizomes. Seedlings with faster growth in the early vegetative phase produce increased numbers of larger rhizomes.

The use of organic fertilizer together with large rhizome seeds produces higher NSR values. The addition of organic fertilizer improves the soil texture and structure, as well as the binding power and drainage of water, and this affects the growth and development of secondary rhizomes in turmeric species. The use of organic matter lengthens the time that nitrogen is available in the soil aggregate; long-term nutrient availability is important to a long-lived plant such as Java turmeric (Kamal & Yousuf 2012). Increasing the organic matter in the soil also increases the availability of chelating agents which bond to dissolved ions and increase soil fertility (Manitoba 2013). Organic matter improves soil quality and therefore counteracts decreased agricultural production due to the decreased quality of the soil. Organic matter also decreases salinity and improves soil structure, water holding capacity, and air permeability in the rooting zone (Hassanpanah & Jafar 2012).

5. Conclussion

The use of organic fertilizer generally increased rhizome production in Java turmeric. Using large rhizome seeds for propagation together with organic fertilizer increased the number, weight, and diameter of secondary rhizomes. High levels of starch in the primary rhizome are important for growth of the plant, therefore the use of large rhizomes for propagation is important in Java turmeric cultivation. Treatment with organic fertilizer produces rhizomes with larger diameters when harvested ten months after planting.

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