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Growth and Yield Characters of Two Cashew (*Anacardium occidentale* L.) Cultivars at Different Ages in Baubau City, South-East Sulawesi Province

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ABSTRACT
Baubau City is one of the cashew (*Anarcadium occidentale* L.) producer area in Southeast Sulawesi with area of 820 ha. This large area of cashew cultivation is not compensated with the productivity due to low production. An effort to overcome this problem is identifying the growth and yield characters of cashew to apply the good agricultural practices for cashew plantation. The objective of this research was to determine the growth and yield of two cashew cultivars at different tree ages and to identify the relationship between the characters and the productivity of cashew trees in Baubau City. The research was arranged in over sites design consisting of 2 cashew cultivars (the cashew with red pseudo-fruit and the cashew with yellow pseudo-fruit), 4 ages of cashew trees (5 years old, 17 years old, 26 years old and 37 years old) and 5 replications. The results showed that both cultivars had no significant different on growth and yield characters. At 37 years old, cashew trees still demonstrated the increasing of the productivity due to the increasing of growth and yield component, i.e. plant biomass, number of flower, number of cashew nut per plant and cashew nut weight per kernel.

Keywords: Cashew, growth, yield, ages

INTRODUCTION

Cashew is one of the plantation commodities having high economic value and a large contribution to the Indonesian economy such as increasing the export value and farmer's income, providing the food industry raw material and providing job opportunities for society. Indonesia is one of the biggest cashew nut production countries in the world. Food and Agriculture Organization (FAO) (2014) data show that Indonesia is the ninth cashew nut producer in the world and the third cashew nut producer in ASEAN after Vietnam and the Philippines.

Southeast Sulawesi is the third biggest cashew nut producer in Indonesia, with an average production of 15.20 tons.year^{-1} (12.94%), after East Nusa Tenggara and South Sulawesi. Cashew nut is one of the important commodities of plantations in Southeast Sulawesi. Baubau City is one of the cashew nut producing areas in Southeast Sulawesi with production area of 820 ha. Cashew nut is also one of the annual sources of income for farmers. However, according to Dirjenbun (2015), the productivity of cashew in Baubau City was still relatively low, which is an average of around 177 kg.ha^{-1}.

Generally, Cashew farmers in Baubau City cultivate two local cultivars namely the cashew with the red color of pseudo-fruit and the cashew with the yellow color of pseudo-fruit. Both of two cashew cultivars have been cultivated for decades by farmers in that region. Unfortunately, there is no detailed information about the characteristics of growth and yield due to the lack of research on cashew in Baubau City, Southeast Sulawesi. Rostiana *et al*. (2017) reported the rare research in distinguishing the quantity and quality of yield between yellow and red pseudo-fruits. On the other hand, the information of growth characteristics and yield are able to be used as a reference for the planting management in optimizing the productivity of cashew plantation such as fertilization, pruning, rejuvenation, and cultivating of the plant material.

The identification of growth characteristics and yield of cashew tree is important to be carried out because

it influences the quantity and quality of cashew. According to Chipojola *et al*. (2009) and Ona *et al*. (2017) the production of cashew tree is strongly influenced by genetic factors. The production is also affected by the physiological characters and plant growth components such as chlorophyll, stomata, leaf area and plant height (Giannakoula *et al.*, 2012; Hammed *et al*., 2011). Higher of leaf chlorophyll content and the number of flower of plant increase the production of cashew (Lakshmipathi *et al*., 2017).

The production of cashew trees is also influenced by differences in plant age. Darwati *et al*. (2013) stated that the cashew trees aged more than 10 years old showed the higher yields compared to younger trees. The difference in yield is closely related to physiological processes, such as photosynthesis. Higher yields plant is usually supported by an optimum photosynthetic rate.

Rostiana *et al*. (2017) reported that the most cultivated varieties of cashew plant in Indonesia were the varieties with the red and yellow color in pseudo-fruit. Both of cashew cultivars could be distinguished from the color of their pseudo-fruit. However, both cultivars also could be distinguished from their flesh, where the red pseudo-fruits have reddish-greed flesh color, while the yellow pseudo-fruits have light green and whitish-green flesh color. There are differences in the physiological character and growth between the genotypes. The objective of this research was to determine the growth and yield of two cashew cultivars at different tree ages and to identify the relationship between the character and the productivity of cashew trees in Baubau City.

MATERIALS AND METHODS

The research was conducted in Baubau City, Southeast Sulawesi, Indonesia, with geographical position between 05°15'– 05°32' SL and 122°30'–122°46' EL, and Laboratory of Crop Production Management, Universitas Gadjah Mada from July 2017 – January 2018. The research was arranged in over site design consisting of 2 cashew cultivars (the cashew with red pseudo-fruit and the cashew with yellow pseudo-fruit), 4 ages of cashew plant (5 years old, 17 years old, 26 years old and 37 years old) and 5 replications. The observed variables were the leaf chlorophyll content, nitrate reductase activity, plant height, stem girth, number of flowers, plant biomass, nut weight and productivity. The observation of chlorophyll content was carried out using spectrophotometry method. 0.1 g of plant leaves was crushed with mortar then extracted with 50 ml of 80% acetone and filtered with filter paper using a funnel in 50 ml Erlenmeyer. Then the extracts were added by 80% acetone until the volume reached 50 ml. The extract then was put into the cuvette and its absorbance was read using the CARY 50 CONC Variant Spectrophotometer at a wavelength of 663 nm and 646 nm. The blank used was Acetone 80%. Leaf total chlorophyll content was measured using formula as follows: Total chlorophyll content = 0.0202 x A645 + 0.00802 x A663. Where, A645 is absorbance at the wavelength of 645 nm and A663 is absorbance at the wavelength of 663 nm.

Nitrate reductase activity was observed using spectrophotometry method. 0.2 grams of plant leaves were cut thin. Dark tube was prepared and filled with 5 ml phosphate buffer solution 0.1 M pH 7. Pieces of leaves were then put in the dark tube and allowed to stand for 24 hours. After 24 hours, the buffer was replaced with 5 ml of new buffer. Then it was added with 0.1 ml of 5 M $NaNO_3$ and the time was recorded as the initial incubation for 2 hours. Meanwhile, the dye reagent was prepared in a test tube consisting of 0.2 ml of 1% sulphanilamide in 3 N HCl and 0.2 ml of 0.02% N-naphthylenediamine solution. After 2 hours, as much as 0.1 ml of incubated liquid from the dark tube was put into the dye reagent. Then it was waited until the color turned to pink as a sign that nitrate to nitrite had been reduced by nitrate reductase enzyme and then it was added with 2.5 ml of distilled water. The solution was read for its absorbance using a CARY 50 CONC Variant Spectrophotometer at a wavelength of 540 nm. The blank used was distilled water.

Plant height was measured from the base of the stem above the soil surface to the highest shoot tip, while the stem girth was measured by using a meter roller at 50–100 cm above the soil surface. The number of flower, the number of primary branch and the number of cashew nut per plant were counted manually by using hand counter. Plant biomass measurement was carried out according to Somarriba *et al*. (2013) method, where the trees diameter was measured at a certain height (15–30 cm), then it was calculated by formula: Log B = (-1.11 + 2.64 x Log (diameter)). The productivity per hectare was calculated by conversion yield per plant to one hectare.

RESULTS AND DISCUSSION

The production of cashew trees is largely determined by several factors, namely genetic, environmental

Table 1. Chlorophyll content ($mg.g^{-1}$) of two cashew cultivars at different ages

Cultivars (Pseudo-Fruit Color)	Plant ages (Years)				Mean
	5	17	26	37	
Yellow	1.05 a	1.12 a	1.07 a	1.08 a	1.08 p
Red	1.07 a	1.00 a	0.99 a	1.12 a	1.05 p
Mean	1.06 a	1.06 a	1.03 a	1.10 a	(-)

Note: Data in the same column followed by the same letters were not significantly different according to DMRT 5%; Notation (-) shown there was no interaction between each factor.

Table 2. Nitrate reductase activity (µmol NO_2^- .g.$hours^{-1}$) of two cashew cultivars at different ages

Cultivars (Pseudo-Fruit Color)	Plant ages (Years)				Mean
	5	17	26	37	
Yellow	0.81 a	1.31 a	1.41 a	0.87 a	1.10 p
Red	0.75 a	1.17 a	1.08 a	0.87 a	0.97 p
Mean	0.78 b	1.24 a	1.25 a	0.87 b	(-)

Note: Data in the same column followed by the same letters were not significantly different according to DMRT 5%; Notation (-) shown there was no interaction between each factor.

and cultivation management factors. If the three factors can be managed properly, the tree will produce yield optimally. The problem in the cashew plantation in Baubau City is the low productivity due to the un-intensive management of plantation. Darwati *et al*. (2013) stated that the most of the productivity declining factor of cashew nuts was caused by unselected cultivars as planting material. The low productivity problems could be handled effectively with appropriate cultivation management practices (Mohapatra *et al*., 2017). One way to determine the proper cultivation management in cashew crops developed by farmers conventionally is to identify physiological and growth characteristics as determinants of production.

Chlorophyll is green pigment having the main role in photosynthesis process. Table 1 indicates there is no difference in chlorophyll content between cultivars and ages of cashew trees in Baubau city. The correlation analysis showed a positive correlation between chlorophyll content and cashew productivity. This result is in accordance with Trivedy *et al*. (2015) result that reported the increasing of chlorophyll content correlated with the productivity of cashew at different genotype. Chlorophyll is the main pigment in plants (Ai and Banyo, 2011) and it has the main function of absorbing sunlight as an energy source in photosynthesis (Holidi *et al*., 2015). Photosynthesis process is the main key to the growth and production of a plant (Darmawan & Baharsjah, 2010).

Nitrate reductase (NR) catalyzes NAD(P)H reduction of nitrate to nitrite. NR serves plants as a central point for integration of metabolism by regulating flux of reduced nitrogen by several regulatory mechanisms. According to Latifa and Anggarwulan (2009) the assimilation of N into organic molecules depends on the reduction of NO_3^- by the enzyme nitrate reductase in plant tissues. The nitrate reductase activity of both cashew cultivars was not significantly different, but it was significantly different based on the plant ages (Table 2). Nitrate reductase activity was relatively low in young trees (5 years old) and it increased in 17 and

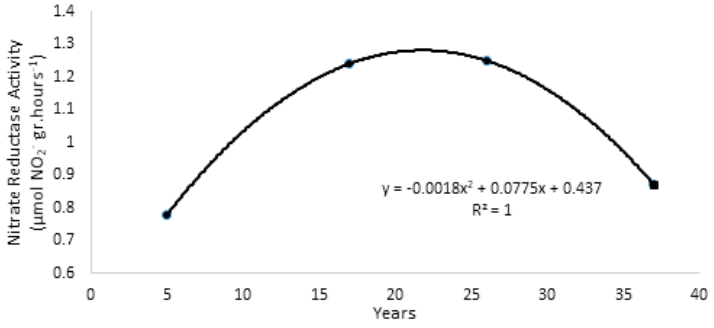

Figure 2. The relationship between plant age and nitrate reductase activity of cashew plant

Table 3. Plant height (m) of two cashew cultivars at different ages

Cultivars (Pseudo-Fruit Color)	Plant ages (Years)				Mean
	5	17	26	37	
Yellow	4.78	5.86	6.42	7.81	6.22 p
Red	4.74	5.76	6.64	7.64	6.20 p
Mean	4.76 c	5.81 bc	6.53 ab	7.72 a	(-)

Note: Data in the column and row followed by the same letters were not significantly different according to DMRT 5%; Notation (-) shown there was no interaction between each factor.

Table 4. Stem girth (cm) of two cashew cultivars at different ages

Cultivars (Pseudo-Fruit Color)	Plant ages (Years)				Mean
	5	17	26	37	
Yellow	54.2	60.6	71.4	88.2	68.60 p
Red	58.0	58.2	70.0	97.8	71.00 p
Mean	56.10 c	59.40 c	70.70 b	93.00 a	(-)

Note: Data in the column and row followed by the same letters were not significantly different according to DMRT 5%; Notation (-) shown there was no interaction between each factor.

Table 5. Number of primary branch of two cashew cultivars at different ages

Cultivars (Pseudo-Fruit Color)	Plant ages (Years)				Mean
	5	17	26	37	
Yellow	22.80	18.20	15.60	17.20	18.45 p
Red	23.60	16.60	18.20	18.60	19.25 p
Mean	23.20 a	17.40 b	16.90 b	17.90 b	(-)

Note: Data in the column and row followed by the same letters were not significantly different according to DMRT 5%; Notation (-) shown there was no interaction between each factor.

26 year-old trees and then decreased in 37 year-old trees. This dynamic was following the quadratic pattern on regression analysis ($y = -0.0018\ x^2 + 0.0775\ x + 0.437$) (Figure 1) . According to that equation, the highest nitrate reductase activity (0.531 µmol NO_2^-.g.hr^{-1}) was reached by cashew trees at the age of 26 years old.

Plant height is one of indicators of the plant growth and development. It always increases with the increasing age of the plant and irreversible. Growth occurs due to cell division and development processes (Gardner *et al*., 2008). Table 3 shows that there is no interaction effect between cashew cultivars and plant age on the plant height. Cashew plant cultivars had no significant effect of the plant height, while the age of trees significantly affected plant height. The increase of the plant age was also increasing the plant height. Cashew trees at 37 years old had a height of more than 7 meters. This result is different from that of Ona *et al*. (2017) indicating that cashew plant height was determined by plant genetics and varying height was around 5.4–13.5 m.

There was no interaction effect between the cashew cultivars and age on the stem girth (Table 4). The cashew cultivars did not show significant effect on the stem girth, while the differences in trees age showed significantly effect. The 37 year-old cashew trees had highest stem girth with an average of 93 cm. This result is linear with the result of Akinrinde and Ayegboyin (2006) reporting that the stem girth was closely related to the plant age, so the older plant showed the greater stem girth due to the effect of cambium activity. According to Salisburi and Ross (1995), the greater plant stem girth was affected by the optimum distribution of water and nutrients from the roots to the leaves by xylem and the distribution of photosynthates from the leaves throughout the plant by the phloem.

Primary branch is a branch that grows on the main stem. Primary branches have an important role in the process of growing cashew trees. The primary branch acts as a place for the growth of productive branches. Table 5 shows that there is no interaction effect between cultivars and plant age on the number of cashew branches. There was no significant effect of cultivars on the number of branches, while the

Table 6. Plant biomass (kg) of two cashew cultivars at different ages

Cultivars (Pseudo-Fruit Color)	Plant ages (Years)				Mean
	5	17	26	37	
Yellow	136.7 c	178.3 c	188.7 c	527.3 a	257.7 q
Red	146.1 c	160.8 c	352.6 b	651.8 a	327.8 p
Mean	141.4 b	169.5 b	270.6 b	589.5 a	(+)

Note: Data in the column and row followed by the same letters were not significantly different according to DMRT 5%; Notation (-) shown there was no interaction between each factor.

Table 7. Number of flowers of two cashew cultivars at different ages.

Cultivars (Pseudo-Fruit Color)	Plant ages (Years)				Mean
	5	17	26	37	
Yellow	694.40	754.80	873.80	1103.50	856.70 p
Red	771.40	742.80	922.80	1022.40	864.85 p
Mean	732.90 b	748.80 b	898.30 ab	1063.10 a	(-)

Note: Data in the column and row followed by the same letters were not significantly different according to DMRT 5%; Notation (-) shown there was no interaction between each factor.

effect of plant age was significant. The 5 year-old cashew trees had the highest number of primary branches. The young cashew plant was still to spur vegetative growth such as branch or shoots growth.

Productivity of cashew trees is influenced by the accumulation of plant biomass. There was no interaction effect between cultivars and age of the plant on the plant biomass (Table 6). However, cashew cultivars and the plant age showed significant single effect on plant biomass. Cashew plant biomass increased with the increasing of the plant age. The highest amount of biomass was found in cashew plants at 37 years old. The cashew with red pseudo-fruit had biomass content higher than the cashew with yellow pseudo-fruit. However, at 5 years old, 17 years old and 37 years old, both cultivars did not exhibit significant difference in biomass content. According to Nagasubramaniam *et al*. (2007) and Jeyakumar *et al*. (2008), biomass content depends on the photosynthesis rate of the plant. The greater the amount of biomass indicated the greater assimilate that was allocated to sink for supporting the plant growth and producing the yield, so that cashew plants would be higher and the stem girth would increase and crop yields would also increase. The higher the biomass produced by cashew crops, the higher productivity would also be. This proved that an increase in productivity was still possible with the increase in biomass.

The Increase of cashew productivity is supported by the number of flowers. According to Sedanantana (2012), the flower of cashew is classified in hermaphrodite flower and there are many flowers on a flower stalk. Table 7 shows the number of flowers in two cultivars of cashew trees at different ages. There was no interaction effect between cultivars and plant age on the number of flowers. Cashew plant with yellow and red pseudo-fruit had no significant different in numer of flowers. Meanwhile, the difference in plant age showed a significant effect on increasing the number of flowers. The number of flowers showed an increase as the increasing of the plant ages. Cashew plant at 37 years old showed the highest number of flowers, which was an average of 1,063.10 flowers per plant. The higher number of flower produced by cashew trees, the higher number of flower would also be. The number of flowers is highly correlated to fruit production as a determinant of the productivity of cashew trees. Plants that had a high the number of flower showed high fruit production. It is supported by Gajbhiye *et al*. (2016) who stated that the high and low production of cashew crops depends on the number of flowers produced. Therefore, to optimize fruit production, an increase in flowering is necessary.

Productivity is also supported by crop yield components such as number of cashew nut per plant and cashew nut weight per kernel. Table 8 shows that there is no interaction effect between cultivars and plant age on the number of harvested cashew nut per plant. Plant cultivars had no significant effect on the number of harvested cashew nut per tree, while plant age had significant effect on this variable. The highest number of harvested cashew nut per plant was observed in 37 year-old cashew trees with an average of 520.90 nuts per tree. The number of fruit harvested per tree is supported by the physiological and growth properties such as chlorophyll content,

Table 8. Number of cashew nut per plant of two cashew cultivars at different ages

Cultivars (Pseudo-Fruit Color)	Plant ages (Years)				Mean
	5	17	26	37	
Yellow	353.60	369.60	316.40	617.00	414.15 p
Red	382.40	331.60	350.00	428.80	372.20 p
Mean	368.00 b	350.60 b	333.20 b	520.90	(-)

Note: Data in the column and row followed by the same letters were not significantly different according to DMRT 5%; Notation (-) shown there was no interaction between each factor.

Table 9. Cashew nut weight per kernel (g) of two cashew cultivars at different ages

Cultivars (Pseudo-Fruit Color)	Plant ages (Years)				Mean
	5	17	26	37	
Yellow	4.47 d	6.42 ab	6.31 ab	6.08 b	5.82
Red	6.48 ab	6.24 ab	5.30 c	6.85 a	6.22
Mean	5.47	6.33	5.80	6.46	(+)

Note: Data in the column and row followed by the same letters were not significantly different according to DMRT 5%; Notation (-) shown there was no interaction between each factor.

Table 10. Productivity (kg.ha^{-1}) of two cashew cultivars at different ages

Cultivars (Pseudo-Fruit Color)	Plant ages (Years)				Mean
	5	17	26	37	
Yellow	327.3	495.9	422.2	768.0	503.3 p
Red	516.7	429.0	386.6	610.2	485.6 p
Mean	422.0 b	462.4 b	404.4 b	689.1 a	(-)

Note: Data in the column and row followed by the same letters were not significantly different according to DMRT 5%; Notation (-) shown there was no interaction between each factor.

amount of biomass and number of flowers. The higher the physiological and growth properties, the higher fruit production would be.

There was interaction effect between cultivars and plant ages on the cashew nut weight per kernel (Table 9). The cashew cultivar with red pseudo-fruit at the age of 5 years old, 17 years old and 37 years old had highest cashew nut weight per kernel and the lowest was at the age of 26 years old. The cashew cultivar with the yellow pseudo-fruit at the age of 17 years old and 26 years old produced the highest cashew nut weight per kernel but it was not significantly different from that of 37 year-old trees. The lowest cashew nut weight per kernel was observed at the age of 5 years old.

At the age of 5 years old, cashew cultivarwith red pseudo-fruit showed higher nut weight compared to cashew cultivar with yellow pseudo-fruit. Meanwhile, at the age of 17 years old, both cultivars didn't show any significant difference in the cashew nut weight per kernel. At 26 years old, cashew cultivar with yellow pseudo-fruit showed higher nut weight compared to cashew cultivar with red pseudo-fruit, while at 37 years old, the cashew nut weight per kernel of cashew cultivar with red pseudo-fruit was higher.

Productivity is the weight of cashew nut produced in one hectare of cashew (kg. ha^{-1}). There were no differences in the productivity between the cashew with red pseudo-fruit and yellow pseudo-fruit (Tabel 10). It indicated that the productivity was not affected by the genotypes. However, the productivity increased with the increasing age of cashew trees. Cashew trees aged 5 years, 17 years and 26 years old showed similar productivity, while 37 year-old cashew trees showed higher productivity than others. The cashew trees at the age of 5 until 17 years old had lower number of generative stem than 37 year-old trees. At the age of 37 years old, cashew trees in the Baubau City showed the highest productivity because it was supported by physiology and growth of primer shoots or productive branches. The cashew nut aged less than 10 years old was dominant on vegetative growth. Darwati et al (2013) also reported that the cashew with age <10 years old had low production because the roots was still short so the water and nutrient adsorption was limited.

At the age of 26 and 37 years old, cashew trees are included in productive phase. Suharto *et al*. (2012) reported that the optimum productive ages of cashew plant varied between 25–30 years old depending on the environmental condition. It indicated that at the age of 26 years old, productivity of cashew trees should be higher than at 5 and 17 years old. The lowest productivity of 26 year-old cashew was influenced by the closing of canopy plant. Daras and Tjahjana (2011) said that the lowest productivity of cashew was caused by the closing of canopy plant and lacking of the light. The higher productivity of 37 year-old cashew trees was supported by characteristics of growth and yield component such as plant biomass, number of flower, number of cashew nut per plant and cashew nut weight per kernel.

CONCLUSIONS

Cashew with red and yellow pseudo-fruit cultivars had no significant difference in the growth and yield at each plant ages. At the age of 37 years old, cashew trees demonstrated the increasing of the productivity due to the increasing of growth and yield component such as the increasing of plant biomass, number of flowers, number of cashew nut per plant, and cashew nut weight per kernel.

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