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Research Article

Assessment of the Effect of Neem Plant Products on House Mosquito Repellency: A Case Study of Burera and Gicumbi Districts

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Abstract

Insect pests, diseases, and weeds are interlinked and complement each other. Mosquito bites constitute a nuisance to man and his environment. The female Anopheles mosquito transmits malaria parasites, Aedes aegygti mosquitoes are known to transmit yellow fever and dengue fever. Therefore, the present study seeks to assess the effect of neem plant products on house mosquito repelling. A case study of Burera, and Gicumbi Districts. A cross-section sampling technique was used in this study. Six respondents were selected from each category to make a sixth (60) respondent sample size. The results of this study indicated that neem oil, neem leaves, and neem smoke were most effective for repelling mosquitoes respectively at ($p < 0.01$). There was a statistically significant difference between the various neem products repelling mosquito bites (Number of observations 60; P-Value < 0.0001, and R^2 of 0.833). The finding of this study also indicated that using neem plant products to repel mosquitoes should increase neem plant product value, reduce costs of chemical insecticides, increase mosquito repellency, reduce disease vectors, increase the use of biological control, control mosquito bites, reduce the death of children under five years, and increase research studies. The high need for support for increasing research on eco-friendly techniques and strategies should be enhanced as well as reducing chemical pesticide use which increases Greenhouse gas emissions and reduction of pollinators.

Keywords

Assessment, Effect, Neem Plant, Products, Mosquito, Repellency

1. Introduction

Insect pests, diseases, and weeds are interlinked and complement each other. Individually, each one of these is responsible for a considerable loss by itself but if one remains neglected, it gives rise to the infestation of the other [8]. Insects are the biggest animal group on earth; the immense biodiversity harbored by the class insect is reflected in the well-known fact that this single class has more species than all the species of all other classes of animals combined. Indeed, insects

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constitute as much as 80% of the animal kingdom [31].

Arthropods are the most diverse group of animals, with 1.7–30 million species estimated to exist. Because it is so diverse, the phylum Arthropoda includes several subphyla, including Chelicerata (spiders, scorpions, mites, etc), Mandibulata (millipedes and centipedes), Crustacea (crustaceans such as crabs and lobsters, although this is not a natural, or monophyletic, group), and Hexapoda (insects, springtails, and relatives) [25, 38].

Some insect pests cause damage to the belongings of a human being like furniture, wool, and paper (e.g. Cockroaches, furniture beetles, sliver fish, etc). While other pests cause painful bites, inject venoms (E.g. Wasps, bees sting us. Hairy caterpillars). Where nettling hairs are poisonous. Mosquitoes and bugs bite, piece, and suck blood from us. In addition, these insects are also disease-causing mosquitoes (Malaria, Filariasis, dengue fever), and houseflies (Typhoid, Cholera, Leprosy, Anthrax) [20].

Diptera is one of the major insect orders and of considerable ecological and human importance. It is one of the largest insect orders containing an estimated 1,000,000 species including horseflies, craneflies, hoverflies, mosquitoes, and others, although only about 125,000 species have been described [16]. Diptera or black flies (mosquitoes and flies) are characterized by a single pair of wings to fly, the hind wings being reduced to club-like balancing organs, hence, are known as halters and balancers. The hind wings of flies are modified into halters, which act like gyroscopes and aid in balance during flight. [17]. The mouth parts of these insects are piercing and sucking type. Life cycle comprises four distinct life stages egg, larva (maggot), pupa, and adult. The damaging stages are adults and maggots [18].

Mosquitoes are flies belonging to the Culicidae family of some 3,600 species of small flies [7]. Mosquito bites constitute a nuisance to man and his environment (M. A. Olufemi, *et al*., 2008) [8]. They are as ancient as man himself and have constituted a threat to man's health and not all species bite man readily, some prefer other animals to man and others feed only on plant juices [13, 15]. The female Anopheles mosquito transmits malaria parasites, Aedes aegygti mosquitoes are known to transmit yellow fever and dengue fever. Anopheles and Culex species have also been incriminated in transmitting lymphatic filariasis [14].

In many species, the female mosquitoes are blood-sucking ectoparasites. However, in some species, a blood meal is essential for egg production; in others, it just enables the female to lay more eggs [30]. Female mosquitoes hunt for hosts by smelling substances such as carbon dioxide (CO_2) and 1-octen-3-ol (mushroom alcohol, found in exhaled breath) produced by the host, and through visual recognition [6]. Mosquitoes prefer to feed on people with type O blood, an abundance of skin bacteria, high body heat, and pregnant women [33, 3]. An anopheline mosquito can fly for up to four hours continuously at 1 to 2 km/h [10] traveling up to 12 km in a night. Males beat their wings between 450 and 600 times per second, driven indirectly by muscles that vibrate the thorax [12, 35].

The biting rate by *Anopheles gambiae s.l.* varied from 0.6 to 10 bites per person per night within sites, with an average of 2.5 bites per person per night. The average biting rate of mosquitoes in general (Culicidae) was 25 bites per person per night and ranging from 11.3 to 46,3 bites per person per night [19].

Fruit flies are used as model organisms in research, but less benignly, mosquitoes are vectors for malaria, dengue, west Nile fever, yellow fever, encephalitis, and other infectious diseases. Vector-borne diseases account for more than 17% of all infectious diseases, causing more than 700,000 deaths annually. They can be caused by either parasites, bacteria, or viruses. Malaria is a parasitic infection transmitted by Anopheline mosquitoes. It causes an estimated 219 million cases globally, and results in more than 400,000 deaths every year. Most of the deaths occur in children under the age of 5 years [40].

One of the biggest factors influencing insect damage and harmful to human beings is the higher reproductive potential. The reproductive potential of insects is high e.g. Egg-laying capacity (fecundity) of queen termites is between 6000 to 7000 eggs per day for 15 long years. Short development period e.g., Corn aphid produces 16 nymphs per female which reaches adulthood within 16 days. Presence of special types of reproduction other than oviparity and viviparity like Polyembryony, Parthenogenesis, and Paedogenesis [20].

Many measures have been tried for mosquito control, including eliminating breeding places, exclusion via window screens and mosquito nets, and biological control with parasites such as fungi [11]. Three general methods for protection against mosquito bites have been reported by [23] as traditional anti-mosquito, plant-based petroleum oils, and conventional protective methods. Vector control is a crucial prevention tool for reducing the burden of malaria. In the past, mosquito eggs, larvae, and pupae are mostly controlled in tropical countries with organophosphates, and indoor residual spraying [1]. The different studies indicated that the mosquito net methods are more frequently used by the most of population of both rural and urban communities in Rwanda because they are available, affordable, and easy to be used effectively. One of the studies conducted in Southern Rwanda showed that although coverage of mosquito bed nets was high (84.1%), their utilization among pregnant women was lower (81.7%) than the national target of 85% (Joseph Kawuki *et al.*, 2023) [9]. Insect repellents are applied on the skin and give short term against mosquito bites. The chemical DEET repels some mosquitoes and other insects [37]. Some Centers for Disease Control and Prevention (CDCP) recommended repellents are picaridin, eucalyptus oil (PMD), and ethyl buthylacethilaminopropionate [2]. However, neem components show multiple effects against different insects such as mosquitoes, flies, triatomine bugs, cockroaches, fleas, lice, and ticks [22, 32]. Therefore, the present study seeks to investigate the effect of

neem plant products on house mosquito repelling. A case study of Burera, and Gicumbi Districts. Specific objectives were to identify the general characteristics of house mosquitoes, to determine the effectiveness of neem plant products in repelling house mosquitoes, and to determine the socioeconomic impact of using neem plant products to repel mosquitoes.

2. Materials and Methods

2.1. Description of the Study Area

This study will be conducted in two districts namely Burera and Gicumbi of the Northern Province of Rwanda. These districts are the entire climate of high altitude with an average temperature of 20 ℃ and rain that varies between 1400 mm and 1800 mm. The production of Maize, Irish potatoes, beans, wheat, sorghum, sweet potato, banana, Fruits, vegetables, flowers, tea, coffee, and pyrethrum is significantly high in the region. The soils found in these districts are mainly volcanic, and andosols for one part of Burera and andosols for Gicumbi [26].

2.2. Study Design, and Sample Size

Both cross-section and purposive sampling techniques will be used in this study. With these two techniques, a multistage sampling technique has been adopted. The first stage was the purposive selection of two districts namely Burera and Gicumbi where the study will be conducted. The second stage was the choice of two health centers, two boarding schools, and five guest houses/ Households in each district selected based on the expected data from respondents. Six (6) respondents were selected from each category for making (60) respondents. The study will be conducted from the end of January 2024 to mid-February 2024. A total of 60 head teachers, teachers, students, nurses, patients, household heads, and or guesthouse managers were purposively selected for sampling. Structured questionnaires were designed and self-administered to the listed above respondents. The questionnaires were both open-ended and closed. This was designed to allow the respondents to contribute their views as guiding their responses.

Table 1. *Study Population and Sample Size.*

District	Target organization	Sample size
BURERA	Bungwe Health Center	6
	Cyili Health Center	6
	G. S APPAPEDIC Bungwe	6
	G. S Kirambo	6
	Household/Guesthouse	6
GICUMBI	Kigogo Health Center	6
	Munyinya Health Center	6
	G. S Karambo	6
	Petit séminaire Rwesero	6
	Household/Guesthouse	6
Total		60

Data Analysis

Data collected will be analyzed using descriptive statistics such as percentage and frequency to show the socio-economic characteristics of respondents and the effectiveness of neem plant products in controlling house mosquitoes. Regression through a STATA 14.0 version will be used, and the difference in difference methods will be employed to determine the effect of neem plant products in different periods in the study area.

3. Results

3.1. Socio-Economic Characteristics of Respondents

The study indicated that 63.3 %of the respondents were male and 36.7% were female. This implies that most of those who participated were male and were the most likely to be

participating in human being welfare. This should positively influence the increase in neem plant products used for house mosquito repelling in the study area as males are the main household heads of the family. Results also indicated that the majority of respondents in the study area are educated 61.7% of respondents reached University level, 30% have secondary school level and 8.3% attended Ordinary Level. This high percentage of educated respondents should have a positive impact on the use of neem plant products through a quick understanding of the benefits of using biological control rather than a chemical one, especially the adoption of new techniques of pest repelling. Results revealed that 51.7% of the respondents are in the range between 31-43 years followed by 25% of the respondents 25% with a range between 44-56 years. This is one of the many factors that increase the positive impact on neem plant products. It is known that mature people learn from their mistakes and improve their efficiency in self-control. Therefore, educated people, mature people of all genders are easy to be trained particularly in pests and disease control through experimental studies and experience. field school in the region.

Table 2. *Socio-economic characteristics of surveyed respondents.*

Gender of respondents	Frequency	Percentage
Male	38	63.3
Female	22	36.7
Age of respondents		
18-30	7	8.3
31-43	31	51.7
44-56	15	25
56 and above	7	15
Education level		
O' Level	5	8.3
Secondary	18	30
University	37	61.7

3.2. General Characteristics of Mosquito

Mosquito, (family Culicidae), is any of approximately 3,500 species of familiar insects in the fly order, Diptera, that are important in public health because of the bloodsucking habits of the females. Mosquitoes are known to transmit serious diseases, including yellow fever, Zika fever, malaria, filariasis, and dengue. The slender, elongated body of the adult is covered with scales as are the veins of the wings. Mosquitoes are also characterized by long, fragile-looking legs and elongated, piercing mouthparts. The feathery antennae of the male are generally bushier than those of the female. The males, and sometimes the females, feed on nectar and other plant juices. In most species, however, the females require the proteins obtained from a blood meal to mature their eggs.

Table 3. *General characteristics of mosquito.*

Mosquito	Part type	Function/Role
Kingdom	Animalia	Identify different species of insects
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	

Mosquito	Part type	Function/Role
Family	Culicidae	
Genus	Culex	
Species	C. pipiensis	
Antennae/Feelers	Plumose/Pilose	Touch, Sense, smell, hear
Eyes	Two compound eyes	Sensitive to motion, and to see in multiple directions
Mouth	Piercing and sucking/ Proboscis	Piercing and sucking of blood from animals
Wings	Halters	Help balance and improve flight, protection, sound production, heat retention, visual communication, and orientation
Legs		Pitch up control
Egg laid	Egg raft/Egg with float	Allow embryo development environments
Larvae	Maggot	Food gatherer, both dispersion and nutrition
Reproduction	Oviparity	Ensures the continuity of the species and keeps it from becoming extinct
Metamorphosis	Complete	It allows juvenile and adult insects to occupy different niches so that juveniles and adults do not compete with each other. Metamorphosis can also provide handy protection from the winter, such as a hard pupal case.
Damaging stage	Adult	Pierce and suck animal and human blood and cause disease

3.3. Effectiveness of Neem Plant Products for Repelling Mosquito

The use of neem plant products as a repellent against mosquito bites recorded the highest frequency 88.3%. Both neem oil and leaves showed the highest effectiveness with 88.3% followed by neem smoke with 66.7% mosquito repellency in Burera district. However, neem oil showed 88.3% followed by neem leaves with 66.7%, and neem smoke with 50% mosquito repellency in Gicumbi District. On the side of the effectiveness of the neem plant products (neem oil, neem leaves, neem stem, neem root, and neem smoke), the results indicated that neem oil, neem leaves, and neem smoke were most effective for repelling mosquitoes respectively at ($p < 0.01$). There was a statistically significant difference between the various neem products repelling mosquito bites (Number of observations 60; P-Value < 0.0001, and R^2 of 0.833) as indicated by results in (Table 4).

Table 4. *Effectiveness of neem plant products for repelling house mosquitoes.*

Location	Neem Plant Part	OBS	Effectiveness					
			Highly effective	Effective	Not effective	Mean	Std. Dev.	P-value
Burera	Neem oil	6	5	1	0	0.215	0.661	0.000
	Neem leaves	6	5	1	0	0.97	0.731	0.005
	Neem stem	6	0	2	4	0.068	0.401	0.781
	Neem root	6	0	1	5	0.394	0.817	0.488
	Neem smoke	6	4	1	1	0.860	1.556	0.031
Gicumbi	Neem oil	6	5	1	0	0.626	0.591	0.001
	Neem leaves	6	4	2	0	0.711	1.048	0.009
	Neem stem	6	1	2	3	0.895	0.327	0.656

Location	Neem Plant Part	OBS	Effectiveness					
			Highly effective	Effective	Not effective	Mean	Std. Dev.	P-value
	Neem root	6	1	1	4	1.143	1.303	0.128
	Neem smoke	6	3	2	1	0.576	1.156	0.067
Number of observations = 60						Pseudo R^2 = 0.833		
Prob > chi2 = 0.0000								

3.4. Social-Economic Impact of Using Neem Plant Products to Repel Mosquitoes

Organic mosquito repellents offer several benefits. Firstly, they are environmentally friendly and pose no harm to human health. Secondly, they are effective in repelling mosquitoes. Natural compounds such as essential oils have been found to have insect-repellent properties and can be used as a safer alternative to synthetic chemicals. Additionally, organic repellents can be used by special communities such as pregnant women and infants without any toxic or side effects. These natural products may also have a synergistic effect, enhancing their efficiency as repellents. Even if organic mosquito repellents may be more expensive than synthetic chemicals, but they offer a safer and more sustainable option for mosquito control.

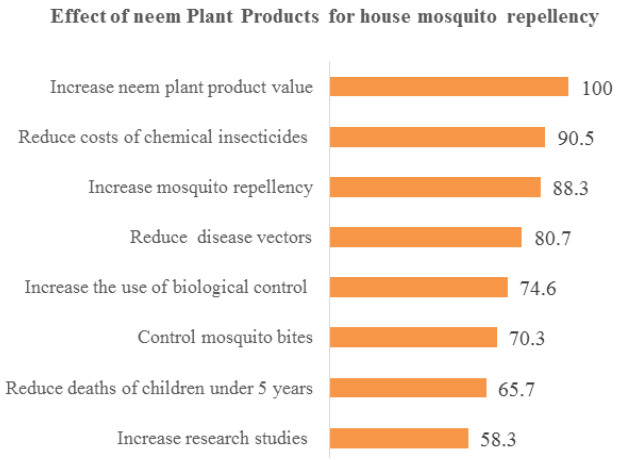

Figure 1. *Social-economic impact of using neem plant products to repel mosquitoes.*

The finding of this study in Figure 1 indicated that using neem plant products to repel mosquitoes should increase neem plant product value, reduce costs of chemical insecticides, increase mosquito repellency, reduce disease vectors, increase the use of biological control, control mosquito bites, reduce death of children under five years, and increase research studies. The findings revealed that the use of neem plant products as mosquito repellency increase neem plant product value (100%), followed by reduction of costs of chemical insecticides (90.5%), increase mosquito repellency (88.3%), reduce diseases vectors (80.7%), increase the use of biological control (74.6) %, control mosquito bites (70.3%), reduce death of children under five years (65.7%), and increase research studies (58.3%).

This implies that biological diversity should be performed through the adoption of the use of using neem plant products to repel mosquitoes rather than synthetic pesticides, which, since misused, are known to kill beneficial organisms (e.g. natural parasites of pests, pollinators, etc.), cause pest resistance, and often pollute the ecosystem. In this study, respondents also said using neem plant products to repel mosquitoes should sustain and enhance the health of ecosystems and organisms particularly human beings. This directly improves environmental quality and will conserve biodiversity in the long run.

4. Discussion

The results of this study were supported by the study of [21] indicated that neem products are capable of producing multiple effects on several insect species, such as anti-feeding effects, growth regulation, fecundity suppression and sterilization, oviposition repellency or attractancy and changes in biological fitness. The results of this study were also supported by the study of S [36, 29] indicated that in some cases, neem has repellent effects where the percentage protection against sand fly bites provided by neem oil was significantly higher than N, N-diethyphenylacetamide (DEPA) when applied at 1% and 2% concentrations. The results of the study are in the same line with the study of [34] in his study conducted in Gambella, western Ethiopia showed that there is a repellent activity against Mansonia spp. Mosquitoes.

The result of the study was also supported by [4, 24] showed that repellency is one of the proven ways of preventing vector-borne illnesses by reducing man-vector contact. Neem products are effective mosquito repellants and are capable of offering about 90–100% protection against malaria vectors. The repellent action of Neem oil as assessed by this

study showed the multifunctional insecticidal activity of Neem oil for mosquito control at the household level. The repellency action of Neem oil observed in this study gave better protection than that reported for Citrus sinensis oil and Hemizygia oil [28, 27, 39]. This could be attributed to the fact that active ingredients of Neem oil in liquid paraffin tend to be more stable and possess a longer duration of action in terms of repellency than Citrus sinensis oil and Hemizygia oil which are essential oils and evaporate readily into the air.

5. Conclusion and Recommendations

The study indicated that 63.3 % of the respondents were male and 36.7% were female. The majority of respondents in the study area are educated with 61.7% of respondents reaching University level. Mosquitoes are known to transmit serious diseases, including yellow fever, Zika fever, malaria, filariasis, and dengue. The use of neem plant products as a repellent against mosquito bites recorded the highest frequency 88.3%. Both neem oil and leaves showed the highest effectiveness with 88.3% followed by neem smoke with 66.7% mosquito repellency in the Burera district. However, neem oil showed 88.3% followed by neem leaves with 66.7%, and neem smoke with 50% mosquito repellency in Gicumbi District. On the side of the effectiveness of the neem plant products (neem oil, neem leaves, neem stem, neem root, and neem smoke), the results indicated that neem oil, neem leaves, and neem smoke were most effective for repelling mosquitoes respectively at ($p < 0.01$). There was a statistically significant difference between the various neem products repelling mosquito bites (Number of observations 60; P-Value < 0.0001, and R^2 of 0.833). The finding of this study also indicated that using neem plant products to repel mosquitoes should increase neem plant product value, reduce costs of chemical insecticides, increase mosquito repellency, reduce disease vectors, increase the use of biological control, control mosquito bites, reduce the death of children under five years, and increase research studies. The high need for support for increasing research on eco-friendly techniques and strategies should be enhanced as well as reducing chemical pesticide use which increases Greenhouse gas emissions and reduction of pollinators.

Abbreviations

CDCP: Centers for Disease Control and Prevention
OBS: Observations
WHO: World Health Organization
NISR: National Institute of Statistics of Rwanda
DEPA: Di Ethy Phenyl Acetamide

Conflicts of Interest

The authors declare no conflicts of interest.

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