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Table of Content: Volume 12 Number 4, April 2018

ARTICLES

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Review

Current outlook and future promise of ethnobotany in Nigeria: A review and personal observation

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This paper reviews the current state and future prospects of ethnobotany in Nigeria. A brief historical background is presented. Books and journals indexed by Scopus and Science Direct were reviewed. Direct search was also made on the official websites of journals specializing in ethnobotany and allied disciplines. The field of ethnobotany manifests in all facets of human activities and relates to cultural and sociological relevance of plants. Ethnobotanical data generated from historical, religious, literary, linguistic, and pharmacological viewpoints serve as useful information regarding indigenous food production, traditional agricultural systems, and source for the development of new medicines. Since the vast majority of ethnobotanical studies conducted in Nigeria center on indigenous medicines, collaborative efforts geared toward efficient health service delivery is essential. This must include accreditation or documentation of traditional healers and herbal medicine vendors as well as policies in drug regulation, quality assurance, and control. Ethical guidelines and equitable sharing of benefits gained from sale of active compounds from source locations should be instituted and implemented. Conservation of indigenous plant resources requires the integration of ethnobotanical knowledge into national development programmes. Curriculum development and inclusion of ethnobotany (as a distinct subject) in Nigerian schools will direct future investigations in this promising field.

Key words: Ethnobotany, indigenous medicine, traditional botanical knowledge, Nigeria.

INTRODUCTION

The birth of ethnobotany

In 1895, a seasoned American floristic and taxonomic botanist, John William Harshberger, conceived the term “Ethnobotany”. In a lecture on “food, dress, household utensils and agricultural tools of plant origin” presented in 1896 at the University of Pennsylvania; he made a formal incorporation of this term into the botanical diction and regarded it simply as “the use of plants by the aboriginal peoples”. Prior to this time, Stephen Powers in 1873 (Cotton, 1996) had termed the concept “Aboriginal Botany” to describe the study of all forms of vegetation which aborigines used for commodities such as medicine, food, textiles and ornaments. Since the introduction of the term, the definition of ethnobotany has changed from the later submission of Robbins et al. (1916) down to Martin

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(1995). At present, a working definition by Cotton (1996) which considers ethnobotany to encompass all studies which concern mutual relationships between plants and traditional people is regarded as widely acceptable. These studies include the ways in which a society relates to its environment; the relationships may be social, economic, symbolic, religious, commercial, and artistic (Aumeeruddy-Thomas and Shengii, 2003). Wickens (2000) informed that all usages are founded on ethnobotany.

The dual ideologies in ethnobotany are people and plants. The people are variously referred to as aboriginal, local, indigenous, native or traditional people by several workers in the field. Ethnobotanists and cultural anthropologists have also reviewed the concepts from "man" to "human" to "people" and from "aborigine" to "primitive" to "traditional" (Bennett, 2006). For a detailed historical background of ethnobotany in the Old and New World, the reader is referred to Cotton's "*Ethnobotany Principles and Applications"* (Cotton, 1996).

The scope of ethnobotany

The field of ethnobotany is inherently multi-institutional and several disciplines have contributed to the growth and progress of the subject. Ethnobotany is a subset of ethnobiology (Stepp, 2005) and ethnobotanical studies form the vast majority of research in ethnobiology due to the greater importance of plants than animals in some human societies and their place in food web and nutrient cycle. Before now, ethnobotany combined the interests of botany and ethnology, and is approached from two perspectives, viz. the practical or utilitarian, and the theoretical or philosophical (Bennett, 2006). At the professional level, botanists appreciate the economic benefits of plants; anthropologists are concerned with traditional perceptions and management of plant resources whereas ecologists study the interrelationships between traditional societies and germplasm. Therefore, botany, anthropology, linguistics, education, archaeology, economics and resource management are often included in the study of ethnobotany. These disciplines are inter-connected to explore the field of ethnobotany in the modernization of traditional agricultural systems, industrialization, food security, documentation and preservation of botanical knowledge, conservation of plant resources, and social integration.

There are four major fields of ethnobotany, viz. basic (documentation of traditional botanical knowledge) (Liengme, 1983; Bhat et al., 1990; Cheikhyoussef and Embashu, 2013); quantitative (evaluation of use-values, relative use-values, proportion of agreement, and preference ranking) (Phillips and Gentry, 1993a, b; Assogbadjo et al., 2011; Avocevou-Ayisso et al., 2011); experimental (assessment of benefits, hypothesis testing and prediction) (Soleri and Smith, 1995; Albuquerque, 2006; Alencar et al., 2009); and applied (practical application of ethnobotanical information in areas such as pharmaceutical prospecting and conservation biology) (Gustafson et al., 1992; Cox, 1994). However, six fields of study (botany, anthropology, ecology, ethno-pharmacology, linguistics and economics) are recognized (Martin, 1995; Cotton, 1996).

The importance of ethnobotany

The significance of ethnobotany cannot be over-stated. Theoretically, the discipline informs the link between people and plants, the cultural significance of plants, as well as ecological relations of plants in human societies. The practical implications of these are the understanding of indigenous food production (Omohinmin, 2012), documentation of traditional botanical knowledge (O'Brien, 2010), and the scientific evaluation of plants used in traditional medicine (Gustafson et al., 1992; Cox and Balick, 1994; Schlage et al., 2000). Ethnobotany also provides explanation for biodiversity, cultural diversity, and indigenous bio-resources management practices. The subject make known the cultural position of the tribes who used plants for food, shelter, clothing, construction, tools, and ceremonies (Bussmann, 2006). Studies in ethnobotany bring to the fore the distribution of plants and the transfer of botanical knowledge from generation to generation together with the modes of transfer (Harshberger, 1896). Today, ethnobotanical studies are providing clues to new lines of production as well as the improvement of stale methods of plant product manufacture.

Ethnobotany as an academic discipline

The activities of the "primitive" people of the Old World played major roles in the history of ethnobotany since they concerned themselves with local ecology and non-industrialised utilization of plant resources. The publication of "Purposes of Ethnobotany" by Harshberger (1896) signalled the genesis of ethnobotany as an academic discipline (Thomas, 2003). However, the history of ethnobotany started with European explorers, travellers, and missionaries who observed and documented the uses of plants by the aboriginal peoples (Cotton, 1996). These explorations and meticulous observations led to the discovery of *Nicotiana tabbacum* by Christopher Columbus and *Banisteriopsis caapi* by Richard Spruce between 1492 and 1870 (Simpson and Conner-Ogorzaly, 1986). Other contributions of renowned naturalists and scientists in America and Europe have been elaborately reported by Cotton (1996). Earlier, economic botanists dominated the field. Ethnologists, archaeologists and linguists have also identified with the history and development of the discipline. This identification led to series of scientific meetings, conferences and collaborations on traditional plant knowledge, evolution, and transmission. The meetings resulted in the formation of international societies and the launch of specific journal outlets for the publication of ethnobotanical research works. Prominent among these are *Economic Botany* (first published in 1947 by the American Society for Economic Botany), *Journal of Ethnobiology* (first published in 1981 by American-based Society of Ethnobiology, and more recently *Ethnobotany Research and Applications* (first published in 2003 by the Botanical Research Institute of Texas). Other outlets that publish sundry manuscripts on people and plants, and applied ethnobotany are *Journal of Medicinal Plants Research, Journal of Ethnopharmacology, Ethnobiology and Conservation, Conservation Biology, Biodiversity Conservation, Bulletin of African Ethnobotany Network, American Anthropologist,* and *Social Pharmacology.*

Ethnobotany became fully academic following the first doctoral degree awarded to David Barrows in 1900 by the University of Chicago; this was followed by the establishment of master's programme in ethnobotany by Castetter between 1930 and 1950 at the University of New Mexico with undergraduate studies in ethnobotany and economic botany (Cotton, 1996). Ethnobotany became a research subject and applied science in China in 1960s, as a taught subject in China in 1987 (Hamilton et al., 2003), an academic programme in the Kumming Institute of Botany, Chinese Academic of Science in 1987, an academic discipline in Thailand in 1990 (Trisonthi and Trisonthi, 2002), an academic institution in China in 1996, and as an academic programme in the UK in 1996 (Hamilton et al., 2003). As at 1996, there were no reports of African institutions offering courses and/or programmes in Ethnobotany and Economic Botany (McClatchey et al., 1999).

Apart from its academic value, many scientists have now recognised the practical value of ethnobotanical data. This has led to a relatively new field known as "applied ethnobotany", which refers to the practical application of ethnobotanical data in such areas such as bio-prospecting and conservation (Cotton, 1996), or simply as ethnobotany applied to conservation and sustainable development (Hamilton et al., 2003).

Much of the early ethnobotanical investigations carried out in the New World were casual observation and free-listing of useful plants. Hence, the field was regarded as non-scientific in scope. Phillips and Gentry (1993a, b) suggested the application of quantitative techniques in the analysis of contemporary plant-use data. This was illustrated in the publication of Soleri and Smith (1995) since studies of multivariate nature are common in ethnobotanical research (Hoft et al., 1999). The employment of quantitative methods in ethnobotanical data collection, processing, and interpretation has improved the indicative value of ethnobotanical studies (Hoft et al., 1999).

This paper aimed to provide an extensive review of ethnobotany in Nigeria. However, it is non-exhaustive of all materials on the subject matter. The objectives of this paper were to: (1) Prepare a review on the current state of ethnobotany as an academic discipline in Nigeria; (2) Highlight the future promise of ethnobotany in Nigeria, and (3) Relate the socio-cultural significance of ethnobotanical studies in Nigeria with biodiversity conservation.

METHODS

Books and journals indexed by Scopus and Science Direct databases were reviewed. Direct search was also made on the official websites of journals specializing in Ethnobotany (*Ethnobotany Research and Applications, Economic Botany, Journal of Ethnobiology and Ethnomedicine*) and allied outlets (*Journal of Ethnopharmacology, Ethnobiology and Conservation, Conservation Biology, Biodiversity Conservation, Journal of Medicinal Plants Research, Bulletin of African Ethnobotany Network, American Anthropologist,* and *Social Pharmacology*). Only papers relating to ethnobotany were considered. Personal interviews of local participants at the 24th Annual Conference of the Botanical Society of Nigeria (BOSON, 2016) held at the Department of Botany, University of Ibadan, Nigeria were also conducted. Information on participants' level (student, lecturer, field researcher etc.), research interests, and undergraduate or graduate programmes focusing on ethnobotany and/or economic botany, and level of programme (academic subject, module within a course or postgraduate course) were solicited.

RESULTS

Ethnobotany as an academic subject in Nigeria

Hitherto, there is no Faculty or Department of Ethnobotany in any Nigerian universities. The subject was incorporated following individual interest (by professors of international exposure) in the field. The first introduction was as a result of the implementation of curriculum review. In some institutions (e.g. University of Ibadan, Ibadan and University of Lagos, Akoka), ethnobotany is regarded as an academic subject and administered up to PhD level while professional programmes in Economic Botany are floated as Master of Economic Botany (MEB). In other institutions Ethnobotany and Economic Botany are offered as courses or modules within an undergraduate programme in Botany or Biological Sciences (e.g. Federal University of Agriculture Abeokuta; Ondo State, University of Science and Technology, Okitipupa, and University of Nigeria, Nsukka) or as postgraduate diploma programme in Ethnobotany and Phytomedicine (e.g. University of Port Harcourt). In some other institutions, students are required to take courses such as Forest Resources and Utilization, Forest Taxonomy etc. These “outside” courses present parts of ethnobotany as ethnomedicine, non-timber forest products, and conservation of plant resources. It is believed that with the present campaign for the inclusion of traditional medicine in the curriculum of medical sciences in Nigeria and the official integration of traditional medicine into Western medicine, ethnobotany will regain its natural glory.

Ethnobotanical studies in Nigeria

Ethnobotanical studies in Nigeria were initially carried out generally on the uses of plants by different ethnic groups (Bhat et al., 1990; Fasola and Egunyomi, 2005; Aiyeloja and Bello, 2006; Erinoso and Aworinde, 2012; Ariwaodo et al., 2012). Later specific research works, classified as ethnomedicine, ranging from plants used in the management of arthritis (Gbadamosi and Oloyede, 2014), sickle cell anaemia (Egunyomi et al., 2009; Gbadamosi et al., 2012), sexually transmitted infections (Gbadamosi and Egunyomi, 2014), breast cancer (Gbadamosi and Erinoso, 2016), infant illnesses (Aworinde and Erinoso, 2015), to skin infections (Ajibesin, 2012; Gbadamosi and Oyedele, 2012; Erinoso et al., 2016) etc. were conducted and reported. Lately, there has been a shift in emphasis from free-listing and systematic botany to a nexus between ethnomedicine and phytochemistry (Gbadamosi et al., 2011; Fasola et al., 2013; Gbadamosi and Oloyede, 2014; Aworinde et al., 2016; Gbadamosi and Aboaba, 2016).

Although most Nigerian supervisors and students share common interest in ethnobotany research and application, majority of the project areas are basic and involve either documentation of traditional botanical knowledge (market surveys and oral interview of herb sellers, farmers/hunters, and traditional doctors) or phytochemical analyses of plants implicated in such surveys. Little or no attention is given to quantitative ethnobotany or test of hypothesis. However, laboratory experiments to confirm ethnomedicinal claims are common (Egunyomi et al., 2010; Gbadamosi and Oyedele, 2012; Gbadamosi and Ogunsuyi, 2014; Aworinde et al., 2016).

A large percentage of the plants implicated in ethnomedicinal studies in Nigeria have not been scientifically validated up to the pre- or clinical stages. Although at the institutional level, active research to evaluate ethnomedicinal claims is being carried out within the available laboratory resources of the Drug Research and Production Unit of the Faculty of Pharmacy, Obafemi Awolowo University, Ile-Ife, Nigeria, and Department of Medicinal Plant Research and Traditional Medicine, National Institute for Pharmaceutical Research and Development, Abuja, Nigeria. Many pharmaceutical companies in Nigeria have showed little or no interest in the funding of ethnobotanical researches in spite of the fact that ethnobotanical studies are valuable sources of new data on plants especially drug plants. McClatchey (2005) noted that in the last 30 years, not one new traditional plant use has been reported and subsequently converted into a pharmaceutical. This may be as a result of some respondents (who hold traditional botanical information) reluctantly disclosing or declining to share information relating to plant use (Sofowora, 2008) and as such no modern inductees into global pharmacopoeia. Cotton (1996) submitted that the collection of useful ethnobotanical data requires some preliminary understanding of the knowledge system in terms of acquisition and subsequent transfer to successive generations.

One of the authors of this paper personally noted a lack of respect for the discipline during his postgraduate studies. At departmental seminars, students and lecturers often referred ethnobotanists as “traditional doctors” or “herbal practitioners” and argued that the subject lacked scientific reputation. As expected, the field attracted little or no funding. However, proposals advertising pharmacognosy/medical botany are funded.

DISCUSSION

Current state of ethnobotanical studies in Nigeria

In Nigeria, traditional medicine is filling the gap of inequalities in access to healthcare and health outcomes (Kadiri et al., 2010). Unlike other science disciples, ethnobotanical research projects in Nigeria have received little or no funding. Individual researchers have carried out ethnobotanical studies with personal earnings. Although most Nigerian institutions have provisions for research and publication allowances, the implementation is subject to availability of funds. It is noteworthy that collaborative efforts geared toward efficient health service delivery is essential to universal health coverage.

The primary focus of most ethnobotanical works in Nigeria has been the cataloguing of useful plants which, more often than not, fall in the domain of medicinal and food plants. Other areas such as plants used as cosmetics, dyes, musical instruments, basketry and household utensils, are rarely recorded. Hitherto, published work on Nigerian ritual plants is non-existent. Available reports are those of Mushroom in Yoruba myths and beliefs with particular attention to their origin and medicinal uses (Oso, 1975, 1977). Also, published information on the ethnobotany of specific tribes or plant species in Nigeria is scarce, as occurs in reports for tribal communities (Smith, 1923; Bussmann, 2006), individual plant species (Houssou et al., 2012; Dafni et al., 2005), plant family (Chhetri, 2010), and socio-cultural significance (Dafni et al., 2006; Dafni, 2007).

The knowledge of plants and their uses has continued to spread in like pace with the plants themselves. The cultural relevance of plants has deep roots in tribal customs and beliefs. Nigeria as a nation is not an exception. Indigenous societies/peoples hold strategic positions in botanical knowledge acquisition, transfer, and development. Indigenous plant knowledge is now considered as a part of national heritage especially with respect to cultural diversity and integration. This traditional botanical knowledge (TBK) has encouraged acculturation and cultural perceptions are incorporated into Western ideas to form an integrated knowledge system (IKS). The integration of TBK and Western Knowledge offers enhanced approach in the management of diseases/ ailments, improvement in healthcare services and delivery, sustainable agricultural systems and better nutrition. This synergy has resulted in a unique synthesis of medical belief and practice, along with the development and processing of innovative and effective drugs.

After a period of relegation of plant significance, causes of which include industrialization, urbanization, and western influence, the usefulness of plants are now gaining new interest, and as such newspaper columnists and television anchors are promoting public awareness on plant-human relations especially in the area of ethnomedicine (e.g. natural healthcare column in Nigerian national dailies: Punch, Guardian, Nigerian Tribune etc.: Nigerian Tribune, Thursday, 28 February, 2013, and other Thursday editions).

The contribution of herbalism to primary health care in Nigeria has been appraised by Kadiri et al. (2010). In Nigeria, the role of traditional medical practitioners, herbalists, herb sellers, traditional orthopaedic specialists, and birth attendants/midwives has made herbal medicine practice worthwhile and commendable. The bulk of ethnobotanical information is held by older people. Thus, in most traditional societies, young fellows acquire TBK and many practical skills as they work alongside parents or older siblings or during apprenticeship programme.

Graduates of botany (especially those having interest in ethnobotany) are myopic as regards occupational prospects of this promising field. McClatchey et al. (1999) informed that pharmaceutical companies, herbal medicine and food industries, state and federal ministries of agriculture, and land management firms employ ethnobotanists. There are also opportunities in conservation organizations, schools and colleges, or field research stations.

Early reports of ethnobotanical researches conducted in other West African countries (Benin, Burkina Faso, Ghana, Togo etc.) followed the same qualitative trend of uses of plants for food, medicine, fuel etc. Later, works on quantitative ethnobotany were reported. In the Republic of Benin, for example, quantitative indices such as use values, use frequency of plant properties, credibility level, use equitability, interviewee diversity value, specific reported use, intra-specific use value etc. have been explored by Fadohan et al. (2010), Assogbadjo et al. (2011), Avocevou-Ayisso et al. (2011) and Koura et al. (2011) on the ethnic differences and use patterns of some plants in Benin. Also, Laleye et al. (2015) investigated and reported plants used in the traditional treatment of diabetes. The authors applied a generalized linear model with a Poisson distribution to assess the effects of social factors on informants' knowledge. Other research papers combining some aspects of ethnobotany and biodiversity conservation have been published by Lokonon et al. (2013), Agoyi et al. (2014), and Salako et al. (2014). A national-scale analysis of plants used in traditional medicine in Burkina Faso (Zizka et al., 2015) showed that indices such as relative importance, relative frequency of citation and use categories lend credence to ethnobotanical studies and could help identify conservation priorities as well as facilitate future research in drug prospection. Asase et al. (2005) combined the fields of ethnobotany and ecology in the study of some Ghanaian antimalarial plants. The authors investigated the range and abundance of the plant species identified during the ethnobotanical survey, and analyzed the data for taxonomic diversity, growth forms, preference etc. In the central region of Togo, Karou et al. (2011) interviewed some traditional healers who were members of a "Study and Research in Applied Medicine Centre". The authors documented indigenous plants used in the management of diabetes and hypertension, and emphasized the sustainable use of plant resources. In contrast, assessment of quantitative parameters in ethnobotanical studies in Nigeria is scarce.

Future promise of ethnobotany and its application in Nigeria

Individual responsibilities

Ethnobotanical data can be generated from historical, religious, literary, linguistic, and pharmacological viewpoints (Pirani et al., 2011). These data serve as useful information regarding indigenous food production, traditional agricultural systems, and source for the development of new medicines. The people of a particular region or locality represent major stakeholders in the health services of a nation. Researchers therefore should allow the spirit of "give and take" which is the hallmark of ethnobiological studies (Bridges, 2004). This could be in the form of community-support assistance (Bridges, 2004) or equitable sharing (with host communities) of the benefits from pharmacological development (Cox, 2001) as well as the protection of the intellectual property rights of the informants.

Liengme (1983) in his review of ethnobotanical research conducted in southern Africa listed uses of plants under food, medicine, magic, ritual and customs, building, household utensils, musical instruments, and firewood. Although the author's paper captured published and unpublished manuscripts, museum and herbarium materials, the review stated the ethnobotanical researches and knowledge in South Africa as carried out by missionaries, botanists, medical experts and cultural anthropologists. Also, the publication of Kose et al. (2015) on the medicinal plants used in the Maseru district of Lesotho, South Africa further emphasized the need to document traditional medicinal practices since ethnobotanical knowledge in majority of human societies is passed on orally from one generation to another. Active documentation reveals gaps in knowledge and new records of medicinal plant use.

Government responsibilities

In Ghana, Mali, Zambia, and Nigeria, 60% of children suffering from malaria/fever receive their first line of treatment from herbal medicine (Abdullahi, 2011). Accreditation or documentation of traditional healers and herbal medicine vendors as well as policies to regulate herbal practice should be the primary concern of the government. Although there is distrust between traditional and modern doctors (Abdullahi, 2011), public awareness (televisions, newspapers, magazines etc.) aimed at botanical literacy and biological diversity should be encouraged by the government. Governments (at state and federal levels) need to encourage herbal medicine apprenticeship (through entrepreneurship and traditional medicine fair programme) as well as the establishment of traditional medicine department in all primary health care centres. Herbal drug regulation, quality assurance and control fall in the domain of government responsibility.

Institutional roles

Institutions and research centres have roles to play in botanical training, plant collection, identification, and screening of plants for possible bio-activity. Because of the inter-disciplinary nature of ethnobotany, knowledge of the environment and cultural significance of plants is considered essential. For many years, aboriginal peoples have used knowledge of their local environment to sustain themselves and to maintain their cultural identity. These natives are better understood when there is no language barrier. Institutes of languages, therefore, can play effective roles in linguistics training as well as professional services of interpretation especially when the researcher is not familiar with the local language of the people. Ethnobotanical inventories to document economically important plants as well as field and laboratory studies to confirm ethnobotanical claims should be conducted. "Traditional Medicine" or "Medicinal Plants" should be taught as part of curriculum of medical schools. Ethical guidelines and equitable sharing of benefits earned from the commercialization of bioactive compounds from source locations should be instituted and implemented.

Socio-cultural consideration and biodiversity conservation

Ethnobotanical studies help in cultural identification and preservation of botanical knowledge. The idea that plants are natural gifts and abundant, and so cannot be exhausted should be relegated. The enforcement of sustainable use of plant resources and the establishment of conservation centres are social interventions required of the government. Idu (2009) informed that the benefits derivable from bio-resources should be considered in the light of environmental concerns and biodiversity conservation; the author further submitted that quantitative evidence, precision and statistical analysis of ethnobotanical data should form the core values of modern ethnobotanical research. Conservation of indigenous plant resources requires the integration of ethnobotanical knowledge into developmental programmes and policies of any nation (Avocevou-Ayisso et al., 2011). Although differences abound in local knowledge, use, and conservation of plant resources among different cultures (Hilgert and Gil, 2006), the socio-economic relevance of these resources may enhance our understanding of the management practices and conservation efforts at local and regional level (Dalle and Potvin, 2004).

CONCLUSION AND RECOMMENDATIONS

This review has highlighted the current status and the future promise of ethnobotany in Nigeria. The field of ethnobotany manifests in all facets of human activities and relates to cultural and sociological relevance of plants. Governments need to encourage herbal medicine apprenticeship, establish traditional medicine department in all primary health care centres as well as herbal drug regulation, quality assurance and control. Researchers should support host communities with benefits gained from the commercialization of pharmaceuticals. The sustainable use of plant resources will ensure continued access. Curriculum development and inclusion of Ethnobotany (as a distinct subject) in Nigerian schools will direct future investigations in this promising field. "Traditional Medicine" or "Medicinal Plants" should be taught as part of curriculum of medical and other related sciences.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abdullahi AA (2011). Trends and challenges of traditional medicine in Africa. Afr. J. Tradit. Complement. Altern. Med. 8(S):115-123.

Agoyi EE, Assogbadjo AE, Gouwakinnou G, Okou FAY, Sinsin B (2014). Ethnobotanical assessment of *Moringa oleifera* Lam. in Southern Benin (West Africa). Ethnobot. Res. Appl. 12:551-560.

Aiyeloja AA, Bello OA (2006). Ethnobotanical potentials of common herbs in Nigeria: A case study of Enugu state. Educ. Res. Rev. 1(1):16-22.

Ajibesin KK (2012). Ethnobotanical survey of plants used for skin diseases and related ailments in Akwa Ibom State, Nigeria. Ethnobot. Res. Appl. 10:463-522.

Albuquerque UP (2006). Re-examining hypotheses concerning the use and knowledge of medicinal plants: a study in the *Caatinga* vegetation of NE Brazil. J. Ethnobiol. Ethnomed. 2:30-39.

Alencar NL, Araujo TA, Amorim ELC, Albuquerque UP (2009). Can the Apparency Hypothesis explain the selection of medicinal plants in an area of *Caatinga* vegetation? A chemical perspective. Sci. Note 1:910-911.

Ariwaodo JO, Chukwuma EC, Adeniji KA (2012). Some medicinal plant species of Asamagbe stream bank vegetation, Forestry Research Institute of Nigeria, Ibadan. Ethnobot. Res. Appl. 10:541-549.

Asase A, Oteng-Yeboah AA, Odamtten GT, Simmonds MSJ (2005). Ethnobotanical study of some Ghanaian antimalarial plants. J. Ethnophamacol. 99:273-279.

Assogbadjo AE, Kakai RG, Adjallala FH, Azihou AF, Vodouhe GF, Kyndt T, Codija JTC (2011). Ethnic differences in use value and use patterns of the threatened multipurpose scrambling shrub (*Caesalpinia bonduc* L.) in Benin. J. Med. Plants Res. 5(9):1549-1557.

Aumeeruddy-Thomas Y, Shengji P (2003). Applied Ethnobotany: case studies from the Himalayan region. People and Plants Working Paper 12, People and Plants Initiative, WWF, Godalming, UK. 38p.

Avocevou-Ayisso C, Avohou TH, Oumorou M, Dossou G, Sinsin B (2011). Ethnobotany of *Pentadesma butyracea* in Benin: A quantitative approach. Ethnobot. Res. Appl. 9:151-166.

Aworinde DO, Erinoso SM (2015). Ethnobotanical investigation of indigenous plants used in the management of some infant illnesses in Ibadan, Southwestern Nigeria. Afr. J. Tradit. Complement. Altern. Med. 12(1):9-16.

Aworinde DO, Erinoso SM, IbukunOluwa MR (2016). Mineral compositions, phytochemical constituents and *in vitro* antimicrobial screening of some chewing sticks from Ibadan, South-western Nigeria. J. Appl. Biol. 101:9589-9597.

Bennett BC (2005). Ethnobotany Education, Opportunities, and Needs in the U.S. Ethnobot. Res. Appl. 3:113-121.

Bhat RB, Etejere EO, Oladipo VT (1990). Ethnobotanical studies from central Nigeria. Econ. Bot. 44(3):382-390.

Bridges KW (2004). Editorial: Give and Take. Ethnobot. Res. Appl. 2:75.

Bussmann RW (2006). Ethnobotany of the Samburu of Mt. Nyiru, South Turkana, Kenya. J. Ethnobiol. Ethnomed. 2:35-44.

Cheikhyoussef A, Embashu W (2013). Ethnobotanical knowledge on indigenous fruit in Ohangwena and Oshikoto regions in Northern Namibia. J. Ethnobiol. Ethnomed. 9:34-45.

Chhetri RB (2010). Ethnobotany of Moraceae in Meghalaya North-East India. Kathmandu Univ. J. Sci. Eng. Technol. 6(1):5-10.

Cotton CM (1996). Ethnobotany Principles and Applications. John Wiley and Sons, New York, USA. 424p.

Cox PA (1994). The ethnobotanical approach to drug discovery: strengths and limitations. In. Chadwick DJ, Marsh J (editors). Ethnobotany and the search for new drugs. John Wiley and Sons, West Sussex. Pp. 25-41.

Cox PA (2001). Ensuring equitable benefits: the Falealupo covenant and the isolation of anti-viral drug prostratin from a Samoan medicinal plant. Pharm. Biol. 39:33-40.

Cox PA, Balick MJ (1994). The ethnobotanical approach to drug discovery. Sci. Am. 270(6):82-87.

Dafni A (2007). Rituals, ceremonies and customs related to sacred trees with a special reference to the Middle East. J. Ethnobiol. Ethnomed. 3:28-42.

Dafni A, Lev E, Beckmann S, Eichberger C (2006). Ritual plants of Muslim graveyards in Northern Isreal. J. Ethnobiol. Ethnomed. 2:38-49.

Dafni A, Levy S, Lev E (2005). The ethnobotany of Christ's Thorn jujube (*Ziziphus spina-christi*) in Isreal. J. Ethnobiol. Ethnomed. 1:8-18.

Dalle SP, Potvin C (2004). Conservation of useful plants: An evaluation of local priorities from two indigenous communities in Eastern Panama. Econ. Bot. 58(1):38-57.

Egunyomi A, Gbadamosi IT, Osiname KO (2010). Comparative effectiveness of ethnobotanical mosquito repellents used in Ibadan, Nigeria. J. Appl. Biosci. 36:2383-2388.

Egunyomi A, Moody JO, Eletu OM (2009). Antisickling activities of two ethnomedicinal plant recipes used for the management of sickle cell anaemia in Ibadan, Nigeria. Afr. J. Biotechnol. 8(1):20-25.

Erinoso SM, Aworinde DO (2012). Ethnobotanical survey of some medicinal plants used in traditional health care in Abeokuta areas of Ogun State, Nigeria. Afr. J. Pharm. Pharmacol. 6(18):1352-1362.

Erinoso SM, Fawibe OO, Oyelakin, AS, Ajiboye AA, Agboola DA (2016). Herbal recipes used for the traditional management of infantile dermatitis in Odeda, Southwestern Nigeria. Afr. J. Tradit. Complement. Altern. Med. 13(3):33-43.

Fadohan B, Assogbadjo AE, Kakai RG, Kyndi T, Caluwe ED, Codija JTC, Sinsin B (2010). Women's traditional knowledge, use value, and the contribution of tamarind (*Tamarindus indica* L.) to rural households' cash income in Benin. Econ. Bot. 64(3):248-259.

Fasola TR, Akinloye AJ, Tossou MG, Akoegninou A (2013). The phytochemical and structural make-up of regrown and original tree barks used in ethnomedicine. World J. Agric. Sci. 9(1):92-98.

Fasola TR, Egunyomi A (2005). Nigerian usage of bark in phytomedicine. Ethnobot. Res. Appl. 3:73-77.

Gbadamosi IT, Aboaba SA (2016). Essential oil constituents and *in vitro* antimicrobial activity of the root of *Mondia whitei* (Hook. F.) Skeels (Periplocaceae). J. Pharmacogn. Phytother. 8(8):163-167.

Gbadamosi IT, Adeyemi SB, Adeyemi AA, Moody JO (2012). In vitro anti-sickling activities of two indigenous plant recipes in Ibadan, Nigeria. Intl. J. Phytomed. 4:205-211.

Gbadamosi IT, Egunyomi A (2014). Ethnobotanical survey of plants used for the treatment and management of sexually transmitted infections in Ibadan, Nigeria. Ethnobot. Res. Appl. 12:659-669.

Gbadamosi IT, Erinoso SM (2016). A review of twenty ethnobotanicals used in the management of breast cancer in Abeokuta, Ogun State, Nigeria. Afr. J. Pharm. Pharmacol. 10(27):546-564.

Gbadamosi IT, Moody JO, Lawal AM (2011). Phytochemical screening and proximate analysis of eight ethnobotanicals used as antimalarial remedies in Ibadan, Nigeria. J. Appl. Biosci. 44:2967-2971.

Gbadamosi IT, Ogunsuyi AO (2014). An appraisal of the potency of roots of *Anogeissus leiocarpus* (DC.) Guill. & Perr. and *Terminalia glaucescens* Benth. in the management of E. coli related infections. J. Appl. Biosci. 78:6646-6653.

Gbadamosi IT, Oloyede AA (2014). The mineral, proximate and phytochemical components of ten Nigerian medicinal plants used in the management of arthritis. Afr. J. Pharm. Pharmacol. 8(23):638-643.

Gbadamosi IT, Oyedele TO (2012). The efficacy of seven ethnobotanicals in the treatment of skin infections in Ibadan, Nigeria. Afr. J. Biotechnol. 11(6):3928-3934.

Gustafson KR, Cardellina JH, McMahon JB, Gulakowski RJ, Ishitoya J, Swallasi Z, Lewin NE, Blumberg PM, Weislow OS, Beutler JA, Buckheit RW, Cragg GM, Cox PA, Bader JP, Boyd MR (1992). A non-promoting phorbol from the Samoan medicinal plant *Homalanthus nutans* inhibits cell killing by HIV-1. J. Med. Chem. 35:1978-1986.

Hamilton AC, Shengji P, Kessy J, Khan AA, Lagos-White S, Shinwari ZK (2003). The purposes of teaching of Applied Ethnobotany. People and Plants Working Paper 11, People and Plants Initiative, WWF, Godalming, UK. 71p.

Harshberger JW (1896). The purposes of ethnobotany. Bot. Gaz. 21(3):146-154.

Hilgert NI, Gil GE (2006). Medicinal plants of the Argentine Yungas plants of the Las Yungas biosphere reserve, Northwest of Argentina used in health care. Biodiver. Conserv. 15:2565-2594.

Hoft M, Barik SK, Lykke AM (1999). Quantitative Ethnobotany: Applications of multivariate and statistical analyses in ethnobotany.

People and Plants Working Paper 6, People and Plants Initiative, UNESCO, Paris. 45 p.
Houssou LG, Lougbegnon TO, Gbesso FGH, Anagonou LES, Sinsin B (2012). Ethno-botanical study of the African star apple (*Chysophyllum albidum* G. Don) in the Southern Benin (West Africa). J. Ethnobiol. Ethnomed. 8:40-49.
Idu M (2009). Current Trends in Ethnobotany (Editorial). Trop. J. Pharm. Res. 8(4):295-296.
Kadiri AB, Adekunle AA, Ayodele AE (2010). An appraisal of the contributions of herbalism to primary health care delivery in Southwest Nigeria. Ethnobot. Leafl. 14:435-444.
Karou SD, Tchacondo T, Agassounon M, Tchibozo D, Abdoul-Rahaman S, Anani K, Koudouvo K, Batawila K, Agbonon A, Simpore J, de Souza C (2011). Ethnobotanical study of medicinal plants used in the management of diabetes mellitus and hypertension in the Central Region of Togo. Pharm. Biol. 49(12):1286-1297.
Kose LS, Moteetee A, Vuuren SV (2015). Ethnobotanical survey of medicinal plants used in the Maseru district of Lesotho. J. Ethnopharmacol. 170:184-200.
Koura K, Ganglo JC, Assogbadjo AE, Agbangla C (2011). Ethnic differences in use values and use patterns of *Parkia biglobosa* in Northern Benin. J. Ethnobiol. Ethnomed. 7(42):1-12.
Laleye FOA, Mensah S, Assogbadjo AE, Ahissou H (2015). Diversity, knowledge, and use of plants in traditional treatment of diabetes inthe Republic of Benin. Ethnobot. Res. Appl. 14:231-257.
Liengme CA (1983). A survey of ethnobotanical research in southern Africa. Bothalia 14 (3-4):621-629.
Lokonon BE, Bonou WN, Kassa B, Azihou AF, Assogbadjo AE, Glelekakai R (2013). Structural and ethnobotanical characterization of velvet tamarind (*Dialium guineense* WILLD): a multipurpose tree species. Agronomie Africaine 25(2):121-131.
Martin GJ (1995). Ethnobotany: A "People and Plants" Conservation Manual. Chapman and Hall, London. 268p.
McClatchey W (2005). Medicinal Bio-prospecting and Ethnobotany Research. Ethnobot. Res. Appl. 3:189-190.
McClatchey WC, Paul WA, Flaster T, McClatchey V (1999). An evaluation of educational trends in economic botany. Centre for International Ethnomedicinal Education and Research, Ethnobotany Educational Publication Series. 1:1-21.
O'Brien CM (2010). Do they really "know nothing"? An inquiry into ethnobotanical knowledge of students in Arizona, USA. Ethnobot. Res. Appl. 8:35-47.
Omohinmin AC (2012). Ethnobotany of *Dacryodes edulis* (G.Don) H.J. Lam in Southern Nigeria 1: Practices and applications among the Yoruba speaking people. Ethnobot. Res. Appl. 10:175-184.
Oso BA (1975). Mushrooms and the Yoruba people of Nigeria. Mycologia 67:311-319.
Oso BA (1977). Mushrooms in Yoruba mythology and medicinal practices. Econ. Bot. 31:367-371.
Phillips O, Gentry AH (1993a). The useful plants of Tambopata, Peru I: Statistical hypotheses tests with a new quantitative technique. Econ. Bot. 47:15-32.
Phillips O, Gentry AH (1993b). The useful plants of Tambopata, Peru II: Additional hypothesis testing in quantitative ethnobotany. Econ. Bot. 47:33-43.
Pirani A, Moazzeni H, Mirinejad S, Naghibi F, Mosaddegh M (2011). Ethnobotany of *Juniperus excels* M. Bieb. (Cupressaceae) in Iran. Ethnobot. Res. Appl. 9:335-341.
Robbins WW, John PH, Barbara FM (1916). Ethnobotany of the Tewa Indians. Bureau of American Ethnology Bulletin. Smithsonian Institution, Washington, DC. 55:1-2.
Salako VK, Fandohan B, Kassa B, Assogbadjo AE, Idohou ME, Gbedomon RC, Chakeredza S, Dulloo ME, Kakai RG (2014). Home gardens: an assessment of their biodiversity and potential contribution to conservation of threatened species and crop wild relatives in benin. Genet. Resour. Crop Evol. 61:313-330.
Schlage C, Mabula C, Mahunnah RLA, Heinrich M (2000). Medicinal plants of the Washambaa (Tanzania): Documentation and ethnopharmacological evaluation. Plant Biol. 2:83-92.
Simpson BB, Conner-Ogorzaly MC (1986). Economic Botany. McGraw Hill, London.
Smith HH (1923). Ethnobotany of Menomini Indians. Bulletin of the Public Museum of the City of Milwaukee. 4(1):1-174
Sofowora A (2008). Medicinal plants and traditional medicine in Africa (3rd edition). Spectrum Books Limited, Ibadan, Nigeria. 436 p.
Soleri D, Smith SE (1995). Morphological and phonological comparisons of two Hopi maize varieties conserved *in situ* and *ex situ*. Econ. Bot. 49:56-77.
Stepp JR (2005). Advances in Ethnobiological Field Methods. Field Methods 17(3):211-218.
Thomas MB (2003). Emerging synergies between information technology and applied research. Ethnobot. Res. Appl. 1:65-73.
Trisonthi C, Trisonthi P (2002). Ethnobotanical studies of the Karen and implications for the teaching of ethnobotany in Thailand. In. unpublished contribution at the 6th congress of the International Society of Ethnobiology, 20th September, 2002, Addis Ababa, Ethiopia.
Wickens GE (2000). Defining Economic Botany and Ethnobotany. Econ. Bot. 54(3):251-253.
Zizka A, Thiombiano A, Dressler S, Nacoulma BMI, Ouedraogo A, Ouedraogo I, Ouedraogo O, Zizka G, Hahn K, Schmidt M (2015). Traditional plant use in Burkina Faso (West Africa): a national-scale analysis with focus on traditional medicine. J. Ethnobiol. Ethnomed. 11:9-18.

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Comparative study on the effect of bio-slurry and inorganic N-fertilizer on growth and yield of kale (*Brassica oleracea* L.)

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Kale is one of the nutritious leafy vegetables with a high nitrogen fertilizer requirement. However, soil fertility is declining progressively due to the imbalanced use of inorganic fertilizer. Discharging bio-slurry as waste will lead to environmental pollution and disposing will also lead to costs because of its large volume. Consequently, replacing chemical fertilizers with bio-slurry can not only achieve efficient resource utilization and disposal cost, but also reduce the amount of chemical fertilizer used and environmental pollution attributed by chemical fertilizers. Therefore, a pot experiment was conducted in a mesh house at Hawassa College of Agriculture to evaluate the combined effect of bio-slurry and inorganic nitrogen fertilizer for growth and yield performance of kale. Five combinations of liquid bio-slurry and inorganic nitrogen fertilizer were used, that is, 25% bio-slurry + 75% nitrogen, 50% bio-slurry + 50% nitrogen, 75% bio-slurry + 25% nitrogen, 100% bio-slurry, 100% nitrogen and 0 use of either fertilizer source as a control. Data on phenology, growth and yield attributes were recorded. Results revealed that the treatment had significant effect on growth and yield attributes of kale. The highest (455.10 g) leaf fresh weight and fresh biomass (814.86 g) was obtained when 100% sole application of liquid bio-slurry was used. Based on these results, it can be concluded that application of 100% bio-slurry can improve the production of kale in the study area.

Key words: Bio-slurry, chemical fertilizers, growth, yield attributes, kale, nitrogen.

INTRODUCTION

Green leafy vegetables occupy an important place among the food crops as they provide adequate amounts of many vitamins and minerals for humans (Fasuyi, 2006; Chinma and Igyor, 2007). Kale (*Brassica oleracea* L.) is one of the highly nutritious green leafy vegetables which belong to the Brassicaceae family, along with Cabbage, Collards and Brussels sprouts (Fadigas et al., 2010).

Kale is a heavy feeder of nitrogen and therefore, good nitrogen source is a paramount importance to optimize its economic yield (Onyango et al., 2012). However, soil fertility is declining progressively due to the imbalance use of inorganic fertilizer and loss of nutrient from the

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soil. Moreover, in the tropical countries including Ethiopia, high cost, scarcity, nutrient imbalance in the soil and soil acidity are problems associated with the use of inorganic fertilizer while bulkiness, low nutrient quality and late mineralization are the bottleneck to the sole use of organic manures for crop production (Uyovbisere et al., 2000). Moreover, alternative soil nutrients sources are expensive for small-scale farmers and the poor timing and awareness of application for improved productivity of kale (Onwonga et al., 2013).

Organic materials are important soil amendments that sustain the productivity of soils in tropical and subtropical regions where there is low soil organic carbon content and low input of organic materials (Huang et al., 2010).

Therefore, there is an urgent need to identify and investigate a cheap, easily available, environmentally friendly source of fertilizers to enhance balanced supply of crop nutrition, sustainable nutrient availability, treat soil acidity and thereby maximize the yield of leafy vegetables. In this regard, bio-slurry can play a vital role in combination with chemical fertilizer and it seems that there is a general consensus on the ability of bio-slurry to improve the physical and biological quality of soil besides providing macro and micro-nutrients for vegetables. At the same time it prevents adverse environmental impacts of urban wastes and reduces the dependence on chemical fertilizers (Karki, 1997).

In Ethiopia, evidence is lacking on the combined effects of bio-slurry and inorganic nitrogen fertilizers on growth and yield of kale. Therefore, the present study was designed to find out the optimum combination of bio-slurry and inorganic nitrogen for better growth and yield performance of kale.

MATERIALS AND METHODS

A pot experiment was conducted under mesh house conditions in 2017 at the experimental site of Hawassa College of Agriculture. The site is located at 273 km from the capital Addis Ababa. It is found at an altitude of 1669 masl and 7°4' N latitude with 38°31' E longitude. The annual rainfall ranges from 900 to 1100 mm and mean annual temperature is 19.5°C. Experimental soil at a depth of 0 to 30 cm was collected from the teaching and research farm of Hawassa University. A 3 kg of sieved (2 mm sieve) soil was filled in the bucket perforated at the bottom to allow air and water movement. The pots were placed on saucers to avoid treatment contamination and leaching and also the leached water on saucers were reapplied on the experimental pots accordingly. Local cultivar of kale seed and liquid bio-slurry were collected from Ziway market and Hawassa town, respectively. Treatment wise liquid bio-slurry was incorporated on the prepared soil containing experimental pot a week before sowing and split application was carried out for the inorganic N (at the time of thinning and 1 month after emergency).

Treatment having five recommended combinations of bio-slurry and inorganic N fertilizer with control treatment were used. The treatments were adjusted based on the N recommendation (100 kg/ha N) for brassica species. The details are presented as follows: T_1 - Control (where no urea/Bio-slurry applied); T_2 - 25% N by Bio-slurry + 75% N by recommended dose of inorganic fertilizer; T_3 - 50% N by Bio-slurry + 50% N by recommended dose of inorganic fertilizer; T_4- 75% N by Bio-slurry + 25% N by recommended dose of inorganic fertilizer; T_5 - 100% N by Bio-slurry; and T_6 - 100% N by recommended dose of inorganic fertilizer.

The treatments were arranged in complete randomized design (CRD) with three replications. The experiment has six level of N source including control treatment. In each treatment there were two pot and two plants per pot with a total of 4 plants per treatment in each replication. Following the usual media preparation practice the pot was conventionally filled with 3 kg of 2 mm sieved soil a weeks before planting. Seeds (15) were sown directly on each pot at a depth of 1 cm and thinning was conducted until it remains two plants per pot just before inorganic N treatment was applied. In accordance with the specifications of the design, each treatment was assigned randomly to the experimental units. Recommended cultural practices (watering, thinning, cultivation and weeding) were applied uniformly throughout the growing period (Haile et al., 2017; Mbatha, 2008; Onwonga et al., 2013).

Data on phenology, growth and yield parameters of kale were recorded. Phenology: days to emergence; growth parameters: plant height (cm), number of leaves per plant, leaf area (cm^2), leaf area ratio (cm^2/g), specific leaf area (cm^2/g); yield parameters: leaf fresh weight (g/plant), leaf dry weight (g/plant), total fresh biomass and total dry biomass (g/plant) was recorded (Mbatha, 2008; Li et al., 2013; Amanullah et al., 2007).

The data recorded for each of the parameters considered in this study were subjected to analysis of variance (ANOVA) using a General Linear Model in SAS software and mean separation was made based on LSD at 5% (P<0.05) level of significance (SAS institute, 2002).

RESULTS AND DISCUSSION

Physicochemical characteristics of the soil and bio-slurry

The physicochemical characteristics of the experimental soil and bio-slurry are shown in Table 1.

Phenology and growth parameters

Days to 50% emergence

The days to 50% emergence were not significantly (P<0.05) influenced by the combined application of bio-slurry with inorganic nitrogen (Table 2). The result is in contrary to the findings of Vaithiyanathan and Sundaramoorthy (2016) who noted that application of recommended doses of organic manures, inorganic fertilizers and bio-fertilizers increased the seed germination percentage of Green Gram.

Number of leaves per plant

Number of leaves per plant of kale was (P<0.001) influenced by the application of liquid bio-slurry with inorganic nitrogen fertilizer (Table 2). The highest (11) number of leaves per plant was obtained from T5 (100% bio-slurry) and it was statistically similar with the pots which received 100 kg/ha of inorganic N (T6). The lowest (4.17) number of leaves per plant were recorded from the treatment that did not receive any N sources (the control

Table 1. The physicochemical characteristics of the experimental soil and bio-slurry analyzed at Hawassa University soil laboratory for the grand project on the effects of combined application of head cabbage, 2017.

Property	Value	
	Soil	Bio-slurry
Chemical		
Total nitrogen (%)	0.50	1.53
Available P (mg P_2O_5/kg soil)	71.6	301.4
Available K (mg K_2O/kg soil)	162.4	715.25
Organic matter (%)	10.1	30.6
pH-H_2O(1:2.5)	6.36	7.33
Exch.Ca^{2+}(cmol/kg soil)	71.97	114.4
Exch. Na^{+}(cmol/kg soil)	0.59	33.2
Exch. K^{+}(cmol/kg soil)	6.50	28.6
Exch.Mg^{2+}(cmol/kg soil)	9.5	17.4
CEC (cmol/kg soil)	30.2	64
Organic carbon (%)	5.9	17.7
Physical		
Sand (%)	61	93.93% Water
Silt (%)	21	6.07% Dry matter
Clay (%)	18	-
Texture class	Sandy loam	-

Table 2. Days to 50% emergence, leaf number and plant height (cm) of kale as affected by the combined application of bio-slurry and inorganic nitrogen**.**

Treatment	Days of 50% emergence	Number of leaf/plant	Plant height (cm)
T1= Control (no urea/Bio-slurry applied)	3.33	4.17^{d}	16.17^{e}
T2= 25% Bio-slurry + 75% recommended inorganic N	3.67	7b^{c}	22.33^{cd}
T3= 50% Bio-slurry + 50% recommended inorganic N	3.33	6.17^{c}	17.83^{de}
T4=75% Bio-slurry + 25% recommended inorganic N	3.67	8^{b}	24.33^{bc}
T5=100% Bio-slurry	4.33	11^{a}	37.33^{a}
T6=100% recommended inorganic N	3.33	10^{a}	28.93^{b}
LSD (5%)	12.11	1.62	5.52
CV (%)	7.44	11.80	12.66

Means followed by the same letters in the same column are not significantly different from each other at 5% level of significance.

treatment); whereas the other treatment combinations were in between the two. From the data presented subsequently, it is evident that, leaf number per plant was the lowest at the control treatment, increased with increasing the concentration of bio-slurry reaching maximum at the maximum concentration of bio-slurry (Table 2). The lowest number of leaves per plant in the control treatment could be due to the insufficient nitrogen supply of plants and resulting in reduction of plant productivity and thereby reducing the number of leaves per plant (Shangguan et al., 2000). Moreover, the finding is also similar to the results reported by Rahman et al. (2008).

Plant height

The result of the comparative study of liquid bio-slurry and inorganic N fertilizer on plant height of kale revealed significant differences (P<0.001) amongst the treatments (Table 2). Application of 100% liquid bio-slurry gave the highest (37.33 cm) plant height. The lowest (16.17 cm) plant height was recorded from the treatment which received no fertilizer treatment (T1, control) and it was statistically at par with T3. The highest value in plant height of kale was significantly increased by 130.86% more than the control treatment. From the aforementioned data obtained, plant height of kale was

Table 3. Leaf area, leaf area ratio and specific leaf area of kale as affected by the combined application of bio-slurry and inorganic nitrogen.

Treatment	Leaf area/plant (cm^2)	Leaf area ratio (cm^2/g)	Specific leaf area (cm^2/g)
T1= Control (no urea/Bio-slurry applied)	548.0^d	5.56^c	5.22^d
T2= 25% Bio-slurry + 75% recommended inorganic N	1822.6^c	7.19^b	7.94^{bc}
T3= 50% Bio-slurry + 50% recommended inorganic N	1830.6^c	7.03^b	7.64^{cd}
T4=75% Bio-slurry + 25% recommended inorganic N	2465.3^{bc}	8.05^{ab}	8.44^{bc}
T5=100% Bio-slurry	4890.3^a	10.03^a	10.97^a
T6=100% recommended inorganic N	3172.6^b	9.11^{ab}	10.08^{ab}
LSD (5%)	1032.90	2.19	2.44
CV (%)	23.65	16.09	16.17

Means followed by the same letters in the same column are not significantly different from each other at 5% level of significance.

influenced by liquid bio-slurry and inorganic N fertilizer. Plant height was least for the control treatment, but increased with increase in the concentration of liquid bio-slurry (Table 2). 100% sole application of liquid bio-slurry showed a better result on plant height than the control treatment. This could be attributed to the improvement in soil structure and enhanced nutrient and moisture availability and uptake that may have favored plant growth due to application of organic fertilizer. The increase in plant height obtained by the application of bio-slurry incombination with inorganic N fertilizer was in line with the results reported by Sarwar et al. (2007, 2010). Moreover, Surindra (2009) noted that the increase in plant height due to increased rate of organic fertilizer like vermin-compost could be attributed to the fact that it contains a good range of some very essential macro and micronutrients other than N and P which are required for healthy plant growth.

Leaf area (LA)

Liquid bio-slurry combined with inorganic N fertilizer had a highly significant (P<0.001) effect on leaf area of kale (Table 3). Increasing liquid bio-slurry from 0 to 100% significantly increased leaf area. The treatment (T5) with 100% liquid bio-slurry produced 792.36% higher LA than the control treatment (Table 3); whereas, the other treatments were in between the two. The results clearly indicated that, LA was influenced by the combined application of liquid bio-slurry with inorganic N fertilizer. LA was the lowest from the plants which did not receive any of the two nitrogen sources (T1, control). It increased with increasing the concentration of liquid bio-slurry, reaching maximum at the highest concentration of bio-slurry (Table 3). Leaf area fairly gives a good idea of photosynthetic capacity of the plant. The treatment T5 (100% bio-slurry) showed significantly higher leaf area which could be due to increased cell division and elongation resulting in increased leaf expansion, more number of leaves due to beneficial influence of bio-fertilizers which release growth promoting substances and enhances the availability of nitrogen (Mog, 2007; Balcau et al., 2012).

Leaf area ratio (LAR)

Leaf area ratio is the ratio of leaf area to the total weight. It is also a measure of photosynthetic machinery per unit of plant biomass (Amanullah et al., 2007). Different concentration of liquid bio-slurry with inorganic nitrogen has highly significantly (P<0.001) affected leaf area ratio of kale plants (Table 3). The highest LAR of 10.03 cm^2/g was noted in those pots to which N was applied in the form of 100% liquid bio-slurry which, however, was statistically similar with T6 (100% inorganic N) and T4 (75% bio-slurry and 25% inorganic N) and the lowest (5.56 cm^2/g) was recorded from T1 (control or 0% N sources). Leaf area ratio increased with increase in the concentration of bio-slurry and decrease in the rate of inorganic N application of kale. This suggests that liquid bio-slurry increased leaf size is an attempt to maximize light interception and plant economy for acquisition of resources needed for growth and development and these results are in conformity with the work of Amanullah et al. (2007).

Specific leaf area (SLA)

Specific leaf area is a measure of leaf thickness of the plant and it was highly significantly (P<0.001) affected by the combined application of liquid bio-slurry with inorganic N (Table 3). Maximum (10.9 cm^2/g) SLA of kale was recorded in those plants to which N was supplied in the form of 100% liquid bio-slurry and it was statistically at par with 100% inorganic N fertilizer (T6), while the lowest (5.22 cm^2/g) SLA was recorded in T1 (control); whereas the other treatments were in between the two (Table 3). These findings showed that the specific leaf area was significantly influenced by combined application

Table 4. Yield and yield components of kale as affected by the combined application of bio-slurry and inorganic nitrogen.

Treatment	Leaf fresh weight (g/plant)	Leaf dry weight (g/plant)	Fresh biomass (g/plant)	Dry biomass (g/plant)
T1= Control (no urea/Bio-slurry applied)	104.95[d]	9.71[d]	139.61[d]	12.93[d]
T2= 25% Bio-slurry + 75% recommended inorganic N	252.19[c]	24.09[c]	366.81[c]	34[c]
T3= 50% Bio-slurry + 50% recommended inorganic N	240.10[c]	22.23[c]	347.22[c]	32.18[c]
T4=75% Bio-slurry + 25% recommended inorganic N	276.62[c]	25.61[c]	389.34[c]	36.06[c]
T5=100% Bio-slurry	455.17[a]	44.40[a]	814.86[a]	75.53[a]
T6=100% recommended inorganic N	376.09[b]	34.82[b]	667.32[b]	61.82[b]
LSD (5%)	77.77	7.55	96.22	8.89
CV (%)	15.56	16.13	11.91	11.87

Means followed by the same letters in the same column are not significantly different from each other at 5% level of significance.

of liquid bio-slurry with inorganic N. SLA was the lowest for the control treatment (T1); it increased with increase in liquid bio-slurry reaching maximum at the maximum liquid bio-slurry treatment (Table 3). The specific leaf area is the indicator of leaf thickness and it was the highest in the highest bio-slurry treatment which may be due to the presence of growth promoting substances present in this organic components. These growth promoting substances were found to have established role in cell division and elongation which might have contributed to increased number of cells and facilitated the better stacking of the mesophyll cells of the leaves. The results are in conformity with the findings of Oscar and Tollennar (2006) who reported that leaf area, leaf area ratio and grain yield of baby corn increased with increase in the level of N.

Yield and yield components

Leaf fresh weight

Data on leaf fresh weight in Table 4 clearly indicated that application of liquid bio-slurry with different level of inorganic N sources has a highly significant ($P<0.001$) effect. Maximum (455.10 cm) leaf fresh weight of kale was recorded in T5 (100% liquid bio-slurry). The lowest (104.95 cm) leaf fresh weigh of kale was recorded from T1 (the control) and the other treatment combination is in between the two. The increase in leaf fresh weight of kale in the liquid bio-slurry was 325.13% more than that of the control. It has also been observed that there was significant difference between other combination treatments. These findings showed that the leaf fresh weight is determined by the application of liquid bio-slurry with different level of inorganic N sources. The increase in leaves fresh weight in response to increased rate of bio-slurry might be ascribed to the availability of optimum nutrients contained in bio-slurry that led to high leaf area index and leaf number per plant through facilitated vegetative growth. This result is in line with the work of Mehdi et al. (2012) who reported that the application of municipal solid waste and vermin-compost significantly increased all the growth attributes such as plant height, stem diameter, number of leaves, and leaf area index under well-watered, moderate and severe stress conditions through which it increases the leaf fresh weight per plant. Similarly, the increase in leaf fresh weight on the application of bio-slurry incombination with inorganic N fertilizer was in line with the results reported by Sarwar et al. (2007, 2010) and Qureshi et al. (2014). Moreover, Weiping et al. (2010) studied the influence of different concentrations of liquid biogas slurry on the quality of radish, and the results of their experiment showed that under applications, equal to that of nitrogen's condition, the biogas slurry was helpful to improve quality of radish, also promoted soil quality when compared with a general chemical fertilizer, and decreased chemical fertilizer quantity that was used.

Leaf dry weight

Leaf dry weight of kale per plant was the lowest (9.71 g) for the treatment that did not receive the fertilizer treatment (control or T1), while it was the highest (44.4 g) for the plants that received 100% liquid bio-slurry (T5); the other treatments scored in between the two treatments (Table 4). It is evident from the data presented subsequently that the leaf fresh weight of kale was determined by liquid bio-slurry with different levels of inorganic N fertilizers. The increase in the leaf dry weight resulting from application of liquid bio-slurry may be attributed to the presence of a readily available form of nutrient i.e. ammonia and nitrate. Moreover, its property to enhance soil aggregation, soil aeration and water holding capacity, offers good environmental conditions for the root system of kale. This better availability of soil nutrients and favorable soil condition resulted in healthy plants with large vegetative growth, which lead to higher dry weight of kale. This finding is in agreement with the results obtained by Wenke et al. (2009) who concluded that biogas slurry is an important byproduct of biogas fermentation, containing abundant nutrient element and bioactive substances and they proved that biogas slurry could significantly improve the vegetable quality and resistances to biotic and abiotic stresses of plants. Moreover, Zhou (2009) conducted an experiment to quantitatively study the effect of application of biogas slurry on growth, yield, nutrition quality of purple cabbage and soil quality and the results showed that the application of biogas slurry could remarkably improve growth and yield.

Fresh biomass

The results of the analysis of variance (Table 4) indicated that different concentration of liquid bio-slurry with inorganic N fertilizer significantly ($P<0.001$) influenced the fresh biomass of kale. Significantly, the highest (814.86 g/plant) fresh biomass was recorded in T5 (100% liquid bio-slurry) followed by T6 (100% inorganic N) which scored 667.32 g/plant. Liquid bio-slurry with inorganic N fertilizer showed significantly the lowest (139.61 g/plant) fresh biomass in the non-fertilized pots (Table 4). Fresh biomass was 82.87% higher than the non-fertilized experimental pots. This finding showed that fresh biomass of kale is significantly influenced by the application of liquid bio-slurry and inorganic N. The increases in fresh biomass of kale due to the application of liquid bio-slurry and inorganic N fertilizer could be attributed to the increase in vegetative growth and increased production of assimilate which is associated with increment in leaf area. The increase in fresh biomass yield of kale due to the application of bio-slurry (a component of several essential macro and micro nutrient) might be due to the effect of these nutrients, which are an integral component of many essential plant compounds like chlorophyll, proteins and amino acids. Plant compounds increase the vegetative growth and produces good quality foliage. These in turn, promote carbohydrate synthesis through photosynthesis and ultimately increased yield of plants (Brady and Weil, 2002). This is also in line with that of Mehdi et al. (2012) who reported that the application of municipal solid waste and organic fertilizer significantly increased growth attributes such as plant height, stem diameter, number of leaves, and leaf area index of canola under well-watered, moderate and severe stress conditions. Similarly, Ding et al. (2011) also studied the effects of biogas slurry on the growth and quality of Tabe bean and the results showed that biogas slurry could not only increase the Tabe bean production, but also improve its nutrition quality. Similar results were obtained by Qureshi et al. (2014).

Dry biomass

Dry biomass yield of kale was highly significantly ($P<0.001$) influenced by liquid bio-slurry with different rates of inorganic nitrogen fertilizer (Table 4). The lowest (12.93 g/plant) and the highest (75.53 g/plant) dry biomass of kale were obtained from T1 (control), which did not receive any source of N fertilizer, and from 100% liquid bio-slurry (T5), respectively. The increase in dry biomass per plant due to increase in the concentration of liquid bio-slurry might be due to the increase in number of leaf per plant. Thus, response of liquid bio-slurry in combination with different inorganic nitrogen significantly influenced the dry biomass of kale. The highest and lowest was achieved by the application of 100% liquid bio-slurry and control treatment, respectively. Nitrogen fertilizer, either organic or inorganic, always affects vegetative growth of the fodder and cereals; and therefore, the increase in the application of liquid bio-slurry and yield maximization of kale was in line with the results reported by Rahman et al. (2008). Similarly, the increase in dry biomass of kale on the application of biogas slurry in combination of N inorganic fertilizer was in line with the results reported by Yu et al. (2010). Moreover, observation and documentation made by Aktar et al. (1996) and Souza et al. (2008) are also supportive of the present findings who reported that when organic fertilizer is used in the soil, some metallic trace elements stimulated root growth that ultimately increases the dry biomass yield of kale crop. In addition, Islam et al. (2010) conducted an experiment to examine the effectiveness of biogas slurry as nitrogen source for the production of maize fodder and based on the result they conclude that application of biogas slurry has a significant effect on dry matter, ash content and it will improve the production of biomass and nutrient content in maize fodder.

Conclusion

Results from the present study showed that the application of bio-slurry as a nitrogen fertilizer stimulated the growth and yield of kale. From the current results, it can be concluded that, growth and yield of kale improved with 100% sole application of bio-slurry. Therefore, this treatment can be suggested for better growth, yield and yield attributing characteristics of kale for Hawassa and areas having similar agro-ecologies.

CONFLICT OF INTERESTS

The authors have not declared any conflicts of interests.

REFERENCES

Aktar S, Noor S, Rahman M, Sultana S, Nandi SK (1996). Effect of organic manure and chemical fertilizer on the yield of broccoli. Bangl. Hortic. 24(1 and 2):59-64.

Amanullah, Jaffar MH, Nawab K, Ali A (2007). Response of Specific Leaf Area (SLA), Leaf Area Index (LAI) and Leaf Area Ratio (LAR) of Maize (*Zea mays* L.) to plant density, rate and timing of nitrogen

application. World Appl. Sci. J. 2 (3):235-243.
Balcau SL, Apahidean M, Saharia A, Pop D (2012). The influence of organic fertilizers concerning the growth and development of *Brassica oleracea*var. acehala plants. Bull. UASVM Hortic. 69(1):64-70.
Brady NC, Weil RR (2002). The nature and properties of soil.13th ed. Pearson Education, Inc. per Saddle River, New Jersey. pp. 143-192.
Chinma CE, Igyor MA (2007). Micronutrients and anti-nutritional contents of selected tropical vegetables grown in South East, Nigeria. Niger. Food J. 25(1):111-116.
Ding GF, Qing WS, Neng QW, Yu ZG, Huai LJ, Bo JH (2011). Effect of biogas slurry on Table Bean Quality and Soil Fertility. China Biogas 29(1):59-60.
Fadigas JC, Santos AMP, Jesus RM, Lima DC, Fragoso WD, David JM, Ferreira SLC (2010). Use of multivariate analysis techniques for the characterization of analytical results for the determination of the mineral composition of kale. Microchem. J. 96:352-356.
Fasuyi AO (2006). Nutritional potentials of some tropical vegetable leaf meals: chemical characterization and functional properties. Afr. J. Biotechnol. 5:49-53.
Haile A, Tesfaye B, Worku W (2017). Seed yield of onion (*Allium cepa* L.) as affected by bulb size and intra-row spacing. Afr. J. Agric. Res. 12(12):987-996.
Huang S, Peng XX, Huang QR, Zhang WJ (2010). Soil aggregation and organic carbon fractions affected by long term fertilization in a red soil of subtropical China. Geoderma 154(3-4):364-369.
Islam R, Rahman SME, Rahman MM, Oh DH, Ra CS (2010). The effects of biogas slurry on the production and quality of maize fodder. Turk. J. Agric. 34:91-99.
Karki KB (1997). Estimation of plant nutrient loss from biogas slurry. Biogas Support Programme. International Congress Series. 1291:42-52.
Li J, Wee C, Sohn B (2013). Effect of Ammonium- and Potassium-Loaded Zeolite on Kale (*Brassica alboglabra*) Growth and Soil Property. Am. J. Plant Sci. 4:1976-1982.
Mbatha AL (2008). Thesis on Influence of Organic Fertilizers on the Yield and Quality of Cabbage and Carrot; Faculty of Natural and Agricultural Sciences Department of Soil, Crop and Climate Sciences; University of the Free State; Bloemfontein. pp.76-94.
Mehdi R, Ali HA, Ghorchiani M (2012). Effect of vermin-compost and municipal solid waste compost on growth and yield of canola under drought stress conditions. Int. J. Agric. Res. Rev. 2(4):395-402.
Mog B (2007). Effect of organics and bio-fertilizers on productivity potential in carrot (DaucuscarotaL.) (MSc. Agric. Thesis in Crop Physiology). Department of Crop Physiology College of Agriculture, Dharwad University of Agricultural Sciences, Dharwad, India.
Onwonga RN, Lelei JJ, Macharia JK (2013). Comparative effects of soil amendments on phosphorus use and agronomic efficiencies of two maize hybrids in acidic soils of Molo County, Kenya. Am. J. Exp. Agric. 3(4):939-958.
Onyango CN, Harbinson J, Imungi JK, Shibairo SS, Kooten OV (2012). Influence of organic and mineral fertilization on germination, leaf nitrogen, nitrate accumulation and yield of vegetable amaranth. J. Plant Nutr. 35:342-365.
Oscar RV, Tollennar M (2006). Effect of genotype, nitrogen, plant density and row spacing on the area-per-leaf profile in maize. Agron. J. 98:94-99.
Qureshi F, Wani JA, Bashir U, Malik MA, Mir SA (2014). Response of farmyard manure and inorganic nitrogen on vegetative growth, leaf yield and quality of kale (*Brassica oleracea* var acephala) in temperate region of Kashmir valley. Biolife 2(3):786-791.
Rahman SME, Islam MA, Rahman MM, Oh DH (2008). Effect of cattle slurry on growth, biomass yield and chemical composition of maize fodder. Asian-Aust. J. Anim. Sci. 21(11):1592-1598.
Sarwar GH, Schmeisky MA, Tahir Y, Iftikhar, Sabah NU (2010). Application of green compost for improvement in soil chemical properties and fertility status. J. Anim. Plant Sci. 20(4):258-260.
Sarwar GN, Hussain H, Schmeisky, Muhammad S (2007). Use of compost and environment friendly technology for enhancing rice-wheat production in Pakistan. Pak. J. Bot. 39(5):1553-1558.
SAS Institute Inc. (2002). Statistical Analysis Software Package, SAS/STAT user's guide version 9. SAS Institute Inc., Cary NC, USA.
Shangguan Z, Shao M, Dyckmans J (2000). Effects of nitrogen nutrition and water deficit on net photosynthetic rate and chlorophyll fluorescence in winter wheat. J. Plant Physiol.156:46-51.
Souza PA, Souza GLFM, Menezes JB, Bezerra NF (2008). Evaluation of cabbage cultivar grown under organic compost and mixed mineral fertilizers. Hortic. Bras. 26:143-145.
Surindra S (2009). Impact of vermin-compost and composted farmyard manure on growth and yield of garlic (*Allium stivum* L.) field crop. Int. J. Plant Prod. 3(1):27-38.
Uyovbisere EO, Chude VO, Bationo A (2000). Promising nutrient ratios in the fertilizer formulations for optimal performance of maize in Nigerian savanna. The need for a review of current recommendations. Niger. Soil Res. 1:29-34.
Vaithiyanathan T, Sundaramoorthy P (2016). Impact of Organic Manure and Inorganic Fertilizers on Seed Germination of Green Gram (*Vignar adiata* L.). J. World Sci. News 35:111-122.
Weiping W, Fengxiang Z, Xiaoyang C, Zhiyong X, Chunlai H, Chuanzhen W, Jian L (2010). Influence of biogas slurry irrigation on the soil environment and radish quality. Anhui Agric. Sci. Bull. 16(17):76-77.
Wenke L, Chang YQ, Qing WS (2009). A review on effect of biogas slurry on vegetables and soil. China Biogas 27(1):43-46.
Yu FB, Luo XP, Song CF, Zhang MX, Shan SD (2010). Concentrated biogas slurry enhanced soil fertility and tomato quality. Plant Soil Sci. 60(3):262-268.
Zhou Q (2009). Effect of biogas slurry application on yield, nutrition quality of purple cabbage and soil quality. Acta Agric. Jiangxi 2:7-27.

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Full Length Research Paper

Morphological characteristics of avocado (*Persea americana* Mill.) in Ghana

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Avocado (*Persea americana* Mill.) is an important economic tree crop grown in home gardens and farms all over Ghana. Although there are some studies on diverse aspects of the crop in several parts of the world, not much has been documented about its morphology in Ghana. This study was therefore conducted to describe the morphology of avocado in the Ashanti and Central Regions of Ghana. Using the avocado descriptor as a guide, morphological analyses of *P. americana* accessions in eight districts in the two regions were conducted. The study revealed that the avocado accessions had variable morphological characteristics but were more close to the Western Indian accession.

Key words: *Persea americana*, accessions, morphology, Ghana, economic tree crop, Western Indian.

INTRODUCTION

Persea americana commonly called avocado is a polymorphic tree crop that originated from a broad geographical area stretching from the eastern and central highlands of Mexico through Guatemala to the Pacific coast of Central America (Popenoe, 1920; Smith, 1966, 1969; Storey et al., 1986; Dreher and Davenport, 2013).

From its origin, the avocado plant spread very fast to many parts of the world due to its nutritional value and the desire for its fruit. The spread to different parts of the world resulted in different names given to it in different parts of the world e.g. “avocado” in English, “aguacate” in Spanish, “avocat” in French and “abacate” in Portuguese (Ochse et al., 1961; Morton, 1987). In West Africa, *P. americana* is also known as “custard apple” (Gustafson, 1976) and in Ghana, it is known locally as “pɛa” or “paya” in Twi, Fante, Ga and Adangme (Irvine, 1961).

The avocado plant is erect and grows up to ≥ 9 to 18 m high with bole diameter ranging from 30 to 60 cm. The leave could be of several shapes including lanceolate, elliptic, oval, ovate or obovate (Morton, 1987; Schaffer et al., 2013) and may be alternate, dark-green, glossy on the upper surface and whitish on the underside. Morton (1987) measured leaf lengths ranging from 7.5 - 40 cm long and found the fruit to be pear-shaped, often necked, oval or nearly round and 7.5-33 cm long in length and may reach 15 cm wide.

The fruit skin is known to be yellow-green, deep-green, reddish-purple or very dark purple to almost black. The

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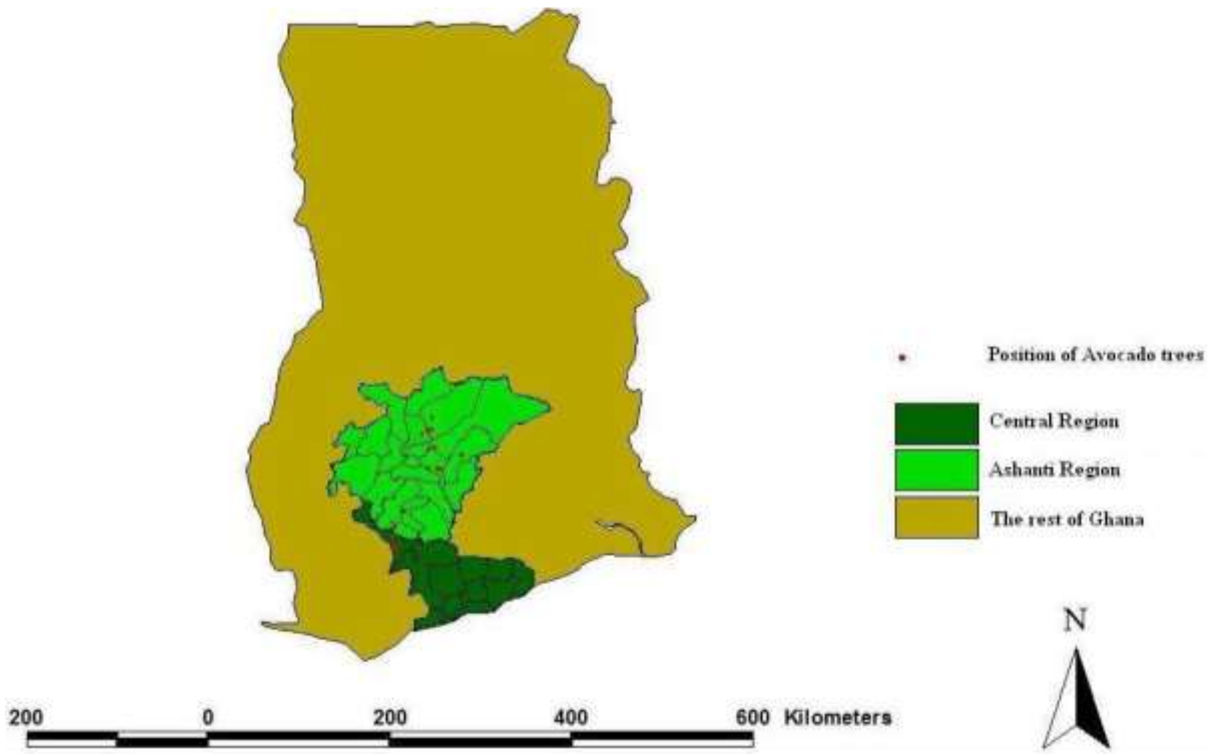

Figure 1. Map of Ghana showing the geographical points of the avocado plants used for the study. Map was produced from the GPS coordinates of each single tree sampled.

fruit may be speckled with tiny yellow dots, may be smooth or pebbled, glossy or dull, thin or leathery and up to 6 mm skin thickness, pliable or granular and brittle (Morton, 1987). Generally, the flesh of avocado is entirely pale to rich-yellow in colour but in some fruits, there is a thin layer of soft, bright-green flesh immediately beneath the skin. The avocado fruit has a single seed enclosed in two brown, thin, papery seed coats often adhering to the flesh cavity and may be oblate, round, conical or ovoid in shape, hard and heavy, ivory in colour and 5-6.4 cm long (Morton, 1987).

The avocado tree crop is one of the most important in Ghana. Local people use the fruit and other parts of the tree for diverse purposes including food and medicine. In the Ashanti region, the avocado fruit is a major component of meals when in season (Abraham, personal observation). The intense utilization of all parts of avocado makes it a crop of great commercial potential in the agricultural sector. The potential for commercialisation has not been utilized in Ghana due to marginalisation of the crop and inadequate documented information on it in Ghana. Moreover, there is the need to conserve all the avocado accessions in Ghana to avoid extinction of any of them. To do this, it is important to determine the accessions of avocado in Ghana. Therefore, this study was conducted to characterize the *P. americana* accessions in the Ashanti and Central regions of Ghana based on their morphology.

MATERIALS AND METHODS

Study area

The study was conducted in eight districts randomly distributed in the Ashanti and Central regions of Ghana between March and October 2008. A minimum of two and a maximum of twelve avocado plants were randomly sampled for study in each study district bringing the grand total of avocado plants studied in all districts to 53 (Adansi South: n = 2; Afigya Sekyere: n = 3; Asante Akyem North: n = 6; Ejisu-Juaben: n = 11; Sekyere East: n = 5; Sekyere West: n = 12; Obuasi: n = 6; Upper Denkyira: n = 8). The GPS coordinates of each plant assessed was recorded and used to produce a map (Figure 1).

Morphological characters studied

Based on a field guide for morphological studies, data on tree, leaf, fruit and seed characteristics were taken for each avocado plant selected for study (IPGRI, 1995).

Tree characteristics

The tree characteristics studied were canopy spread, tree height, trunk surface, branching pattern, distribution of branches and a measure of the truck circumference at 30 cm above ground level.

To determine the canopy spread, the distance from the centre of the crown to the tip of the outermost leaves on two opposite sides of the tree was measured using a 100 m fibreglass measuring tape [Rollins & Sons (London) Ltd, Harlow, Essex, UK]. Tree height was measured with a suunto clinometer (PM-5 Suunto, Valimotie, Finland). The tree heights were classified into 1-4, > 4-8, >8-12, >12-16 and >16 m. The appearance of the trunk surface of the avocado trees was scored according to the criteria described by the IPGRI (1995) such that a score of 3 represented a smooth surface, 7 represented a rough surface and 9 represented very rough. Other tree characteristics such as branching pattern, distribution of branches and the measure of the truck circumference at 30 cm above ground level were described following the avocado descriptor (IPGRI, 1995).

Leaf characteristics

Leaf shape was described according to the criteria suggested by the avocado descriptor (IPGRI, 1995). Data on leaf shape, number of primary veins, leaf apex shape and leaf blade length (cm) were taken.

Fruit characteristics

Fruit shape, ridges on fruit, pedicel position on fruit, pedicel length and nailhead pedicel apex shape, colour of flesh next to skin, colour of flesh next to seed, fruit skin colour and gloss on fruit skin were observed and recorded following IPGRI (1995). Moreover, the fruit length (cm) as the longest part of the fruit, fruit diameter (cm) (the mid-section of each fruit), fruit weight (g), peduncle length (cm) and peduncle diameter (mm) were measured. Fruit skin surface was observed and classified as smooth, intermediate or rough. Using an electronic digital calliper (Powerfix®, Milomex Ltd, Bedfordshire, UK), the average fruit skin thickness of five fruits were determined. Adherence of skin to flesh was graded as slightly, intermediate or strong.

Seed characteristics

For every avocado fruit studied, the shape of the seed and attachment of cotyledons to seed were noted. Moreover, the seed weight (g) was measured with an electronic weighing balance (Sartorius AG, Göttingen, Germany), and the length of seed cavity (cm), diameter of seed cavity (cm), length of seed (cm), diameter of seed (cm) and free space of the seed cavity were measured with an electronic digital calliper (Powerfix®). The length of seed was taken as the measure of the longest part of the seed and the diameter measurement was taken from the mid section of the seed with the base and tip of the seed as reference points.

Data analysis

The frequency of occurrence of the various morphological characters of the avocados was determined. Since a cluster analysis defines a natural population of the same species into distinctively related phylogenetic main groups and subgroups, the morphological characters were studied. The protocol utilized characteristics of the tree, leaves, fruit and seed. In the analysis, the hierarchical single linkage and Euclidean distance method was used to produce a dendrogram of morphological similarities (Statistica, version 7; StatSoft Inc., Tulsa, OK, USA).

RESULTS

Tree characteristics

The tree characteristics varied among the avocado trees studied (Figure 2). Other tree characteristics were:

Canopy spread

The tree spread (canopy spread) of the avocado trees studies ranged from 4.9 - 13.17 m with an average of 8.43 ± 0 .25 m. Most (92.4%) of the trees had canopy spreads between 6 and 12 m.

Trunk circumference

The trunk circumference ranged between 46.30 and 283.10 cm. The modal circumference was 111.0 cm. The mean tree circumference was 133.04 cm. Majority (77.4%) of the plants had circumferences between 70 and 160 cm.

Leaf characteristics

The avocado trees studied had several leaf shapes (Figure 3A) with different leaf apex shapes (Figure 3B).

Number of primary veins

A large percentage (71.7%) of the plants under study had between 14 and 16 primary veins. Only 3.8% had 18 primary veins. The least number of venation being 12 was represented by 11.3% of the trees.

Leaf blade length

The least average leaf blade length recorded was 12.92 cm while the highest average leaf blade length recorded was 28.64 cm. The mean average leaf blade length of the samples used for the study was 19.03 cm.

Fruit characteristics

Fruit shape

The shapes of fruit studied included pyriform (Figure 4A), narrowly obovate (Figure 4B and C), ellipsoid (Figure 4D), clavate (Figure 4E), rhomboid (Figure 4F), oblate (Figure 4G) and spheroid (Figure 4H). Other fruit shapes included high spheroid and obovate. The trees studied had various fruit characteristics (Figure 5).

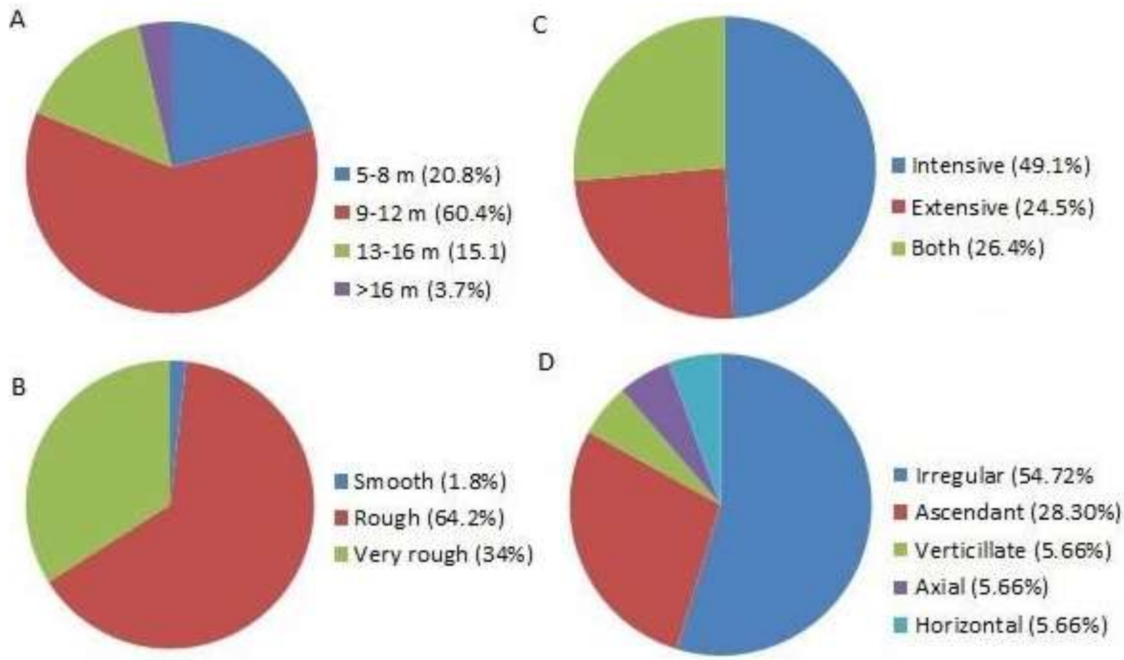

Figure 2. Percentage of the avocado trees studied with (A) tree heights ranging from 5 m to more than 16 m, (B) trunk surface being smooth, rough or very rough (C) branching pattern with intensive, extensive or both branching patterns and (D) distribution of branching being irregular, ascendant, verticillate, axial and horizontal.

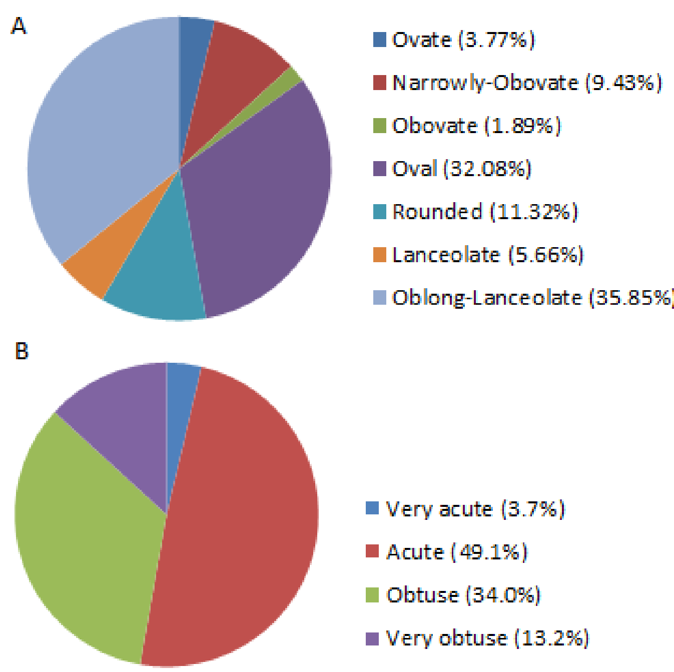

Figure 3. Leaf shapes (A) and leaf apex shapes (B) of avocado trees studied.

Ridges on fruit

More than half (54.7%) of fruits had partial ridges on them and 17% were entirely covered with ridges (Figure 6A). There were no ridges on fruits of 28.3% of the plants (Figure 6C).

Figure 4. Avocado fruits showing various morphological characters. (A) Pyriform shape, broadly ovate seed, cotyledon not attached to seed; (B and C) Narrowly obovate shape; (D) Ellipsoid shape, free space on seed base; (E) Clavate shape; (F) Rhomboidal shape, small seed, cotyledon not attached to seed; (G) Oblate shape, base flattened apex rounded seed; (H) Spheroid shape. Photos: Janice D. Abraham

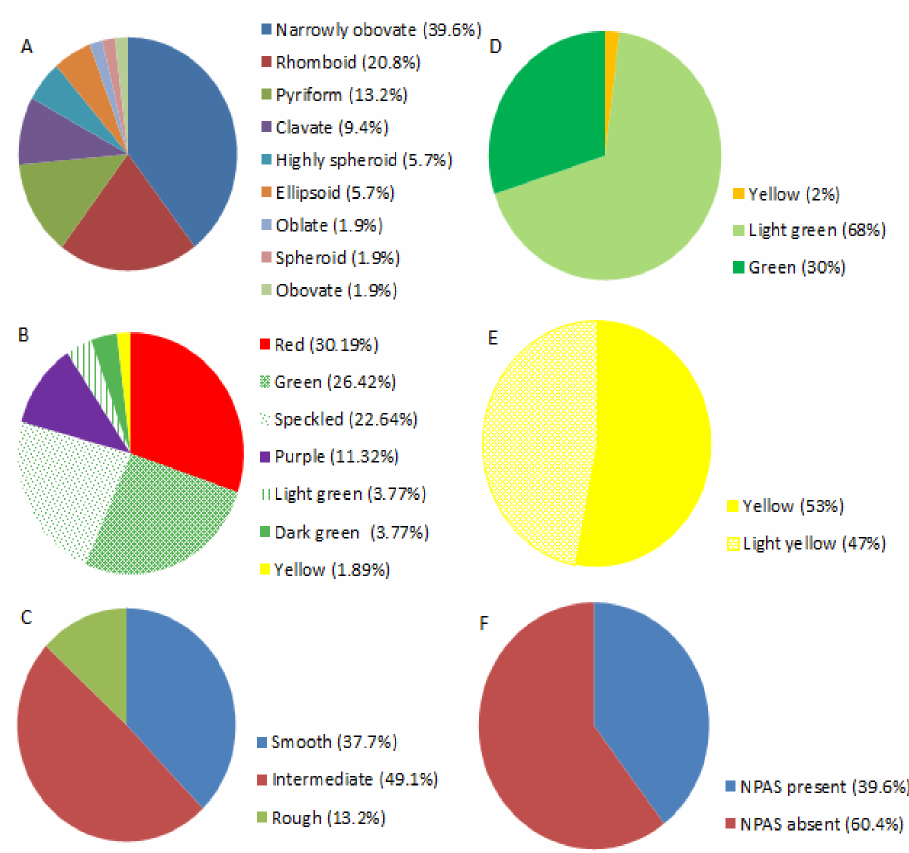

Figure 5. Percentage fruit shape (A), fruit skin colour (B), fruit skin surface texture (C), colour of flesh next to skin (D), colour of flesh next to seed (E) and Nailhead pedicel apex shape avocado fruits studied (F). NPAS = Nailhead pedicel apex shape.

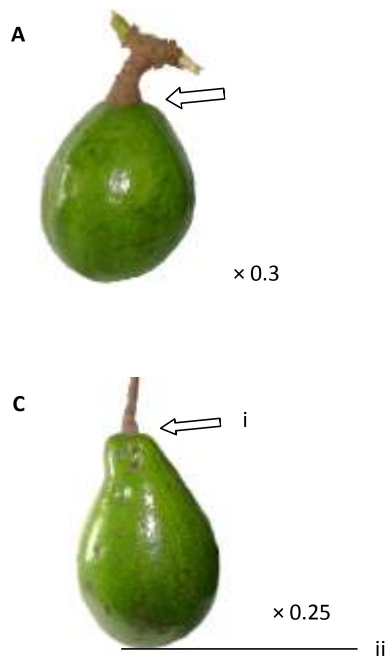

Figure 6. Avocado fruits showing different morphological characters. (A) a fruit with a conical pedicel shape (arrowed), (B) a rounded pedicel shape fruit (arrowed) with a weak glossy skin,(C) a fruit with (i) a central pedicel position on fruit and (ii) a central fruit apex position, (D) fruit with a very asymmetrical pedicel position (arrowed) and a strong glossy skin. Photos: Janice D. Abraham.

Pedicel position on fruit

The pedicels were either centrally (50.9%) or asymmetrically (49.1%) positioned on fruits (Figure 6C and D).

Pedicel length

Pedicel lengths ranged from 0.68 to 1.5 cm. The pedicel length of 96.2% of the fruits was > 1.5 cm.

Gloss on fruit skin

Fruits had a strong glossy skin (35.8%) (Figure 6D), medium glossy skins (35.8%) or weak glossy skin (28.3%).

Fruit length

The lengths of the fruits ranged between 7 and 19 cm with an average of 11.10 ± 1.52. About half (49.1%) of the fruits were between 10 and 13 cm long, 34% were up to 10 cm long and 17% were more than 13 cm long.

Fruit diameter

Most (81.1%) of the fruits were in the same diameter range of 7 to 9 cm. Only 1.9% was in the range of 9 to 11 cm, while a relatively small percentage (17%) was between 5 and 7 cm.

Fruit weight

Fruit weight of avocado studied was variable; however, more than half (58.6%) of them weighed between 220 and 370 g. Only 18.9% weighed more than 420 g, while 11.3% weighed between 170 and 220 g. Another 11.3% weighed between 370 and 420 g.

Peduncle length

There was a wide range of peduncle length of fruits studied. Most (83%) of the fruits had peduncle lengths between 2 and 6 cm. About 47% of the fruits had peduncle lengths of 4 to 6 cm. Very few (7.6%) had their peduncle lengths over 8 cm long.

Peduncle diameter

A much larger percentage (92.5%) of fruits had their peduncle diameters between 4 and 8 mm. Only 7.6% of the fruits had peduncle diameters between 8 and 12 mm.

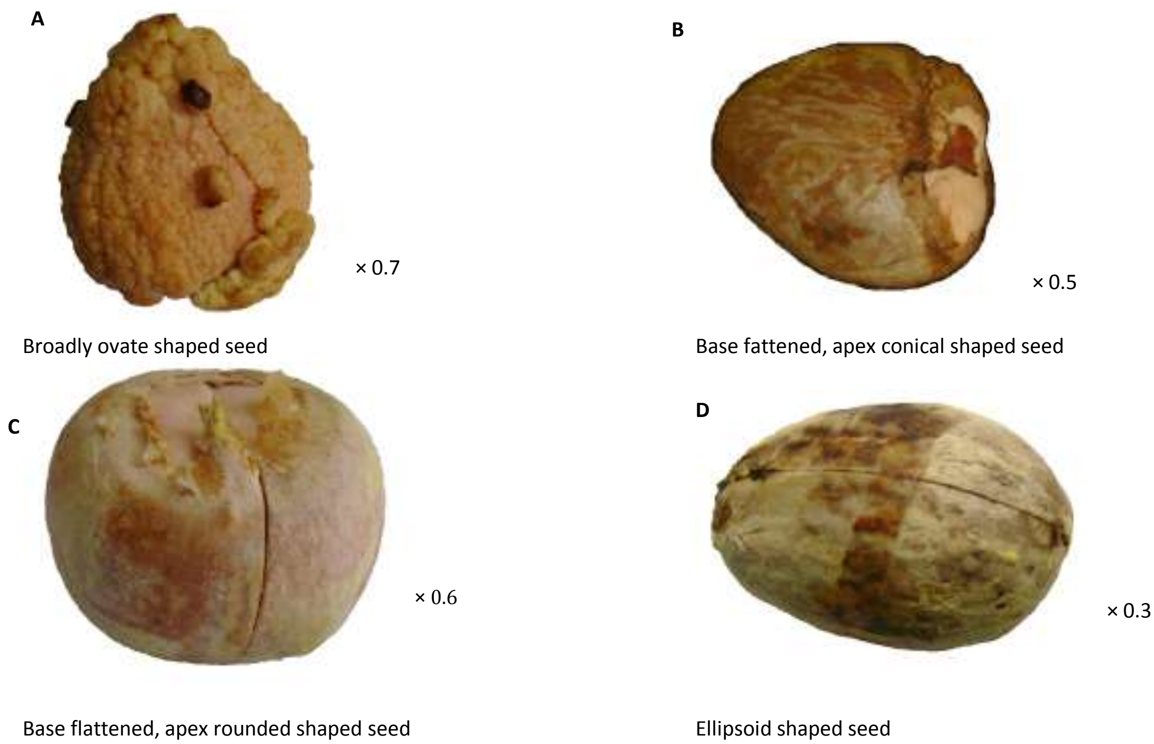

Figure 7. Various seed shapes of avocado. Photos: Janice D. Abraham.

Fruit skin thickness

The skin of the fruit had thickness ranging between 2 and 8 mm. The skin thickness of 96.2% of the fruit was between 2 and 6 mm. Only 3.8% had skin thickness of 7 mm.

Adherence of skin to flesh

There was a strong attachment of flesh to skin in 13.2% of the fruits; 67.9% had a slight attachment, while 18.9% had an intermediate strength of attachment.

Seed characteristics

Shape of the seed

Among the avocado fruits studied, five different seed shapes were identified: broadly ovate (Figure 7A; 37.7%), base flattened and conical apexes (Figure 7B; 35.8%), base flattened and rounded apexes (Figure 7C; 18.9%), cordiform (5.7%) and ellipsoid (Figure 7D; 1.9%).

Some of the seeds had their cotyledons attached to the seeds while others did not (Figure 8A). The weights of avocado seeds studied were between 25 and 125 g (Figure 8B). The diameter of seed cavity and diameter of seeds were different (Figure 8C and D, respectively).

Length of seed cavity

The seed cavities of 92.4% of fruits studied were between 4 and 8 cm, and 7.5% had seed cavities of 8 to 10 cm.

Length of seed

The seeds were between 2 and 8 cm in length: 2-4 (1.9%), 4-6 (84.9%), 6-8 cm (13.2%).

Free space of the seed cavity

Seed cavity space was as follows: space on the seed base only (66%), spaces on both seed apex and seed base (32.1%) and space on the seed apex only (1.9%).

A dendrogram of the relationships between all avocado plants based on 35 morphological characters identified three major distinct groups (Figure 9). The first distinct group (A) was defined with samples one and eight at either ends, with four subgroups. The four subgroups had samples 1-30, 42-50, 40-33; however, sample eight stood alone. The second distinct group (B) had samples three and six at either ends. This also had four subgroups made up of samples 3-17, 15-21, 37-19 and 23-6. The third distinct group (C) was between samples 11 and 39. This group had three subgroups made up of samples 35-

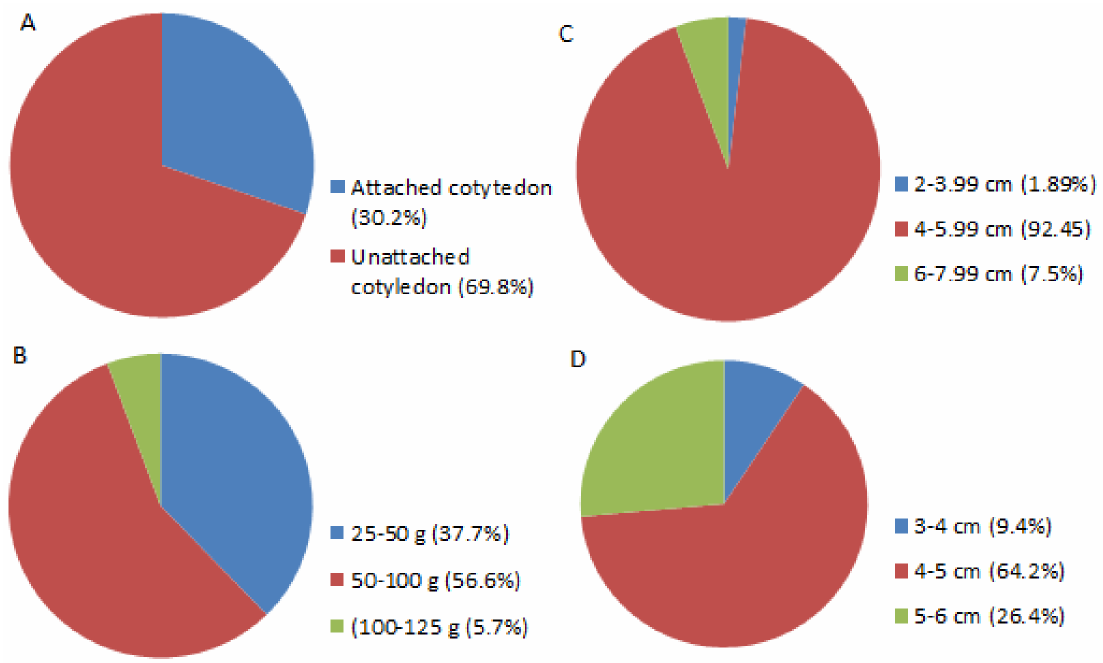

Figure 8. Percentage of seeds with cotyledon attached or not attached (A), seed weight (B), diameter of seed cavity (C) and diameter of seeds (D) of avocado fruits studied.

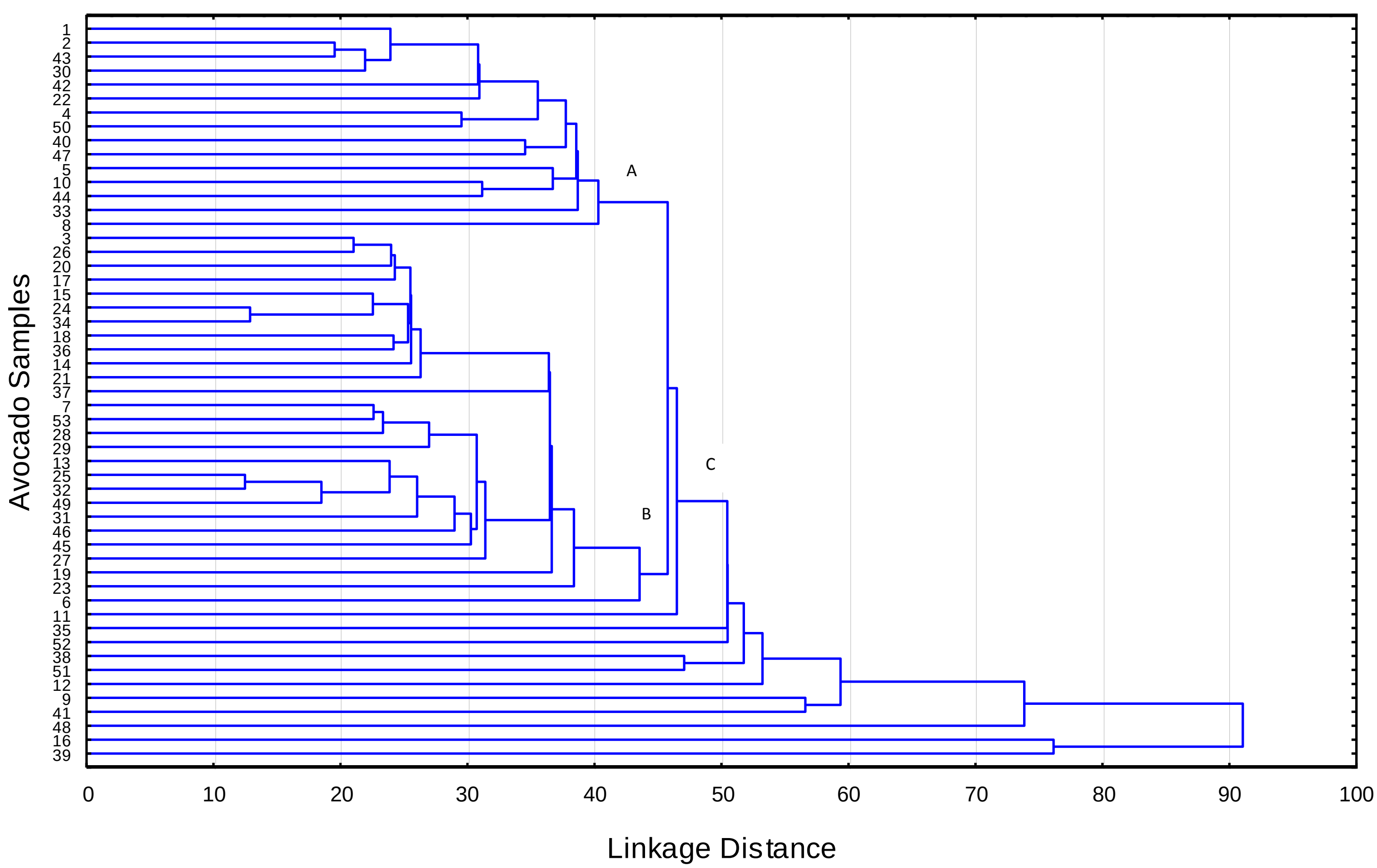

Figure 9. Single-joining tree of avocado individual plants, using Euclidean distances from morphological parameters.

51, 12-41 and 48-39.

DISCUSSION

All the avocado plants studied had heights above 5 m, suggesting that all the plants were fully matured. In terms of management, it has been suggested that avocado plants between the heights of 3 and 4.5 m are relatively easier to manage and more productive than taller plants (Partida Jr., 1996). This implies that, it will be very difficult for the farmers to manage their tall plants. It is therefore necessary for breeders to try to cross the existing trees with improved accessions that have shorter heights to enhance commercialisation and easy harvest of fruits. This is because harvesting from tall trees is very difficult and expensive. Shorter avocado trees with good canopy development produce more fruits than taller ones.

In California, it has been reported that, avocado fruit yield reduced from about 2,177 to 725 kg/ha over a three year period when the canopies were crowded such that there was not enough sunlight through (Partida Jr., 1996). When such trees were pruned to open up the canopy to allow more light through, and the tree heights limited to about 3.6 m, yield increased again (Partida Jr., 1996). It has also been observed that not only did the fruit yield increase but cost of harvesting was significantly reduced on pruned trees. It is thus possible that, Ghanaian avocado farmers might have better yield and income from their avocado farms and plantations when the trees are pruned down to between 3 m and 4.5 m in height. The average canopy spread of avocado plants studied was 8.4 m, and the crowns ranged between 4.9 and 13.17 m. Such large crowns may be too much for proper management. Management of such trees will be relatively easier when the crowns are pruned.

The trunk circumference of avocado trees range between 46.30 and 283.10 cm which is equivalent to diameters between 14.74 and 90.11 cm. Such plants are considered very large fruit plants. However, the sizes of the avocados are evidence of good and healthy growth.

The most common branching distribution of the plants studies was irregular. However, Paz-Vega (1997) noted that horizontal branching could enhance flowering. By tipping the branches, more side shoots were formed. This created complex branching systems in avocado. This method could thus be effectively used to control the size and shape of avocado plants, as well as enhance yield. Removal of excess branches by girdling could reduce vegetative growth; and thus increase flowering and fruiting (Núñez-Elisea and Crane, 2000; Kim et al., 2017). The study results showed that, nearly half of the avocado plants had intensive branching.

Avocado leaves have variable lengths. They may have lengths of up to 22 cm (Irvine, 1961) or 40 cm (Morton, 1987). The leaves of the avocado plants sampled in this study had leaf blade length between 12.92 and 28.40 cm long. Large leaf is distinctive of both West Indian and Guatemalan races, and their hybrids, but the West Indian species are said to have the largest leaf size among the species (Bergh and Lahav, 1996). Hence, the plants studied might very well relate to these two species. Almost 50% of the trees had leaves with acute apex. This is a feature of a normal avocado leaf. However, improved cultivars have some leaf shape variations. The observation therefore means that new improved cultivars have not been introduced in the study area. The accessions spreading are the ones which were introduced over a century ago. There is therefore the need to introduce come improved cultivars to the area to bring more diversity and enhance the commercial value of the existing plants. This will make commercialisation of the plants more attractive to farmer.

The average avocado fruit length of 11.10 ± 1.52 in this present study is comparable to previous measurements of West Indian Avocados averaging 15 cm (Crane, 2008). Most of the avocados had fruit lengths above 10 cm which suggest that there are more West Indian avocado than Guatemalan in Ghana. Indeed, about 72% of all avocados studied had ridges on them. This is also a characteristic morphological feature of West Indian avocado. The shapes of the avocado fruits studied, including obovate, rhomboid, pyriform and ellipsoid are typical of West Indian avocados. Over 70% of all the avocados studied had these shapes, pointing to the West Indian as the origin of these avocados. These facts strongly suggest that there were more West Indian avocado in Ghana. Furthermore, more than 70% had medium to strong glossy skin. Very few (13.2%) had rough skin which is characteristic of Guatemalan avocado (Bergh and Ellstrand, 1986).

A typical avocado fruit weighs about 200 to 300 g fresh weight (Paz-Vega, 1997). In the study, more than 50% of the avocado fruits sampled weighed between 220 and 370 g. These weights are impressive in a developing country like Ghana where no plant growth regulators (PGR) (Lovatt, 2005) are used to enhance growth and development of crops. This implies that, there are potentially a lot of avocado accessions in Ghana that could do without the use of PGRs. Majority of the fruits had thin skin thickness with a few thick skin thickness of 5 mm. Thin and medium fruit skin thickness is a characteristic feature of West Indian species and their varieties.

The results showed five different seed shapes. Majority of the fruits had large seeds, while a few had small seeds. Literature shows that large seeds are characteristic features of Mexican and West Indian races while small seeds are typical characteristic features of the Guatemalan race (Bergh and Lahav, 1996).

Three major clusters were obtained using the characters measured in a dendrogram. This indicates that avocado samples from the various districts in the Ashanti and Central Regions of Ghana were not exclusively different. It is likely that the same set of planting materials circulates in the study areas and that one should not expect much morphological variations in these areas. Many farmers in Ghana are migratory whose produce are sold in other parts of the country such as the Greater Accra, part of the Western, Central and some parts of the Volta Regions. The seeds of the fruits they sell are used as propagules in these places.

Avocado samples with similar morphological characters were grouped together such that samples 1, 2, 43 and 30 though collected from different locations shared a lot of morphological characters as compared to samples 1 and 3 which were collected from the same location. These two samples did not have many characters in common. The samples in the second distinct group were closely linked. This implies that these samples share a lot of morphological features together when compared with the samples in the third distinct group which appear to have much diversity within the group. Some of the samples in the third group (e.g. sample 48) stood independent almost to the end of the link before joining the group. Samples 16 and 39 were joined to the tree at the last cluster; this showed that they share very few morphological characters with the other samples. This showed that there were some degree of morphological diversity between the avocado accessions found in the study area.

These diverse morphological variations suggest genetic diversity and ecological adaptation of accessions which have common ancestor. This may have resulted from the different climatic and soil conditions in the environment in which the seeds were planted. In addition to the environmental adaption, cross pollination between the populations found at a place over a long period of cultivation may have led to the variation observed. The similar feature observed between accessions from different locations may have resulted from the retention of some parent gene over the long period of crossing with other accession. There is therefore the need for identification of these genes to enhance breeding and commercialisation of the plant if the traits are good.

Conclusion

All the avocado trees studied had height above the 3 and 4.5 m range which is recommended for high fruit productivity. This means that the trees studied may not reach their optimum productivity as expected and harvesting may be expensive for the farmers. The leaves and other morphological characters of the avocados studied exhibited characteristics that relate to the West Indian and Guatemalan races. Moreover, the results of the field work indicate the samples from the various districts were not exclusively different from each other. A probable reason may be that the seeds of the same accessions might have been used as propagules by migratory farmers. The accessions in the area might be the same as the ones introduced over a century ago. There is the need to introduce some commercially improved accession to the old stock to bring more genetic diversity and enhance the chances of commercialisation and export of the avocado to make farming and propagation attractive to farmers. There is need for germplasm collection of the existing stock to enhance conservation of genes.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Bergh B, Ellstrand N (1986). Taxonomy of the Avocado. California Avocado Society Yearbook, 70:135-146.

Bergh BO, Lahav E (1996). Avocados. In: Janick J, Moore JN (Eds.), Fruit Breeding 1: Tree and Tropical Fruits, New York: John Wiley and Sons, pp. 113-166.

Crane J (2008). Minor Cultivars: Early Season - West Indian seedling. Tropical research and education (TREC), University of Florida. http://trec.ifas.ufl.edu/crane/avocado/west-indian-seedling.shtml. Accessed 28 August 2016.

Dreher ML, Davenport AJ (2013). Hass avocado composition and potential health effects. Crit. Rev. Food Sci. Nutr. 53:738-750.

Gustafson CO (1976). World avocado production-1976. In. Sauls JW, Phillips RL, Jackson LK (Eds.). The avocado. Proc. 1st International tropical fruit short course. University of Florida, Cooperative Extension Service, Gainesville, FL., pp. 1-9.

International Plant Genetic Resources Institute (IPGRI)(1995). Descriptors for avocado (*Persea* spp.). International Plant Genetic Resources Institute, Rome, Italy, 52p.

Irvine FR (1961). Woody plants of Ghana, London, Oxford University press, 868p.

Kim BS, Gu M, Cho KC, Jung SK, Choi HS (2017). Effect of tree and branch thinning on growth, yield, and fruit quality of persimmon trees in a high-density orchard. J. Hortic. Sci. Biotechnol. 92(4):432-438.

Lovatt CJ (2005). Plant growth regulators for avocado production. California Avocado Society Yearbook 88:81-91.

Morton JF (1987). Fruits of warm climates. Julia F. Morton, Miami, Florida, 505p.

Núñez-Elisea R, Crane JH (2000). Selective pruning and crop removal increase early-season fruit production of carambola (*Averrha carambola* L.). Sci. Hort. 86:115-126.

Ochse JJ, Soule MJ Jr., Dijkman MJ, Wehlburg G (1961). Tropical and subtropical agriculture 1, New York: Macmillan, 760p.

Partida Jr. GJ (1996). Avocado canopy management for greater yields and orchard efficiency. California Avocado Society Yearbook, 80:117-131.

Paz-Vega S (1997). Alternate bearing in the avocado (*Persea americana* Mill). California Avocado Society Yearbook, 81:117-148.

Popenoe W (1920). Manual of tropical and subtropical fruits. New York: Macmillan, 52p.

Schaffer B, Wolstenholme BN, Whiley AW (2013). The avocado: botany, production and uses. CABI. 560p. https://www.cabi.org/cabebooks/ebook/20133051561.

Smith CE Jr. (1966). Archaeological, evidence for selection in avocado. Econ. Bot. 20:169-175.

Smith CE Jr. (1969). Additional notes on pre-conquest avocados in Mexico. Econ. Bot. 23:135-140.

Storey WB, Bergh BO, Zentmyer GO (1986). The origin, indigenous range and dissemination of the avocado. California Avocado Society Yearbook, 70:127-133.

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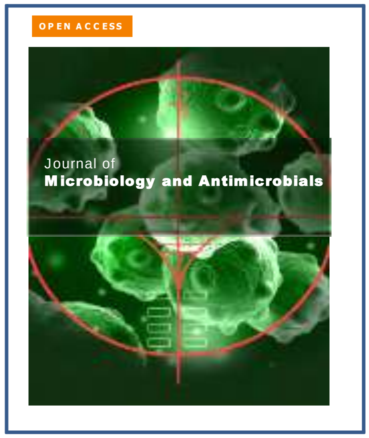

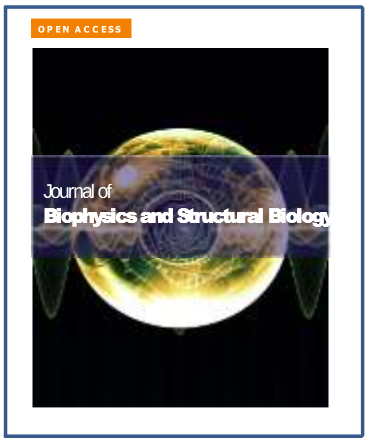

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