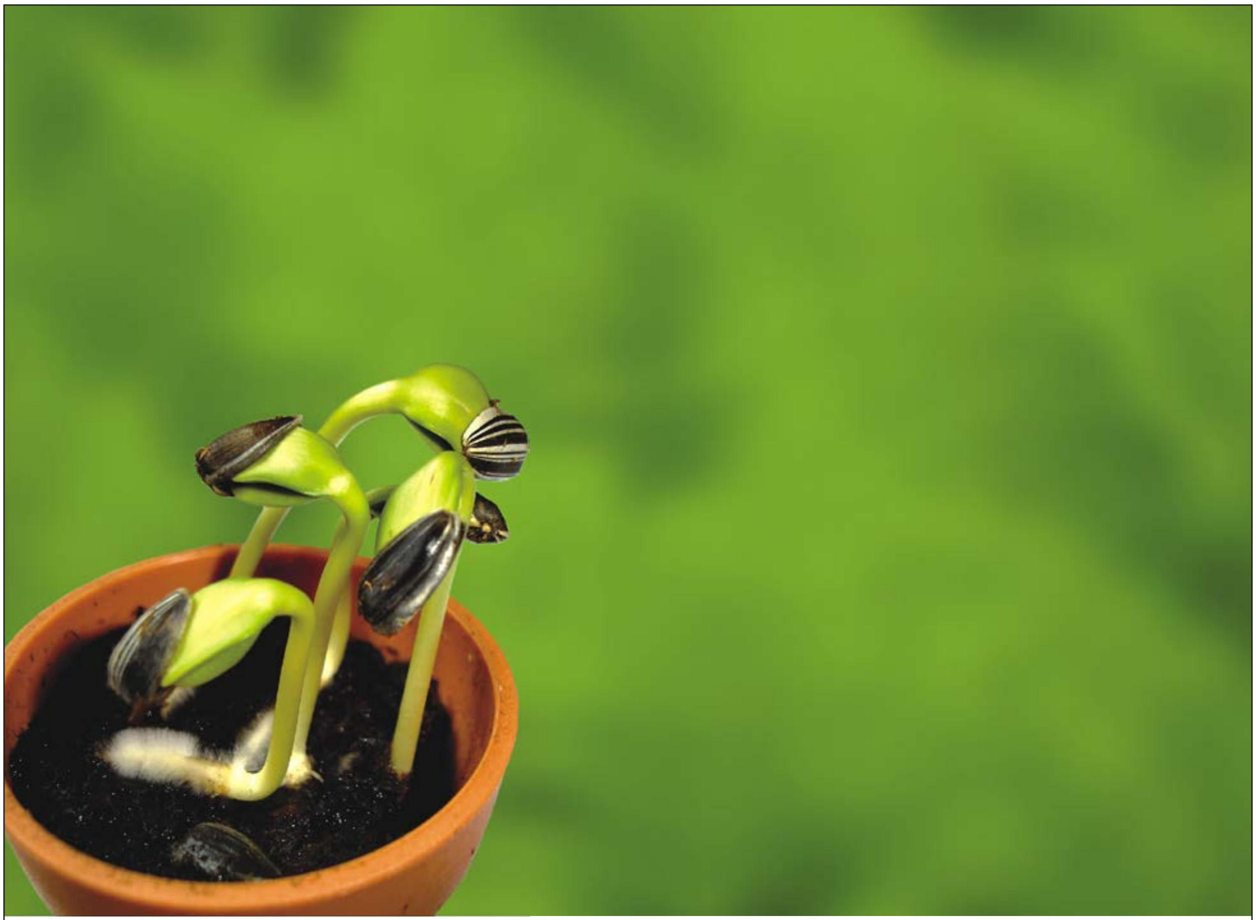


International Journal of

Plant Breeding and Genetics

ISSN 1819-3595

Academic
Journals Inc.

www.academicjournals.com

International Journal of Plant Breeding and Genetics 7 (2): 76-91, 2013
ISSN 1819-3595 / DOI: 10.3923/ijpbg.2013.76.91

Genetic Diversity among Local and Introduced Avocado Germplasm Based on Morpho-agronomic Traits

George Oduro Nkansah, Kwabena Godfred Ofosu-Budu and Alex Williams Ayarna
University of Ghana, College of Agriculture and Consumer Sciences, Institute of Agricultural Research, Forest and Horticultural Crops Research Centre-Kade, P.O. Box LG68, Legon, Accra, Ghana

Corresponding Author: George Oduro Nkansah, University of Ghana, College of Agriculture and Consumer Sciences, Institute of Agricultural Research, Forest and Horticultural Crops Research Centre-Kade, P.O. Box LG68, Legon, Accra, Ghana

ABSTRACT

Appreciating the nature and extent of variability among avocado (*Persea americana* Mill.) genotypes for traits of economic importance are essential to plan effective breeding and germplasm conservation programs. This study was undertaken to estimate the existing genetic diversity within and among some local avocado germplasm collections kept at the University of Ghana Forest and Horticultural Crops Research Centre, Kade based on agro-morphological traits which included leaf shape, colour and leaf margin, tree shape and trunk surface, fruit shape, fruit habit, fruit apex shape, ridges on fruit, pedicel position on fruit, gloss of skin as well as fruit number and fruit weight. A total of one hundred and one (101) local landraces collected from different ecozones of Ghana were studied in Experiment 1 while in Experiment 2, five (5) introduced world leading varieties obtained from South Africa and thirteen (13) selected lines in Experiment 1 were used in the studies. The five introduced and exportable varieties are 'Hass', 'Fuerte', 'Ryan', 'Ettinger' and 'Nabal'. Morphological characterization of the germplasm using the plant descriptors outlined in the IPGRI publication, Descriptors for Avocado (*Persea* sp.) have been described. The results indicated genetic diversity among the avocado lines and cultivars in terms of leaf, tree, fruit and yield characteristics. Spearman's rank correlation coefficient revealed significant positive correlations among plant height, canopy width, stem girth and number of branches. Future improvement of the crop plant should exploit the genetic variability available in the newly introduced world cultivars as well as the local germplasm collections.

Key words: Conservation, improvement, genetic diversity, landraces, introduced cultivars, physiological activities

INTRODUCTION

Avocado (*Persea americana* Mill) belongs to the family Lauraceae and today there are three botanical varieties or subspecies of the cultivated crop. These are the Mexican (var *drymifolia*), Guatemalan (var. *guatemalensis*) and the West India types (var *americana*) (Popenoe, 1927; Bergh, 1992; Scora and Berg, 1992). In addition to the above recognized varieties, Kopp (1966) and Ben-Ya'acob *et al.* (2003) reported other types of *P. americana*, among them var. *nubigena* (L. Wms.) Kopp and var. *costaricencis*. The dispersal of avocado to other parts of the wold and its adaptation to different ecological zones is well documented (Diamond, 2002; Perales *et al.* 2005).

As one of the popular fruit crops grown and consumed in Ghana, it is commonly grown in home gardens because of ease of adaptability to the environment as well as its tolerance to rainfall during flowering. The fruit is sold fresh to the local market and can be processed into oil. The oil contains protein, vitamins A, D and E, amino acids and lecithin thus highly therapeutic (Nakasone and Paul, 1998).

The crop without doubt has the potential to become a new export commodity for developing countries and for that matter Ghana. Eventhough, it is unknown when the avocado crop was brought into Ghana, it is a fact that it was first introduced into the country by the missionaries and the first planting was in Aburi, a town near Ghana's capital city, Accra from where avocado cultivation spread to other areas in 1907 (Anonymous, 1961). Later, between 1907 and 1960, cultivars like Booth 7, Booth 8, Fuchsia, Lula, Monroe, Trapp, Choquette, Collinson, Waldin, Duke', 'Ettinger' and 'Fuerte' were introduced (Acheampong *et al.*, 2008). Unfortunately, these cultivars at the moment cannot be identified or located making identification of races and cultivars and their crosses very difficult.

Currently, production is by small holdings and these farms can be found in small acreages of about 0.5-2.0 acres in several places in the 8 out of the 10 regions of Ghana. Fruits from these plants have been observed to be of different shapes, sizes and taste, an indication of a large genetic pool and diversity (Nkansah *et al.*, 2007).

The lack of information or little research (Acheampong *et al.*, 2008) on avocado with regards to characterization and correct identification of germplasm collections limits the efforts of genetic improvement of avocado in Ghana. The knowledge of the genetic diversity is fundamental for development of any meaningful strategy for gemplasm collection, management and conservation, domestication and improvement of the species genetic resources (Chiveu *et al.*, 2009). The present study aim to evaluate the genetic diversity among local and some leading world avocado varieties based on morpho-agronomic differences in leaf, tree, fruit and yield traits that are related to the success of species establishment and future evaluations for export and breeding purposes.

MATERIALS AND METHODS

Location and climatic site under study: The studies were conducted at the University of Ghana Forest and Horticultural Crops Research Centre Farms at Kade in the forest zone. The location is 114 m above sea level on latitude 6°.1573'N and longitude 0°.9153'W. The dominant soil is Haplic Acrisol (FAO/UNESCO, 1990; Nkansah *et al.*, 2007). The annual rainfall amount ranges between 1300-1700 mm and the distribution is bi-modal with two peaks around June-July and September-October. Temperature ranges between 25-38°C (Ofosu-Budu, 2003).

In experiment 1, One hundred (100) local accessions were collected from different avocado growing areas in four regions of Ghana and planted in 2004 while in experiment 2, five world leading varieties (Plate 1) namely 'Hass', 'Fuerte', 'Ryan', 'Ettinger' and 'Nabal' obtained from South Africa plus seven local accessions selected from 2006 based on taste and yield were planted in 2010.

Parameters measured: In experiment 1, morphological characterization (leaf, tree and fruit) for fingerprinting of individual accession was done using the International Plant Genetic Resource Institute (IPGRI, 1995) Descriptors for Avocado (*Persea* sp.). The leaf characters measured included, leaf shape, colour and leaf margin. Tree characters determined were shape and trunk surface while fruit characters taken included fruit shape, fruit habit, fruit apex shape, ridges on fruit, pedicel position on fruit and gloss of skin. Fruit yield including fruit number per plant and fruit weight per plant were determined. In experiment 2, plant height, girth, canopy size and number of branches were measured. Physiological characters like photosynthetic rate, transpiration rate, stomatal conductance, water use efficiency could not be measured due to lack of equipments.

Statistical analysis: Analysis of variance was performed using Genstat version 11 and means separated using the Least Significant Differences (LSD) at p = 0.05. Correlation analysis was also established for the parameters taken using Spearman's rank correlation coefficient at p = 0.05.

RESULTS

General observation: Descriptive statistics for the traits including leaf, tree, fruit and yield traits exhibited wide range of variation in both experiments.

Experiment 1

Agro-morphological characterization

Leaf characteristics: Five leaf shapes were observed in the accessions as shown in Fig. 1. These are roundish (32%), lanceolate (28%), obovate (5%), oval (3%) and oblong-lanceolate (32%). In Fig. 2 the results show the distribution of leaf colour at green, dark green and light green in the population. The percentages of distribution are 48, 43 and 10% for green, dark green and light green respectively. Figure 3 results indicate that two leaf margins were observed in the accessions, undulate (47%) and entire (53%). Figure 4 also indicate that two leaf base shapes were observed in the population, acute (72%) and obtuse (28%).

Evaluation of fruit Characteristics: Results in Figure 5 show that seven (7) fruit shapes were present in the accessions, obovate (32%), narrowly obovate (18%), pyriform (18%), rhomboidal (18%), high spheroid (8%), spheroid (5%) and clavate (2%).

In terms of fruit habit, two types of fruits were observed among the population, clusters (83%) and single (17%) (Fig. 6). The data in Fig. 7 also showed that four fruit apex shapes were found in the accessions. These are flattened (38%), rounded (27%), slightly depressed (27%) and deeply depressed (8%).

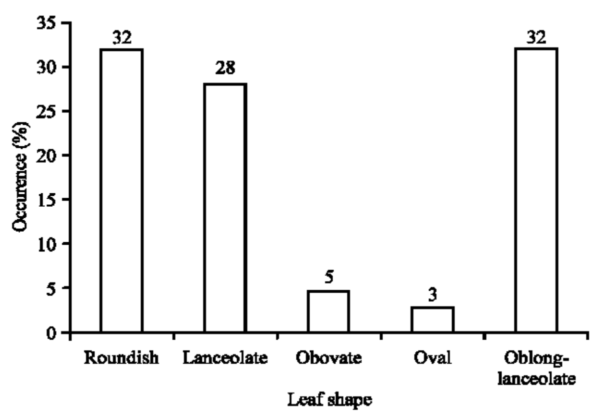


Fig. 1: Distribution of leaf shapes within some avocade accessions

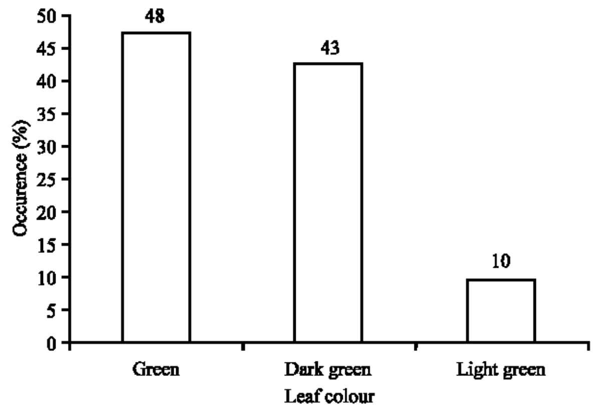


Fig. 2: Distribution of leaf color in some accessions

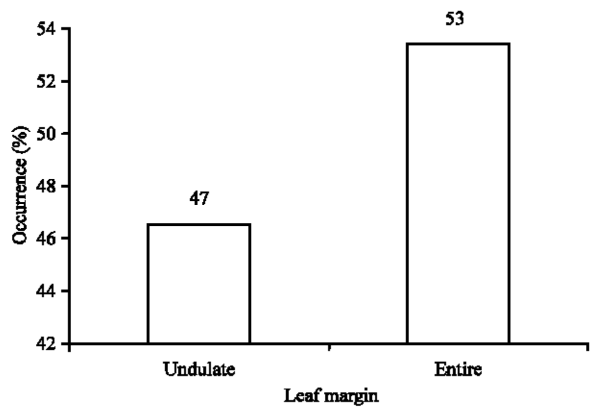


Fig. 3: Distribution of leaf shapes within some avocade accessions

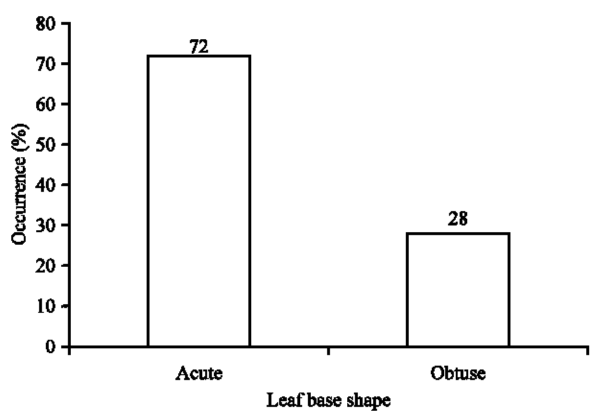


Fig. 4: Distribution of leaf bade shapes within some avocade accessions

Figure 8 shows that ridges on fruits were in four categories, absent (74%), present (3%), partial (21%) and entire (2%).

Evaluation of tree characteristics: Figure 9 shows the distribution of tree shape within the accessions studied. It ranged from 5.9 to 27.5%. Seven tree shaped were observed. These are

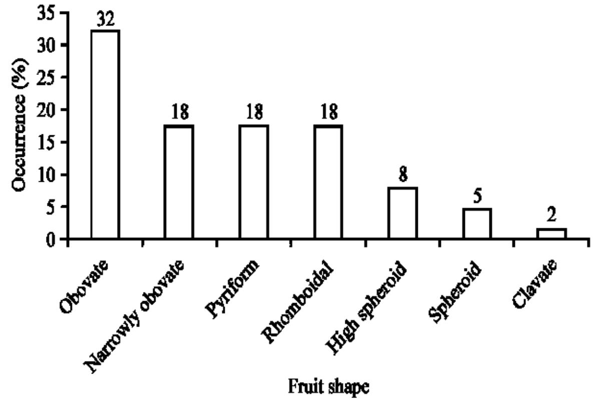


Fig. 5: Distribution of fruit shapes in some accessions

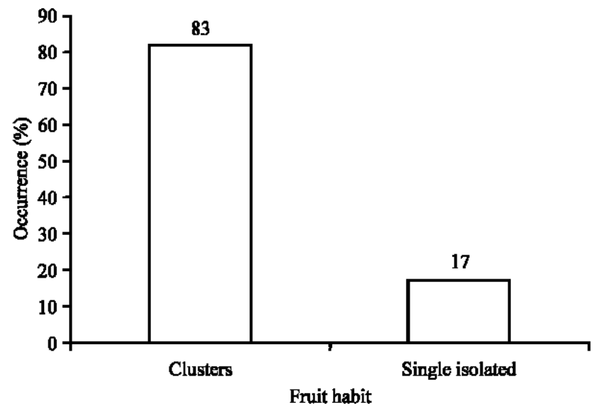


Fig. 6: Distribution of fruit habit in some accessions

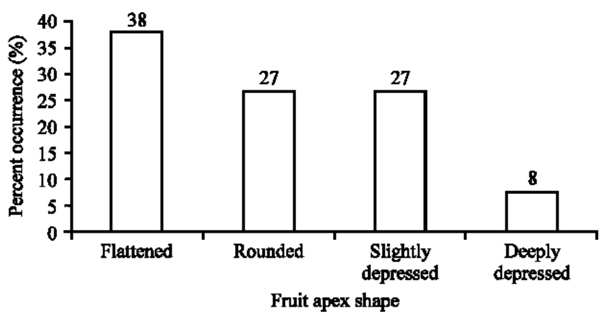


Fig. 7: Distribution of fruit apex shape in some accessions

circular (27.5%), semi-circular (8.8%), obovate (15.7%), columner (20.6%), pyramidal (9.8%), semi-elliptic (5.9%) and rectangular (11.8%). In terms of tree branching pattern, the distribution was either extensive (35%) or intensive (65%) (Fig. 10).

Evaluation of yield characteristics: Significant differences in fruit number and weight per plant as well as the yield in tonnes were observed (Table 1). The number of fruits per plant ranged from 5 to 240 while fruit weight per plant ranged from 0.66 kg to 78.6 kg per plant. Yield (t ha^{-1}) also ranged from 0.28-15.72 t ha^{-1}.

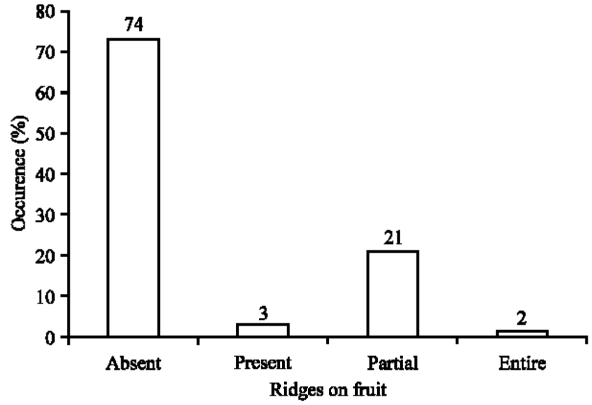


Fig. 8: Distribution of ridges on fruit in some accessions

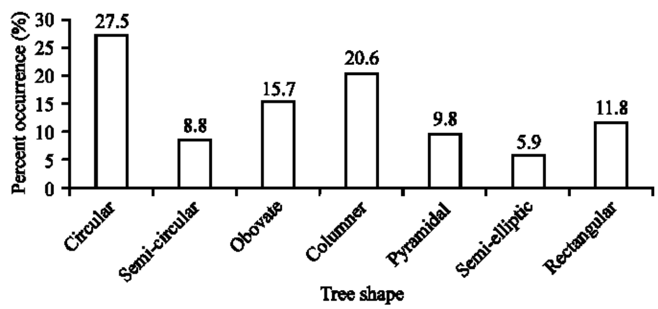


Fig. 9: Distribution of tree shapes within some accessions

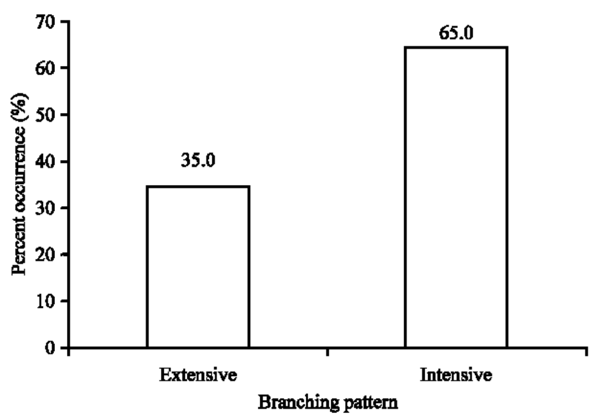


Fig. 10: Distribution of tree branching pattern in some accessions

Experiment 2

Growth performance of introduced and local cultivars/accessions: Large variations were observed in the morphological traits studied (Table 2). Plant height varied significantly among the introduced and local lines (Table 1) and ranged between 315.0 cm (Sehwi)-96.5 cm (Fuerte). Plant girth exhibited wide range of variation and ranged between 95.0 mm (Sewhi)-32.9 mm (Hass). Canopy size differed significantly and was highest in the accession 'Sewhi' (310 cm^2) and lowest in 'Ryan' (124.8 cm^2). There was also wide variation in terms of number of branches in the accessions or varieties. It ranged from 29.4-7.0.

Table 1: Yield performance of some avocado accessions 6 years after transplanting

Accession No.	Fruit No. (No. plant^{-1})	Fruit weight (g plant^{-1})	Yield (t ha^{-1})
1	16.0	1196.0	1.20
2	2.0	300.0	0.30
3	9.0	654.0	0.65
4	8.0	462.0	0.46
5	4.0	440.0	0.44
6	4.0	300.0	0.30
7	42.0	2520.0	2.52
8	60.0	2500.0	2.50
9	8.0	700.0	0.70
10	12.7	8859.0	8.86
11	56.0	3432.0	3.43
12	31.0	1662.0	1.66
13	78.0	5094.0	5.09
14	10.0	582.0	0.58
15	48.0	2254.0	2.25
16	38.0	2564.0	2.56
17	95.0	6032.0	6.03
18	169.0	1008.0	10.08
19	97.0	4308.0	4.31
20	28.0	1366.0	1.37
21	36.0	1740.0	1.74
22	37.0	1650.0	1.65
23	24.0	1588.0	1.59
24	25.0	1388.0	1.39
25	27.0	1294.0	1.29
26	64.0	5120.0	5.12
27	135.0	9494.0	9.49
28	60.0	4338.0	4.34
29	174.0	8430.0	8.43
30	4.0	280.0	0.28
31	184.0	9624.0	9.62
32	27.0	2118.0	2.12
33	65.0	5320.0	5.32
34	43.0	3292.0	3.29
35	32.0	2200.0	2.20
36	182.0	8248.0	8.25
37	51.0	2446.4	2.45
38	31.0	1660.0	1.66
39	7.0	400.0	0.40
40	10.0	1052.0	1.05
41	4.0	240.0	0.24
42	116.0	9521.2	9.52
43	47.0	2276.0	2.28
44	142.0	8970.0	8.97
45	36.0	1992.0	1.99
46	65.0	3964.0	3.96
47	12.0	776.0	0.78
48	12.0	782.0	0.78

Table 1: Continue

Accession No.	Fruit No. (No. plant^{-1})	Fruit weight (g plant^{-1})	Yield (t ha^{-1})
49	14.00	3534.0	3.53
50	14.25	5066.0	5.07
51	36.00	2022.0	2.02
52	178.00	9167.0	9.17
53	149.00	6883.8	6.88
54	40.00	2728.0	2.73
55	58.00	4013.6	4.01
56	176.00	14044.8	14.04
57	15.00	849.0	0.85
58	217.00	10514.0	10.51
59	55.00	3619.0	3.62
60	58.00	3132.0	3.13
61	25.00	1955.0	1.96
62	15.75	5000.0	5.00
63	13.65	4620.0	4.62
64	15.8.0	5600.0	5.60
65	15.5.0	5360.0	5.36
66	14.48	4940.0	4.94
67	15.50	5060.0	5.06
68	15.00	5700.0	5.70
69	15.50	4340.0	4.34
70	92.00	4738.0	4.74
71	30.00	5400.0	5.40
72	30.00	1800.0	1.80
73	46.00	3339.6	3.34
74	51.00	5544.0	5.54
75	6.00	432.0	0.43
76	50.00	2420.0	2.42
77	15.00	957.0	0.96
78	193.00	8858.7	8.86
79	22.00	132.0	0.13
80	22.00	1940.4	1.94
81	63.00	5798.0	5.80
82	87.00	6246.6	6.25
83	26.00	2199.6	2.20
84	89.00	6016.4	6.02
85	77.00	4689.3	4.69
86	146.00	9767.4	9.77
87	95.00	7790.0	7.79
88	219.00	13884.6	13.88
89	27.00	1722.6	1.72
90	21.00	1247.4	1.25
91	104.00	7415.2	7.42
92	38.00	505.4	0.51
93	20.00	1288.0	1.29
94	215.00	15716.5	15.72
95	82.00	4337.8	4.34
96	7.00	443.8	0.44

Table 1: Continue

Accession No.	Fruit No. (No. plant^{-1})	Fruit weight (g plant^{-1})	Yield (t ha^{-1})
97	11.00	700.70	0.70
98	157.00	12198.90	12.20
99	12.00	1068.00	1.07
100	60.00	3768.00	3.77
101	107.00	6484.20	6.48
102	14.00	795.20	0.80
Lsd (0.05)	6.89	134.53	1.26

Table 2: Growth performance of some selected accessions and world leading cultivars

Var/Ac	Plant height (cm)	Plant girth (cm)	Canopy size (cm^2)	No. of branches (No./tree)
NK	1229.00	66.900	245.20	29.40
NK	2209.20	45.000	205.40	10.70
NK	3214.20	69.500	227.60	15.40
NK	4199.10	56.000	198.70	10.00
NK	5199.30	61.700	193.30	8.00
NK	6259.00	67.200	207.30	12.50
NK	7217.30	69.700	233.30	11.00
NK	8228.00	62.000	180.00	16.00
NK	9256.30	67.900	244.10	12.70
Ankobra	226.00	60.520	04.00	11.00
Brazilia	174.00	55.510	98.50	9.00
Olaf	215.40	55.510	85.00	12.50
Sehwi	315.00	95.030	10.00	21.00
Ettinger	124.40	41.710	59.80	7.00
Fuerte	96.54	0.416	4.40	7.00
Hass	98.63	2.912	9.60	8.00
Nabal	106.10	44.510	27.00	11.00
Ryan	99.63	6.610	24.80	7.00
Lsd (0.05)	29.29	8.340	9.05	3.00

NK means Nkansah

A comparative analysis between the commercial cultivars from South Africa and the local accessions revealed that the local accessions or lines significantly performed better than the introduced varieties (Table 3). Plant height, girth, canopy size and number of branches per tree were 226.3 cm, 64.0 mm, 217.9 cm^2 and 13.8 for the local and 105.0 cm, 39.2 mm, 141.1 cm^2 and 8.0 for the commercial respectively (Table 3).

Correlation coefficient relationships: Spearman's rank correlation was used to establish the relationship among the morphological characters studied (Table 4). Plant height showed significant and positive correlation with canopy (0.812*) and stem girth (0.766*) as well as number of branches (0.684*). There was also strong correlation between canopy width and stem girth (0.816*) and number of branches (0.668*). Stem girth also correlated significantly with number of branches (0.676*).

Table 3: Comparative growth traits of commercial and local accessions

Cultivar/Accession	Plant height (cm)	Plant girth (cm)	Canopy size (cm^2)	No. of branches
Commercial	105.0	39.2	141.1	8.0
Local	226.3	64.0	217.9	13.8
Paired t-test (p = 0.05)	*	*	**	*

*,**Significant at p = 0.05 and 0.01, respectively

Table 4: Spearman correlation among different morphological traits of avocado

Plant height	Plant height	Canopy width	Stem girth
Canopy width	0.812 **		
Stem girth	0.766**	0.816**	
No. of branches	0.684**	0.668**	0.676**

**Significant at p = 0.01

DISCUSSION

The avocado germplasm were collected from four out of 8 avocado producing ecological zones of Ghana. These avocado accessions have developed traits adaptable to the peculiar environments in which they have evolved. The pattern of variation exhibited for various characters were substantially different. This observations agree with reports by Baye and Becker (2005) and Baye *et al.* (2001).

Variations in leaf shape may express the extent of leaf area hence seasonal integral of light interception which may be correlated with yield. Variations in accessions with respect to leaf colour may be significant in photosynthesis as dark green leaves tend to have high chlorophyll content which may be associated with high yields.

It was also observed that, there were distinct variations in fruit shape which ranged from obovate, pyriform, rhomboidal, spheroid and clavate. Fruit shapes like obovate and pyriform conform to that of commercial cultivars like Hass (obovate) and Fuerte (Pyriform) as reported by De Villiers (2001). The distinct variation in fruit habit with respect to the clustering of fruits may be of yield significance. More fruit clusters per axil may be of good genetic material for breeding purposes. The twenty four percent (24%) pattern in the gloss of skin colour is significant as these materials may be used to breed cultivars that have waxy fruit skin surfaces.

Variations in tree shape were distinct with a higher percentage of the accessions being circular and the least semi-elliptic. In terms of branching pattern a higher percentage (65%) of the accessions was intensive while thirty five percent branched extensively.

The great variability observed in this study in terms of quantitative traits in trees, leaves and fruits of avocado are similar to the findings of Ashworth and Clegg (2003). Further findings have claimed variability in avocado accessions by means of morphological data (Rodriguez *et al.*, 2007), isoenzymes (Lima *et al.*, 1982; Sanchez-Romero *et al.*, 1993), different DNA markers (Ramirez *et al.*, 2002; Chang *et al.*, 2003; Rodriguez *et al.*, 2003; Ramirez *et al.*, 2005) and minisatellites (Davis *et al.*, 1998; Cuiris-Perez *et al.*, 2009). Genotypic variation has also been observed in wheat by several workers (Kheiralla *et al.*, 1993, Gupta and Verma, 2000; Jedynski, 2001).

Growth traits of the commercial varieties introduced from South Africa in terms of height, stem girth and canopy size and number of branches differed significantly from the local accessions. This may be attributed to the fact that the trees from South Africa are now adapting to the environment as they were transplanted about two years ago. This result showed close resemblance with the report of Baye and Becker (2005).

The significant correlations established among the morphological traits are in also agreement with Baye and Becker (2005). Similar findings were observed by Tamam *et al.* (2000), Fida *et al.* (2001) and Korkut *et al.* (2001). In this study, an increase in plant height correspondingly lead to an increase in the other traits measured and vice versa which can result in increase in productivity. Generally, the positive association among plant height, canopy width and stem girth indicate the possibility of improving these important traits simultaneously.

Genetic differentiation among the relatedness of accessions: NTSYSPC 2.02I data were used to generate a genetic distance matrix. Genetic distance values among accessions ranged from zero (closely-related material) to one (non-related material). From the genetic distance matrix a dendogram was constructed (Fig. 11). The dendogram indicates that at 0.03 coefficient of dissimilarity, sixty-six major groups were clearly distinguished. Forty six independent groups (Acessions 1, 3, 64, 63, 62, 86, 76, 59, 58, 56, 54, 53, 53, 85, 50, 49, 98, 75, 88, 44, 43, 42, 90, 66, 82, 36, 34, 84, 31, 81, 29, 73, 27, 26, 23, 22, 20, 19, 18, 15, 13, 11, 70, 7, 91) and twenty cluster groups comprising of cluster 1 (A2, 6, 5, 30 and 41), cluster 2 (A39 and 96), cluster 3 (A79 and 80), cluster 4 (A57, 77 and 68), cluster 5 (A55 and 60), cluster 6 (A47, 48, 99), cluster 7 (A37 and 74), cluster 8 (A35 and 83), cluster 9 (A33 and 46), cluster 10 (A25, 93, 32 and 89), cluster 11 (A24 and61), cluster 12 (A21, 45 and 51), cluster 13 (A17 and 87), cluster 14 (A16 and 92), cluster 15 (A14 and 40), cluster 16 (A12 and 38), cluster 17 (A10 and 78), cluster 18 (A8, 100, 28, 95, 69, 65

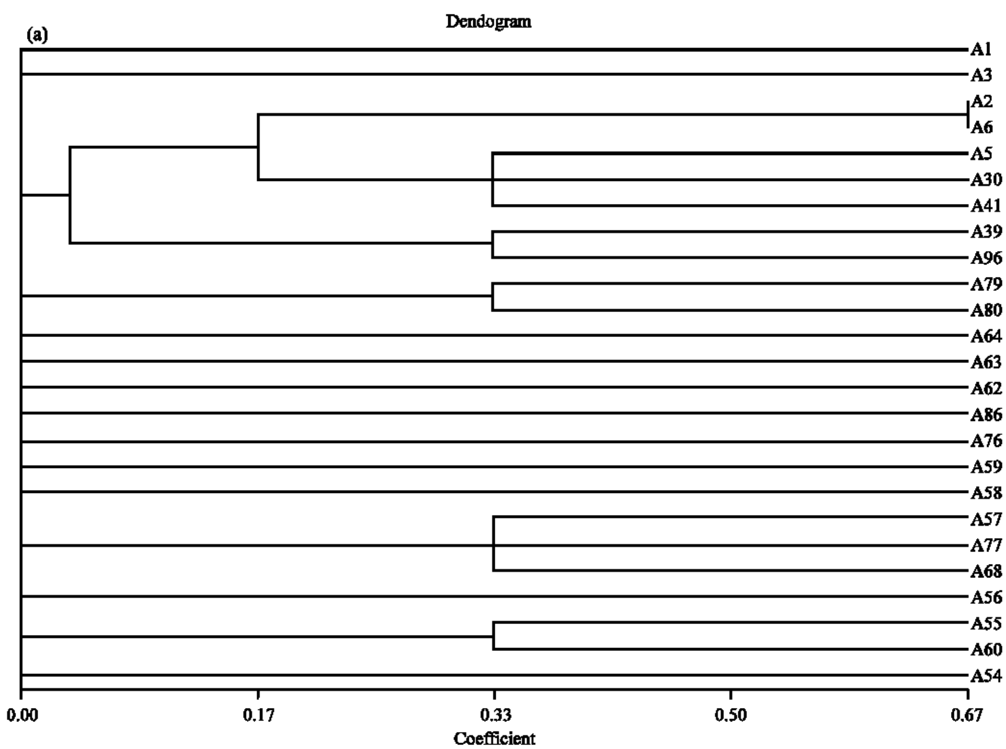
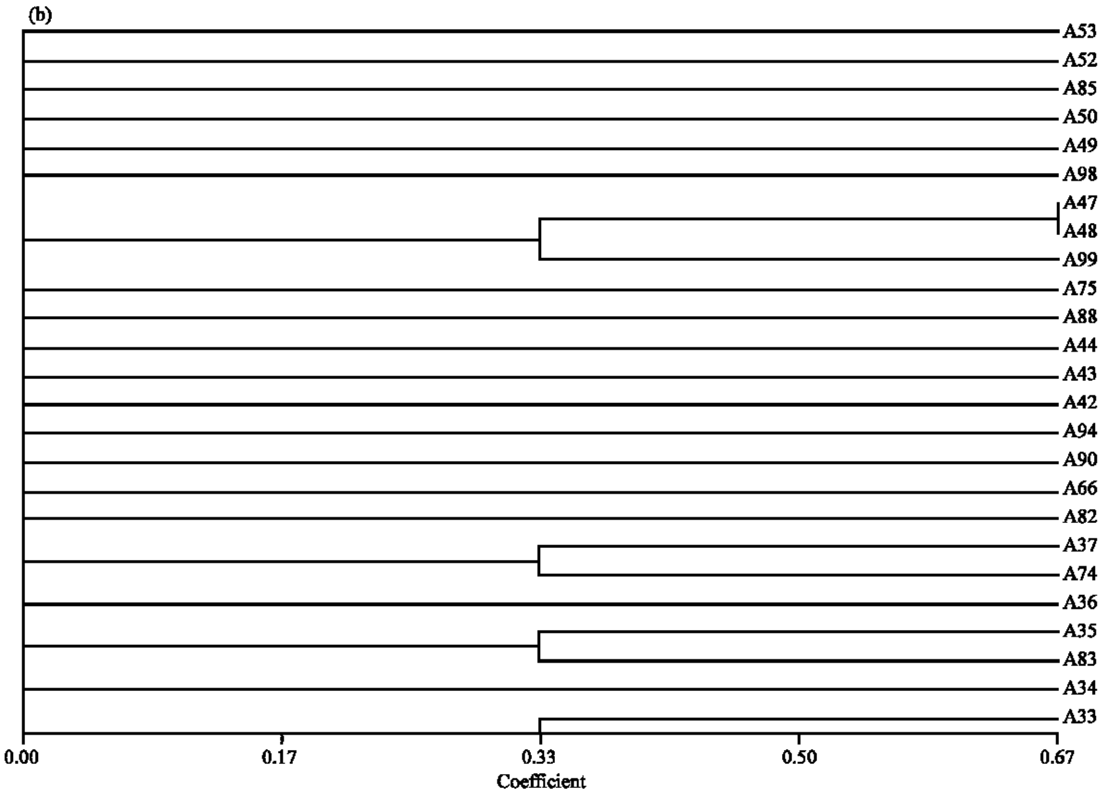


Fig. 11(a-d): Continue



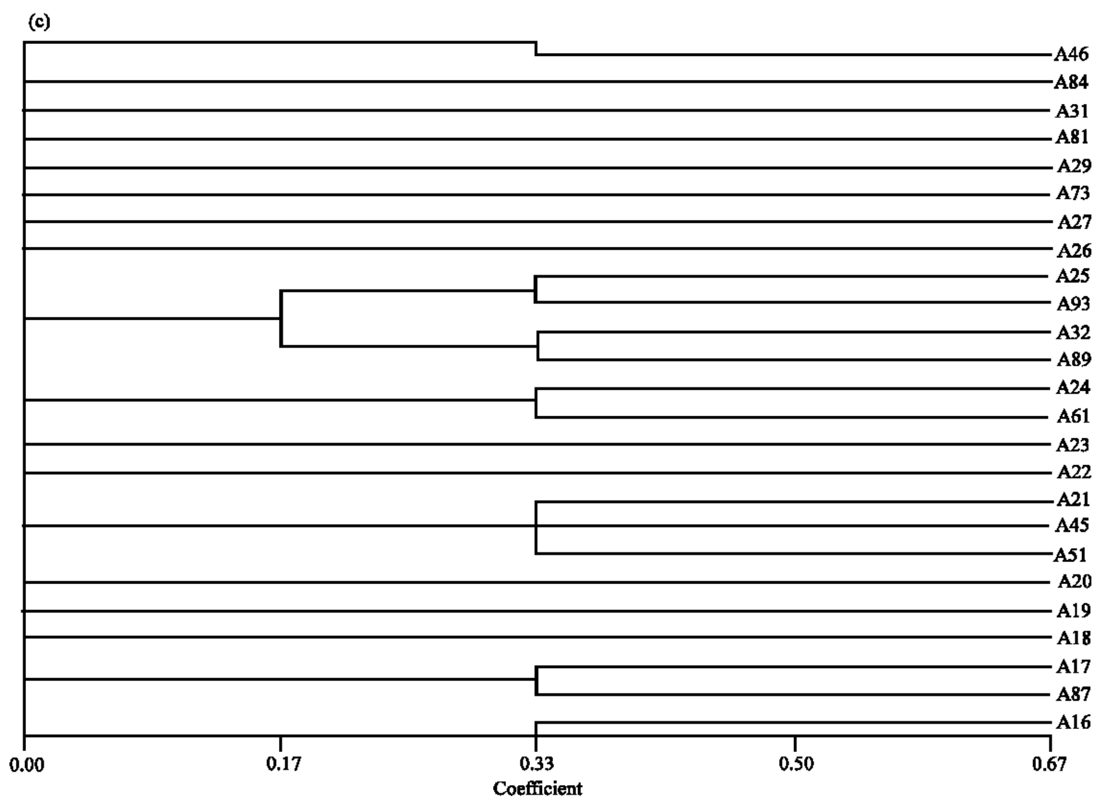


Fig. 11(a-d): Continue

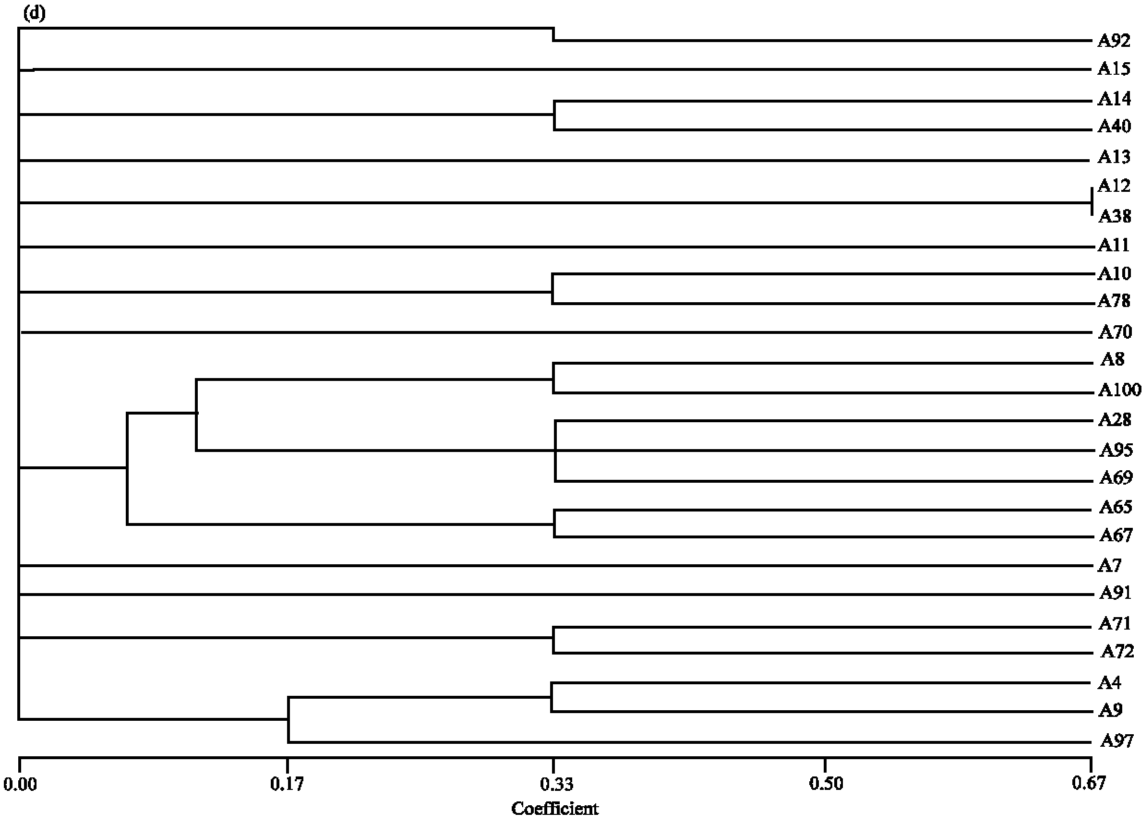


Fig. 11(a-d): Dendogram of 100 avocado (*Persea americana* Mill.) accessions

and 67), cluster 19 (A71 and 72) and cluster 20 (A4, 9 and 97) were identified. The assumption is that in selecting one member representative from the twenty cluster groups we have twenty accessions which when added to the forty six independent accessions will in total give a core collection of sixty-six different accessions out of the one hundred accessions. The usefulness of cluster analysis to detect genetic variation among avocados was confirmed in this research and was in agreement with other works in avocado (Clegg *et al*, 1999; Alcaraz and Hormaza, 2007). Molecular markers can be used to reduce duplications from the sixty-six accessions which have been identified as the core groups for the centre.

CONCLUSION

The present study shows that 66 groups of different accessions comprising of 46 independent accessions (individual lines) and 20 clusters were identified an indication of wide genetic variability in the avocado germplasm at the centre. Correlations between various traits determine productivity and are therefore imperative to be considered in evaluating the potential of avocado germplasm for improving important traits through breeding practice. The introduction of commercial cultivars at the Forest and Horticultural Crops Research Centre, Institute of Agricultural Research, is the first in Ghana and will serve as avocado Germplasm bank in the country.

Further work is also needed on molecular, genetic, physiological as well as biochemical studies on the 66 groups identified to remove duplicates for further breeding purposes to strengthen the avocado industry in Ghana.

ACKNOWLEDGMENT

The authors acknowledge with thanks the assistance of the University of Ghana Research Fund for funding this project. We are also grateful to Rubber plantations (Ghana) Ltd and Export Development and Investment Fund (EDIF) for financial support.

REFERENCES

Acheampong, A.K., R. Akromah and F.A. Ofori, 2008. Genetic characterization of Ghanaian avocados using microsatellite markers. J. Am. Soc. Hort. Sci., 133: 801-809.

Alcaraz, M.L. and J.I. Hormaza, 2007. Molecular characterization and genetic diversity in an avocado collection of cultivars and local Spanish genotypes using SSRs. Hereditas, 144: 244-253.

Anonymous, 1961. Miscellaneous information. The Ghana Farmer. Vol. XIII No. 1 Division of Agriculture, Accra.

Ashworth, V.E.T.M and M.T. Clegg, 2003. Microsatellite markers in avocado (*Persea americana* Mill.): Genealogical relationships among cultivated avocado genotypes. J. Heredity, 94: 407-415.

Baye, T., H. Kebede and K. Belete, 2001. Agronomic evaluation of *Vernonia galamensis* germplasm collected from Eastern Ethiopia. Ind. Crops Prod., 14: 179-190.

Baye, T. and H.C. Becker, 2005. Genetic variability and interrelationship of traits in the industrial oil crop *Vernonia galamensis*. Euphytica, 142: 119-129.

Ben-Ya'acob, A., A. Solis-Molina and G. Bufler, 2003. The mountain avocado of Costa-Rica. *Persea americana* var. *costaricensis*, a new sub-species. Proceedings of the 5th World Avocado Congress, October 19-24, 2003, Consejeria de Agricultura y Pesca, Malaga, Spain, pp: 27-33.

Bergh, B.O., 1992. The origin, nature and the genetic improvement of the avocado. California Avocado Soc. Yearbook, 76: 61-75.

Chang, T.L., M.T. Lu, C.A. Lui, and L.Z. Chen, 2003. Genetic diversity analysis of Taiwan avocado accessions. Proceedings of the 5th World Avocado Congress, October 19-24, 2003, Malaga, Spain, pp: 55-59.

Chiveu, C.J., O.G. Dangasuk, M.E. Omunyin and F.N. Wachira, 2009. Quantitative variation among Kenyan populations of *Acacia senegal* (L.) Willd. for gum production, seed and growth traits. New For., 38: 1-14.

Clegg, M.T., M. Kobayashi and J.Z. Lin, 1999. The use of molecular markers in the management and improvement of avocado (*Persea Americana* Mill.). Revista Chapingo Serie Horticult., 5: 227-231.

Cuiris-Perez, H., H. Guillen-Andrade, M.E. Pedraza-Santos, J. Lopez-Medina and I. Vidales-Fernandez, 2009. Genetic variability within Mexican race avocado (*Persea americana* Mill.) germplasm collections determined by ISSRs. Revista Chapingo Serie Horticultura, 15: 169-175.

Davis, J., D. Henderson, M. Kobayashi, M.T. Clegg and M.T. Clegg, 1998. Genealogical relationships among cultivated avocado as revealed through RFLP analyses. J. Heredity, 89: 319-323.

De Villiers, E.A., 2001. The Cultivation of Avocado. ARC-Institute for Tropical and Sub-tropical Crops, Agricultural Research Council, South Africa, ISBN: 13-9780958433747, Pages: 370.

Diamond, J., 2002. Evolution, consequences and future of plant and animal domestication. Nature, 418: 700-707.

FAO/UNESCO., 1990. FAO/UNESCO soil map of the world. Generalized from the FAO/UNESCO soil map of the world (FA), 1971-1981. Proceedings of the 14th International Congress of Soil Science, July 22-27, 1990, Kyoto, Japan.

Fida, M., H. Daniel, K. Shahzad and H. Khan, 2001. Heritability estimates for yield and its components in wheat. Sarhad J. Agric., 17: 227-234.

Gupta, S.K. and S.R. Verma, 2000. Variability, heritability and genetic advance under rain fed conditions in durum wheat (*Triticum aestivum* Desf.). Indian J. Agric. Res., 34: 122-125.

IPGRI, 1995. Descriptors for avocado (*Persea* spp.). International Plant Genetic Resources Institute, Rome, Italy.

Jedynski, S., 2001. Heritability and path-coefficient analysis of yield components in spring wheat. Proceeding of Symposium on Grupy Problemowej Hoodowli Pszenicy, (SGPHP'01), Zakopane, Poland, pp: 203-209.

Kheiralla, K.Z., I. Baser and O. Bilgin, 1993. Selection response for grain yield and its components in a segregation population of spring wheat. Assist. J. Agric. Sci., 24: 87-93.

Kopp, L.E., 1966. A Taxonomic Revision of the Genus Persea in the Western Hemisphere (Persea: Lauraceae). New York Botanical Garden Press Dept., USA., ISBN-13: 9780893270490, Pages: 117.

Korkut, K.Z., I. Baser and O. Bilgin, 2001. Genotypic and phenotypic variability, heritability and phenotypic correlation for yield and yield components in bread wheat varieties. Acta Agron. Hung., 43: 237-242.

Lima, H., O.L. Rodriguez and H. Acosta, 1982. Enzymatic polymorphism as genetic markers in avocado. I. Peroxidases. Ciencia y Tecnica en la Agricultura, 5: 123-132.

Nakasone, H.Y. and R.E. Paul, 1998. Tropical Fruits. CAB International, Wallingford, UK, Pages: 101.

Nkansah, G.O., P. Okyere, R. Coffie and J.M. Voisard, 2007. Evaluation of four exportable hybrid okra varieties in three different ecological zones of Ghana. Ghana J. Hortic., 6: 25-31.

Ofosu-Budu, K.G., 2003. Performance of citrus rootstocks in the forest zone of Ghana. Ghana J. Hort., 3: 1-9.

Perales, H.R., B.F. Benz and S.B. Brush, 2005. Maize diversity and ethnolinguistic diversity in Chiapas, Mexico. Proc. Natl. Acad. Sci. USA., 102: 949-954.

Popenoe, W., 1927. Manual of Tropical and Sub-Tropical Fruits. The Macmillan Co., New York, USA.

Ramirez, I.M., J.L. Fuentes, N.N. Rodriguez, J. Cueto and W. Rohde, 2002. DNA polymorphisms in Cuban varieties of avocado (*Persea Americana* Mill.) as detected by Inverse Sequence Tagged Repeat (ISTR) analysis. Cultivos Tropicales, 23: 85-88.

Ramirez, I.M., J.L. Fuentes, N.N. Rodriguez, O. Coto, J. Cueto, D. Becker and W. Rhode, 2005. Diversity analysis of Cuban avocado varieties based on agro-morphological traits and DNA polymorphisms (*Persea americana* Mill.). J. Genet. Breed., 59: 241-252.

Rodriguez, N.N., W. Rohde, C. Gonzalez, I.M. Ramirez and J. Sources *et al.*, 2003. Characterization morphological, biochemical and molecular of avocado cultivars (*Persea americana* Mill.) in Cuba. Proceedings of the 5th World Avocado Congress, October 19-24, 2003, Malaga, Spain, pp: 47-53.

Rodriguez, N.N., J.L. Fuentes, O. Coto, V.R. Fuentes and I.M. Ramirez *et al.*, 2007. Comparative study of polymorphism level, discrimination capacity and informativeness of AFLP, ISTR, SSR and isoenzymes markers and agro-morphological traits in avocado. Proceedings of the 6th World Avocado Congress, November 12-16, 2007, Vina Del Mar, Chile, pp: 76.

Sanchez-Romero, C., M.L. Garcia-Gomez, F. Pliego-Alfaro and A. Heredia, 1993. Peroxidase activities and isoenzyme profiles associated with development of avocado (*Persea americana*, M.) leaves at different ontogenetic stages. J. Plant Growth Regul., 12: 95-100.

Scora, R.W. and B.O. Berg, 1992. Origin of and taxonomic relationships within the genus Persea. Proceedings of the 2nd World Avocado Congress, April 21-26, 1991, Orange, CA., USA., pp: 505-514.

Tamam, A.M., S.A.M. Ali and E.A.M. Sayed, 2000. Phenotypic genotypic correlations and path coefficient analysis in some bread wheat crosses. Asian J. Agric. Sci., 31: 73-85.