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A Comparative Study Of Morphoanatomical, Phytochemical And Mosquito Repellence Of Five Selected Plants In Family Piperaceae

[1]Theertha Prakash, [1]Dr. Sandhya P.

[1]PG and Research Department of Botany, N. S. S. College, Pandalam, University of Kerala

Abstract: Plants provided essential treatments for a wide range of health issues, laying the foundation for many modern medicinal practices. Mosquitoes pose a significant danger to mankind due to their ability to transmit deadly diseases. They are the primary vectors for diseases such as malaria, dengue fever, Zika virus, chikungunya, and yellow fever. The growing resistance of mosquitoes to synthetic insecticides has severe implications, including diminished control efficacy, ecological disruption, and human health risks, all exacerbated by the cumulative buildup of toxic substances in the environment and food chain. Plants contain some phytochemicals which may result in defence against mosquitoes. The presence of characteristic aroma and pungent smell might be indication of larvicidal activity. Phenols, terpenoids, flavanoids and saponins play role in antimicrobial and mosquito repellent activity. Five selected members of family Piperaceae were compared on the basis of morphology, anatomy, phytochemical analysis and mosquito repellency. The aim of the study was to finding the most effective plant against the mosquitoes and identifies a plant-based repellent with proven efficacy.

Key words: Mosquito repellent, phytochemicals, lethality, leaf extract, burning ability.

1. INTRODUCTION

Mosquitoes, members of the Culicidae family, are a group of small flies consisting of 3,600 species. Despite their small size, they have a significant impact on human health and comfort. These bothersome insects are well-known for their itchy bites and for transmitting harmful diseases. Mosquitoes are carriers of numerous diseases, including malaria, dengue, West Nile virus, chikungunya, yellow fever, and Zika. It is crucial to understand their role in disease transmission. By acknowledging the threats these small insects pose, we can take proactive measures to avoid their bites and minimize the spread of these illnesses. This knowledge is crucial in developing effective strategies for mosquito control and disease prevention.

Culex quinquefasciatus is the mosquito taken for the study. Average lifespan of the mosquito is less than two months with males having the shortest life span which usually is 10 days or less, and females about six to eight weeks, under ideal conditions. The females lay eggs about every three days during this period. Females of hibernating species may live up to six months.

The threat of mosquito-borne diseases necessitates an evaluation of current control measures. While commercially available chemical formulations have been widely used, they have significant drawbacks, including the development of mosquito resistance and ecological imbalances. In response, attention has turned to vegetable insecticides as a more sustainable and environmentally friendly alternative. For generations, plant-based repellents have been employed in traditional practices to protect against host-seeking mosquitoes. Plant-derived natural products are promising candidates for controlling insect pests. Plants have long been known for their significant insecticidal properties, making them viable alternatives in the fight against mosquito-borne diseases. Extracts from plant sources have shown considerable potential as effective insecticidal or larvicidal agents. Mosquitoes of the genera Anopheles, Aedes, and Culex are the major vectors that transmit diseases like

malaria, dengue, chikungunya, Zika, and filariasis. To combat the effects of such diseases, vector control, by insecticides or through biological control, is one of the key options (Bharat Singh *et al.*, 2024).

Piper species are used in traditional medicine, particularly in Ayurveda (India) and folklore medicine in Latin America and the West Indies. These plants have been studied for their potential to provide new natural products with various beneficial properties, including antioxidant, antimicrobial, antifungal, anti-inflammatory, antileishmanial, and insecticidal activities. In recent years, several reports have been published regarding the composition and the biological activities of the essential oils of Piper species. These studies have highlighted the existence of marked chemical differences among oils extracted from different species or varieties (Wan Mohd Nuzul *et al.*, 2014).

In this study, the comparative effect of five Piperaceae family members on mosquito larvae was done. The insecticidal property of two varieties of *Piper betle* (different cultivars; brown stemmed and green stemmed), *Piper longum*, *Piper nigrum* and *Peperomia pellucida* was tested. Morphological characters like habit, internodal length, petiole colour, petiole length, stem colour, leaf shape, leaf size and leaf area were compared. Testing the phytochemical content of plants involves analyzing their chemical compounds to understand how these substances influence the plant's properties and behaviour.

2. MATERIALS AND METHODS

Materials

Studies were conducted in five medicinally important and mosquito repellent plants *Piper betle* – two varieties; brown stemmed (S1) and green stemmed (S2), *Piper longum* (S3), *Piper nigrum* (S4) and *Peperomia pellucida* (S5) belonging to Piperaceae family.

Methods

Cultivation

Five plants were cultivated in the same environmental conditions through vegetative propagation. Stem cuttings of *Piper betle* (both varieties) and *Piper nigrum* were propagated in separate pots. *Piper longum* and *Peperomia pellucida* were propagated vegetatively by rooted vine cuttings. All the five plants were watered twice daily and the growth responses were observed regularly.

Morphological Parameters

The characters namely habit, internodal length, petiole colour and length, stem colour, leaf arrangement, leaf colour, leaf margin, leaf venation, leaf shape, leaf nature, leaf size, and leaf area were observed in the vegetative phase of the plant.

Anatomical Characters

Anatomical observations included the transverse sections of the leaf through the midrib, petiole, and stem.

Phytochemical Analysis

Phytochemicals are naturally occurring compounds in plants with protective properties, including antimicrobial activity. The study focused on screening the leaves for compounds like phenols, terpenoids, flavonoids, and saponins. Extracts were prepared in different forms – fresh (F), fresh boiled (FB), dried powder (D), and dried boiled (DB) and were qualitatively analyzed for these phytochemicals.

Test for phenols (Iodine test): When 1 ml extract was mixed with dilute iodine solution, a transient red colour indicates the presence of phenols.

Test for terpenoids: Fresh leaf extract mixed with 0.5 ml chloroform and 1.5 ml concentrated sulphuric acid carefully added to form a layer.

Test for flavonoids: Freshly prepared leaf extract was added to 0.1 ml sodium hydroxide and observed yellow colouration.

Test for saponins (Foam test): 1 ml extract was diluted with 20 ml distilled water and shaken well in a graduated cylinder for 15 minutes. The formation of foam to a length 1 cm indicated the presence of saponins.

Mosquito repellent capacity

Trial experiment was conducted in mosquito repellent ability of the five selected medicinally important plant leaf extracts by directly applying into small plastic container with mosquito larvae. The leaf extracts were

applied in different forms - fresh leaf extract, fresh boiled extract, dried powder and dried boiled extract. Rate of lethality and larval expressions were noted.

The leaf extracts of the five plants were prepared by cutting the leaves into pieces and squeezed well and extract was collected. The fresh boiled extract was prepared by boiling 500 mg of shredded fresh leaves in 50 ml water. Dried powder of the leaves were prepared by drying the leaves in sunlight and grinded to fine powder. The dried boiled extract was prepared by boiling 500 gm of dried powder in 50 ml water. For each of the leaf extracts of five selected treatment materials, three concentrations (2.5 ml, 5 ml and 10 ml) were added to beakers containing 25 ml water with mosquito larvae. For control (Co), one beaker containing 25 ml tap water with mosquito larvae without adding leaf extracts was taken.

Burning ability

To study the burning ability of leaves, dough form of dried leaves of *Piper betle* (two varieties), *Piper longum*, *Piper nigrum* and *Peperomia pellucida* were made and shaped as sambrani stem (dhoom stick) and moulded in oven. These were burned and burning ability observed.

3. RESULTS AND DISCUSSION

Morphological parameters

All the five selected plants had shown differences in their morphology (Fig. 1). The characters studied and differences observed are recorded in Table 1.

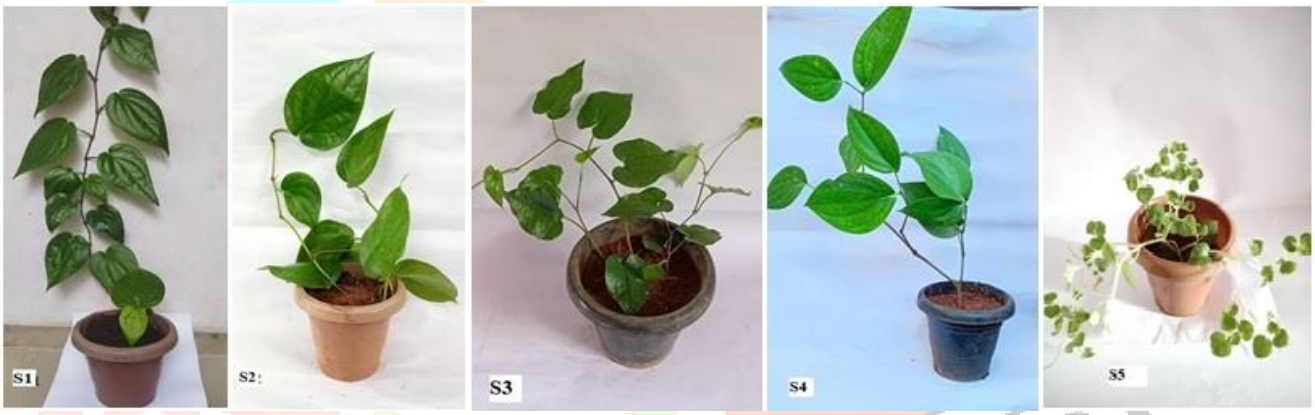


Fig. 1: Selected Plants

Table 1: Morphology of Selected Plants

Sl. No.	Characters	S1	S2	S3	S4	S5
1	Habit	Climber	Climber	Climber	Climber	Herb
2	Internodal length (cm.)	5.2	11.5	4.1	10.8	3.8
3	Petiole colour	Brown	Light green	Light green	Green	Pale green
4	Petiole length (cm.)	5	4.5	2.8	3.4	1.3
5	Stem colour	Brown	Light green	Dark green	Dark green	Pale green
6	Leaf arrangement	Alternate	Alternate	Alternate	Alternate	Alternate
7	Leaf colour	Dark green	Light green	Dark green	Dark green	Dark green
8	Leaf margin	Entire	Entire	Entire	Entire	Entire
9	Leaf venation	Reticulate	Reticulate	Reticulate	Reticulate	Reticulate
10	Leaf shape	Heart shape	Heart shape	Ovate to reniform	Ovate to oblong	Ovate to triangular

11	Nature of leaves	Glossy	Glossy	Glossy	Glossy	Fleshy, shiny and glossy
12	Leaf length (cm.)	4.7	1.3	3.7	13	1.9
13	Leaf breadth (cm.)	4.1	7.3	3.4	6.2	1.9
14	Leaf area (sq. cm.)	16.8	56.9	12.7	58.9	3.65

Anatomical characters

The anatomy of the five Piperaceae members shows similarities and differences. Internal structures of the stem, petiole and leaf of these mosquito repellent plants had shown variation between them.

Cross section of stem (Fig. 2): In brown stemmed *Piper betle*, trichomes were 1-4 celled. Stem had oval outline with ridges and furrows. Epidermis was single layered, closely packed cells. Cortex was 4-5 layered. Endodermis was having wavy outline with casparian thickening. Vascular bundles were arranged in two concentric rings. Xylem was arranged towards centre and phloem towards periphery. Trichomes were present in the cross section of green stemmed *Piper betle*. It was having a wavy outline with ridges and furrows. Epidermis was single layered. Cortex was 5-6 layered. Endodermis was also wavy. Vascular bundles were arranged in 2 rings. Xylem was towards innerside and phloem towards outside. In *Piper longum* Small trichomes were present and were 1-4 celled. Epidermis was single layered with cuticle and hypodermis was 3-4 layered. Cortex was parenchymatous. Wavy endodermis was present. Cortical and medullary vascular bundles were present. Central mucilage canal was present. Xylem was towards the pith and phloem towards periphery. Small trichomes and single layered epidermis with thick cuticle were present in *Piper nigrum*. Cortex was having chlorenchymatous, collenchymatous and parenchymatous regions. Cortical and medullary vascular bundles were seen. In cortical region, small and large vascular bundles arranged alternatively. Endodermis was with pericycle. Vascular bundles were conjoint and collateral. One central mucilage canal was present. Large pith was having phloem outside and xylem towards inside. *Peperomia pellucida* was different from other Piperaceae members, due to succulent nature. Round outline with thin, single layered epidermis was found and cortex was large. Small vascular bundles scattered throughout the structure. Pith was large, which was filled with water.

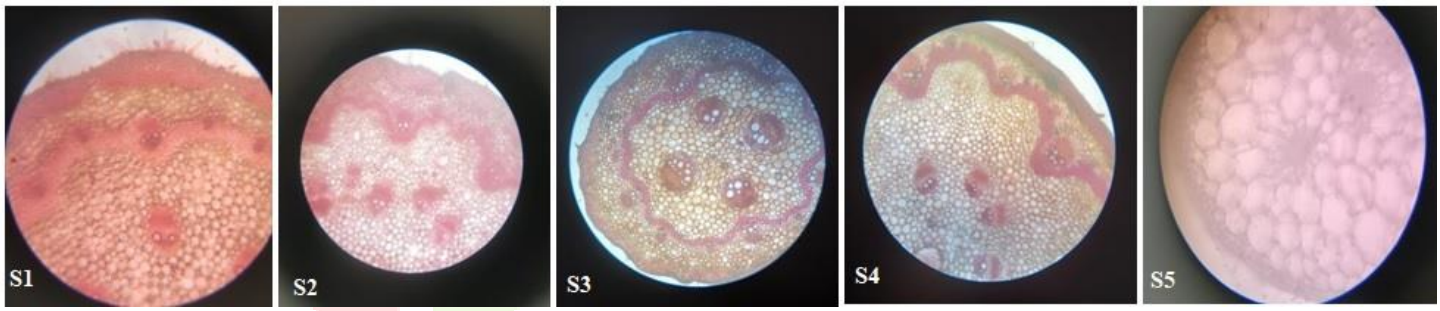


Fig. 2: Cross Section of Stem

Cross section of petiole (Fig. 3): Single layered epidermis with tightly packed cell was seen in brown stemmed *Piper betle* and 2-5 celled trichomes were present. Cortex was parenchymatous and loosely arranged. Seven large vascular bundles alternate with 4 small vascular bundles and mucilage canal was present. Epidermis was single layered in green stemmed *Piper betle* and trichomes were present. Cortex was parenchymatous and contained loosely arranged cells. Vascular bundles were arranged in ring-like manner. Mucilage canal was present. Brown stemmed and green stemmed *Piper betle* had almost similar anatomical characters. In *Piper nigrum* trichomes were absent. Single layered epidermis was present and cortex was many layered. Ten vascular bundles were in a U shape, xylem and phloem arranged side-by-side manner. Pith was large in size. Trichomes were absent in *Peperomia pellucid* also. Epidermal cell was thin-walled with delicate cuticle. Cortex was 5 layered, cells having rhomboid shape and intercellular space was small. Vascular bundles were scattered throughout the section.

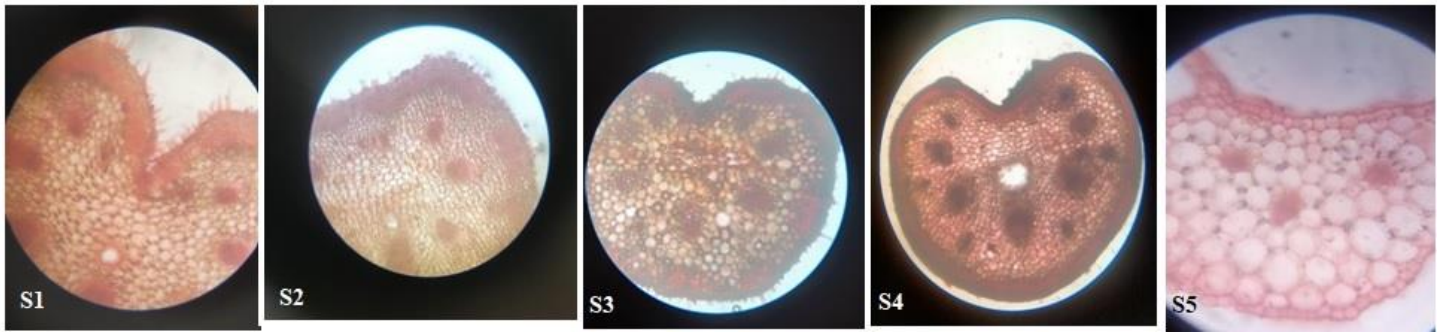


Fig. 3: Cross Section of petiole

Cross section of leaf (Fig. 4): In brown stemmed *Piper betle*, upper epidermis and lower epidermis was present. Stomata was absent in upper epidermis. Palisade in single layered and spongy parenchyma was 3-4 layered. Vascular bundles were single and collateral. Trichomes were present in green stemmed *Piper betle*. Upper and lower epidermis was present. Upper hypodermis was double layered and lower hypodermis was single layered. Vascular bundles were collateral. Midrib region was with furrows and ridges in both brown stemmed and green stemmed *Piper betle*. In *Piper longum*, trichome present on lower epidermis and were 1-3 celled. Midrib was having no ridges and semicircular shaped. Both upper hypodermis and lower hypodermis were double layered. Vascular bundles were single and collateral. Trichome was absent in leaf of *Piper nigrum*. Upper epidermis and lower epidermis was present. Midrib region was flattened. Upper hypodermis was double layered and lower hypodermis was 3 layered. Collateral vascular bundles were seen. In *Peperomia pellucida*, upper epidermis was single layered, cells were having quadrangular shape. Palisade cells were oval shaped and spongy parenchyma was irregular and loosely packed.

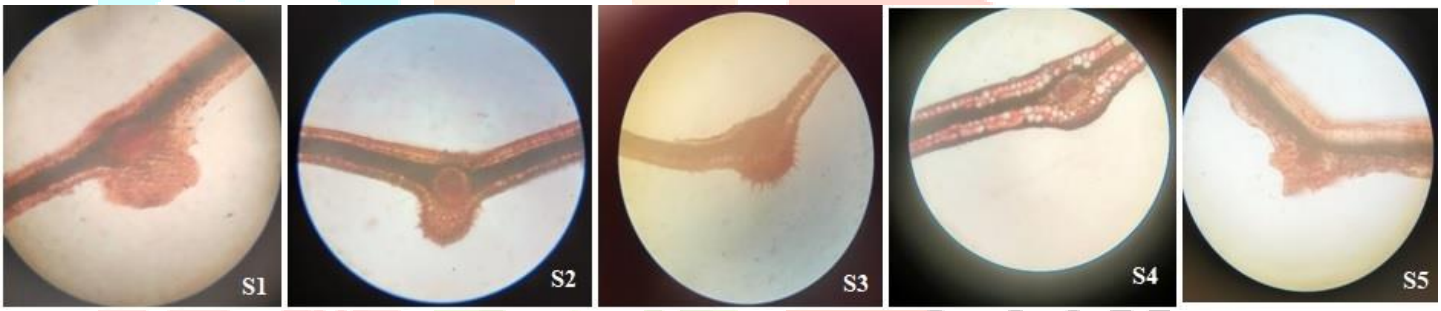


Fig. 4: Cross Section of Leaf

Phytochemical analysis

Qualitative tests for phenols, terpenoids, flavonoids and saponins in fresh extract (F), fresh boiled extract (FB), dried powder (D) and dried boiled extracts (DB) of all the five selected plant leaves revealed the presence of those phytochemicals in them. The results observed are represented in Table 2. Number of '+'indicates the presence and strength of phytochemicals. Phenolic expression was highest in fresh extract of *Peperomia pellucida*, fresh boiled extract, dried powder and dried boiled extracts of *Piper nigrum*. Terpenoid expression was highest in fresh extract, dried powder and dried boiled extract of *Peperomia pellucida* and fresh boiled extract of *Piper nigrum*. Fresh extract and fresh boiled extract of green stemmed *Piper betle*, dried powder of brown stemmed *Piper betle* and dried boiled extract of *Piper longum* showed highest expression of flavonoids. Saponin content was highest in fresh extract and dried powder of *Piper longum*, fresh boiled extract of *Piper nigrum* and dried boiled extract of *Peperomia pellucida*.

Table 2: Expression of Phytochemicals in Different Extracts of Selected Plant Leaves

Sample	Phenols	Terpenoids	Flavonoids	Saponins
FS1	++++	+	+++	+
FS2	++++	++	++++	++
FS3	+++	+++	+	+++++
FS4	++	++++	++	+++
FS5	+++++	+++++	+	++++
FBS1	+++	++++	+	+++
FBS2	+++	+++	+++++	++++
FBS3	+++	++	++	++
FBS4	+++++	+++++	++++	+++++
FBS5	+++	+	+++	+
DS1	+	+	+++++	+
DS2	++	++	+	++
DS3	+++	+++	++	+++++
DS4	+++++	++	+++	+++
DS5	++++	+++++	++	++++
DBS1	++	++++	+++	+++
DBS2	+	+	+	++++
DBS3	++++	+	+++++	+
DBS4	+++++	+++	++++	++
DBS5	+++	+++++	++	+++++

Mosquito repellent capacity

Mosquito Culex sps. are responsible for different diseases. Their life cycle is completed through water only. So, we conducted the experiments to destroy the larvae through the mosquito repellent plants. The leaf extracts of selected plants were applied in different forms - fresh leaf extract, fresh boiled extract, dried powder and dried boiled extract.

Trial study: Three trials were conducted in each experiment. In the trials, the five selected plants had shown different mortality rates. The lethality in each experiment was recorded and analyzed statistically (Tables 3-6).

Table 3: Lethality Rate in Fresh Extract of Selected Plant Leaves

Source	df	MSS	F	SE	CD			TS
							Co	0
TS	5	9550.74	82.52 **	4.39	12.8197		TS1	30.56
Tl	1	1736.23	15 **	2.54	7.4015		TS2	38.89
TS.Tl	5	1587.93	13.72 **	6.21	18.1298		TS3	94.44
Error	24	115.7331					TS4	100
							TS5	77.78

The Fresh Extract experiment was found to be very effective in effecting lethality for the treatment TS levels and the concentrations trial level combinations ($F_{5, 24} = 13.72$, $p<0.01$). All the concentrations of TS4 and TS3 were the most effective treatments, with their lethality rates showed far exceeding the rates of other treatment combinations in the experiment. The control treatment was least effective with zero lethality in both trials (concentrations).

Table 4: Lethality Rate in Fresh Boiled Extract of Selected Plant Leaves

Source	df	MSS	F	SE	CD			TS
							Co	29.63
TS	5	8790.99	17.8 **	7.41	21.2648		TS1	100
Tl	2	432.14	0.88	5.24			TS2	100
TS.Tl	10	333.37	0.68	12.83			TS3	70.37
Error	36	493.7899					TS4	100
							TS5	44.44

In the case of fresh boiled extracts, the lethality rates of the treatments (TS levels) were found to be

significantly effective (F5, 36 = 17.8, p < 0.01), with the control treatment showing least lethality and TS1, TS2 and TS4 giving total lethality. Either the extract concentrations or its combination with the treatment levels were not found to be significant impact on lethality.

Table 5: Lethality Rate in Dried Powder Extract of Selected Plant Leaves

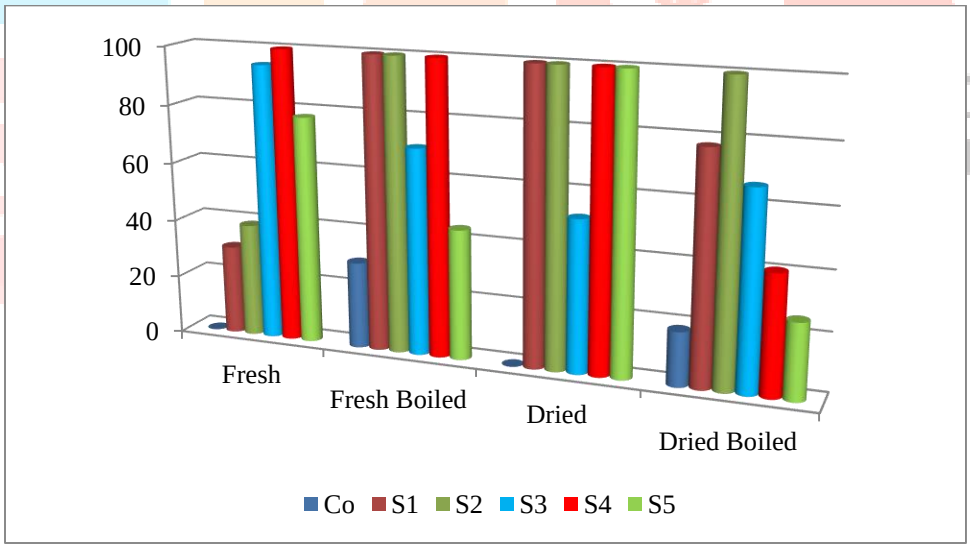
Source	df	MSS	F	SE	CD			TS
							Co	0
TS	5	15588.73	108.22 **	4	11.4853		TS1	100
Tl	2	144.03	1	2.83			TS2	100
TS.Tl	10	144.03	1	6.93			TS3	51.85
Error	36	144.0478					TS4	100
							TS5	100

The lethality rates of the treatments using dried powder extracts were found to be very effective (F5, 36=108.22, p<0.01). Among the samples, TS1, TS2, TS4 and TS5 had shown complete lethality.

Table 6: Lethality Rate in Dried Boiled Extract of Selected Plant Leaves

Source	df	MSS	F	SE	CD			TS
							Co	18.52
TS	5	9107.4	13.83 **	8.55	24.5549		TS1	77.78
Tl	2	267.46	0.41	6.05			TS2	100
TS.Tl	10	390.91	0.59	14.81			TS3	66.66
Error	36	658.4106					TS4	40.74
							TS5	25.92

In the case of dried boiled extracts, lethality among the treatments when compared to control, 100% was observed in TS2 (F5, 36=13.83, p<0.01). TS1, TS3 were effective than TS4 and TS5. The combined lethality in different extracts of selected plant leaves are represented in Graph 1.



Graph 1: Combined Lethality in Different Extracts of Selected Plant Leaves

Burning ability

The dhoom sticks prepared using the leaves of the selected plants were burned (Fig. 5). The fumes produced by the dhoom sticks varied depending on the phytochemicals present in each of the plant leaves. Dhoom sticks prepared using all the selected materials combined when burned released fragrant thick smoke due to the essential oils in the leaves.

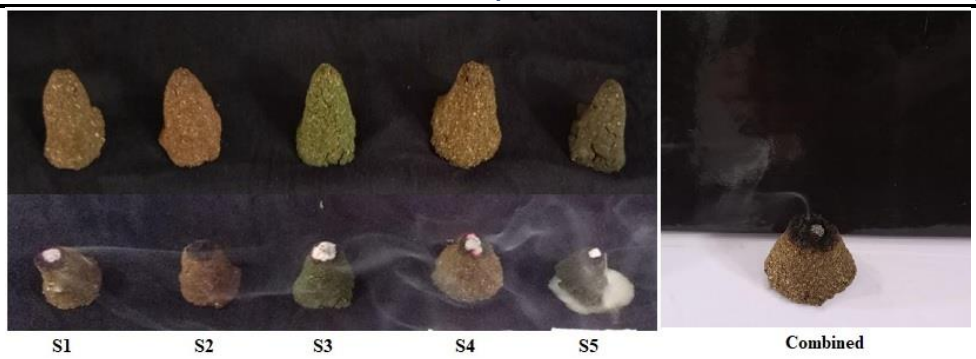


Fig 5: Burning ability

Mosquito-borne diseases, also known as mosquito-borne illnesses, are caused by bacteria, viruses, or parasites transmitted by mosquitoes. Remarkably, mosquitoes can transmit these diseases without being affected themselves. These insects are responsible for more human suffering than any other organism, with over one million deaths globally each year due to mosquito-borne illnesses.

Among the five plants examined, *Piper betle* (both the brown stemmed and green stemmed varieties), *Piper longum* and *Piper nigrum* all shared the presence of trichomes on their stems. Trichomes are hair-like structures that can provide protection and contribute to the plant's defence mechanisms. In contrast, *Peperomia pellucida* was unique in that it lacks trichomes entirely. This absence of trichomes in *Peperomia pellucida* may be linked to its different ecological adaptations compared to its Piper relatives. The phenolic content of the plants, which can affect their coloration and other properties, was notably higher in fresh forms of *Piper betle*, particularly the brown-stemmed variety. This higher phenolic content was evident in the stained transverse sections of the stem, leaf, and petiole, as well as in unstained sections of the stem. The presence of phenolic compounds is often associated with a plant's response to environmental stress and its overall biochemical profile. Anatomically, *Piper longum* was characterized by a ring of vascular bundles in the pith region. The pith in *Piper longum* was relatively small compared to that of *Piper nigrum*. *Piper nigrum*, on the other hand, featured larger pith and had a number of vascular bundles scattered within it. In unstained sections, *Piper nigrum* showed a red coloration in certain areas, which correlates with its high phenolic expression in various forms, including fresh, boiled, dried, and dried boiled states. This red coloration is indicative of the high levels of phenolic compounds present in the plant. *Peperomia pellucida* stands apart from its Piper relatives in terms of anatomical structure. Its succulent nature was reflected in its anatomy, which features a single, thin layer of cuboidal epidermal cells. The vascular bundles in *Peperomia pellucida* were scattered rather than organized in a distinct pattern, which is a significant departure from the more structured vascular bundle arrangements seen in Piper species.

The chemical content in black pepper is saponins, flavonoids, essential oils, chavisin, resins, egg white, starch, piperine, piperylline, piperoleine, piperanine, dihydrocarveol, karyo fillene oxide, cariptone, tran piocarrol and Pepper oil (Winda Wulandari *et al*., 2021).

Piper betle leaf extract contains large number of bioactive Molecule like polyphenol, alkaloids, steroids, saponin and tannin. Piper betel has light yellow aromatic essential oil with sharp burning taste. The main constituents are Hydroxychavicol (HC)/Hydroxychavicol acetate (HCA), Allylpyrocatechol (APC), Chavibetol (CHV), Piperbetol etc. Other constituents are arecoline, carvacrol, caryophyllene, piperitol, piperbetol,eugenol, isoeugenol, Allylpyrocatechol, chavicol, safrole, anethole, chavibetol, cadinene Hydroxychavicol, β-sitosterol, β-sitosteryl palmitate, dotriacontanoic acid, tritriacontane, stearic acid, cepharadione, piperine, Piperlonguminine, chavibetol acetate, allylpyrocatechol monoacetate, allyldiacetoxy benzene, estragole, methyl eugenol and hydroxycatechol, methylpiperbetol, piperol A and piperol B, cavacrol, eugenol acetate and allyl pyrocatechol diacetate etc. (Chandra Vikash *et al*., 2012).

Thorough studies and research is done on phytochemistry of plant parts such as roots, fruit of *Piper longum* and immense number of bioactive compounds have been reported which are alkaloids, amides, lignans, esters and volatile oils. *Piper longum* fruits contain large number of alkaloids which is Piperine along with methyl Piperine, iperonaline, asarinine, pellitorine, piperlongumine, piperlonguminine, Brachystamide-A, Pipercide and piperidine (Pandey, 2018).

Phytochemical composition of *Peperomia pellucida* leaves shows that their concentration was in this order

alkaloids > saponin > flavonoids > tannins > phenol (IbeDiala and Igwe, 2022). The comparative study found out that phenolic expression was highest in *Peperomia pellucida* in fresh extract form. In fresh boiled, dried and dried boiled forms, phenols were highest in *Piper nigrum*. Expression of terpenoids was highest in *Peperomia pellucida* in fresh, dried and dried boiled forms. Terpenoids was high in *Piper nigrum* in fresh boiled form. Flavonoids content was high in green stemmed *Piper betle* in fresh and boiled forms. In dried and dried boiled forms, flavonoids was rich in brown stemmed *Piper betle* and *Piper longum* respectively. Saponin was in high concentration in *Piper longum* in fresh and dried forms. In fresh boiled form *Piper nigrum* had more saponin. In dried boiled form, *Peperomia pellucida* had high saponin content.

Studies were conducted to analyse the protection power of betle leaves extract in the concentrations of 20%, 40%, and 80% against Anopheles Spp. People can use betle leaves extract with a minimum concentration of 80% as a repellent against mosquitoes, especially Anopheles spp (Khomsatun *et al*., 2019). The study evaluated the toxic effects of the essential oils, aqueous and methanolic extracts of *Piper nigrum* (black pepper) and *Curcuma longa* (turmeric) extracts on the larvae, pupae and adults of *Anopheles gambiae*. The essential oils were most effective against *Anopheles gambiae* larvae showing 100% mortality for both *Piper nigrum* and *Curcuma longa*. Therefore, *Piper nigrum* and *Curcuma longa* can serve as repellents against *Anopheles gambiae*, and can be used in integrated vector management control programs (Kehinde *et al.*, 2018).

Studies have shown that the plant *Peperomia Pellucida* exhibited several pharmacological activities such as antimicrobial, antioxidant, anti-angiogenic, anti-inflammatory, analgesic, antipyretic, neuropharmacological, antisickling, anticancer, enzyme inhibitory, antiulcer, hypotensive, immunostimulatory, fracture healing and antidiabetic activities which support the traditional use of the plant. Purified chemicals from the plant have also shown to exhibit certain pharmacological activities such as antiulcer, anticancer and antimicrobial activity (Raghavendra and Prashith, 2018).

From the comparative study of the five selected members of Piperaceae it was understood that fresh extract of *Piper nigrum* showed highest lethality rate (100%). Fresh boiled extract of two varieties of *Piper betle* and *Piper nigrum* showed 100% lethality. Dried powder of two varieties of *Piper betle*, *Piper nigrum* and *Peperomia pellucida* showed high lethality. Dried boiled extract of green stemmed *Piper betle* had shown highest lethality. Two varieties of *Piper betle* (fresh boiled, dried, dried boiled forms) and *Piper nigrum* (fresh, fresh boiled and dried forms) showed maximum lethality. Dried forms showed more lethality than other three forms.

Mosquito-borne diseases are the largest contributor to human vector-borne disease burden. Herbal products are the best method to manage this. The selected plant leaves were having aromatic smell and they were dried and powdered. Dough forms of these were made like dhoom sticks which produce fumes with pungent smell when burned and are proved to repel mosquitoes. This eco-friendly method can be adopted for controlling insect pests by establishing herbal mosquito repellent products in different shapes and forms according to convenience. This is an innovative approach which is useful to man and the whole environment and helps to develop a sustainable environment.

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