International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 21, No. 2, p. 411-418, 2022

RESEARCH PAPER OPEN ACCESS

Growth and yield response of fever plant "Scent leaf" (*Ocimum gratissimum*) in degraded oxisols using different soil media

Emmanuel Chukudinife Enujeke*[1] and Collins Egbuchua

Department of Agronomy, Faculty of Agriculture, Delta State University, Abraka, Delta State, Nigeria

Key words: Growth, Yield, *Ocimum gratissimum*, Different Soil media, Degraded oxisols

http://dx.doi.org/10.12692/ijb/21.2.411-418 Article published on August 20, 2022

Abstract

A study was carried out during the 2019-2021 farming season on a degraded oxisols of a humid environment to evaluate the growth and yield response of *Ocimum gratissimum* L. using four (4) different soil media. The soil media were sand, loam, sandy loam and sandy clay loam established using particle size distribution analysis and USDA textural triangle. The growth media were randomly analysed for their physico-chemical properties before three (3)kg of each growth medium was potted and arranged in a complete randomized design (CRD) replicated 3 times. 3-seedlings were transferred into each pot and later thinned to one. Data were collected on plant height, stem girth, number of leaves/branches and leaf area at 4, 8 and 12 Weeks After Transplanting (WAT). Data on number of inflorescence and total weight of fresh leaves were collected at 12 and 16 WAT. Data collected were subjected to Analysis of Variance procedure. Results of the study showed that the measured growth parameters did not differ statistically at the 4th and 8th WAT on the different growth media even when there was increase in various growth rates. At 12th and 16th WAT, there was a significant difference (P = 0.05) in plant height, stem girth, number of leaves/branches and weight of fresh leaves at 16 WAT. Loam soil was the most promising with 8.85 and 20.56kg/ha followed by sandy clay loam 8.65 and 18.92kg/ha in the number of florescence and total number of leaves at 16 WAT.

* **Corresponding Author:** Enujeke ✉ enujeke@yahoo.com

Introduction

Ocimum gratissimum L. variously known as African basil, Fever plant or Scent leaf is one of the most important commonly used vegetable to both local diets and ethno-medicine in the Subsahara Africa especially South South Nigeria, it belongs to the family Labiatae and widely distributed in the warm tropical regions of the world (Orwa, 2009). It is a perennial herb that is grown essentially for its aromatic leaves (Scent leaf), inflorescence and oils (Adeoye, 2009). The plant grows up to 1.5–2m tall at maturity and possesses small crown of pointed leaves resting on a few branches which in turn are carried by tall straight stem. The plant in most cases is grown in the wild. Few domestication of the plant is recorded, except in few homes where it is essentially used as medicinal vegetables.

Traditionally, the leaves and young inflorescence are either chopped or grinded and used to season meat especially the goat meat which has a characteristics offensive smell when slaughtered and cooked (Ojeifo and Denton, 1993). The plant is also used as food preservative agent and provides a natural alternative to chemical preservative as the extracts of the plant are used to control black pod disease of cocoa and cowpea wilt in the field (Owusu, 2005).

Several researchers have reported the relevance of the leaf extracts of *Ocimum gratissimum* species, including presence of phytochemicals (Shafqatullah *et al.*, 2013; Mallikarjuna *et al.*, 2011; Devendran *et al.*, 2011; Suprasanna *et al.*, 2012), Ethnomedical importance (Qureshi *et al.*, 2011) and insecticidal activity (Kovenda *et al.*, 2009; Singha *et al.*, 2011; Govindarajan *et al.*, 2008).

In the African local parlance, the leaves are used most frequently as sponge to remove skin blemishes and for treating dermatological disorders as well as for the formulation of tooth paste for maintaining oral hygiene (Atusa, Ojeifo and Akparobi, 2019). The most ethanolic extracts of the leaves are traditionally used for the treatment of feverish condition in human, inflammatory conditions of the throat as well as menstrual and abdominal pains in women including diarrhoea (Nweze, Bayen and Quincy, 2005). The essential oil from the leaf extract is known to have antiseptic and antibacterial properties which have been traditionally formulated into local soaps of importance (Ojeifo and Dentons, 1993).Presently, the plant *Ocimum gratissimum* L. is one of the most endangered species of plants in Africa with utmost disregard of its medicinal values to mankind which has remained unexploited in favour of western medicines. Now that the world is going organic in response to various health challenges ravaging the world population, it becomes important that *Ocimum gratissimum* should be studied to unfold its numerous medicinal values. Against this background, the objective of this study is to assess the growth and yield responses of the plant using different soil media in a degraded oxisols of humid environment.

Materials and methods

Description of the study area

The experiment was carried out in 2019–2021 farming season at the Teaching and Research Farm of Delta State University, Asaba Campus. The study area is located between Latitude 6°14`N and Longitude 6°49` E in a typical rainforest zone in Nigeria. The mean annual rainfall is about 1,845.3mm, mean annual temperature 26.3°C, mean annual humidity of about 75.5% and monthly sunshine hours of 4.7 bars (NIMET, 2017). The topography of the study area is generally undulating and the soil environment is essentially oxisols (USDA) with characteristic sandy loam to loamy surface soil texture (Egbuchua, 2017). The general vegetation is essentially secondary which have been subjected to constant clearing and burning thus crop species such as grasses, sedges and few trees plants dominate the entire environment. Land use is arable crop farming based on the onset of rainfall. The main crops cultivated include tuber and root crops, vegetables, pulses and cereals.

The Experiment

This consisted of a mini-nursery establishment and field pot experiment. The soils were collected from surrounding upland and valley bottom formed from sedimentary sandstones. The soils were assessed for their textural classes using the particle size distribution analysis (Bouyoucous hydrometer method) and defined textures of the soils determined by the USDA textural triangle. On the basis of this, four (4) distinct soil types namely, sand, loam, sandy loam and sandy clay loam were established and used for the study. Their particle size distribution are shown in (Table 1).

Seed procurement and Planting

Seeds were obtained from the wild and planted in a mini-nursery establishment broadcasted unevenly. The nursery establishment was properly nurtured by regular watering using water-hose and weeded until sprouting emerged at 3 weeks after planting. The seedlings were in the nursery for a period of two (2) months for proper establishment before being transferred to the field in pots.

Pot Experiment

Three (3) kilograms of four (4) different soil types namely sand, loam, sandy loam and sandy clay loam were weighed into 4 plastic pots replicated three times. Each of the plastic pots has a diameter and depth of 15cm and 23cm and a volume of 2.94cm^3. The experiment was arranged in a completely randomized design (CRD).

Laboratory Studies

From each of the soil types used for the study, representative samples were collected with a tubular sampling auger and bulked respectively. The samples were air-dried in an ambient room temperature of 27.5°C for 3-days, crushed and passed through a 2mm sieve mesh for laboratory analysis of their chemical properties. Soil pH was measured by using a pH meter in a 1:1 soil/water solution. Total nitrogen was estimated by the Kjeldhal method (Bremner and Mulvaney, 1982) and the organic carbon in the solution by Dichromate oxidation and titrating with Ferrous ammonium sulphate (Agbenin, 1996).

Available phosphorus was determined colorimetrically after Bray-1 extraction. Exchangeable bases were extracted with neutral 1N NH_4OAC. Total Na and K^+ were measured by using a flame photometer while Ca^{2+} and Mg^{2+} by Na-EDTA titration (Agbenin, 1990). Cation exchange capacity (CEC) was determined by Ammonium acetate solution.

Sowing/Data Collection

Three (3) seedlings of *Ocimum gratissimum* L. were transplanted into the complete randomised design arrangement in pots on the 18/6/2019. The seedling plants were later thinned to 2-plants per pot and covered shallowly with mulch materials. The pots were replicated 3-times to give a total of 12 pots. The pots were regularly watered during the early growth transplant and at 5-days interval. Data for plant height, stem girth, number of leaves/branches, leaf area were collected at 4 weeks interval on 4,8,12 and 16th week after transplanting (WAT). The heights of the plants were measured from the ground level to the apex of the last leaf using centimetre rule. Stem girth was measured using vernier caliper, number of leaves/branches were taken by counting, leaf area index was measured by multiplying the length and width of leaf. Number of inflorescences were determined by counting while total weight of fresh leaves were determined at the end of the experiment at 16th weeks after transplanting using weighing balance.

Statistical Analysis

All the crop data collected were statistically analysed using the analysis of variance package. Significant differences among means were determined using the Duncan Multiple Range Test (DMRT) procedure.

Results and discussion

The initial physico-chemical properties of the different soil media is shown in (Table 1). The sand growth medium had a particle size distribution of 92% sand, 3% silt and 5% clay-contents. This showed that the growth medium is loose, porous, incoherent due to its low clay content. The implication of these characteristics is the lack the strong ability to hold water and plant nutrient. It is also liable to strong leaching due to erosion effects. Loam soil has a good proportion of sand (48%), silt (28%) and clay (24%). Thus exhibits good permeability, water and nutrient holding capacity. Agriculturally, it is very good for crop production purposes (Acquaah, 1996).

The sandy loam growth media equally shared good proportion of sand (52%), silt (28%) and clay (20%) by textural classification (USDA). The sandy loam growth media by its composition allows for good aeration (water and air) permeability and water/nutrient holding ability because of its relative clay content. Agriculturally, then sandy loam is good for crop production practices. The sandy clay loam showed that the sand fraction was (46%), silt (19%) and clay (35%) respectively (Table 1). Thus the excellent drainage, ease of tillage, moderate permeability of silt content, and the high water and nutrient holding capacity of clay and its difficult erodibility factor make the sandy clay loam largely good for crop production (Acquaah, 1996). Because of the good physical attributes (particle size distribution) loam, sandy loam and sandy clay loam media can sustainably support the growth of *Ocimum gratissimum*. The potentials of these growth media (loam, sandy loam and sandy clay loam) have being variously buttressed Jibril, (2011), Okolie and Uduak, (2016), Nesiagho (2014) who attributed good permeability, ease of tillage, excellent water holding and nutrient holding ability, resistance to soil erosion and nutrient leaching as their good physical characteristics.

Chemical Properties

The chemical properties of the different soil growth media (Table 1) showed that sand with a pH of 5.5 loam, 5.8 sandy loam pH 5.3) depict that they were all strongly acid in reaction while sandy clay loam with a pH of 6.2 was slightly acid. The acidic nature of the soil media could be attributed to the high rainfall nature of the environment which in most cases exceed 1,750mm/annum with its attendance evils of soil erosion and nutrient leaching of the soil. The organic carbon across were generally low with sand having the lowest value of 4.78 gkg^{-1}. This was followed by sandy loam 7.68 gkg^{-1}, loam 8.34 gkg^{-1} and sandy clay loam 8.78 gkg^{-1} (Table 1).

The low organic carbon as observed could be associated with the rainfall activities in the study area with its effect on soil erosion and nutrient leaching. Other factors of organic carbon depletion include continuous cultivation and frequent bush-burning. Total nitrogen and available phosphorus are organic matter dependent in the absent of applied chemical fertilizers (Akachukwu, 2001). Thus, they were seemingly low especially with sand 0.06 gkg^{-1} and 4.35 $mgkg^{-1}$ (N and P).

Table 1. Particle Size Distribution and Chemical Properties of the Different Growth Media.

Growth media	Sand	Loam	Sandy loam	Sandy clay loam
Sand	92	48	52	46
Silt	3	28	28	19
Clay	5	24	20	35
Chemical properties				
Soil Ph	5.5	5.8	5.3	6.2
Organic carbon (gkg^{-1})	4.78	8.34	8.76	8.74
Total nitrogen (gkg^{-1})	0.06	0.08	0.07	0.12
Available p ($mgkg^{-1}$)	4.35	9.76	5.84	9.88
Exchangeable Cations ($cmolkg^{-1}$)				
Ca	3.46	5.24	4.12	6.45
Mg	0.76	1.52	0.88	1.75
K	0.14	0.16	0.14	0.20
Na	0.03	0.03	0.02	0.02
CEC ($cmolkg^{-1}$)	4.3	6.4	5.2	8.15

The low total nitrogen content is attributed to the same factors that affected organic carbon content, while low phosphorus status was due to phosphorus fixation and high acid condition of the environment (Brady and Weil, 2005, Egbuchua, 2014). The contents of exchangeable bases (Ca, Mg. K and Na) were generally low in all the growth media (Table 1) depicting the 1:1 clay mineralogy of the study area. The cation exchange capacity (CEC) was generally low thereby reflecting the intensely weathered status of the parent rocks. The general chemical properties of the various growth media showed that the soils were deficient in major plant nutrients and this is typical of the oxisols in the humid environment. According to

Agboola *et al.* (1997), the bulk of potential arable land in the tropics consisting of Alfisols, Ultisols and Oxisols have low activity clay, low inherent fertility and various nutrient imbalances.

Effects on Growth and Yield Parameters

The main effects of the different growth media on plant height, stem girth, number of leaves/ branches and leaf area was not statistically significant (P≥ 0.05) at 4 and 8[th] (WAT). Although there was observed increase in the morphological growth parameters measured, nonetheless, sand showed the least response while loam and sandy clay loam responded better in all growth parameters at 4[th] and 8[th]week after transplanting (WAT) (Tables 2 and 3) respectively.

Table 2, Effects of Growth Media on Plant height, Stem girth, No. of leaves, No. of branches and Leaf area at 4 WAT of *O. gratissimum* L. in a degraded Oxisols of humid environment.

Growth media	Plant height (cm)	Stem girth (cm)	No. of leaves	No. of branches	Leaf area (cm)
Sand	8.52[a]	1.24[a]	2.52[a]	2.42[b]	1.34[a]
Loam	8.73[a]	1.28[a]	2.58[a]	3.24[b]	1.38[a]
Sandy loam	8.58[a]	1.32[a]	2.69[a]	2.62[ab]	1.36[a]
Sandy clay loam	8.73[a]	1.36[a]	2.75[a]	3.35[a]	1.38[a]

Values along the column carrying the same letters are not significantly different (P≤0.05) level of probability. using Duncan Multiple Range Test (DMRT)

NS = Not significantly different * = Significantly different at p< 0.05

Table 3. Effects of Growth Media on Plant height, Stem girth, No. of leaves, No. of branches and Leaf area at 8 WAT of *O. gratissimum* L. in a degraded Oxisols of humid environment.

Growth media	Plant height (cm)	Stem girth (cm)	No. of leaves	No. of branches	Leaf area (cm)
Sand	10.35[b]	1.26[a]	5.24[b]	4.52[b]	1.36[a]
Loam	12.54[a]	1.32[a]	8.72[a]	6.46[a]	1.98[a]
Sandy loam	10.64[b]	1.28[a]	5.72[b]	5.38[a]	1.58[a]
Sandy clay loam	12.75[a]	1.36[a]	8.78[a]	6.85[a]	1.92[a]

Means in the same column with similar alphabets are not significantly different at P≤ 0.05 using Duncan Multiple Range Test (DMRT)

NS = Not significantly different * = Significantly different at p< 0.05

At 12[th] and 16[th] (WAT), the effects on the measured plant growth characteristics were obvious. Plant height, stem girth, number of branches/leaves, leaf area as well as numbers of inflorescences were all significantly influenced (P>0.05) on loam and sandy clay loam growth medium (Tables 4 and 5). The total weight of fresh leaves at harvest 16[th] WAT were significantly different (P≥0.05). the total weight of fresh leaves 18.72kg/ha, obtained from loam and 18.92kg/ha from sandy clay loam respectively were significantly different to 12.53kg/ha and 13.10kg/ha obtained from sand and sandy loam (Table 5).

Table 4. Effects of Growth Media on Plant height, Stem girth, No. of leaves, No. of branches, Leaf area and No. of inflorescence at 12 WAT of *O. gratissimum* L. in a degraded Oxisols of humid environment.

Growth media	Plant height (cm)	Stem girth (cm)	No. of leaves	No. of branches	Leaf area (cm)	No. of inflorescence
Sand	15.56[d]	2.15[a]	8.35[b]	4.20[ab]	1.38[a]	2.50[ab]
Loam	30.14[a]	3.56[a]	10.88[a]	5.76[a]	1.74[a]	3.85[a]
Sandy loam	18.45[c]	2.18[a]	8.76[b]	5.32[a]	1.42[a]	3.65[a]
Sandy clay loam	28.10[b]	3.14[a]	10.46[a]	5.26[a]	1.52[a]	3.72[a]

Means having the same letters in the same column are not significantly different at P≤ 0.05 using Duncan Multiple Range Test (DMRT)

NS = Not significantly different * = Significantly different at p< 0.05

Table 5. Effect of Growth Media on Plant height, Stem girth, No. of leaves, No. of branches, Leaf area, No. of inflorescences and Total fresh weight of leaves at 16 WAT (Harvest).

Growth media	Plant height (cm)	Stem girth (cm)	No. of leaves	No. of branches	Leaf area	No. of inflorescence	Total weight of fresh leaves (Kg/ha)
Sand	25.5[c]	2.18[a]	32.18[a]	5.75[b]	3.24[b]	5.20[a]	12.53[c]
Loam	28.16[b]	3.82[b]	43.14[b]	8.70[a]	5.80[b]	8.85[b]	20.56[a]
Sandy loam	27.48[b]	2.19[a]	33.14[a]	5.85[b]	3.84[a]	8.52[b]	18.72[b]
Sandy clay loam	35.14[a]	3.52[b]	42.75[b]	7.72[a]	5.34[a]	8.65[a]	18.92[b]

Means with similar alphabets in the same column are not significantly different at P≤ 0.05 using Duncan Multiple Range Test

NS = Not significantly different

The results of the study clearly defined loam and sand clay loam growth media as being better for the growth of *Ocimum gratissimum*. The reasons were the combined physical attributes of good aeration, moderate permeability and water and nutrient holding capacity. The sand and sandy loam were more porous, liable to nutrient losses through their high susceptibility to water erosion.

The findings from the present study are in harmony with the reports of many researchers (Acquaah, 1996; Nesiagho, 2014; Egbuchua, 2014).

Conclusion

Ocimum gratissimum is one of the critically endangered crop species in the Sub-Saharan Africa despite its huge medicinal values if properly cultivated with applied agronomic practices. Now that the world is going organic as an option to the manufactured drugs which currently are proving less potent in tackling the ravaging disease throughout the world presently, it becomes important that the crop is studied in all its ramifications. Although the crop is known to survive in any soil environment.

The present study shows that its commercial cultivation can best be achieved in loam and sand clay loam soils, hence thee soils are recommended as appropriate soil media for increased production of *O. gratissimum* in the study.

References

Acquaah G. 1996. Principles of crop production Theory, Techniques and Technology. Prentice-Hall of India, New Delhi India 460 p.

Adeoye E. 2002. Nitrogen recovery, essential oil yield and quality of *Ocimum gratissimum* under different crop geometrics and nitrogen rates. Indian Journal of Agronomy **30,** 23-32.

Agbenin JO. 1996. Laboratory manual for soil and plant analysis (selected methods and data analysis). Dept. of Soil Science Ahmadu Bello University, Zaria, Nigeria 140p.

Agboola AA, Eneji AE, Aiyelari EA, Tijani-Eniola A. 1997. Marginal lands, water quality and agricultural land pollutants in Nigeria. Proceedings of the 23rd Annual Conference of Soil Science Society of Nigeria March pp. 303-315.

Akachukwu 2000. Agricultural potentials, problems and sustained uses of inland valley Agroecosystem in Nigeria: In Proceedings of the 33rd Conference of agricultural Society of Nigeria (ASN) pp 203-207.

Atusa K, Ojeifo IM, Akparobi SO. 2019. Effects of some agronomic practices on plant growth and yield of fever plant (*Ocimum gratissimum*) in Delta State, Nigeria. Ph.D Thesis of the Delta State University, Abraka, Nigeria. (unpublished).

Brady NC, Weil RC. 2005. The nature and properties of soil 13th edition Pearson Prentice-Hall Inc. New Delhi India pp. 881.

Bremner JM, Mulvaney CS. 1982. Total nitrogen In: Page, A.L., Miller, R.H. and Keeney, D.R. (eds) Methods of soil analysis Part 2 Agronomy 9. Madison W.I. p. 595-624.

Cheng SS, Chua MT, Chang, EU, Huang CO, Chen WI, Chang ST. 2009. Variations in insecticidal activity and chemical compositions of leaf essential oils from *Cryptomeria japonica* at different ages. Bioresource Technology **100,** 465-470.

Devendran O, Balasubramanian U. 2011. Qualitative phytochemical screening and GC-MS analysis of *Ocimum sanctum* L. leaves. Asian Journal of Plant Science & Research 44-48.

Egbuchua CN. 2014. Characteristics and distribution of phosphorus in weathered oxisols of Anwai-Asaba, Delta State, Nigeria. Nigeria Journal of Agriculture and Food Environment. **1(2),** 87-96.

Egbuchua CN. 2017. Characterization of soils of Anwai and their productive potentials for arable crops. Journal of Applied Science **12(8),** 72-78.

Govindarajan M, Jebanesan A, Pushpanathan T. 2008. Larvicidal and ovicidal activity of Cassia fistula Linn. Leaf extract against filarial and malarial vector mosquitoes. Parasitology Research **102,** 289-292. DOI: 10.1007/s00436-007-0761-y

Jibril AD. 2011. Effects of variety and rates of poultry manure-based compost on the growth, yield and yield components of pepper. *Proceedings of the 35th Annual Conference of the Soil Science Society of* Nigeria (SSSN) 7th – 11th March, 2011 FUTO Minna, Nigeria P.83-90.

Kovendan K, Murugan K, Thiyagarajan P, Naresh K, Abirami O, Asaikkutti A. 2009. Impact of climate change on the filarial vector, *Culex quinquefasciatus* Say Diptera: Culicidae). In: International Congress of Global Warming on fliodiversity of Insects: Management and Conservation, 9-12 February Tamil Nadu, India **62.**

Mallikaiunaa K, Narasimha O, Dillipa G, Praveen B, Shreedhar B, Sree LC. 2011. Green synthesis of silver nanoparticles using *Ocimum* leaf extract and their characterization. Digest Journal of Nanomaterials Biostructructure **6,** 181-186.

Nesiagho EU. 2014. Effects of different soil media and stem cutting lengths on growth and yield of physic nut (*Jatropha curcas* L.) M.Sc Research Project of the Delta State University, Abraka, Nigeria (unpublished).

NIMET- Nigeria Meteorological Station 2007. Climatic information of Asaba and Environment (In house publication) **52(8),**12-15.

Nwaeze B, Bayan SS, Quincy N. 2005. Justification for the use of *Ocimum gratissimum* in herbal medicine and its interaction with disc antibiotics. BMC Complementary and Alternative Medicine (5) DOI: 10.1186/1472-6882-9-37

Ojeifo IM, Denton L. 1993. Growing *Ocimum gratissimum* in Nigeria, outlook of botany, Economic importance , cultivation and Research strategies. Okojie and Okoli D.U.U. (eds) *Lost crops of Nigeria:* Implication of food security; University of Agriculture, Abeokuta Conference Proceedings Series No. **3,** pp 230-235.

Okolie, PD, Uduak AC. 2016. Effects of different sources of soil growth media on the early sprouting of Native African Pear in the tropics. Nigeria Journal of Soil Research **8(5),** 78-102.

Orwa T. 2009. In vivo use of extracts from *Ocimum gratissimum* and lymbopogan nitrates against phytophtora palmvora causing black pod disease of cocoa. Anals of Applied Biology **12(1),** 173-178.

Owusu-Ansah E, Oppong-Boachie FK, Awuah RT. 2005. Control of blackpod disease of cocoa using leaf extract of *Ocimum gratissimum* L. Asian Journal of Chemistry **17.** 2004-2006.

Qureshi R, Maqsood M, Arshad M, Chaudhry AK. 2011. Ethnomedicinal uses of plants by the People of Kadhi Areas of Khushab, Punjab, Pakistan. Pakistan Journal of Botany 121-133.

Saiprasanna BS, Manohar BY, Roja R, Prasanta KC. 2012. Hepatoprotective Effects of *Ocimum canum* Sims Hydroalcoholic Leaf Extract in hR Induced Hepatic Injury in Rats Journal of Gastroenterology and Hepatology Research **211(lo),** 266-273.

Shafqatullah M, Khurram A, Khaliqurrehman Khan FA. 2013. Comparative Analyses of Ocimum sanctum Stem and Leaves for Phytochemicals and Inorganic Constituents, Middle-East Journal of Scientific Research **13(2),** 236-240,

Singha UA, Goutam C. 2011. Smoke repellency and mosquito larvicidal potentiality of Mesua ferra L. leaf extract against filarial vector Culex quinquefasciatus Say. Asian Pacific Journal of Tropical Biomedicine 119-123.

Tawátsin A, Asavdachanukorn P, Thavara U, Wongsinkongman F, Bansidhi J, Boonruad T. 2006. Repellency Of essential oils extracted from plants in Thailand against four mosquito vectors (Diptera: Culicidae) and oviposition deterrent effects against 4edes aegypti (Diptera: Culicidae). Southeast Asian Journal of Tropical Medicine Public Health **37,** 915-931.

Thamaraiselvi P, Lalitha P, Jayanthi. 2012. Preliminary studies on phytochemicals and Antimicrobial activity of solvent extracts of *Eichhornia crassipes* (Mart.) Solms. Asian. Plant Science Research **2,** 115-122.

WHO. 2007. Combating waterborne diseases at the household level Part 1. WHO, Geneva.