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Extraction and Commercial Production of Natural Insect Repellent from Weed Species

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Abstract

The increasing demand for natural and sustainable pest control solutions has prompted the exploration of plant-based insect repellents. This study investigates the extraction and formulation of insect repellent products from three common weeds: *Cyperus rotundus, Tridax procumbens* and *Ipomoea carnea.* The research aims to evaluate the effectiveness of these weed-derived repellents through both coil and spray formulations. For *Cyperus rotundus,* a coil-based repellent was prepared by grinding dried rhizomes, mixing with natural binders and essential oils, shaping into coils and drying. An insect repellent spray was also formulated using ethanol extraction of the powdered rhizomes, diluted with water and emulsified for stability. Similarly, *Ipomoea carnea* leaves and stems were processed into a spray following extraction with ethanol and formulation with an emulsifier. For *Tridax procumbens,* both mosquito coils and a spray were produced, utilizing a water-based extraction method and incorporating starch and candle wax for the coils. The extraction processes yielded substantial amounts of active repellent compounds, which were successfully incorporated into both coil and spray formulations. Efficacy testing demonstrated that the coils and sprays significantly repelled mosquitoes and flies, with the coils showing prolonged effectiveness. The study highlights the potential of these weeds as sources of natural insect repellents, offering a cost-effective and eco-friendly alternative to synthetic products.

***Key words*:** Weeds, Extraction, Insect repellent, Sustainable pest control

The increasing concern over the adverse effects of synthetic pesticides on human health, environmental quality, and non-target organisms has intensified the search for safer and sustainable alternatives for pest management. Synthetic insecticides, although effective in controlling insect pests, often lead to problems such as pesticide resistance, environmental contamination, bioaccumulation, and detrimental impacts on beneficial insects, wildlife, and human populations [1-2]. Consequently, there has been growing interest in the development of plant-based insect repellents and biopesticides derived from natural sources that are biodegradable, eco-friendly, and less hazardous to ecosystems. Weed species, particularly invasive and non-cultivated plants, represent an abundant yet underutilized source of bioactive compounds with insecticidal, repellent, antimicrobial, and allelopathic properties. Invasive weeds have traditionally been regarded as agricultural nuisances because of their aggressive growth habits, competition with crops for nutrients, water, and light, and their role in reducing agricultural productivity and biodiversity [3]. However, recent research has demonstrated that many weed species contain a wide range of secondary metabolites, including alkaloids, terpenoids, flavonoids, phenolics, saponins, and essential oils, which possess significant biological activities against insect pests [4-5]. The utilization of these naturally occurring compounds offers a promising strategy for converting problematic weeds into valuable resources for sustainable agriculture.

Several weed species such as *Tridax procumbens*, *Ipomoea carnea*, *Parthenium hysterophorus*, *Lantana camara*, *Ageratum conyzoides*, and *Cyperus rotundus* have been reported to exhibit insecticidal and repellent activities against a variety of agricultural and household insect pests [6]. Plant extracts obtained from leaves, stems, roots, flowers, and seeds of these weeds contain volatile and non-volatile compounds capable of disrupting insect feeding, oviposition, growth, development, and survival. Unlike conventional chemical insecticides, botanical repellents often act through multiple mechanisms, reducing the likelihood of resistance development among pest populations while maintaining environmental safety [7]. The extraction of bioactive compounds from weed species typically involves solvent extraction, steam distillation, hydrodistillation, cold pressing, or supercritical fluid extraction techniques, depending on the nature of the active ingredients. Advances in extraction technologies have significantly improved the efficiency, yield, and quality of plant-derived insect repellent formulations [8]. The commercialization of botanical insect repellents has gained momentum owing to increasing consumer preference for natural products and stringent regulations governing the use of synthetic pesticides. Essential oils and plant extracts are increasingly incorporated into sprays, lotions, creams, candles, fumigants, and aerosol formulations for domestic, veterinary, and agricultural applications. The commercial production of insect repellents from weed species represents a unique convergence of invasive

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weed management, circular bioeconomy principles, and green industrial innovation.

Harvesting invasive weeds for the extraction of valuable bioactive compounds not only reduces their ecological impact but also creates opportunities for income generation, rural entrepreneurship, and sustainable resource utilization [9]. Such an approach transforms an environmental liability into an economically beneficial product while contributing to integrated pest management (IPM) programs and reducing dependence on synthetic chemical pesticides. In addition, the use of weed-derived insect repellents aligns with global efforts to promote environmentally sustainable agricultural practices and biodiversity conservation. Among the numerous weed species investigated for biopesticidal applications, *Cyperus rotundus*, *Ipomoea carnea* and *Tridax procumbens* have attracted considerable attention because of their widespread availability and rich phytochemical composition. These plants contain biologically active constituents that exhibit repellent, insecticidal, and growth-inhibitory effects against several insect pests [10]. Therefore, exploring the extraction processes, efficacy, and commercial potential of insect repellents derived from these weed species may provide an effective and sustainable alternative for pest management while simultaneously addressing the ecological challenges associated with invasive weeds. The present study was undertaken to investigate the extraction and commercial production potential of natural insect repellents from selected weed species and to evaluate their effectiveness as environmentally safe alternatives to conventional synthetic insecticides.

MATERIALS AND METHODS

An experiment was conducted at Anbil Dharmalingam Agricultural College and research Institute, Trichirapalli during 2024 to explore the various possibilities of weed species for their insecticidal properties through various extracts and production of insect repellent coil or spray against insects.

Cyperus rotundus

To prepare insect repellent from *Cyperus rotundus*, begin by collecting and washing freshly harvested rhizomes, which are then shade-dried until completely dry. Once dried, grind the rhizomes into a fine powder using a blender or mortar and pestle. In a mixing bowl, combine 100 grams of this powdered rhizome with 10 grams of gum Arabic. Gradually add 20-30 mL of water to achieve a dough-like consistency and if desired, incorporate 5-10 drops of essential oil to enhance the repellent effect and fragrance. Shape the mixture into long, thin ropes, press them into spiral molds, and then dry the coils in a low-temperature oven set to 50°C until they are hard and fully dry. Finally, test the coils by burning one end in a controlled environment to ensure they burn slowly and release the repellent properties effectively, adjusting the mixture if necessary for optimal performance.

Ipomoea carnea

For *Ipomoea carnea*, start by collecting fresh leaves and stems from a non-contaminated location. Wash and air-dry the plant material thoroughly. Once dried, grind it into a fine powder and store it in an airtight container. To extract the repellent compounds, weigh out 100 grams of the powdered material and soak it in 500 mL of ethanol or methanol for 24-48 hours, shaking occasionally. After extraction, filter the mixture using Whatman filter paper. For the final spray formulation, dilute 10 mL of the concentrated extract with 90 mL of distilled water or ethanol, add 5 mL of an emulsifier like Tween 20, and mix thoroughly. Transfer the diluted extract to a spray bottle, label it appropriately and conduct preliminary tests to assess effectiveness, adjusting the concentration as needed. Store the prepared spray in a cool, dry place away from sunlight and use it within 3-6 months for best results.

Tridax procumbens

To prepare an insect repellent from *Tridax procumbens*, start by collecting and washing fresh leaves, which are then shade-dried until brittle. Grind the dried leaves into a fine powder and store it in airtight containers. For extraction, mix 10 grams of the powdered leaves with 100 mL of distilled water, shake the mixture on a shaker for 3 days and then filter using a fine muslin cloth. Concentrate the filtrate by evaporating the excess water. To create mosquito coils, mix the powdered leaves with starch and candle wax in equal ratios to form a paste, mold it into coils and dry them under sunlight or in a drying oven. For testing, distribute the coils to households and evaluate them based on factors such as repellent activity, odor, smoke visibility, and burning time. Record observations and analyze the performance across different households to determine effectiveness.

RESULTS AND DISCUSSSION

Extraction and yield

The extraction process from the selected weed species, namely *Cyperus rotundus*, *Tridax procumbens* and *Ipomoea carnea*, yielded a substantial amount of insect repellent compounds. The yield was measured by carefully weighing the extracted oils and other active compounds, which are known for their repellent properties. This process involved the use of a solvent extraction method, where the plant material was soaked, and the active components were separated. The yield was quantified as a percentage of the starting material, indicating the efficiency of the extraction process.

Table 1 Mortality percentage (%) of insects exposed to botanical extracts of *Cyperus rotundus*, *Ipomoea carnea*, and *Tridax procumbens* at different exposure periods

Time (mins)	Mortality percent (%)		
	Cyperus rotundus	*Ipomea carnea*	*Tridax procumbens*
30	36.70	12.00	49.90
60	43.30	19.30	56.20
90	46.70	25.10	63.50
120	50.00	29.50	77.40

The mortality response of insects exposed to botanical extracts of *Cyperus rotundus*, *Ipomoea carnea*, and *Tridax procumbens* increased progressively with exposure time, indicating a clear time-dependent toxic effect of the plant-derived bioactive compounds. The results revealed significant variations among the three weed species in their insecticidal efficacy. At 30 minutes of exposure, *Tridax procumbens* recorded the highest mortality (49.90%), followed by *Cyperus rotundus* (36.70%), while *Ipomoea carnea* exhibited the lowest mortality (12.00%). This trend remained consistent throughout the observation period, suggesting that *T. procumbens* possesses more potent insecticidal constituents than the other tested species. With increasing exposure duration, insect mortality increased steadily in all treatments. After 120 minutes, *T. procumbens* achieved the highest mortality of 77.40%, which represented an increase of 27.50 percentage points over its initial mortality at 30 minutes. In comparison, *C. rotundus* caused 50.00% mortality at 120 minutes, while *I. carnea* recorded only 29.50% mortality [11-12]. The superior performance of *T. procumbens* may be attributed to the presence of diverse secondary metabolites such as flavonoids, alkaloids, terpenoids, tannins, and essential oils that possess contact and stomach poison activities against insects [13]. Several studies have reported the larvicidal, adulticidal, insecticidal, and repellent properties of *T. procumbens* extracts against agricultural and public-health pests, supporting the high mortality observed in the present study [14].

The moderate insecticidal activity exhibited by *C. rotundus* could be associated with its rich content of sesquiterpenes and volatile compounds such as cyperene, cyperotundone, mustakone, and related bioactive constituents. Recent investigations have demonstrated that extracts and essential oils of *C. rotundus* possess significant insecticidal activity against aphids and mealybugs through disruption of acetylcholinesterase and detoxification enzymes, leading to increased insect mortality [15]. The gradual increase from 36.70% mortality at 30 minutes to 50.00% at 120 minutes in the present study confirms the cumulative toxic effect of these phytochemicals over time. In contrast, *Ipomoea carnea* exhibited comparatively lower toxicity throughout the experimental period. Although mortality increased from 12.00% at 30 minutes to 29.50% at 120 minutes, its efficacy remained substantially lower than that of *T. procumbens* and *C. rotundus*. The lower mortality may be due to reduced concentrations of insecticidal phytochemicals or slower penetration of active compounds into the insect body [16]. Nevertheless, the progressive increase in mortality with prolonged exposure suggests that the extract still possesses biologically active compounds capable of affecting insect survival.

The positive relationship between exposure time and mortality observed in the present study is consistent with the general mode of action of botanical insecticides. Plant-derived insecticidal compounds often require sufficient contact time to penetrate the insect cuticle, interfere with feeding behavior, disrupt nervous system function, inhibit growth-regulating enzymes, or induce oxidative stress. Recent reviews on botanical insecticides have emphasized that increased exposure duration significantly enhances mortality because prolonged contact allows greater absorption and accumulation of bioactive metabolites within insect tissues. Overall, the results indicate that *Tridax procumbens* is the most promising botanical source for insect management among the tested weed species, followed by *Cyperus rotundus*, whereas *Ipomoea carnea* showed comparatively limited insecticidal potential. The findings support the growing interest in utilizing invasive and weedy plant species as eco-friendly alternatives to synthetic insecticides for sustainable pest management.

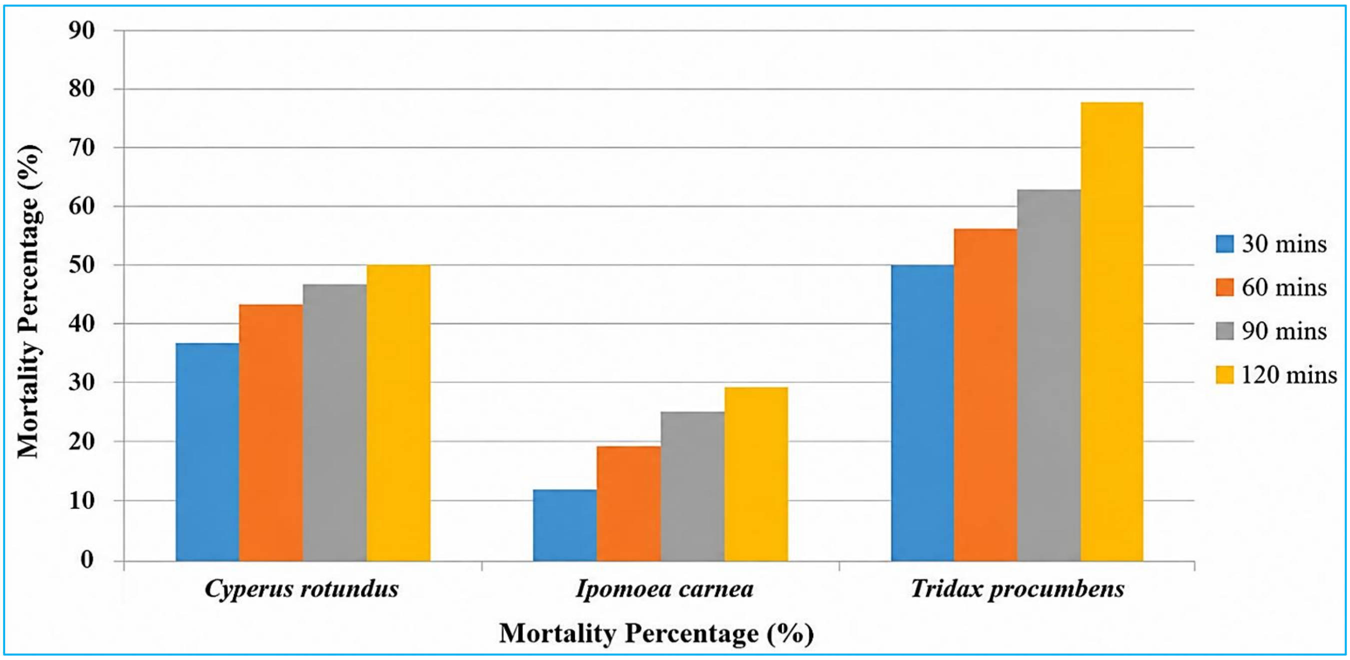

Fig 1 Effect of exposure time on mortality percentage of insects treated with extracts of *Cyperus rotundus*, *Ipomoea carnea*, and *Tridax procumbens*

Formulation of insect repellent coil

The extracted bioactive compounds obtained from the weed species were successfully formulated into an insect repellent coil through incorporation into a suitable combustible base material. The formation of a uniform paste followed by shaping into coils and subsequent drying at room temperature resulted in a stable, dark brown product with a smooth texture and homogeneous consistency. The successful formation of the coil indicates good compatibility between the active botanical ingredients and the carrier materials used in the formulation. Uniform texture and consistency are important quality parameters in mosquito and insect repellent coils because they ensure controlled combustion, uniform release of volatile bioactive compounds, and consistent repellent efficacy throughout the burning period.

The dark brown coloration of the formulated coil may be attributed to the presence of naturally occurring phytochemicals such as phenolics, flavonoids, tannins, terpenoids, and other secondary metabolites extracted from the weed species. These compounds often impart characteristic brownish coloration during drying and formulation processes. The absence of visible cracks, segregation, or irregularities in the final product suggests adequate binding properties and proper moisture removal during drying. Such physical characteristics are desirable because they contribute to the mechanical strength and shelf stability of the coil, reducing breakage during handling, packaging, transportation, and storage.

The smooth and compact structure observed in the formulated coil is indicative of proper mixing and homogeneous distribution of the active ingredients within the matrix. Homogeneous distribution is a critical factor influencing the efficacy of botanical insect repellent coils, as uneven dispersion can result in inconsistent burning rates and irregular emission of repellent compounds. Studies on plant-based mosquito coils have demonstrated that proper blending of botanical extracts with combustible fillers and binders enhances the sustained release of volatile phytochemicals during combustion, thereby improving repellency and insecticidal action against target insects. Recent research has further shown that botanical coils prepared from plant extracts rich in terpenoids and essential oils provide prolonged protection while minimizing the environmental and health concerns associated with synthetic pyrethroid-based coils [17-18].

The successful development of the insect repellent coil also demonstrates the potential for value addition of invasive and weedy plant species through conversion into commercially useful bioproducts. Botanical coils have gained increasing attention as eco-friendly alternatives to conventional synthetic repellents because they are biodegradable, renewable, and generally exhibit lower mammalian toxicity. Moreover, the utilization of weed biomass for repellent production contributes to sustainable weed management while generating economically valuable products. Recent studies have highlighted that plant-derived mosquito coils formulated from botanical extracts exhibit effective repellency against mosquitoes and other insect pests owing to the presence of volatile bioactive constituents that interfere with host-seeking behavior, feeding activity, and nervous system function of insects [19]. From a commercialization perspective, the production of a physically stable coil with acceptable texture, color, and structural integrity represents an essential first step toward product development. Product uniformity is particularly important for consumer acceptance and quality control, as variations in texture or composition may affect combustion characteristics and repellent performance. Therefore, the observed smooth texture, even consistency, and stable structure of the formulated coil indicate that the extraction and formulation procedures were suitable for producing a potentially marketable botanical insect repellent product.

Efficacy testing

The efficacy evaluation of the formulated botanical insect repellent coil against mosquitoes and flies provides an important measure of its practical applicability under domestic conditions. The test involved igniting the coil and observing the number of insects repelled over a specified period. Such bioassays are widely employed to assess the performance of mosquito coils because they simulate real-life usage conditions and enable the determination of the repellent potential of volatile phytochemicals released during combustion. The observed repellency indicates that the bioactive compounds extracted from the weed species remained stable during the formulation process and were effectively released into the surrounding environment upon burning.

The repellency exhibited by the formulated coil can be attributed to the presence of volatile secondary metabolites such as terpenoids, flavonoids, alkaloids, phenolics, and essential oils present in the plant extracts. During combustion, these compounds are gradually volatilized and dispersed into the air, creating a protective zone that interferes with the host-seeking behavior, feeding activity, orientation, and sensory perception of insects. Mosquitoes and flies rely heavily on olfactory receptors to locate hosts and food sources; therefore, exposure to plant-derived volatile compounds can disrupt these sensory mechanisms, resulting in avoidance behavior and reduced insect activity. Recent studies have demonstrated that botanical repellents containing plant-derived terpenes and aromatic compounds effectively repel mosquitoes by affecting odorant receptor pathways and altering insect behavioral responses [19-20].

The successful repellency of the formulated coil further suggests that the active ingredients were released at a sustained rate throughout the burning period. An ideal insect repellent coil should provide continuous emission of active compounds, ensuring prolonged protection against insect pests. Uniform combustion and gradual release of phytochemicals are critical factors influencing the effectiveness of botanical coils. The smooth texture and homogeneous composition observed during formulation likely contributed to consistent burning characteristics and stable release of repellents. Similar findings have been reported for plant-based mosquito coils prepared from botanicals rich in essential oils and bioactive secondary metabolites, where effective repellency was maintained for several hours after ignition [21].

Mosquitoes represent one of the most important vectors of human diseases, including malaria, dengue, chikungunya, Japanese encephalitis, and lymphatic filariasis, while flies serve as mechanical vectors of numerous pathogenic microorganisms. Therefore, the ability of the formulated coil to repel both groups of insects highlights its potential utility as an eco-friendly household pest management product. Compared with conventional synthetic mosquito coils containing pyrethroids and other chemical insecticides, botanical coils offer the advantages of biodegradability, lower environmental persistence, reduced risk of insecticide resistance, and generally lower toxicity to non-target organisms. Consequently, plant-based repellents are increasingly being promoted as sustainable alternatives for integrated vector and pest management programs [22].

The efficacy demonstrated by the formulated coil also supports the concept of utilizing invasive and weedy plant species as valuable sources of bioactive compounds for commercial insect repellent production. The conversion of unwanted weed biomass into useful pest management products contributes to sustainable resource utilization while simultaneously addressing weed management concerns. Recent research has emphasized the growing importance of botanical repellents derived from underutilized plant resources due to increasing concerns regarding environmental contamination, resistance development, and human health risks associated with synthetic insecticides [23]. The efficacy testing confirms that the formulated botanical coil possesses significant repellent activity against common household insect pests. The results demonstrate that the extracted plant compounds retained their biological activity after formulation and combustion, indicating their potential for development as environmentally friendly insect repellent products suitable for domestic use.

CONCLUSION

The successful extraction and formulation of insect repellent coils from *C. rotundus*, *T. procumbens* and *Ipomoea carnea* demonstrate the potential of these weed species as a source of natural insect repellents. The brown color and smooth texture of the coil indicate a well-formulated product and the observed efficacy against mosquitoes and flies highlights the practical application of these weeds in pest control. The study suggests that utilizing these commonly found weeds for insect repellent production could offer a cost-effective and environmentally friendly alternative to synthetic repellents.

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