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Full Length Research Paper

Adoption of climate change friendly New Rice for Africa (NERICA) varieties among farmers in Mwea West Sub-county, Kenya

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Climate change and inefficient water utilization have led to marked fluctuations of the mean rice crop production in sub-Sahara Africa. In order to improve food security and households' income, adaptation strategies to climate change such as the adoption of new rice varieties are inevitable. This study examined the farmers' perception and adoption of climate change friendly New Rice for Africa in Mwea West Sub-county. The study applied the descriptive survey design with questionnaires being administered to a sample of 376 farmers. Key informants included four officers from Mwea Irrigation Agricultural Development and the Ministry of Agriculture. Quantitative data were analysed using Statistical Package for Social Sciences whereas qualitative data were analysed through establishing the categories and themes, relationships/patterns, and conclusions drawn in line with the study objectives. Results indicated a highly significant difference in adoption between farmers affiliated to Mwea Irrigation Scheme and the out-growers ($X^2 = 18.5$, df =2, p= 1.67×10^{-6}). The study concluded that the adoption of New Rice for Africa varieties in the Mwea West Sub-county is low and slow. This is mainly caused by inadequate information among the farmers as well as low market demand for the rice varieties. There is a need to enhance these rice varieties by intensifying efforts to sensitize farmers.

Key words: Climate change, new rice for Africa, adaptation strategies.

INTRODUCTION

Climate change is defined by IPCC (2007) as "a change in the state of average weather patterns attributed to both human and natural induced factors and which in addition to variability persists over long periods." According to Speranza (2010), climate change and variability has resulted in variations in temperature, rainfall patterns, and wind direction in many parts of the world. Kenya is one of the countries that have experienced serious climate change and variability. The country is already experiencing rising temperatures, erratic rainfall, increased frequency of torrential rainfall, melting and retreat of mountain glaciers, and occurrence of drought and floods (Ndiritu, 2013). Major droughts in Kenya occur every decade and their impacts are felt by the already high population and more so by the less resilient and ecologically fragile arid and semi-arid lands. This calls for intense food security measures that will help feed millions of Kenyans who continue to face severe to acute food

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insecurity (USAID, 2017a).

Rice is a significant crop in Africa, both for food security and commerce (Manneh et al., 2007). Though domestic rice production has gone up in Africa in the recent past, it has not matched with the demand. There is a need to achieve necessary adaptation to the effects of climate change (severe temperatures, numerous flooding, droughts, and high salinity of water used for irrigation) which negatively affect production to bridge the demand gap. According to United States Department of Agriculture (2017), rice imports in sub Saharan Africa will grow from 12.3 million tons in 2017 to 15.4 million by 2026. These imports are expected to exceed those of Asia, making sub-Saharan Africa to become the leading destination in the global rice trade.

Rice cultivation has helped Kenya to cope with food insecurity and is rated as the country's third staple food after maize and wheat. National rice consumption is estimated at 550,000 metric tonnes whereas the country produces only 150,000 metric tonnes of rice every year (Atera et al., 2018). The shortfall is made up through rice importation. The low production is attributed to poor water management, drought, late maturity and poor adaptability of new varieties, floods, pests and diseases, poor seed delivery systems, limited national breeding capacities, weeds, soil infertility, soil salinity and iron toxicity, lodging, high cost of production and erratic weather patterns (Olembo et al., 2010). This deficit in the supply of rice has led to a continuous increase in rice prices.

The New Rice for Africa (NERICA) is bred from African rice (*Oryza glaberrima*) and Asian rice (*Oryza sativa*) developed through the effort of the West African Rice Development Association (WARDA)/Africa Rice Center (Olembo et al., 2010). There are two types of NERICA varieties: upland NERICAs and lowland NERICAs adapted for either rain-fed or irrigated environments. In total, there are now 82 NERICA varieties – 18 uplands, 60 rainfed lowland and 4 irrigated varieties (Africa Rice Centre, 2020). The NERICA varieties for various rice ecologies are a significant international public good.

The varieties commonly planted in Kenya are NERICA 1, 4, 10 and 11. The upland varieties can grow without flooding and thus are water efficient. The varieties are also blast tolerant, resistant to logging, tolerant to soil acidity and iron toxicity, early maturing, and high yielding compared to both parents (JICA, 2006). To improve food security, households' income and reduce importation of rice, the adoption of new rice varieties such as NERICA is unavoidable. The annual rice consumption in Kenya is increasing at a higher rate compared to wheat and maize (Atera et al., 2018). On the other hand, rice yield in Mwea declined from 6.6 tonnes/ha in the 1970s to 4.0 tonnes/ha in the 1990s (Wanjogu et al*.,* 1995). Overall, rice yield in Kenya recorded a decline from 5.91 tonnes/ha in 1963 to 3.98 tonnes/ha in year 2000 (Kuria, 2004).

Studies have shown that there is a distinct flux of the mean rice crop production which has been attributed to poor water utilization and other climatic factors in Kenya (Nyamai et al., 2012). According to Hussain et al. (2020), nearly 51% of rice cultivation and production would be reduced in the ensuing century as a result of global climate change. The promotion of rice under global climate change thus remains a major challenge necessitating the development of the National Rice Development Strategy (NRDS) to promote rice production and curb food insecurity. The National Rice Development Strategy (2008-2018) reckons that to enhance water use efficiency and environmental conservation in the production of rice, there should be a drift towards upland rice production (MoA, 2009). FAO (2012) on the other hand notes that in order to realize food security for the increasing population and mitigate the effects of climate change there is a necessity to transform agriculture without further degrading the natural resource base.

The adoption of NERICA varieties though in a limited way has extended to parts of Uganda where it has become quite famous among some farmers making them abandon tobacco which is one of the country's largest cash crops (Kijima et al*.,* 2007). This has seen rice production in these areas greatly increased. However, a study conducted by Diagne et al*.* (2010) to determine the adoption level of NERICA and its determinants in rural Uganda, three years after it was introduced, found the adoption level to be only 4%. The government of Kenya has put in efforts to popularise NERICA varieties through the provision of seeds to farmers. However, most irrigation schemes in the country have not yet embraced the NERICA varieties (Abuje, 2013). Diagne (2006) observed that the high-yielding attribute of NERICA varieties does not guarantee high adoption rates as other factors such as poverty hinder its adoption.

Since NERICA varieties adaptability trials in Kenya began in the year 2003, and successful field demonstrations were done, very little information is available concerning its awareness and adoption. It is on this basis that this study was carried out to assess the farmer's perception and adoption of NERICA varieties including the factors influencing its adoption among farmers in Mwea West Sub-county, Kenya.

MATERIALS AND METHODS

Study area

The study was conducted in the Mwea West Sub-county which is in Kirinyaga County (Figure 1). The area is located between latitudes 0° 32` S and 0° 46'S and longitudes 37° 13` E and 37° 30`E, (Nyamai et al., 2012). The diurnal temperature ranges between 15 and 30°C while annual rainfall ranges between 356 and 1626 mm with an average of 950 mm (MoA, 2008). The rainfall is erratic with a bimodal distribution.

Mwea West Sub-county has different types of soils. Most of the area is covered by black cotton soils intercepted by other clay soils. There are sheets of sandy and silty soils as a result of run-offs here and there. The main types of vegetation are crops such as rice

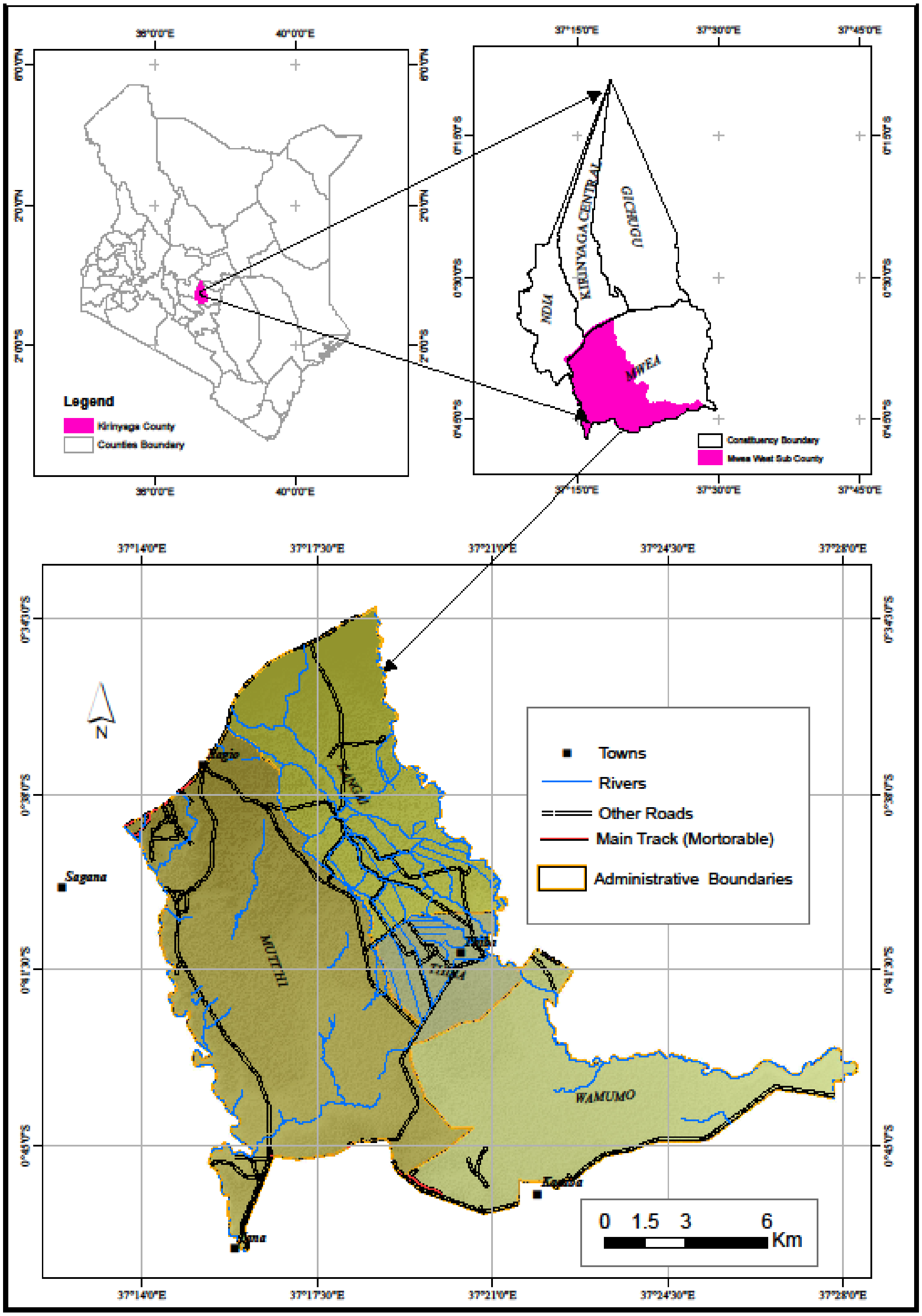

Figure 1. Map of the Study Area.
Source: Directorate of Resource Survey and Remote Sensing, Kenya.

which is mainly grown in paddies and horticultural crops such as tomatoes and French beans which are primarily grown under irrigated conditions (GoK, 2013). The area exhibits two types of settlements; clustered settlements around Kagio urban centre and scattered settlements occupying the lower arid parts of Mwea (GoK, 2013).

The rice farming scheme has a total area of 30,350 acres out of which about 15,000 acres have been developed for paddy rice production. The scheme is divided into five sections namely Tebere, Nguka, Thiba, Wamumu, and Karaba with an average area of 3,000 acres each. It supports approximately 3,242 farm families living in 36 villages (GoK, 2013). All the land is held in trust by Kirinyaga County Government and the National Irrigation Board (NIB). Farmers are given licenses to till the land which can be passed to their children (NIB, 2012).

The study targeted rice farmers in two Assembly Wards (Thiba and Mutithi) in Mwea West Sub-county. These two wards have a population of 67,964 persons represented in 19,648 households (KNBS, 2009). The farmers comprised of those under the Mwea Irrigation Scheme as well as out-growers. The study also targeted key informants from MIAD and the Ministry of Agriculture such as Agricultural Extension Officers and experts who are involved in research and dissemination of rice varieties.

Sample size and sampling procedure

The sample size was determined using the Krejcie and Morgan (1970) published table. The sampling unit was the household and a population of 19,648 households gave a sample size of 376 households. The farmers were stratified into out-growers and those under Mwea Irrigation Scheme. One hundred and eighty-eight respondents were selected using purposive sampling in each stratum. Both adopters (respondents who had adopted NERICA) and non-adopters (respondents who had not adopted NERICA) in each stratum were sampled. A total of four experts from MIAD and the Ministry of Agriculture were also purposively sampled to focus on the ones involved in the dissemination of NERICA.

Data collection instruments

Robert (2013) suggested that the research instruments used should remove any subjectivity that may be introduced in course of getting data. The study involved both primary and secondary sources of data. The instruments used to collect primary data included questionnaires and interview schedules. Secondary data was obtained from a wide range of sources ranging from published and non-published sources such as books, journals, and the internet. The combination of these instruments and sources ensured that the data collected was comparative and more precise. These tools barred the alteration of judgment based on a unilateral source of facts and figures.

Data analysis methods

Quantitative data were analysed using the Statistical Package for Social Sciences (SPSS). Qualitative data were analysed thematically to obtain useful conclusions and recommendations. Descriptive and inferential statistical analyses were done. Two measures of central tendency (mean and median) and two measures of dispersion (Variance and standard deviation) were also obtained. On the other hand, for inferential and comparative purposes, correlation analysis and chi tests were used to compare the information from farmers in the MIS and out-growers.

RESULTS AND DISCUSSION

Perception about NERICA varieties among farmers in Mwea West Sub-county

The study showed that 30.32% of the respondents agreed to the statement that most farmers were aware of NERICA varieties (Figure 2). However, the majority (59.04%) of the respondents disagreed with the statement while 10.64% were uncertain.

These results indicated that the farmers' level of awareness about NERICA rice varieties in the study area was low. However, many farmers noted that they had only heard about NERICA but had inadequate information about its management and benefits. Thus, the low level of information regarding NERICA in the Mwea West Sub-county contributed to its low adoption. This corresponds to findings by Olembo et al. (2010) which showed that before farmers adopt new agricultural technologies, they first seek information on (among other factors) water requirements, demand, the technology needed, maturity, high yields, and production cost. Lack of information was also noted as a limiting factor to devising adaptation strategies by small-scale farmers in Yatta District by Mburu et al. (2015).

Several socioeconomic characteristics were found to be important determinants of NERICA awareness and adoption among the farmers. These included but were not limited to age, major occupation, gender, years of experience, and training. These results further corroborate the findings of a study done by Nguezet et al. (2012) which revealed that people will adopt various farming practices based on awareness.

Farmers' affiliation and rate of NERICA adoption

The study established that only 19.68% of all out-growers adopted growing NERICA varieties (Table 1). On the other hand, only 31.38% of the farmers under MIS adopted NERICA. Overall, 74% of all the farmers (MIS and out-growers) in the Mwea West Sub-county had not adopted NERICA.

Drawing comparisons from the findings, it was clear that those farmers under MIS were better adopters than the out-growers. Indeed there was a highly significant difference in adoption of NERICA between out-growers and farmers in MIS ($X^2 = 18.5$, df $= 2$, p= 1.67×10^{-6}). This could be attributed to information facilitation by the scheme through extension services. These findings corroborate the findings by Muchiri (2013) which established that farmers in the MIS were better adopters of new agricultural technologies since they could easily get extension services, training, seeds, and the necessary assistance in their farms.

Factors influencing adoption of NERICA by farmers in Mwea West Sub-county

The study found that 99.47 and 98.67% of the respondents felt that water crisis and seasonal trends are the major factors influencing adoption of NERICA

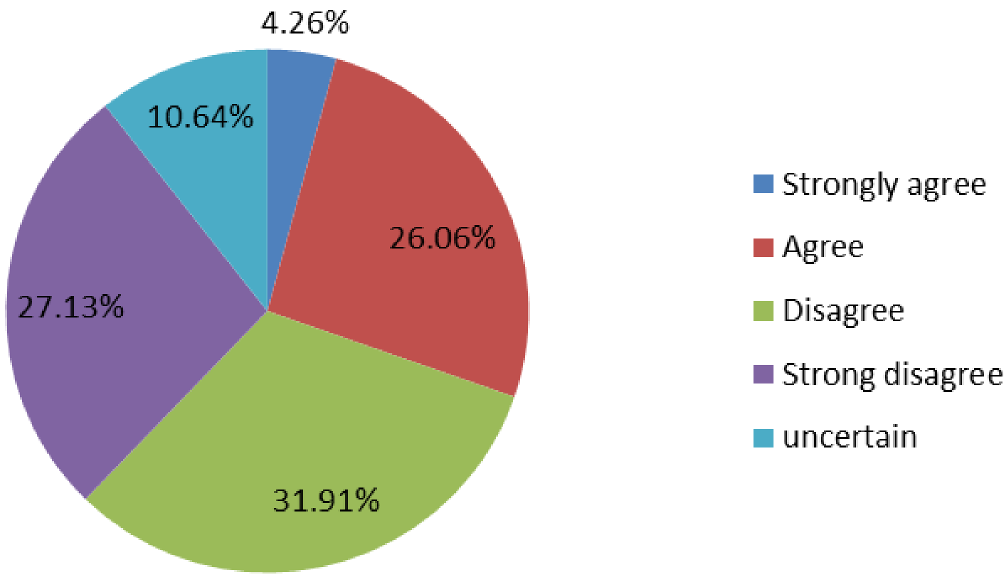

Figure 2. Perception about NERICA varieties among Mwea West Sub-county farmers.

Table 1. Farmers' affiliation and NERICA adoption by farmers in Mwea West Sub-county.

Farmer Affiliation	Adopted NERICA	Not Adopted NERICA	Totals	%
Out-grower	37 (19.68%)	151 (80.32%)	188	50
MIS	59 (31.38%)	129 (68.62%)	188	50
Total	**96 (26%)**	**280 (74%)**	**376**	**100**

Table 2. Factors influencing farmers' choice of NERICA in Mwea West Sub-county.

Factor	Frequency	%
Water crisis	374	99.47
Market forces	69	18.35
Low cost of production	287	76.33
Awareness	314	83.51
Government intervention	153	40.69
Seasonal changes	371	98.67
Maturity duration	365	98.07
High yields	278	73.94
Influence from other farmers	64	17.02

varieties respectively (Table 2). The farmers felt that there was little information regarding the continuous fluctuations in the rainfall trends in Mwea West Sub-county. This is closely linked to the water crisis which is a critical factor in irrigated rice growing. Other key factors influencing the adoption of NERICA varieties included: duration of maturation (98.07%) and awareness (83.51%). Other influencing factors were low cost of production, high yields, government intervention through provision of seeds, market forces, and other people's influence.

These findings are in agreement with those by Uwaegbuonu (2010) which indicated that awareness of any technology and upcoming farming practice is crucial in determining if individuals will adopt it or not. Farmers were aware of the existence of NERICA but lacked the necessary information and knowledge required about seed treatment, land preparation, pest, and disease

Table 3. Challenges faced by NERICA farmers in Mwea West Sub-county (N= 96).

Challenges in the cultivation of NERICA	Frequency	Percentage
Low yields	75	78
Difficulty in threshing	64	67
Low demand	93	97
Poor climatic conditions	69	72
Informational crisis	81	84
Lack of seeds	66	69

Table 4. Strategies that can spur NERICA rice adoption in Mwea West Sub-county**.**

Strategies for the adoption of NERICA	Frequency	Percentage
Training farmers	356	95
Ensure seed availability	353	94
Marketing strategies	312	83
Field demonstrations	289	63
Technological advancements	238	75

control among other key aspects associated with the propagation of NERICA. A study conducted in Nigeria funded by the Gatsby Foundation notes that; "although farmers who have access to and have adopted NERICA varieties are deriving higher yields and income, those who do not have regular access to seeds have abandoned NERICA lines in favour of low yielding local varieties" (Spencer and Leisel, 2012). This is also a reason why farmers in Mwea West Sub-county are reluctant to cultivate NERICA. Seeds have not been readily available to all farmers in the Agrovet outlets near them. The main supplier of the seeds is the Ministry of Agriculture and thus most of the farmers find it difficult to go for the seeds and opts for the readily available ones.

Challenges to adoption of NERICA by farmers in Mwea West Sub-county

The results showed that out of the 96 households that had adopted cultivation of NERICA in Mwea West Sub-county, the majority (97%) had a challenge of the produce having low demand in the market (Table 3). 82% of the adopters lacked the necessary information needed to cultivate NERICA successfully from planting to harvesting whereas 78% had a challenge of low yields from the variety. Poor and unpredictable climatic conditions also proved to be a challenge to the farmers who felt that erratic rainfall patterns had affected the adoption of NERICA varieties in the Mwea West Sub-county. This agrees with the UNFCCC (2006) report which indicated that cyclical and erratic movements in rainfall and temperatures in many parts of the world lead to high crop failures amongst many households.

Although earlier research by Abuje (2013) and Dibba (2013) had shown that NERICA exhibits high yields characteristics, farmers in Mwea West Sub-county lacked the necessary know-how or approaches to ensuring high yields from NERICA. Apart from low yields and poor markets, the study further established that NERICA farmers had difficulties in threshing the rice and accessing seeds. According to Braun and Herstatt (2009), technology must be compatible, have some relative advantage, simple to apply and capable of future changes and accommodation of future technologies. Therefore, individuals will tend to discontinue those technologies, which have no value addition even after implementation.

Although NERICA varieties have high yielding rates comparatively, it is not a guarantee that there will be high adoption rates. Studies by Diagne et al. (2010), Yanagihara et al. (2011) and Tuong (2009) have shown that other underlying factors have discouraged the adoption of NERICA rice amongst many farmers including poverty. Farmers will always tend to plant what has high demand in the market and as such the government must work harder to popularise NERICA in Kenya.

Strategies to improve adoption of NERICA in Mwea West Sub-county

The farmers in Mwea West Sub-county felt that various strategies can be employed to improve the adoption of NERICA. 95% of the respondents noted that training farmers is paramount to improving adoption (Table 4).

As noted earlier, NERICA varieties adaptability trials in

Kenya began in the year 2003 and successful field demonstrations were done. However, there was inadequate information about its management and benefits. This emphasizes the fact that before farmers adopt new agricultural technologies, they first seek information. An equal number of farmers also felt that NERICA seeds should be made more readily available in the local agro vet shops as opposed to the current situation where only the Ministry of Agriculture distributes them.

Other strategies highlighted by the farmers include advancement in technology and marketing. The Kenyan rice market is heavily dominated by Pishori variety and a lot needs to be done to ensure NERICA penetrates the market. Most consumers go for Pishori rice in Kenya increasing its demand and market (Muchiri, 2013). NERICA is not famous among many farmers mainly due to competition from these pre-existing varieties like Pishori, BW IR, and ITA which have gained market and are in high demand. These results corroborate the findings by Kijima and Sserunkuuma (2013) that suggested that NERICA rice cultivation requires a strategic approach to ensure that farmers are aware and prepared to adopt the varieties in Sub-Saharan Africa.

Conclusion

Despite the efforts that have been put in place to popularize NERICA varieties by the Kenyan government and JICA, its adoption as an adaptation strategy to climate change is low and slow in Mwea West Sub-county. This is mainly caused by inadequate information among the farmers as well as low market demand of NERICA as experienced by those who already had cultivated the variety. The availability of seeds also posed a major problem to the farmers since they were not readily available especially for out-growers who opted to plant those varieties of rice whose seeds were readily available. Farmers in Mwea West Sub-county lacked enough technology to apply in their farming practices to ensure that the cultivation of NERICA was successful and beneficial for them.

On the other hand, those farmers affiliated with Mwea Irrigation Scheme were slightly better adopters of NERICA compared to out-growers. The farmers were keen to adopt rice varieties that would take minimum time to mature and help them cope with problems of water scarcity during dry seasons. Thus, given the right information, most farmers would adopt NERICA since it takes lesser time to cultivate and harvest.

RECOMMENDATIONS

Based on the findings of this research, there is a need to sensitize the farmers' regularly on climate change and the strategies that could be employed to curb the dangers associated with the change in Mwea West Sub-county. The government should also intensify programs to educate farmers on NERICA with regard to requirements, land preparation, seed treatment, and better technologies of farming. Information regarding the benefits of planting NERICA should also be passed on to the rice farmers through agricultural extension officers, Non Governmental Organisations and Community Based Organisations. This should be accompanied by thorough marketing strategies by the central and county governments to popularise NERICA. The central and county governments could also consider offering material incentives such as free seeds to the farmers.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Chemical characterization of Kenyan *Cupressus lusitanica* Mill., *Ocimum americanum* L. and *Lippia Javanica* (Burm.f.) Spreng essential oils

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The study was designed to chemically characterize essential oils from Kenyan *Cupressus lusitanica*, *Ocimum americanum* and *Lippia javanica* and bio-prospect for new compounds as possible biocontrol agents of insect pests. Leaf essential oils of the three test plants were obtained by hydro-distillation. GC-MS analysis of leaf oils revealed that monoterpenes were the major group of chemical constituents in all plants. In *C. lusitanica* oil, 91 compounds were identified with α-pinene (13.8%), umbellulone (12.66%), δ- cadinene (7.47) and Limonene (6.64%) being major compounds. The *O. americanum* oil had 72 compounds with geraniol (18.72%), 1, 8- cineole (17.48%), elemicin (8.20%) and camphor (7.55%) being main chemical constituents. Results also in *L. javanica* oil, the 47 compounds identified were dominated by ipsdienone (26.07 %), ocimenone (14.32%), bicyclo [3.1.1] hept-3-en-2-one, 4,6,6-trimethyl-, (1S)-(10.91%) and myrcene (7.04%). The chemotypes of essential oils from the tested plants may be considered as α-pinene-umbellulone, geranial-1, 8-cineole and ipsdienone-ocimenone for *C. lusitanica, O. americanicum* and *L. javanica* respectively. The chemical constituents such as α-pinene, umbellulone, geraniol, 1, 8-cineole and myrcene are known to have insecticidal properties. Therefore, the essential oils have possible uses in production of natural pesticides of plant origin for sustainable management of insect pest.

Key words: Essential oil, *Cupressus lusitanica*, *Ocimum americanum*, *Lippia javanica*, botanical pesticide.

INTRODUCTION

Essential oils are secondary plant metabolites that defend plants directly or indirectly against microorganisms and herbivores (Isman et al., 2011; Regnault-Roger et al., 2012; Isman, 2020). Many researchers have reported that essential oils mainly consist of monoterpenes, sesquiterpenes, phenylpropanoids, alcohols, esters, aldehydes, ketones, among others (Castillo et al., 2009; Bett et al., 2016). Furthermore, plants belonging to the families of Annonaceae, Asteraceae, Apiaceae, Chenopodiaceae, Cupressaceae, Lauraceae, Lamiaceae,

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Meliaceae, Myrtaceae, Poaceae, Piperaceae, Rutaceae, Verbenaceae and Zingiberaceae were reported as promising sources of botanical insecticides (Souza et al., 2008; Castillo et al., 2009; Ogendo et al., 2012; Bett et al., 2016; Kiplagat et al., 2020). However, many important compounds have been identified from plants but many remain to be identified and tested for their activity against many organisms. This huge pool of natural chemicals is largely underutilized for development of pesticides. Different authors have reported the medicinal value of *C. lusitanica*, *O. americanicum* and *L. javanica* but there been few reports of the pesticidal properties of leaf essential oils from the plants (Viljoen et al., 2005; Mujovo et al., 2008; Chikukura et al., 2011; Teke et al., 2013; Kipkore et al., 2014).

Cupressus lusitanica has been reported to have phytochemical, ethno-botanical, agricultural, ornamental and industrial importance (Kamatenesi-Mugisha et al., 2013; Teke et al., 2013). In other research reports, the essential oil *C. listanica* has been shown to have antibacterial and antifungal activities against *Bacillus cereus* and *Aspergillus niger,* respectively (Hassanzadeh et al., 2010). On the other hand *O. americanum* is useful in medical practice in treatment of dysentery, leprosy, pruritus, parasitic infections helminthiasis, anorexia, dyspepsia, flatulence, vomiting, poisonous affections, fever among others (Yamada et al., 2013). The screening of *L. javanica* for pharmacological activity has indicated that its activities include antimalarial, antimicrobial, antioxidant, antiplasmodial, anticancer, antiamoebic, antidiabetic, and pesticidal properties (Viljoen et al., 2005; Van Wyk, 2011; Mujovo et al., 2008).

It is also a known fact that plants with medicinal properties are likely to have reproductive inhibition antifeedant, toxic, repellent properties against field and stored product insect pests (Pandey et al., 2017). Furthermore, reports on the qualitative and quantitative variations of chemical constituents among plants from same species and growing in different parts of the world may be associated to environmental conditions and genetic differences. Variations in analytical methods can also be responsible. Therefore, it is scientifically stimulating to screen essential oils from different plant species to determine whether they possess pesticidal properties. In addition, few research efforts have directed towards determining chemical constituents of aromatic plants of medicinal and pesticidal importance in the Eastern African region. Therefore, the main focus of the current study was to determine chemical constituents of essential oils of *C. lusitnica*, *O. americanum* and *L. iavanica* growing in Kenya.

MATERIALS AND METHODS

Plant materials collection and essential oil extraction

The fresh plant leaves were collected from different geographic regions in Kenya: *C. lusitanica* from Busia (0º25'20.02"N, 35º7'45.00"E, 1215 MASL), *O. americanum* from Homa Bay (0º22'03''S, 35º16'59''E, 2002 MASL) and *L. javanica* from Nakuru (0º20'23.52''S, 35º56'34.67'', 2250 MASL), Kenya in December, 2019. The fresh plant leaves were separately packed in paper bags and transported to the laboratory for essential oil extraction. The identification of plant species was carried out on sight based on professional expertise, literature materials and pictorial aids (Bett et al., 2016). The preserved samples of each plant species were presented to Plant Taxonomist, from Department of Biological Sciences, Egerton University for confirmation of identity. The preserved voucher samples of plant materials were then deposited at the herbarium of Egerton University. The fresh leaves of *C. lusitanica, O. americanum* and *L. javanica* weighing 500g were water extracted using a modified Clevenger-type apparatus. After 4 (h) of hydro-distillation the floating oil on top of the water was collected. The remaining water in the oil removed over anhydrous sodium sulphate (Na2SO4) and dried oil stored in the refrigerator at below 4 ºC until use (Bett et al., 2016).

GC-MS analysis and determination of essential oil constituents

The chemical constituents of essential oils from plant leaves were analysed using an HP-7890A Gas Chromatograph (GC) connected to an HP 5975 C Mass Spectrometer (MS) (Agilent, Wilmington, USA) at the International Centre of Insect Ecology and Physiology (ICIPE), Nairobi. From each sample 1mg was separately weighed and dissolved in 1 mL dichloromethane, dried using anhydrous sodium sulphate (Na2SO4) to make a stock solution (1 mg/mL). The experimental sample was obtained whose final concentration was 100 ng/µL. The samples were analyzed on an GC-MS in in full scan mode and a HP-5 MS low bleed capillary column (30 m × 0.25 mm i.d., 0.25 µm) (J and W, Folsom, CA, USA). The carrier gas was Helium (1.25 ml/min, constant flow mode) and the injection mode was split mode. The oven temperature was programmed at 35 ºC (for 5 min) to 280 ºC at 10 ºC/ min(5.5min) and then at 285ºC @50ºC/min (14.9 min) and the total run time was 50 min. The electron ionization mass spectra were acquired at 70 eV within a mass range of 38–550 Daltons (Da) during a scan time of 0.73 scans s-1 whereas the ion source was maintained at a temperature of 230 ºC. The essential oil constituents were identified by comparing mass spectra with library data (NIST05a and Adams MS HP, USA) and by comparison of the retention times with mass spectra (Adams et al., 1997).

RESULTS

The percentage yields (w/w) of essential oil extraction indicate that *C. lusitanica* leaves were richer (0.35 ± 0.2%) in essential oils as compared to *O. americanum* (0.27 ± 0.06%) and *L. javanica* (0.15 ± 0.09%). Tables 1 to 3 shows the retention time (min) identified chemical constituents and percentage concentration of oils obtained from *C. lusitanica, O. americanum* and *L. javanica.* The results of *C. lusitanica*, *O. americanum* and *L. javanica* essential oil extraction and GC-MS analysis showed that the oils were dominated by monoterpenes. However, each of the essential oils had different major chemical constituents. In *C. lusitanica* oil, 91 compounds were identified, corresponding to 99.8% of the total essential oil composition. The monoterpene hydrocarbons were 38.63%- dominated by α-pinene (13.8%), limonene

Table 1. Retention time (min), Retention Index (RI) identified chemical constituents and percentage concentration of oils obtained from *C. lusitanica* leaves.

PK No.	Retention time	Retention index	Compound name	Mean % concentration (n=3)
1	7.38	823	(E)-3-Methylpenta-1,3-diene-5-ol	0.01
2	8.56	869	2-Heptanol	0.06
3	8.90	882	Tricyclene	0.07
4	9.31	898	α-Pinene	13.80
5	9.52	908	Camphene	0.28
6	9.66	914	2-methyl-5-(1-methylethyl)-, (1.α.,2.α.,5.α.)-Bicyclo[3.1.0]hex-3-en-2-ol,	0.04
7	10.11	934	Sabinene	3.41
8	10.29	942	1-Octen-3-ol	0.05
9	10.50	952	Myrcene	2.32
10	10.72	962	α-Phellandrene	0.85
11	10.82	966	δ-3-Carene	0.56
12	10.97	973	δ-2-Carene	1.70
13	11.18	982	ortho-Cymene	4.07
14	11.27	986	Limonene	6.64
15	11.58	1000	(E)-β-Ocimene	0.11
16	11.77	1012	γ-Terpinene	1.72
17	11.91	1021	cis-Sabinene hydrate(IPP vs OH)	0.07
18	12.29	1043	Terpinolene	2.05
19	12.34	1046	2-Nonanone	0.21
20	12.68	1067	1,3,8-para-Menthatriene	0.06
21	12.84	1077	cis-para-Menth-2-en-1-ol	0.13
22	13.07	1091	bis(1-methylethylidene)-Cyclobutene	0.06
23	13.14	1095	E,E-2,6-Dimethyl-1,3,5,7-octatetraene	0.30
24	13.30	1104	Camphene hydrate	0.22
25	13.49	1116	2,6,6-trimethyl-, (1.α,2β.,5.α.)-Bicyclo[3.1.1]heptan-3-one	0.02
26	13.83	1136	Umbellulone	12.66
27	13.87	1138	Terpinen-4-ol	1.37
28	13.90	1098	α,α,4-trimethyl-Benzenemethanol,	0.18
29	13.96	1143	Cryptone	0.19
30	14.00	1145	α-Terpineol	0.42
31	14.33	1165	1-(2-furanyl)-Ethanone	0.03
32	14.43	1171	Propanoic acid, 2-octyl ester, (R or S)	0.34
33	14.50	1175	3,7-dimethyl-2-Octen-1-ol	0.09
34	14.74	1189	Carvacrol methyl ether	0.33
35	14.93	1200	3-methyl-6-(1-methylethyl)-2-Cyclohexen-1-one	0.09
36	15.24	1220	4-(1-methylethyl)-1-Cyclohexene-1-carboxaldehyde	0.10
37	15.37	1229	Bornyl acetate	0.28
38	15.44	1234	Thymol	0.31
39	15.56	1242	3,7,7-trimethyl-Bicyclo[4.1.0]hept-2-ene	0.25
40	15.73	1254	2E,4E-Decadienol	0.15
41	15.92	1266	Myrtenyl acetate	0.10
42	16.09	1277	(1R)-2,2-dimethyl-3-methylene-Bicyclo[2.2.1]heptane	0.08
43	16.64	1315	*α*-Copaene	0.48
44	16.89	1333	cis-Muurola-3,5-diene	0.15
45	16.93	1336	1-methyloctyl ester-Butanoic acid	0.09
46	17.00	1341	α-Funebrene	0.18
47	17.10	1348	Acora-3,7(14)-diene	0.08
48	17.16	1352	α-Cedrene	0.34
49	17.24	1359	E-Caryophyllene	1.33

Table 1. Contd.

50	17.63	1386	Dauca-5,8-diene	0.81
51	17.68	1390	α-Humulene	0.46
52	17.75	1395	δ-Cadinene	0.31
53	17.81	1399	*β*-Cubebene	1.62
54	17.91	1407	trans-Cadina-1(6),4-diene	0.46
55	18.00	1414	27.96 Curcumene<ar->	2.10
56	18.17	1427	cis- Muurola-3,5-diene	1.69
57	18.26	1434	Amorpha-4,7(11)-diene	2.99
58	18.38	1443	β-Curcumene	2.71
59	18.46	1449	γ-Cadinene	3.13
60	18.58	1458	δ- Cadinene	7.47
61	18.67	1465	trans-Cadina-1,4-diene	0.52
62	18.72	1469	α-Cadinene	1.09
63	18.95	1487	trans-Dauca-4(11),7-diene	0.29
64	19.02	1492	α-Calacorene	0.13
65	19.18	1505	1,6-dien-5-ol-Germacra	0.59
66	19.26	1512	Germacrene B	0.21
67	19.53	1534	Cedrol	0.54
68	19.64	1543	1,10-di-epi-Cubenol	0.48
69	19.79	1556	1-epi-Cubenol	0.78
70	19.84	1560	Italicene	1.44
71	19.97	1570	γ-Cadinene	4.79
72	20.13	1584	α-Cadinol	3.99
73	20.39	1606	α-Bisabolol	0.57
74	20.81	1642	6-Isopropenyl-4,8a-dimethyl- 1,2,3,5,6,7,8,8a-octahydro-naphthalen-2-ol	0.10
75	20.94	1653	Cyclopentadecanolide	0.09
76	22.02	1766	6,10,14-trimethyl-2-Pentadecanone	0.03
77	22.58	1826	Cis-A/B-Sclareoloxide	0.02
78	22.75	1842	Isopimara-9(11),15-diene	0.02
79	23.43	1906	Isophyllocladene	0.61
80	23.66	1931	13-epi-Manool oxide	0.27
81	23.81	1947	4-methylene-2,8,8-trimethyl-2-vinyl-Bicyclo[5.2.0]nonane	0.02
82	23.92	1960	Phyllocladene	0.07
83	24.09	1978	7-butyl-1-hexyl-Naphthalene	0.02
84	24.23	1994	(4aS-trans)1,2,3,4,4a,9,10,10a-octahydro-1,1,4a-trimethyl-7-(1-methylethyl)Phenanthrene	0.20
85	24.40	2012	5-α-Androst-16-en-3-one	0.04
86	24.50	2022	Abietadiene	0.13
87	24.93	2068	Nezukol	0.21
88	25.46	2124	Sandaracopimarinal	0.05
89	26.25	2212	Sempervirol	0.08
90	26.48	2238	trans-Totarol	0.29
91	26.62	2255	cis- Ferruginol	0.17
			Total identified (%)	99.8
			Monoterpene hydrocarbons	38.63
			Oxygenated monoterpenes	15.77
			Sesquiterpene hydrocarbons	35.37
			Oxygenated sesquiterpenes	6.56
			Diterpenes	2.14
			Others	1.53

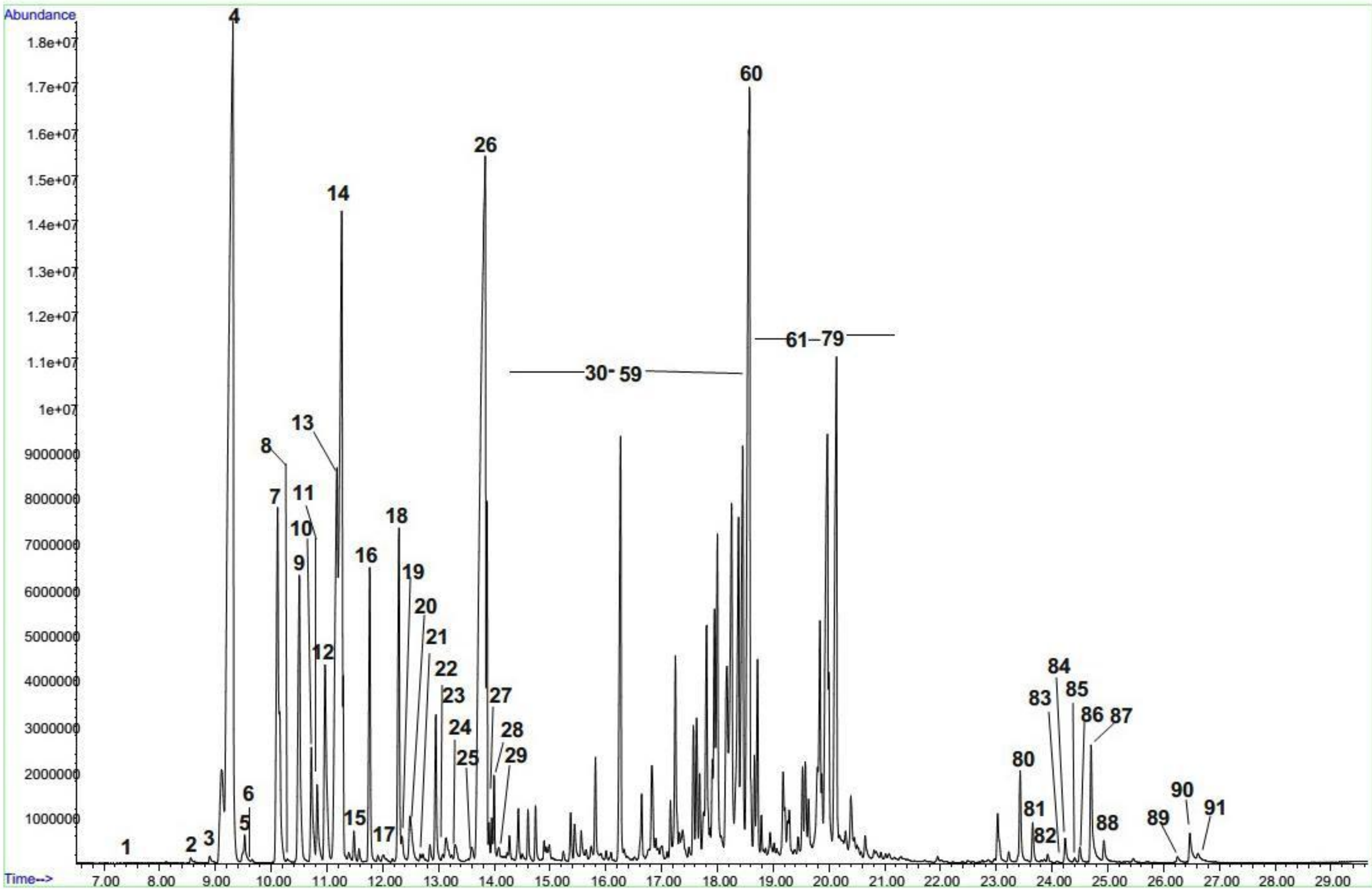

Figure 1. Representative of total ion chromatogram of the leaf essential oil of *C. lusitanica*, Peaks 1 to 91 indicate the essential oil components identified in Table 1.

(6.64%) and ortho-cymene (4.07%). On the other hand oxygenated monoterpenes were 15.77% with umbellulone (12.66%) and Terpinen-4-ol (1.37%) as major compounds. The sesquiterpene hydrocarbons and oxygenated sesquiterpenes were 35.37 % and 6.56% respectively. The major sesquiterpene hydrocarbons and oxygenated sesquiterpenes were cadinene (7.47%) and α-cadinol (3.99%), respectively (Table 1 and Figure 1).

Table 2 and Figure 2 shows the retention time (min) identified chemical constituents and percentage concentration of oils obtained from *O. americanum.* In total, 72 compounds were identified, corresponding to 99.5 % of the total essential oil composition. The leaf essential oil contained 36.32, 36.19, 24.4 and 1.85% monoterpenes hydrocarbons, oxygenated monoterpenes, sesquiterpene hydrocarbons, and oxygenated sesquiterpenes, respectively.

The major monoterpenes hydrocarbons were1, 8-cineole (17.48%), camphor (7.55%) and myrecene (2.75%) whereas oxygenated monoterpenes were geraniol (18.72%), Eugenol (6.40%), and geranyl propanoate (3.91%). On the other hand, sesquiterpenes hydrocarbons were represented by elemicin (8.20%), β-bisabolene (3.78%) and caryophyllene (E) (2.22%) whereas oxygenated sesquiterpenes were in trace amounts. The composition of the essential oil of *L. javanica* is listed in Table 3 and the peaks depicted in Figure 3. As shown, a total of forty-seven (47) compounds were identified, consisting of mainly of oxygenated monoterpenes (67.82%) followed by sesquiterpene hydrocarbons (19.35%), monoterpene hydrocarbons (10.95%) and oxygenated sesquiterpenes (1.34%). It's noted that the major monoterpene hydrocarbon was myrcene(7.04%) whereas oxygenated monotwerpenes were mainly ipsdienone (26.07%), ocimenone (14.32%), and bicyclo [3.1.1]hept-3-en-2-one, 4,6,6-trimethyl-, (1S)-(10.91%), On the other hand sesquiterpene hydrocarbons were dominated by caryophyllene(E) (5.11%) and germacrene D (4.78%). When the chemical constituents of the three essential oils were compared, the highest amounts of monoterpenes were found in *L. javanica* (87.77%), followed by O. *americanum (*72.51%) and *C. lusitanica* (54.40%) in decreasing amounts, respectively. The converse was the

Table 2. Retention time (min), Retention Index (RI) identified chemical constituents and percentage concentration of oils obtained from *O. americanum* leaves.

PK No.	Retention time	Retention index	Compound name	Mean % concentration (n=3)
1	9.07	889	α-Thujene	0.04
2	9.19	894	α-Pinene	0.59
3	9.51	907	Camphene	0.48
4	10.12	935	β-Pinene	1.81
5	10.29	942	1-Octen-3-ol	0.15
6	10.43	949	6-methyl-5-Hepten-2-one	0.45
7	10.49	951	Myrcene	2.75
8	10.61	957	3-Octanol	0.17
9	10.71	961	α-Phellandrene	0.33
10	10.95	972	δ-2- Carene	0.33
11	11.11	979	para-Cymene	0.15
12	11.18	982	D-Limonene	0.88
13	11.31	988	1,8-Cineole	17.48
14	11.38	991	(Z)-β-Ocimene	1.16
15	11.52	997	Phenylacetaldehyde	0.05
16	11.57	1000	(E)-β-Ocimene	1.09
17	11.75	1011	γ-Terpinene	0.46
18	11.91	1020	trans-Sabinene hydrate(IPP vs OH)	0.30
19	12.17	1036	trans-(-)5-methyl-3-(1-methylethenyl)-Cyclohexene	0.04
20	12.43	1051	1-(6,6-dimethylbicyclo[3.1.0]hex-2-en-2-yl)-Ethanone	0.07
21	12.49	1055	Linalool	2.34
22	12.63	1064	Ketone, isopropylidenecyclopropyl methyl	0.11
23	12.75	1011	2-methyl-6-methylene-1,7-Octadien-3-one	0.08
24	12.97	1084	allo-Ocimene	0.93
25	13.18	1097	neo-allo-Ocimene	0.15
26	13.27	1103	Camphor	7.55
27	13.52	1117	Pinocarvone	0.09
28	13.70	1128	4-methyl-Phenol	0.06
29	13.75	1131	Terpinen-4-ol	0.66
30	13.97	1143	α- Terpineol	1.31
31	14.05	1149	(-)-Myrtenol	0.52
32	14.52	1176	Nerol	0.46
33	14.71	1187	Neral	0.16
34	15.02	1206	Geraniol	18.72
35	15.16	1215	Geranial	0.47
36	15.57	1243	Geranyl formate	0.13
37	15.72	1253	(Z)-7-methyl-,2-Decene	0.05
38	16.26	1289	α-Cubebene	0.17
39	16.39	1297	Eugenol	6.40
40	16.54	1308	E-Isoeugenol	0.45
41	16.67	1317	Geranyl propanoate	3.91
42	16.78	1325	β-Bourbonene	1.00
43	16.82	1328	Germacrene D	0.53
44	17.04	1344	8,9-dehydro-Cycloisolongifolene,	0.13
45	17.10	1348	α-Gurjunene	0.07
46	17.24	1359	E-Caryophyllene	2.22
47	17.35	1366	β-Copaene	0.32
48	17.39	1369	α-cis-Bergamotene	0.56
49	17.48	1375	Sesquisabinene	0.08

Table 2. Contd.

50	17.55	1380	Germacrene B	0.14
51	17.61	1385	(E)-beta-Farnesene	1.11
52	17.67	1389	α-Humulene	0.41
53	17.79	1398	trans-5-diene-Muurola-4(14),	0.22
54	17.93	1409	γ-Amorphene	0.15
55	18.02	1415	Germacrene A	0.76
56	18.08	1420	α-trans-Bergamotene	0.38
57	18.16	1426	Z-Methyl isoeugenol	0.41
58	18.21	1430	α- Muurolene	0.26
59	18.31	1438	β-Bisabolene	3.78
60	18.41	1446	trans-Muurola-4(14),5-diene	0.29
61	18.50	1453	δ-Amorphene	0.51
62	18.63	1462	cis-Cadina-1,4-diene	0.09
63	18.70	1468	(Z)-α-Bisabolene	1.79
64	18.76	1473	α-(eller b-) Calacorene	0.13
65	18.86	1480	Elemicin	8.20
66	19.16	1503	2,7-dimethyl-5-(1-methylethenyl)-1,8-Nonadiene	0.19
67	19.25	1511	1,Z-5,E-7-Dodecatriene	0.40
68	19.29	1514	Caryophyllene oxide	1.14
69	19.89	1564	4,4-dimethyl-Tetracyclo[6.3.2.0(2,5).0(1,8)]tridecan-9ol	0.34
70	19.97	1570	Elemicin	0.20
71	20.08	1579	α-Cadinol	0.14
72	25.12	2088	Octadecanoic acid	0.02
			Total identified (%)	99.5
			Monoterpene hydrocarbons	36.32
			Oxygenated monoterpenes	36.19
			Sesquiterpene hydrocarbons	24.4
			Oxygenated sesquiterpenes	1.85
			Diterpenes	-
			Others	1.24

situation with sesquiterpenes, with the highest percentage detected in *C. lusitanica* (41.93 %) followed by *O. americanum* (26.25%) and *L. javanica* (20.69 %), respectively. Diterpenes were found in trace amounts (2.14%) in *C. lusitanica* leaf essential oils.

DISCUSSION

The chemical constituents of *C. lusitanica*, *O. americanum* and *L. javanica* essential oils revealed in the present study indicate a variation in yield, number and concentration of chemical constituents. However, the main chemical constituents in oils of the three plant species were dominated by monoterpene hydrocarbons. It is noted that in *C. lusitanica* oil, the major compounds were; α–pinene, umbellulone and Limonene. The finding of the current study are also comparable to previous researches which have shown chemical composition of *C. lusitanica*, *O. americanum* and *L. javanica* varied with countries and region. For instance Teke et al. (2013) found *C. lusitanica* to contain mainly germacrene D (18.5%), epi-zonarene (8.2%), cis-calamenene (8.2%), terpinen-4-ol (6.3%), linalool (6.0%) and umbellulone (6.0%). Similarly, the main components *C. lusitanica* oils has been found also to contain α-pinene (70.1%), δ-3-carene (45.4%), umbellulone (15.2%), β-phellandrene (10.8%) terpinen-4-ol (9.7%) and myrcene (5.8%) (Bett et al., 2016). On the other hand, the main chemical constituents in *O. americanum* essential oil were Geraniol, 1, 8-cineole, elemicin and Camphor. In other studies, the main chemical constituents in *O. americanum* oil have been reported to include citral, linalool, geraniol, citronellol and 1, 8-cineole (Ilboudo et al., 2010; Yamada et al., 2013). In the same way, *L. javanica* oil was dominated by ipsdienone, ocimenone, and bicyclo [3.1.1] hept-3-en-2-one, 4, 6, 6-trimethyl-, (1S)-, myrcene, caryophyllene (E) and germacrene D.

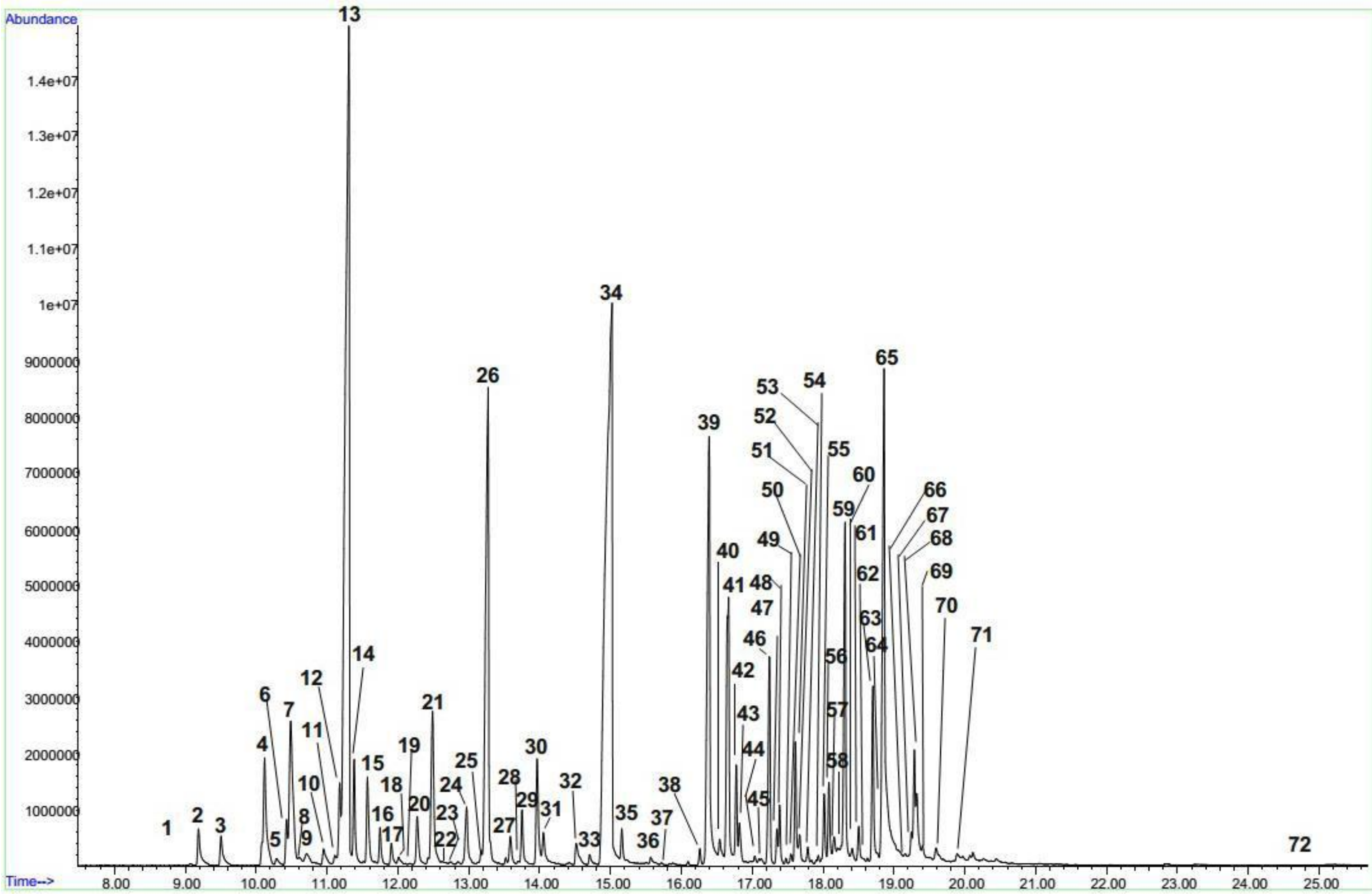

Figure 2. Representative of total ion chromatogram of the leaf essential oil of *O. americanum*, Peaks 1 to 72 indicate the essential oil components identified in Table 2.

Several other authors have indicated that *Lippia javanica* oil is rich in caryophyllene, carvone, ipsenone, ipsdienone, limonene, linalool, myrcene, myrcenone, ocimenone, *p*-cymene, piperitenone, sabinene, and tagetenone (Viljoen et al., 2005; Lukwa et al., 2009; Chagonda and Chelchat, 2015; Maroyi, 2017).

However, Viljoen et al. (2005) using cluster analysis, found that *L. javanica* chemotypes growing in South Africa and Swaziland, were rich in myrcenone (36 to 62%), carvone- (61 to 73%), piperitenone- (32 to 48%), ipsdienonerich (42 to 61%), and linalool (>65%). The variations observed in chemical constituents and concentrations may be influenced by climatic and soil conditions in different the regions, which directly affect the metabolic processes of the plant (Chéraif et al., 2007), but also may arise from interaction of different biotic components. In addition, it has also been found that chemical constituents of essential oils could differ with species of plant, season, geographic region, and age of the plant, and the method used to extract essential oil extraction (Brooker and Kleinig, 2006, Bernard et al., 2020; Baccaria et al., 2020).

The chemical constituents found in oils in current study have been found in previous studies to have insecticidal properties against insect pests (Lee et al., 2003; Rosman et al., 2007 and Nivea et al., 2013). This supports the findings of Ilboudo et al. (2010); Olivero-Verbel et al. (2013) who reported that 1, 8-cineole, limonene and α-pinene were associated with contact toxicity of essential oils against insect pests. Similarly, Rozman et al. (2007) reported essential oils constituents containing, eugenol, 1,8-cineole, camphor and linalool to cause mortality of 85-100, 80-100 and 0-13% mortality of adult *Sitophilus oryzae*, *Rhizopherta dominica* and *Tribolium castaneum,* respectively.

The repellent properties of the major chemical constituents of essential oils of plant leaves for instance 1, 8-cineole, terpineol and α-pinene have also been reported in different researches (Tapondjou et al., 2005; Toloza et al., 2006; Bett et al., 2016). Furthermore, constituents of essential oils such as 1, 8-cineole, *p*-cymene, and γ-terpinene and α-pinene have earlier been reported to possess reproductive inhibition properties against insect pests (Sedaghat et al., 2011; Alzogaray et

Table 3. Retention time (min), Retention Index (RI) identified chemical constituents and percentage concentration of oils obtained from *L. javanica* leaves.

Peak No.	Retention Time	Retention Index	Compound name	Mean% concentration (n=3)
1	9.28	897	Camphene	0.18
2	9.86	923	Sabinene	0.15
3	10.07	932	1-Octen-3-ol	0.41
4	10.28	942	Myrcene	7.04
5	10.81	966	Menthatriene<1,3,8-para->	1.50
6	10.97	973	Limonene	0.32
7	11.01	975	Eucalyptol	0.14
8	11.17	982	Ocimene<(Z)-beta->	0.40
9	11.36	990	Ocimene<(E)-beta->	0.85
10	11.45	995	Tagetone<dihydro->	2.40
11	11.64	1004	2-Methyl-6-propylphenol	0.25
12	11.76	1011	2,4,6-Octatriene, 2,6-dimethyl-, (E,Z)-	0.05
13	12.16	1035	Epoxymyrcene<6,7->	0.34
14	12.28	1043	1,6-Octadien-3-ol, 3,7-dimethyl-	3.78
15	12.70	1068	Chrysanthenone	0.40
16	12.76	1072	Ocimene<allo->	0.43
17	13.01	1087	Camphor	0.60
18	13.18	1097	Ipsdienone	26.07
19	13.34	1106	Sorbic acid vinyl ester	1.35
20	13.61	1122	Anethole<E->	0.42
21	13.77	1132	a- Terpineol	2.05
22	14.06	1149	Verbenone	0.86
23	14.44	1171	Ocimenone<E->	14.32
24	14.55	1177	Bicyclo[3.1.1]hept-3-en-2-one,4,6,6-trimethyl-, (1S)-	10.91
25	14.99	1200	2-Cyclohexen-1-one, 6-(1-hydroxy-1-methylethyl)-3-methyl-	2.62
26	15.28	1200	1,3-Cyclohexadiene-1-carboxaldehyde, 2,6,6-trimethyl-	0.66
27	15.88	1263	Germacrene B	0.23
28	15.95	1268	Piperitenone	0.51
29	16.04	1274	Muurola-3,5-diene<cis->	0.25
30	16.16	1282	Eugenol	0.44
31	16.42	1299	Copaene<alpha->	0.32
32	16.55	1308	Bourbonene<beta->	0.39
33	16.62	1313	Elemene<beta->	0.60
34	17.02	1343	Caryophyllene(E-)	5.11
35	17.13	1351	Copaene<beta->	1.56
36	17.33	1364	Cadinene<gamma->	0.58
37	17.45	1373	Humulene<alpha->	1.36
38	17.55	1380	Aromadendrene<allo->	0.55
39	17.72	1393	Cadinene<gamma->	0.31
40	17.80	1399	Germacrene D	4.78
41	17.94	1409	Cadinene<gamma->	0.31
42	18.01	1415	Muurolene<gamma->	1.35
43	18.19	1428	Muurola-4(14),5-diene<trans->	0.29
44	18.28	1435	Cadinene<delta->	0.65
45	19.05	1495	Caryophyllene oxide	0.33
46	20.25	1593	Germacra-4(15),5,10(14)-trien-1-alpha-ol	0.22
47	24.78	2052	3-Methylbut-2-enoic acid, 4-nitrophenyl ester	0.47
			Total identified (%)	99.7

Table 3. Contd.

Monoterpene hydrocarbons	10.95
Oxygenated monoterpenes	67.82
Sesquiterpene hydrocarbons	19.35
Oxygenated sesquiterpenes	0.54
Diterpenes	-
Others	1.34

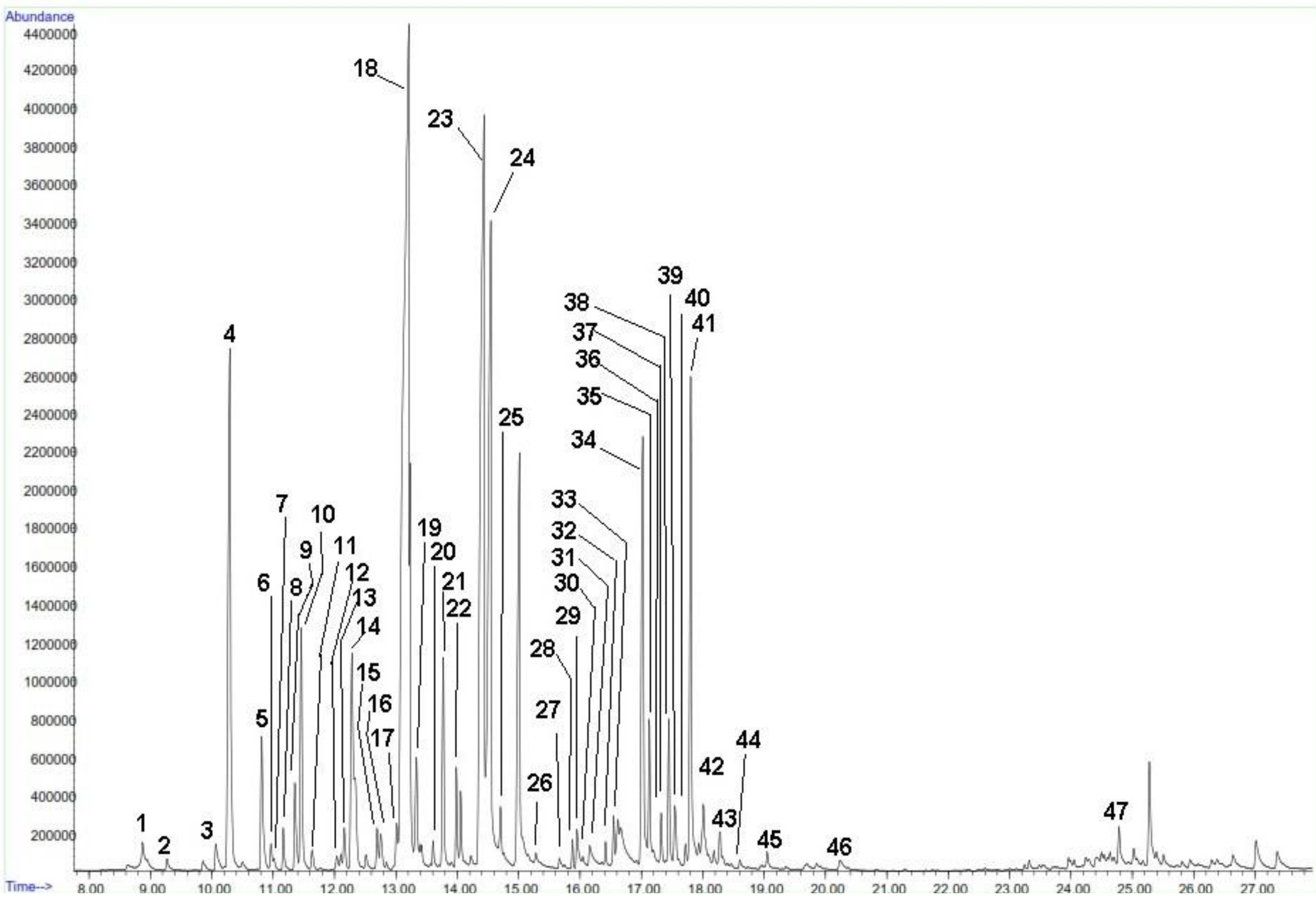

Figure 3. Representative of total ion chromatogram of the leaf essential oil of *L. javanica*, Peaks 1 to 47 indicate the essential oil components identified in Table 3.

al., 2011 and Gomah et al., 2015). For instance essential oils of *Cupressus arizonica* been found to have larvicidal activity against larvae of *Anophhleles stephensi*. The main essential oils constituents in the oil *C. arizonica* include limonene (14.44%), umbellulone (13.25%) and α-pinene (11%) (Sedaghat et al., 2011). Hence, the findings of this study is a proof that *C. lusitanica*, *O. americanum* and *L. javanica* and others possess pesticidal properties that may be exploited sustainably and cheaply for use in agriculture and related applications.

Conclusion

From the results of this study, it may be concluded that essential composition of *C. lusitanica*, *O. americanum* and *L. javanica* composition and classification were into various chemotypes varied with plant species. The essential oil constituents consisted mainly of monoterpenes that are known to have antifeedant, repellent, reproductive inhibition and insecticidal properties against insect pests of field and stored products insect pests. The presence of potentially insecticidal bioactive compounds in *C. lusitanica*, *O. amicanum* and *L. javanica* provides scientifically stimulating since natural insecticides are ecologically and environmentally friendly for the management of insect pests.

RECOMMENDATIONS

The authors recommended more studies to be carried out on the bioactivity of the essential oils against various field and stored insect pests' product. Therefore, the results of present study may lead to the formulation of new natural insecticides for management of insect pests.

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CONFLICT OF INTERESTS

The authors have not declared any conflicts of interests.

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