

Selection of Avocado Plants Based on Fruit Characters, Fat Content, and Continual Harvest along the year in West Java-Indonesia

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Abstract— Avocado (*Persea americana* Mill.) belongs to *Lauraceae* family, is originated from lowland and highland tropical America region. Avocado plant was introduced to Indonesia in 1750 by Spanish. Fruit of avocado contains high unsaturated (healthy) fat, protein, fiber, vitamins, minerals, and energy. Fruit of avocado can be eaten freshly, used as an additional ingredient cooking and material for cosmetics. Avocado fruits are available along the year in market cities of Indonesia but their fruits fluctuate in quantity and uncertain quality. It because the plants commonly come from seeds and grown in home-yards or small areas by small farmers. The purposes of this research were to evaluate and select some cultivars for parent plants that produce good fruit characters, high content of fat, and continual yield along the year. The research was started on January 2011 until 2013 for obtaining data, collecting avocado fruits and scions in West Java province, which is the biggest avocado fruit production in Indonesia. From 180 accessions of avocado fruits, there were 31 potential accessions for selecting good cultivars and 6 accessions of them (10, 5, 39, 48, 61, 123) were selected. The selected fruit character had scores 72 – 80 of maximum 100, fat content 9.78% – 20.57%, and harvest periods from January to December. These accessions as grafted plants have grown and propagated in our research station of the Indonesian Institute of Sciences (LIPI) in Cibinong for further study and for releasing to the farmers.

Keywords— avocado; fruit character; fat content; continual harvest; West Java

I. INTRODUCTION

Avocado, belongs to *Lauraceae* family, originated from high and lowland of Central America. The native habitat cover areas from hot and humid with short dry season forest, a tropical highland with year-round cool conditions, until the frost-elevated location with 6-8 months winter-spring dry period of Mexico region [1]. Recognition of nutritional value of avocado fruit caused colonizers of the America to distribute this crop to new climate permitted regions [1]. Avocado was introduced to Indonesia by Spanish merchants in 1750 so it has spread and adapted to the Indonesian archipelago [2].

FAOSTAT Database stated that avocado production of Indonesia in 2013 was 276,311 metric tons (m.t.), which was the 5th in the world after Mexico (1,467,837 m.t.), Dominican Republic (387,546 m.t.), Colombia (303,340 m.t.), and Peru (288,387 m.t.), but Indonesia did not be recorded as avocado exporter country because of very small volume [3]. Total production of avocado in the world in 2013 was 4,717,102 m.t. [3].

Avocado has many uses, such as fresh fruit for mix food (salad and other meals), drink (ice cream, milk shake), cosmetic; leaf and seed for medicine; also plant for ornamental [1, 4, 5]. Fruit flesh reaches 65-75% of fruit total weight. Every 100 g of fruit flesh consist of 65-86 g water, 1-4 g protein, 5.80-23.00 g fat, 3.40-5.70 g carbohydrate, 0.80-1.00 g iron, 75-135 IU vitamin A, 1.50-3.20 mg vitamin B complex, and 600-800 kJ energy [6].

In horticulture, avocado plants are grouped into 3 races, those are Mexican, Guatemalan, and West Indian [3, 7, 8]. Mexican race is well adapted to highland and cold resistance; smooth, glossy, and thin peel; big seed and loose in cavity; small fruit with high fat content and peanut taste. Guatemalan race is adaptable to highlands and cold resistance; thick and commonly rough/ woody/ stiff peel; small seed tight in cavity; large fruit, long ripening time, and high savory nutty flavour. West Indian race is adapted to lowland and not resistance to cool, smooth and elastic-like leather, green/yellowish/reddish colour; big seed with rough cotyledon surface and loose in cavity; medium fruit with low fat content [3, 7, 8]. The most avocado race commonly found in Indonesia is West Indian, although there are some plants resulted crossing with Guatemalan or Mexican race.

On January 14, 1987, 2 cultivars had determined by the Minister of Agriculture --the long green and circular green. There is avocado germplasm collection of Research Installation and Technology Assessment in Tlekung, East Java. The research station had no less than 21 cultivars including the Long Red, Circular Red, Dickson, Butler, Winslowson, Benik, Puebla, Fuerte, Collinson, Waldin, Ganter, and Mexcola [9, 10].

Location of a region will affect the time of flowering and fruit harvesting, as well as genotype of the plant. California state in the west and Florida state in the east of USA, which are avocado producing regions, have different time of flowering and harvesting [7]. Indonesia with a vast territory, extending from 94° - 141° east longitude and 6° north latitude - 11° south latitude (almost same distance from California to Florida), will affect the flowering and fruiting time of avocado. Quantity of fruit availability is not evenly distributed throughout the year because there are different months of heavy fruiting plants in each province in Indonesia, i.e. DKI Jakarta: December-February, West Java: October-February, Central Java: September-February, North Sumatra: June-August, West Sumatra: January-April, Jambi: March-April, Lampung: January-February, South Sulawesi: May-June, Bali: December-February, West Nusa Tenggara: April-June, North Sulawesi: December [11]. Eventhough, there are some deviaton of fruit season of avocado in certain location because of different genotype.

In Indonesia, avocado fruits are available throughout the year, but those fluctuate in term of quantity and uncertain quality. Those are produced by small farmers on small areas without any care enough. The avocado plants have not yet been planted on a big scale plantation system, usually can only be found in home-yards . Few varieties as result of research in government institutions are still planted in their research field as collection of germplasm. Therefore, study concerning the quality of the fruit should be supplemented with information on fruit characters, harvesting time, and their yield.

This research conducted to evaluate and select some cultivars for parent plants that produce good fruit characters, high content of fat, and continual yield along the year. This research will be a great means for increasing fruit production and fruit quality, also fruit availability throughout the year in Indonesia.

II. MATERIALS AND METHODS

Exploration and observation had been done from January 2011 to December 2013 in all regions in West Java Province, which is the highest avocado fruit production in Indonesia. Field measurements and observations were conducted on tree location and laboratory, including fruit, flower, leaf, and tree morphology, also its environmental condition. Tools for tree masurements and observations includes tape measure (50 m) and diameter tape (20 m x 5 m, Tool No. D-5M, Yamayo, Japan). Tools for measurement and observation of

fruit samples in the laboratory included digital caliper (200 mm, Mitutoyo CO, Japan) and digital weight scale (capacity 2 kg).

Ecological habitat data of avocado trees were also collected. Data were collected consisted of latitude, altitude, land slope, pH, soil moisture content, light intensity, relative air humidity, and air temperature. Tools for observing these parameters were Global Positioning System (GPS Garmin) navigation device, thermohygrometer (Haar-Synth-Hygro, Germany), soil tester (TEW Type 36, Demetra, Japan), altimeter, clinometer (Suunto PM-5/360), light meter (LX-101 A, Lutron, Taiwan) and Digital refractometer (Palette Series PR 101 α , ATAGO CO., LTD, Japan). Interview with owner of each avocado plant samples was also conducted to identify the history of the plant including age, flowering and fruiting seasons, fruit production and quality. The exploration was conducted to collect samples as accessions for evaluation of avocado based on Descriptors for Avocado of IPGRI (Table 1) [12].

TABLE I
CHARACTERS FOR EVALUATION AND SELECTION OF AVOCADO TREE
AND FRUIT

No.	Character
1	Size, shape, and age of tree (approximate)
2	Length, diameter, and color of twigs
3	Flowering and fruiting period
4	Size, shape, texture, smell and color of leaves
5	Weight, shape, size and uniformity of fruit
6	Color, thickness, type and weight of fruit skin
7	Color, fiber compound, thickness, weight and fruit flavour
8	Seed position in fruit
9	Weight, shape, color and size of seed
10	Edible Portion of Fruit (Weight percentage)
11	Soluble solid content of fruit flesh (°Brix)

The evaluation and selection were also conducted on fruit quality and harvest period. Measurements and observations on fruits were taken on several parameters and the result were used as basic data for further analysis. Data were analysed using scoring system to select the prominent varieties among 180 accessions. Several aspect of fruit that considered to be important in selection are shape, weight, skin condition, fruit flesh condition and seed character. Each character has percentages of weight that contribute to the total final score (Table 2.) [13]. Flavour of fruit was tested by 3 persons to get summary results. Fat content of selected avocado fruit was done using soxhlet method [14]. Result on fruit nutrition analysis namely fat compound content has also become an important aspect in selection. Score more than 67 and contain more than 6,9 % fat were considered as potential accessions for selecting good cultivars. Score more than 72, contain fat more than 9.78%, and different month harvest were considered as selected accessions.

TABLE II
SCORE SHEET FOR EVALUATING RIPE AVOCADO FRUITS

No	Character Description	Score	No	Character Description	Score
	EXTERNAL		6	Fruit Flesh	
1	Shape (5%)		a	Color (5 %)	
	Ovoid or round	4 - 5		yellow to dark yellow	4 - 5
	Pyriform or pear-shape	2 - 3		greenish yellow	2 - 3
	Bottled-necked or elongated	1		Light green to green	1
2	Weight (10 %)		b	Texture (10 %)	
	Very large (>500 gr)	8 -10		Smooth and Firm	8 -10
	Large (351 - 500 gr)	5 - 7		Intermediate	4 - 7
	Medium (200 - 350 gr)	3 - 4		Soft and Soggy	1- 3
	Small (< 200 gr)	1	c	Flavor (15 %)	
3	Fruit skin condition (5 %)			Buttery and Nutty	10 -15
	None	4 - 5		Intermediate	5 - 9
	Scanty to Moderate	2 - 3		Flat or off-flavored	1 - 4
	Severe	1	d	Thickness (10 %)	
4	Fruit skin color (5 %)			Thick (>2.5 cm)	7 - 10
	Green to light green	4 - 5		Intermediate (1.5 - 2.5 cm)	4 - 6
	Yellowish, Redish, Purple	2 - 3		Thin (<1.5 cm)	1- 3
	Black	1	e	Fiber (5 %)	
	INTERNAL			None to Scanty	4 - 5
5	a Fruit Skin			Moderate	2- 3
	Thickness (5 %)			Abundant	1
	Thick (>1.00 mm)	4 - 5	f	Edible Part (5 %)	
	Intermediate (0.5 - 1.0 mm)	2 - 3		High	4 - 5
	Thin (<0.5 mm)	1		Moderate	2 - 3
	b Texture (5 %)			Low	1
	Though and leathery	4 - 5	3	Seed	
	Intermediate	2 - 3	a	Weight (5 %)	
	Soft and Tender	1		Small (< 50 g)	4 - 5
	c Easiness to Peel (5 %)			Intermediate (50 to 100 g)	2 - 3
	Easily peels	4 - 5		Large (> 100 g)	1
	Intermediate	2 - 3	b	Stickiness on Seed Cavity (5 %)	
	Sticks to pulp	1		Tight	4 - 5
				Intermediate	2 - 3
				Loose	1
				TOTAL	15 -100

III. RESULTS AND DISCUSSIONS

There were 180 accessions of avocado plants have been collected during harvesting period, consisted of 67 accessions from Bogor and Depok cities, 12 accessions from Cianjur, 19 accessions from Sukabumi, 48 accessions from Garut, 12 accessions from Bandung and Subang, 11 accessions from Tasikmalaya, and 11 accessions from Ciamis. The plants were located at the area of 140 – 1234 m

above sea level with air relative humidity 48 % - 90 %, air temperature 26 °C – 35 °C, soil humidity 40 % – 88 %, soil pH 4.00 – 7.00, and plant age 5 - 60 years old (Table 3). The areas observed represented humid tropical region of Indonesia, with soil pH acid to neutral. Tree age varied from beginning of producing fruit until relatively old tree (65 years).

TABLE III
CITY LOCATION AND HABITAT CONDITION OF AVOCADO PLANT ACCESSIONS

No	City (number of plants)	Elevation (m dpl)	Air Relative humidity (%)	Air temperature (° C)	Soil humidity (%)	Soil pH	Age of plant (years old)
1	Bogor and Depok (67 plants)	140 - 953	55 - 90	26 - 34	40 - 90	4.40 - 7.00	5 - 40
2	Garut (48 plants)	723 - 1038	58 - 81	26 - 34	30 - 90	5.00 - 7.00	10 - 65
3	Cianjur (12 plants)	520 - 616	52 - 76	26 - 33	45 - 50	6.40 - 7.00	15 - 60
4	Sukabumi (19 plants)	315 - 872	58 - 80	28 - 35	40 - 50	5.60 - 6.80	8 - 15
5	Bandung, Lembang and Subang (12 plants)	618 - 1234	48 - 74	26 - 33	40 - 65	5.20 - 7.00	8 - 50
6	Tasikmalaya (11 plants)	286 - 665	55 - 83	28 - 35	50 - 78	4.20 - 7.00	8 - 20
7	Ciamis (11 plants)	36 - 738	50 - 84	27 - 34	10 - 62	5.40 - 7.00	8 - 45

The overall results of observation on avocado plants, leaves and fruits from some cities in West Java could be seen at Table 4. Height of plants varied in between 8.50 m – 20.00 m, trunk diameter 26.04 cm – 66.00 cm, canopy width 5.75 m – 36.00 m, height of first branch 0.30 m – 7.50 m (Table 4). Results of characters of plants, leaves, fruit and seed were also varied. Plant shape were pyramidal, obovate, circular, semicircular, semielliptic, irregular, whereas the variation of avocado leaves shape were ovale, ovate, oblong lanceolate, rhomboidal, roundish, spheroid. The shape of fruits were oblate, spheroid, high spheroid, ellipsoid, narrowly obovate, obovate, pyriform, clavate, rhomboidal and the shape of seeds were oblate, spheroid, ellipsoid, ovate, broadly ovate, cardiform, base flattened apex rounded, base flattened apex conical (Table 4).

Colour of avocado leaves varied namely light green, green and dark green, whereas peel of fruit colour were green, dark green, yellowish, purple, black and variation of pulp colour were yellow, deep yellow, light yellow, light green (Table 4). Size and weight of fruit and seed varied also and could be seen in detail at Table 4. Edible portion of fruit based on

weight were in between 48.20 % and 86.30 %. On the other hand, the fruit taste varied as nut character, bitter and sweet low, middle and high. The pulp texture of avocado observed were including buttery and watery. Soluble solid content of fruit pulp were in between 6.3 °Brix and 8.4 °Brix (Table 4).

Plants character varied, since age of the plant were not same, the genetic and environment condition also varied. The avocado trees and fruits were also very diverse because the tree was generally derived from seed, whereas avocado plant is usually crossed pollination. The variation of the vegetative parts and fruit character of avocado in West Java represented those of race West Indian or Guatemalan or hybrid of those races. Avocado plants originating from seed will be vary, rarely equal the parental plant [7, 8, 15]. The avocado trees for commercial growers should be planted in large-scale field and using seedling from vegetative propagation, such as grafting with scion from the good parent stock.

TABLE IV
CHARACTERIZATION OF PLANTS, LEAVES AND FRUIT OF AVOCADO SAMPLES FROM WEST JAVA

No	Plants Character	Minimal	Maximal
1	Plant height (m)	5.00	20.00
2	Trunk diameter (cm)	26.40	66.00
3	Canopy width (m)	5.75	36.00
4	Height of first branch (m)	0.30	7.50
5	Plant shape	Pyramidal, obovate, circular, semicircular, semielliptic, irregular	
6	Leaf shape	Ovale, ovate, oblong lanceolate, rhomboidal, roundish, spheroid	
7	Leaf length (cm)	4.27	30.28
8	Leaf width (cm)	4.11	22.13
9	Leaf texture	Soft, semihard, hard	
10	Leaf colour	Light green, green, dark green	
11	Fruit shape	Oblate, spheroid, high spheroid, ellipsoid, narrowly obovate, obovate, pyriform, clavate, rhomboidal	
12	Fruit weight (g)	126.49	1265.88
13	Fruit length (cm)	6.20	23.55
14	Fruit diameter (cm)	5.86	12.08
15	Colour of fruit skin/peel	Green, dark green, yellowish, purple, black	
16	Peel thickness (mm)	0.48	2.77
17	Flesh/Pulp thickness (mm)	0.73	5.72
18	Colour of flesh/pulp surrounding seed	Yellow, deep yellow, light yellow, light green	
19	Fruit taste	Poor, fair, good, excellent	
20	Other fruit taste characteristic	Nut (low, intermediate, high), Bitter (low, intermediate), sweet (low, intermediate)	
21	Fruit flesh texture	Buttery, watery	
22	Fruit fibre	Low, intermediate	
23	Edible Portion (%)	48.20	86.30
24	Soluble solid content (°Brix)	6.00	8.40
25	Seed shape	Oblate, spheroid, ellipsoid, ovate, broadly ovate, cardiform, base flattened apex rounded, base flattened apex conical	
26	Seed weight (g)	27.13	133.53
27	Seed length (cm)	3.07	8.45
28	Seed width	3.03	6.82

Score value of all avocado samples were in between 47 and 82, whereas as many as 14 avocado trees had score value 63 and only 1 avocado tree had score value 51, 54, 77, 79 and 82 (Table 5). As many as 111 avocado trees from 180 had score values in between 59 and 69, this represent the

most avocado from West Java score values. Based on the score value, fat nutrition content and fruit harvest periods, there were 31 potential accessions for selecting good cultivars from 180 accessions. The range scores of these accessions were 68 – 80, range fat content were 6.92% -

20.57%, and harvest periods were January - December (Table 6). The cultivars were from Bogor, Garut, Cianjur, Bandung, Subang and Sukabumi cities. There were 6 accessions from the potential accessions were selected for parent stock based on the highest score and fat content, also continual harvest, i.e. accession number 10, 5, 39, 48, 61, and 123.

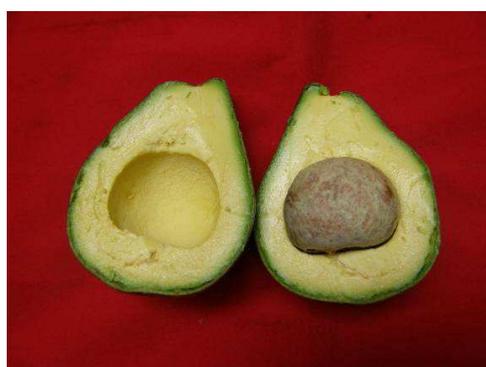
All 31 potential accessions for selected good cultivars were propagated by shoot tip grafting and have grown in the research station of LIPI in Cibinong, Bogor. All potential accessions were planted, since habitat of trees from Bogor were varies and about half of the plants were from different cities than Bogor. The character of the fruits of potential selected avocado trees may change if being planted at different environment conditions in Cibinong. The expression of an avocado cultivar's genetic characters

(including yield, fruit size and quality, fruit season of maturity and bearing habit) varies with environmental influences associated with climate and seasonal variation in temperature, relative humidity and rainfall [15]. Therefore, the evaluation of the potential selected avocado plants grown in Cibinong, Bogor is still required.

There were some other studies related with avocado cultivar selection beside for fruit quality and continual yield along the year. The studies for examples were for selecting potential cold tolerance [16, 17, 18], decreasing the risk of major pest and disease invasions [19] and for resistance to soil stress factor of rootstock [20]. The soil stress included salinity, calcareous and alkaline soils, acidity, poorly aerated soil, root rot disease and combination of soil stress factor [20].



Accession number 10



Accession number 5



Accession number 39



Accession number 48



Accession number 61



Accession number 123

Figure 1. The 6 selected superior quality avocado from West Java that had harvest periods from January to December.

TABLE V
SCORING VALUE (15-100) FOR SELECTION OF AVOCADO FRUITS FROM WEST JAVA

No	Scoring Value	Number of avocado tree	No	Scoring Value	Number of avocado tree
1	82	1	17	63	14
2	80	3	18	62	10
3	79	1	19	61	8
4	78	2	20	60	10
5	77	1	21	59	8
6	75	3	22	58	5
7	73	5	23	57	5
8	72	5	24	56	3
9	71	7	25	55	7
10	70	4	26	54	1
11	69	9	27	53	3
12	68	9	28	52	4
13	67	10	29	51	1
14	66	9	30	50	2
15	65	13	31	49	3
16	64	11	32	47	3
TOTAL					180

TABLE VI
EVALUATION OF AVOCADO ACCESSIONS BASED ON SCORE VALUE, FAT CONTENT AND HARVEST PERIODS

No	Accession Number	Location	Score Value	Fat (%)	Harvest Period
1	1	Bogor	73	8.48	February – March
2	2	Bogor	70	11.76	January – February
3	5	Bogor	79	14.15	February – March
4	10	Bogor	75	10.97	January - February
5	13	Bogor	72	12.89	March – April
6	14	Bogor	73	13.35	March – April
7	25	Garut	71	6.92	April – May
8	28	Garut	73	9.67	April – May
9	39	Garut	72	20.57	April, November
10	45	Cianjur	71	10.79	May – July
11	47	Cianjur	80	7.57	May - July
12	48	Cianjur	78	9.78	May – July
13	53	Sukabumi	72	11.14	June
14	61	Bandung	80	14.53	June – November
15	62	Bandung	78	7.32	July – August
16	63	Subang	71	10.11	July – August
17	67	Cianjur	75	8.21	July
18	68	Cianjur	71	10.40	July – August
19	71	Bogor	71	10.21	September – October
20	90	Garut	70	15.73	March, June, September
21	123	Bogor	73	10.77	December
22	130	Garut	80	9.51	February - March
23	137	Garut	68	13.76	March - April
24	146	Bogor	69	11.29	February - March
25	158	Bogor	68	16.99	April
26	160	Bogor	69	13.20	May
27	175	Bogor	68	10.58	September-October
28	177	Bogor	68	10.82	October
29	180	Bogor	71	10.13	September - October
30	181	Bogor	68	10.29	October - November
31	182	Bogor	70	11.69	October - November

IV. CONCLUSIONS

This research collects nowadays 31 accession numbers (about 3,000 plants) as grafted avocado plants in Cibinong Science Center, West Java as potential for selection of good quality avocado plant. Among them, there were 6 accessions avocado selected for good parent stock in West Java, Indonesia, which were number 10, 5, 39, 48, 61, and 123. Those scores value were 75, 79, 72, 78, 80, and 73, respectively. Those fat content were 10.97%, 14.15%, 20.57%, 9.78%, 14.53%, and 10.77%, respectively. Those harvest periods were January – February, February – March, April & November, May – July, June – November, and December, respectively. These accessions could be used for parent stock and propagated for orchard, especially in West Java.

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