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Growth and Yield Evaluation of Avocado (*Persea americana*) Varieties in Lowland Agro Ecology of Raya Azebo, Southern Zone of Tigray Region, Northern Ethiopia

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Abstract. Avocado is among the subtropical fruit crops produced in Ethiopia; however, the production and Productivity of avocado is influenced by different factors; of which lack of improved and well adapted varieties are the major one. So, an experiment was conducted at Fachagama from 2013 to 2019 to evaluate and select the best adaptable avocado variety/ies at Raya Valley. Six avocado varieties namely Ettinger, Fuerte, Pinkarton, Hass, Naba and Bacon were laid in RCBD and replicated three times. To achieve the objective, the growth, phenological and yield data were collected and analyzed using SAS software. Accordingly, above graft union stem girth diameter was significantly (P≤0.01) affected by variety, while tree height and canopy diameter were not significantly ascertained by variety. All the tested avocado fruit yield parameters were significantly (P≤0.01) influenced by variety throughout the three years except marketable fruit yield tree^{-1} and the total yield tree^{-1} which was not significantly (P≥0.5) determined by variety during 2017 fruit harvesting year. Variety exerted significant (P≤0.01) variation on fruit length (cm) fruit weight (g) and seed weight respectively, throughout the three years (2016-2018), the two years (2017 and 2018) and the two years (2016 and2018). The highest girth diameter (61.44mm) was obtained on Nabal variety. Likewise, the highest (15.51 and18.88kg tree^{-1}) total yield was recorded in Pikerton and Bacon varieties respectively during 2016 and 2018 respectively. From the result Pinkerton and Bacon are recommended for Raya Valley and other areas having similar agro-ecologies. However, it is important to consider the water requirements in terms of irrigation depth and frequency of avocado.

Keywords: canopy diameter; fruit number per tree; fruit weight; graft union; marketable yield

INTRODUCTION

Avocado (*Persea americana* Mill.) is a native tree of Central American countries, the northern coast of South America and the West Indies (Chen et al. 2007; Bayram et al. 2012; Flores et al. 2019). It has been reported that the cultivation of avocado for commercial purposes began in California and Florida and then in Israel, South Africa and Chile. Although a range of avocado cultivars are grown, Hass is one of the world's most widely grown, imported and exported cultivar (Shepherd and Bender 2002). According to Garner *et al.* (2008) this fruit is characterized by excessive flower and fruit abscission.

According to Flores *et al.* (2019) avocado is a fruit with a high nutritive value and contains monounsaturated fatty acids (MUFA) dietary fiber, essential nutrients and phytochemicals. However, the outstanding compositional feature is the high fat content, which varies significantly between different cultivars due to climatic and soil difference (Flores et al. 2019). It has a bland nature with particularly high nutritional value containing 15-30% oil, vitamins viz. vitamin A, B6, B12, C, K, E, Folacin, and Niacin), minerals, high caloric value 123-387 kcal/kg of edible avocado, and has low sugar content (Wong *et al.*, 2010; Villa-Rodriguez *et al.*, 2011; Edineia Dotti Mooz *et al.*, 2012; Tan *et al.*, 2017).

In Ethiopia the tree was first introduced in 1938 by private orchardists in Hirna and Wondogenet and gradually adapted to different agro ecologies of the country (Etissa 1997). The introduced avocado varieties include "Ettinger", "Fuerte", "pinkarton", "Hass" "Naba "and "Bacon" which are known for bearing uniform and good quality fruits (Ketema et al. 2010).

According to CSA (Central Statistical Agency) (2017) report, in 2015 and 2016, in Ethiopia the total production of avocado was 538245.79 and 649,821.04 quintals, respectively which was increased by 20.73 %. In the same year the area covered by avocado was 16665.45 and 17834.58 ha, respectively which was increased by 30.51

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percent. Similarly, in Tigray the crop is now produced by more than four thousand farmers who collectively farm more than 10.64 ha (CSA, 2017).

Avocado is a fruit grown mainly in warm temperate and subtropical climates throughout the world (Tan *et al.,* 2017; Flores *et al.*, 2019). However, limited cultivation areas, high nutritional value and a distinctive flavor are the causes for high prices for avocados in world markets (Poudel et al. 2018).

In Ethiopia, particularly in Raya valley of Tigray region, absence of improved and adapted avocado varieties are limiting the production, productivity and profitability of the crop where the crop is highly demanded and the agro-ecology also favor the crop production. So far, there were no studies done to select the adaptable and high yielding varieties in Tigray region in general; rather some nurseries were established and distributed seedlings of some fruit crops (Mango and Avocado) varieties which are not studied and recommended to the local areas. Taking into account the above mentioned gaps, the aim of this study was to evaluate the performance of six avocado varieties for their growth, yield and fruit quality parameters at the Raya valley.

METHODS

Description of the Experimental Site

A study was conducted at Mehoni Agricultural Research Center (MhARC) Fachagama testing site in the Raya Valley, Northern Ethiopia from August 2013 to June 2019. It is located at 668 Km from the capital Addis Abeba and about 125 Km south of Mekelle, the capital city of Tigray regional state. Geographically, the experimental site is located at 12° 41'50" North latitude and 39° 42'08" East longitude with an altitude of 1578 m.a.s.l. Data from the meteorological class of the center shows mean annual rainfall of 539.32 mm with an average minimum and maximum temperature of 12.81 and 23.24°C, respectively. The soil textural class of the experimental area was clay loam with pH of 7.9.

Experimental Materials

Seedlings of six improved Avocado varieties namely Ettinger, Fuerte, pinkarton, Hass, Naba and Bacon were collected from Melkassa Agricultural Research Center, Ethiopia to test the performance of the varieties at Fachagama during July 2013.

Design and Experimental Procedure

A completely randomized block design (RCBD) and replicated three times. Seedlings were planted in a plot having of 7*7*6m (294m^2) size i.e. 7m between plants and rows and 6 plants per plot and the net area of the experimental area was 5292m^2(294*3*6). All agronomic practices like cultivation, weeding and harvesting were done at standard time. Pits or holes (60cmx60cm) for planting were prepared two months before planting and the subsoil and topsoil were kept separately. A well decomposed manure with the topsoil was mixed and filled back the prepared pits. To help the planters to exactly locate the center of the pit during planting a stake were placed at the center of the hole. And the seedlings were planted on the center of the hole and pressed the soil.

Data Collection and Measurements

Measurement of avocado traits beginning from 2016 to 2018 data on Tree height, average canopy diameter, average tree trunk diameter (Above Graft union), fruit diameter (cm): fruit length (cm), average fruit weight (gr), average juice weight (gr), average seed (stone) weight (gr), marketable yield, unmarketable fruit yield (fruit which cracked, decayed, split, insect damaged or diseased fruit and healed abrasion injuries) and total fruit yield (summation of marketable and unmarketable) in kg were collected.

Data Analysis

Collected data were subjected to analysis of variance (ANOVA) following a procedure appropriate to a randomized complete block design as suggested by (Gomez and Gomez,

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1984). LSD was used for comparison of means at $P \leq 0.05$.

RESULTS AND DISCUSSION

1. Plant Growth Parameters

Tree Height at First Harvest and Canopy Diameter (m)

Tree height at the first fruit harvesting year (2016) was not significantly ($P \geq 0.05$) influenced by avocado varieties (Table 1). Though the longest and shortest tree heights were recorded, on Fuerte and Pinkerton varieties respectively (Table 4). Variety exerted non-significant effects on avocado canopy spread during the first fruit harvesting year (2016) as indicated in the Anova table (1). Even though, numerically, the maximum (3.23m) and minimum (2.53 m) canopy spreads was recorded on Fuerte and Nabal varieties (Table 4). The results of this finding disagreed with the result of (Chen et al. 2007) who reported the significant effects of avocado genotypes on plant height and canopy diameter. Generally, plant growth and yield characters of avocado are highly influenced by the age of the plant.

Above graft Union Girth Diameter (mm)

At the first fruit harvesting season (2016), the variety maintained significant ($P \leq 0.01$) effects on the above graft union girth diameter (Table 1). Nabal variety showed the maximum, which however was not statistically different from Fuerte and Bacon; while, Pinkerton showed the minimum girth diameter yet statistically not different from Ettinger and Hass. This finding is in agreement with Chen *et al.* (2007) who reported that there is significant difference on the canopy and girth diameter among Gwen, Bacon, Fuerte, and Zutano varieties.

2. Yield Parameters

Marketable Fruit Number

The marketable fruit number was significantly ($P \leq 0.01$) affected by avocado varieties in all seasons of fruit harvesting season (2016, 2017 and 2018 years) (Table 2). Significantly the highest number of fruits per tree was harvested from Pinkerton variety in 2016 and 2017cropping years respectively. In contrast, the lowest number of fruits per tree was recorded on Fuerte during 2016 and 2017 cropping years respectively. In 2018, the maximum number of fruits per tree was harvested from Hass variety; while the lowest number of fruits per tree was recorded on Nabal variety (Table 5).

Similarly, Bayram *et al.* (2012) found a significant difference among avocado cultivars. This could be attributed to inherent characters and wider adaptability of the variety. Also, Abbas *et al*. (2020) and Emire *et al*. (2021) reported the average number of fruits per tree of the six improved avocado varieties was varied statistically in which Hass avocado produced a significantly higher number of fruits per tree and Pinkerton produced the least number of fruits per tree. Smith (2006) indicated that the yield varies greatly with cultivar, age of tree, location, weather and other conditions. The level of yield per hectare obtained also depends on cultivars, effective pollination and crop husbandry practices (Ettisa, 1997; Linda, 2006).

Marketable Fruit Yield Tree^{-1} (Kg)

Avocado variety exerted significant ($P \leq 0.01$) effects on the marketable yield tree^{-1} during 2016 and 2018; however, marketable yield tree^{-1} was non-significantly ($P \geq 0.5$) affected by variety in 2017 cropping year (Table 2). Pinkerton variety gave the maximum fruit yield during 2016 and 2018 fruit harvesting seasons, which however was not statistically different from Bacon variety during 2018 harvesting year (Table 5). The result is in agreement with the findings of Bayram *et al.* (2012) who reported significant effect of variety on marketable fruit yield tree^{-1}. Fruit quality is one of the most important factors that determine the desirability of avocados during marketing and which are highly linked with the agro-

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ecological condition under which the crop is produced, management practices made and the genetic contribution.

Unmarketable Fruit Number Tree^{-1}

Anova table (2) indicated the significant ($P\leq 0.01$) effects of varieties on unmarketable fruit number tree^{-1} in all fruit harvesting years (2016, 2017 and 2018). The highest unmarketable fruit number per tree was obtained from Nabal Variety in the 2016 fruit harvesting year. The maximum number of unmarketable fruits per tree was observed on Bacon which was statistically similar with Ettinger and Pinkerton varieties (Table 5). Unmarketability in this case is attributed to smaller sized fruit which may be the matter of genetic characters and management practices.

Unmarketable Fruit Yield Tree^{-1} (Kg)

Unmarketable fruit yield of avocado was significantly ($P\leq 0.01$) altered by variety during 2016, 2017 and 2018 crop harvesting years (Table 2). Significantly the highest unmarketable fruit yield per tree was recorded on Pinkerton variety during 2016; though Fuerte and Ettinger gave no unmarketable yield yet statistically not different from Bacon (Table 5). During 2017, the highest unmarketable yield was recorded on Fuerte followed by Hass; however, no unmarketable yield was recorded on Pinkerton, Bacon, Nabal and Ettinger (Table 5). Similarly, the largest and lowest unmarketable fruit yield was recorded, respectively from Bacon and Fuerte varieties during 2018 fruit harvesting season.

Total Fruit Yield Tree^{-1} (Kg)

The total yield of avocado was significantly ($P\leq 0.01$) determined by variety throughout 2016 and 2018, while non-significant ($P\geq 0.5$) effects of variety on yield was recorded during 2017 cropping year (Table 2). Significantly highest and lowest fruit yield was recorded from Pinkerton and Nabal varieties during 2016 fruit harvesting year. Besides, during 2018 fruit harvesting year, the maximum fruit yield was obtained on Bacon variety; which is statistically not different from Pinkerton variety. However, the lowest fruit yield was recorded from Nabal Variety during the 2018 cropping year (Table 5).

In agreement with the present (2016 and 2018) finding, the significant effects of variety on the cumulative yield of avocado was previously reported by (Bayram et al. 2012). Lovatt *et al.* (2015) also reported that a mean yield of Hass avocado is 51 kg/tree at a typical California planting density condition. Furthermore, fruit yield of 5 varieties of avocado exhibited significant results when analyzed statistically at 5 % level of significance (Abbas *et al*., 2020). The growth and performance of avocado is extremely influenced by environmental conditions however, the adaptability varies among varieties. For instance, low winter temperatures occurred in different years, causing damage on vegetative and generative parts of the trees in various extents whereby Reed, Pinkerton, Corona, Hass and Rincon were the cultivars most affected than the other (Demirkol *et al*., 2002). The annual yields of all the cultivars lack consistency, and in some years the yield was negligible. This variability in production of the three cultivars is probably reflecting a tendency to biennial bearing on some varieties. In fact, the yielding capacity of a fruit crop is attributed to the agro ecological condition, genetic potential and management practices just like other crops.

3. Fruit Quality Parameters

Fruit Length (cm)

Fruit length was significantly ($P\leq 0.01$) influenced by variety throughout 2016, 2017 and 2018 crop harvesting seasons (Table 3). As presented on Table (6), Ettinger variety gave the highest fruit length during 2016, yet statistically not different from Bacon and Pinkeron. Fuerte was also devoted the maximum fruit length which is statistically identical with Ettinger in 2017. Fuerte (13.02 cm), Pinkerton (12.77 cm) and

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Ettinger (12.41 cm) varieties gave the highest fruit length which are significantly similar with each of them during 2018. The current results are in agreement with the findings of Poudel *et al.* (2018), who reported the significant effects of avocado genotypes on fruit length in Nepal. Similarly, Bayram *et al.* (2012) has also reported that there was variation in fruit length among avocado genotypes. Moreover, data regarding fruit size of different varieties of avocado found statistically significant when analyzed at 5 % level of significance (Abbas *et al*., 2020). This might be due to genotype constituent of the varieties and variation in degree of adaptability to the environment.

Fruit Diameter (cm)

Anova table (3) showed that the significant (*P≤0.01*) effects of variety on avocado fruit diameter during 2017; however, fruit diameter was not statistically affected (*P≥0.05*) by avocado varieties in 2016 and 2018 crop harvesting years. Significantly the largest fruit diameter was found on Hass variety during 2017 fruit harvesting season; however, the lowest fruit diameter was obtained from Fuerte variety yet statistically not different from Bacon, Ettinger, Pinkerton and Nabal varieties (Table 6). In line with the results during 2017, Poudel *et al.* (2018) also reported that significant variations among avocado genotypes for fruit diameter. Likewise, Bayram *et al.* (2012) reported that fruit width difference between Reed and Hass. Also significant difference was observed among avocado varieties on fruit width whereby the highest fruit width was obtained from Bacon variety and the least was obtained from Hass avocado variety (Emire *et al*., 2021) which is highly the contribution of genotype and crop husbandry.

Average Fruit Weight (gr)

Variety exerted highly significant (*P≤0.01*) differences on average fruit weight during 2017 and 2018, while in the 2016 crop harvesting year, fruit weight was significantly (*P≤0.05*) determined by variety (Table 3). Statistically the highest fruit weight was obtained from Ettinger variety during 2016 fruit harvesting year, yet statistically not different from Bacon, Pinkerton and Fuerte varieties. Similarly, Nabal showed the maximum fruit weight on 2017 fruit harvesting year but statistically not different from Pinkerton variety. In addition to this, Nabal gave the highest fruit weight during 2018, yet statistically not dissimilar from Bacon variety (Table 6). Significant effects of variety on individual fruit weight of avocado was also previously reported by (Bayram et al. 2012; Poudel et al. 2018). Likewise, Gregoriou and Economides (1991) reported that fruits of 'Ettinger' had the highest weight and fruits of 'Hass,' the lowest. This is highly dependent on the size of the fruit which is influenced by the management practices and the inherent characters of the varieties.

Average Fruit Flesh (Juice) Weight per Fruit (gr)

Highly significant (*P≤0.01*) effects of avocado variety on flesh weight was exerted during 2016 and 2018 crop harvesting years, although in 2017, flesh weight was significantly (*P≤0.05*) affected by variety (Table 1). Statistically the highest juice (flesh) weight was recorded from Pinkerton variety during 2016, yet it was statistically not different from Ettinger and Bacon varieties. Likewise, the maximum flesh (juice) weight was recorded from Nabal variety in 2017 fruit harvesting year. In addition to this, during the 2018 crop harvesting year, the most prominent juice weight was obtained on Fuerte variety (Table 6). But then, Nabal variety gave the lowest fruit flesh (juice) weight in 2016 and; in 2017 and 2018, Hass variety gave the lowest juice weight (Table 6). Fruit size and seed size in the fruit significantly affect the juice constituent of avocado cultivars. Moreover, the fruit size and seed size of avocado varieties which influence the juice content of avocado are governed by genetic

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constituents of the cultivar, crop management practices and environmental conditions.

Average Stone (seed) weight of Fruit^{-1}(gr)

The average stone (seed) weight of avocado was significantly ($P \leq 0.05$) ascertained in *2016,* 2018 and 2017 year (3). The maximum avocado seed weight was found on Ettinger during 2016 crop harvesting year, which however was not statistically different from Pinkerton and Bacon (Table 6). Similarly, during 2017, the highest avocado seed weight was recorded on Nabal variety but it was statistically similar to the Hass variety (Table 6). Bacon showed the highest seed weight, yet statistically similar from Ettinger as indicated on (Table 6). However, during 2016 and 2018, Nabal variety gave the minimum seed weight; while during 2017, the minimum seed weight was recorded on Hass variety (Table 6). The present results accorded with the reports of Poudel *et al.* (2018) who reported a highly significant difference among avocado genotypes for seed weight. Similarly, Gregoriou and Economides (1991) reported the highest tone weight in Ettinger fruits and lowest stone weight in Hass fruits.

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Table1. Mean squares from the first year (2016) analysis of variance for the tree growth performance of avocado varieties at Raya valley condition

Source of Variance	D.F	Tree Growth Parameters		
		Tree height at First Harvest (m)	Canopy Diameter (m)	Above Graft union Girth Diameter(mm)
Treatment	5	0.282^{ns}	0.212^{ns}	180.1896**
Error	10	0.215	0.332	29.777
CV		20.34	21.25	10.11

* and **, significant at P≤0.05 and p≤0.01 probability levels respectively; ns= not significant, DF= Degree of freedom; SOV= Source of Variation

Table 2. Mean squares from the three years (2016,2017 and 2018) analysis of variance for avocado yield parameters at Raya valley condition

SOV	DF	Mean Squares														
		Marketable Fruit Number Tree^{-1}			Marketable Yield Tree^{-1} (Kg)			Unmarketable Fruit Number Tree^{-1}			Unmarketable Yield Tree^{-1} (Kg)			Total Yield Tree^{-1}(Kg)		
		2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
TRT		485.33**	771.66**	1048.82**	66.95**	28.52^{ns}	58.84**	2.66**	7.26**	30.22**	0.096**	0.57**	2.03**	67.79**	21.977^{ns}	73.24**
Error		11.22	69.63	68.76	1.21	9.55	4.09	0.001	0.02	2.37	0.001	0.001	0.04	1.219	9.352	3.865
CV		10.91	14.11	18.29	12.92	18.99	16.83	11.99	15.30	29.16	20.26	11.25	16.37	12.75	18.48	14.89

** significant at p≤0.01 probability levels respectively; ns= not significant, DF= Degree of freedom; SOV= Source of Variation;

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Table 3. Mean squares from the three years (2016, 2017 and 2018) analysis of variance for avocado yield parameters at Raya valley condition

SOV	DF	Mean Squares														
		Fruit Length (cm)			Fruit Diameter (cm)			Average single Fruit Weight (gr)			Average single fruit Juice Wt. (gr)			Average Seed (stone) Wt. (gr)		
		2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
TRT		17.80**	8.86**	8.65**	2.85^{ns}	4.98**	0.46^{ns}	9783.42*	10275.86**	6310.26**	4213.12**	5376.15*	3874.48**	978.64**	457.76*	10.44**
Error		2.77	0.69	0.51	0.92	0.64	0.125	2374.89	1174.81	197.42	223.69	1203.52	122.23	53.91	109.84	15.00
CV		15.31	7.45	6.22	13.06	10.76	5.18	19.51	14.28	4.94	10.38	21.88	5.50	13.96	20.10	10.44

* and ** significant at P≤0.05 and p≤0.01 probability levels respectively; ns= not significant, DF= Degree of freedom; SOV= Source of Variation

Table 4. Mean tree growth performance of avocado varieties grown at Raya Valley

Varieties	Tree Growth Parameters		
	Tree height at First Harvest (m)	Canopy Diameter (m)	Above Graft union Girth Diameter (mm)
Pinkerton	1.95	2.62	43.927^{c}
Hass	2.25	2.56	50.46^{bc}
Fuerte	2.71	3.23	61.40^{a}
Nabal	2.06	2.53	61.44^{a}
Bacon	2.59	2.74	59.42^{ab}
Ettinger	2.10	2.58	47.17^{c}
LSD	0.84	1.048	9.93
CV	20.34	21.25	29.98
Error Mean Square	0.21	0.33	29.78

Columns means followed by the same letter are not significantly different at P≤0.05 probability level *VAR:* Variety , Err.MSq. Error Mean Square

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Table 5. Mean performance of avocado varieties for yield and yield components during 2016,2017 and2018 fruit harvesting years at Raya Valley

VAR	Marketable Fruit Number Tree^{-1}				Marketable Yield Tree^{-1} (Kg)				Unmarketable Fruit Number Tree^{-1}				Unmarketable Yield Tree^{-1} (Kg)				Total Yield Tree^{-1}(Kg)			
	2016	2017	2018	Mean	2016	2017	2018	Mean	2016	2017	2018	Mean	2016	2017	2018	Mean	2016	2017	2018	Mean
Pinkerton	49.92^{a}	81.00^{a}	49.89^{bc}	60.27	15.10^{a}	18.23	17.04^{a}	16.79	1.83^{a}	0.00^{c}	7.00^{a}	2.94	0.41^{a}	0.00^{c}	1.00^{c}	0.47	15.51^{a}	18.23	18.04^{a}	17.26
Hass	35.11^{b}	73.00^{ab}	73.51^{a}	60.54	6.13^{d}	14.32	12.64^{b}	11.03	1.10^{b}	2.00^{b}	4.14^{b}	2.41	0.16^{c}	0.33^{b}	0.76^{c}	0.42	6.29^{d}	14.65	13.40^{b}	11.44
Fuerte	14.44^{d}	44.25^{de}	32.75^{d}	30.48	4.45^{de}	11.02	10.62^{b}	8.70	0.00^{c}	3.67^{a}	3.05^{bc}	2.24	0.00^{d}	1.08^{a}	0.86^{c}	0.65	4.45^{de}	12.10	11.47^{b}	9.34
Nabal	20.00^{d}	39.33^{e}	22.33^{d}	27.22	3.05^{e}	18.30	5.11^{c}	8.82	2.00^{a}	0.00^{c}	0.67^{c}	0.89	0.33^{b}	0.00^{c}	0.20^{d}	0.18	3.37^{e}	18.52	5.31^{c}	9.07
Bacon	36.58^{b}	59.49^{bc}	57.75^{b}	51.27	12.20^{b}	19.10	16.44^{a}	15.91	0.06^{c}	0.00^{c}	8.72^{a}	2.93	0.02^{d}	0.00^{c}	2.44^{a}	0.82	12.22^{b}	19.097	18.88^{a}	16.73
Ettinger	28.08^{c}	57.72^{cd}	35.75^{cd}	40.51	10.11^{c}	16.71	10.22^{b}	12.34	0.00^{c}	0.00^{c}	8.11^{a}	2.70	0.00^{d}	0.00^{c}	1.91^{b}	0.64	10.11^{c}	16.71	12.12^{b}	12.98
LSD	6.093	15.18	15.09		1.999	5.62	3.68		0.18	0.26	2.80		0.057	0.05	0.36		2.009	5.56	3.58	
CV	10.91	14.11	18.29		12.93	18.99	16.83		11.99	15.30	29.16		20.26	11.25	16.37		12.75	18.48	14.89	
Err. M.Sq.	11.218	69.63	68.76		1.207	9.55	4.09		0.010	0.021	2.37		0.001	0.0007	0.04		1.219	9.35	3.87	

Column means followed by the same letter are not significantly different at P≤0.05 probability level *VAR:* Variety , Err.MSq. Error Mean Square

Table 6. Mean performance of avocado varieties for fruit quality components during 2016, 2017 and 2018 fruit harvesting years at Raya valley

VAR	Fruit Length (cm)				Fruit Diameter (cm)				Average single Fruit Weight (gr)				Average single fruit Juice Wt. (gr)				Average Seed (stone) Wt. (gr)			
	2016	2017	2018	Mean	2016	2017	2018	Mean	2016	2017	2018	Mean	2016	2017	2018	Mean	2016	2017	2018	Mean
Pinkerton	12.11^{abc}	11.31^{bc}	12.77^{a}	12.06	8.17	7.21^{b}	6.79	7.39	292.67^{ab}	269.42^{ab}	293.18^{bc}	285.09	189.16^{a}	159.21^{bc}	213.39^{b}	187.25	62.65^{ab}	61.08^{a}	31.44^{bc}	51.72
Hass	9.48^{bcd}	9.85^{cd}	8.38^{c}	9.24	6.37	9.89^{a}	6.10	7.45	206.0^{bc}	143.23^{c}	196.85^{d}	182.02	128.99^{b}	99.59^{c}	135.18^{c}	121.25	37.97^{c}	28.80^{b}	30.39^{c}	32.39
Fuerte	9.18^{cd}	13.24^{a}	13.02^{a}	11.81	8.64	6.46^{b}	6.89	7.33	224.33^{abc}	251.56^{b}	329.92^{a}	268.60	112.32^{bc}	154.75^{bc}	242.37^{a}	169.81	52.48^{b}	48.89^{a}	37.54^{b}	46.30
Nabal	7.79^{d}	11.68^{b}	10.90^{b}	10.12	6.46	7.70^{b}	7.19	7.12	170.67^{c}	318.99^{a}	283.36^{c}	257.67	94.87^{c}	230.43^{a}	202.36^{b}	175.88	24.81^{c}	61.73^{a}	28.41^{c}	38.32
Bacon	12.45^{ab}	8.53^{d}	11.31^{b}	10.76	7.68	6.63^{b}	7.15	7.15	296.00^{a}	217.12^{b}	308.92^{ab}	274.01	166.56^{a}	142.39^{bc}	216.44^{b}	175.13	65.64^{ab}	57.34^{a}	50.02^{a}	57.66
Ettinger	14.24^{a}	12.33^{ab}	12.14^{ab}	12.90	6.62	6.68^{b}	6.81	6.70	309.00^{a}	239.72^{b}	294.42^{bc}	281.04	172.82^{a}	164.90^{b}	196.61^{b}	178.11	71.93^{a}	55.08^{a}	44.83^{a}	57.28
LSD	3.030	1.51	1.29		1.740	1.45	0.64		88.66	62.36	25.562		27.21	63.11	20.12		13.36	19.07	7.05	
CV	15.31	7.45	6.22		13.06	10.76	5.18		19.51	14.28	4.94		10.38	21.88	5.50		13.96	20.10	10.44	
Err. M.Sq.	2.77	0.69	0.51		0.92	0.64	0.12		2374.89	1174.81	197.42		223.69	1203.52	122.25		53.91	109.84	15.00	

Column means followed by the same letter are not significantly different at P≤0.05 probability level *VAR:* Variety, Err.MSq. Error Mean Square

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CONCLUSION

The result obtained from investigation made on six avocado cultivars indicated that the variation among varieties were observed on growth, yield and fruit qualities of avocado. However, the result was not consistent for all growth, yield and fruit quality parameters throughout the years. In general, Pinkerton and Bacon varieties gave the highest marketable fruit yield, total yield per tree, average single fruit weight and juice weight, thus, both varieties were recommended for growers in Raya valley and other areas having similar agro-ecologies. However, it is important to study the water requirements in terms of irrigation depth and frequency in Ethiopia at all.

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