Traditional Eco-friendly Pest Management Practices in the Dimapur district of Nagaland, India

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Research

Abstract

Background: The study was conducted to investigate the phytopesticides used by farmers in the Dimapur district of Nagaland along with their traditional methods of preparation. This study aimed in general to contribute to the modern formulation of plant-based pesticides.

Methods: The field survey was conducted in Dimapur district of Nagaland between December 2022 and January 2024. Data was collected through interviews and a semi-structured questionnaire.

Results: Thirty-five locally grown phytopesticidal species belonging to 31 genera and 21 families were recorded. Asteraceae and Zingiberaceae possessed the highest number of species, with 4 each followed by Solanaceae and Lamiaceae (3 species each). Twenty types of insect pests were reported. Eight different parts of the plant were used as phytopesticides. The plant part that was used the most was the leaf with 80% of the reports of use. Quantitative indices such as the use value (UV), the family use value (FUV), and the informants consensus factor (ICF) of the phytopesticides were calculated. *Azadirachta indica* A. Juss has shown the highest use value (0.56). Similarly, Caricaceae showed the highest FUV of 0.52, and Cucurbitaceae and Fabaceae showed the lowest FUV of 0.06 each. The highest ICF value was recorded for gundhi bug (0.98) whereas the lowest ICF was recorded for armyworms (0.94).

Conclusions: Five different phytopesticide preparation methods were recorded. Farmers found these formulations to be very effective against insect pests. In the near future, such plants will contribute to the formulation of modern plant-based pesticides with better results.

Keywords: Ethnobotany, formulation, insect pests, plant-based pesticides, use value.

Background

Using synthetic chemical pesticides to protect crops in the field and after harvest has been a major component of agricultural pest management for the past 50 years, but they pose an immense threat to the environment and mankind (Tewary *et al.* 2005). Furthermore, growing evidence of the harmful effects of synthetic pesticides on the environment and human health, as well as environmental regulations for pesticides (Isman 2000), has led to increasing enthusiasm for the creation and application of botanical pest control. Plants have always played a vital role in the traditional herbal medicine systems in developing countries (Rajalakshmi *et al.* 2015). The use of herbal remedies in place of modern medicine is quite frequent in underdeveloped countries (Rates 2001; Sheng-Ji 2001; Muhammad & Awaisu 2008), and among the numerous applications of medicinal plants, their use as a pesticide in agricultural practices is very common (Mwine *et al.* 2011). Many ethnic groups rely on plant pesticides or phytopesticides, which have historically been used by farmers to protect their crops from insect pests (Abate *et al.* 2000; Al- Rubae 2009). Both pre-harvest and post-harvest pests are managed with the help of herbal insecticides (Lehman *et al.* 2007). The viability, biodegradability, minimal harmfulness and availability of raw materials are attributed to the importance of botanical pesticides (Neeraj *et al.* 2017). Herbal or phytopesticides are becoming more and more popular, since they are ecofriendly and have a lucrative market among consumers ready to pay extra for naturally produced food (Misra 2014).

The search for innovative plant-based pest management solutions is still expanding but is not always producing results and benefits (Isman & Grieneisen 2013). However, there are many potential plant species with established pesticidal capabilities whose chemistry and performance in the laboratory are well understood and could be quickly transformed into novel products (Stevenson 2017). Isman, 2017 has argued that for farmers to use natural pesticides more frequently, research must be done on how to use them effectively in difficult agro-ecological settings. This research should focus on how various pesticidal plant species behave when used in various crops in various growing environments. Due to the typical presence of several bioactive compounds, their low environmental persistence, and their generally affordable cost of use, using unprocessed botanical extracts for insect management has several benefits, especially for small-scale cultivators with limited resources (Angioni *et al.* 2005; Caboni *et al.* 2006; Isman 2008). Delivering an organic and environmentally sound pest control strategy requires a great deal of traditional or ethnobotanical knowledge about the use of plant-based insecticides (Altieri 1993). According to reports, pesticidal plants have less of an adverse effect on the ecosystem, particularly when it comes to beneficial insects (Rathi & Gopalakrishnan 2006; Devanand & Rani 2008; Akhtar *et al.* 2008).

The native population of Nagaland is comprised of about 15 tribes, with people from other states/ districts of India residing in a few large cities. Each of these tribes has a rich culture of traditional botanical medicines (Jamir *et al.* 1999). Different ethnic farmers of the state use their own traditional phytomedicines to control pests in their vegetable farming. Unfortunately, there are very few scientific studies on this traditional pest management system reported so far. These studies cover ethnobotanical investigation on indigenous pest control methods including pesticidal and piscicidal plants in contemporary and jhum cultivation in Nagaland (Bhattacharjee & Ray 2010; Dominic & Ramanujam 2012; Dutta *et al.* 2019; Nath & Puzari 2022; Benjongtoshi *et al.* 2023). There is no discrete scientific work recorded on the local pest management practices of the Dimapur district of Nagaland.

Therefore, this study aims to document the locally used plants to eliminate agricultural pests in the Dimapur district of Nagaland along with their usage pattern. The main objectives of this study are- (1) to document and identify pesticidal plants of the study site (2) to study the traditional formulation of plant pesticides (3) to study their mode of administration.

Materials and Methods

Study area

Research was carried out in the Dimapur district of Nagaland. The district, which is located at 25.9091 ° N and 93.7266 ° E, is one of the bordering districts of Assam. The Dimapur district is located between 160 and 350 meters above mean sea level. The lowest and highest average temperatures are 21 ° C and 26°C, respectively, while the annual rainfall ranges from 1000 to 1500 mm. According to the Dimapur District Inventory of Agriculture, ICAR (2015), the area is designated as a humid "Subtropical Agro-climatic Zone", which has a cold winter and a hot and humid summer. Much of the land is covered with deep and unmanaged forests. For the study, 9 villages were selected in the district. The villages were Indisen, Borlengri, Kacharigaon, Aoyimti, Aoyimsen, Aoyimkum, New shouba, Old shouba, Kushiabill sector 4 (Fig. 1).

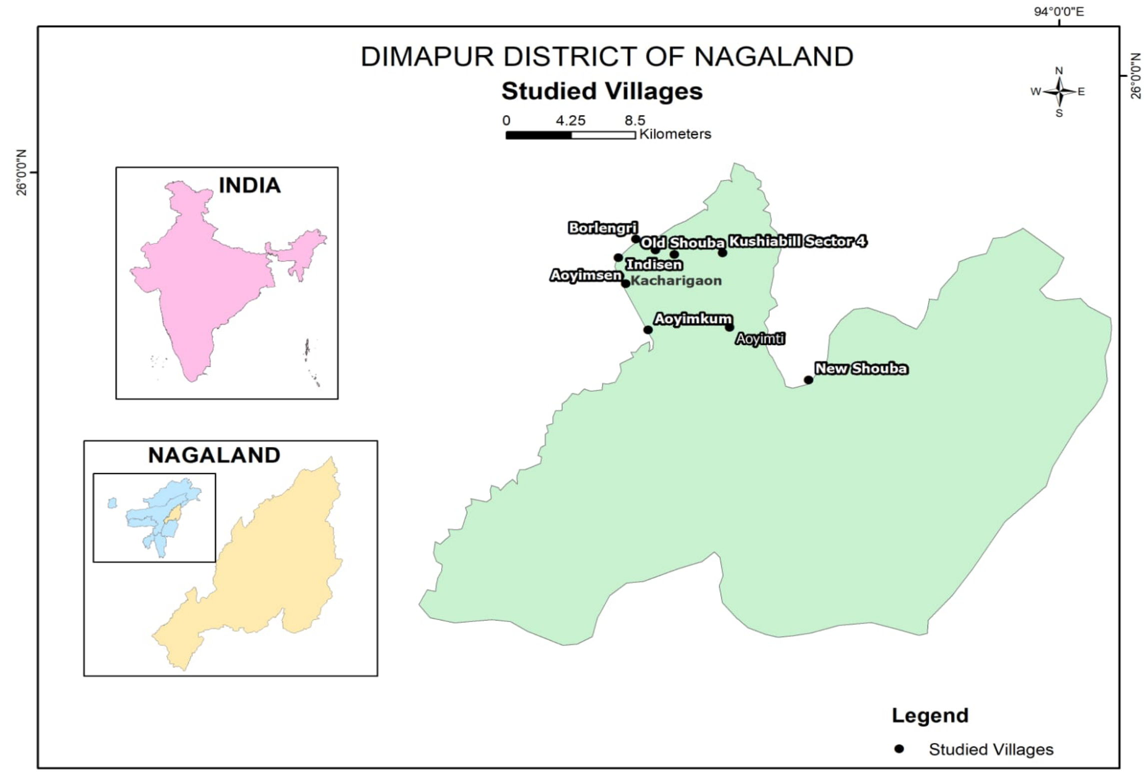

Figure 1. Map of the study sites in Dimapur district of Nagaland

Data collection

Between December 2022 and January 2024, data were collected. To conduct interviews and collect data, a semi-structured questionnaire based on the medicinal and pesticidal uses of plants was used. 116 informants were interviewed for the study, and the majority of them were between 35 and 70 years of age. Interviews were conducted to record details on the plants, including their local name, pesticidal use, useful parts and habits, formulation type, and mode of application. Most of the respondents worked in agriculture and lacked higher education.

Collection and identification of plant species

The specimens were gathered locally, catalogued, numbered, pressed, dried, and deep frozen for identification after collection from the field. Specimen identification was done at the Department of Botany of St. John College Dimapur, Nagaland with the help of a subject expert. The website of world flora online (World flora online 2023) was used afterwards to confirm the valid names. After the identification was done, the specimen was preserved in the form of herbarium. Herbaria were stored in the Department of Science and Humanities, NIT Nagaland.

Identification of pests

For the identification of vegetable pests, an insect identification guide was used initially (https://www.pestworld.org/). For confirmation of identified pests' names, further consultation was made with subject expert.

Data analysis

Use Value

The relative significance of each plant species used locally is measured by its use value (UV). The formula used to calculate it is as follows.

$$UV = \Sigma \mathrm{U}/\mathrm{n}$$

Where "UV" is the use value of the species; for each plant species, "U" is the number of use reports cited by each informant, and "n" is the total number of informants questioned for that plant. UV is used to determine which plants are most useful for a given disease (Nath & Puzari 2022).

Family Use Value (FUV)

It is estimated to identify the most important pest-repellent plant species in the study region. The following formula was used to calculate FUV

$$FUV = \Sigma \mathrm{UVs}/\mathrm{Ns}$$

"UVs" is the total use value of all species in a specific family, and "Ns" denotes the total number of species in that family (Nath & Puzari 2022).

Informants Consensus Factor (ICF)

To determine the homogeneity of the data collected on the usage of plant species for a particular therapy among the plant users, the informants' consensus factor (IFC) was utilized (Nath & Puzari 2022). The following formula was used to determine the ICF.

$$ICF = (Nur - Nt)/(Nur - 1)$$

Where "Nur" is the total number of usage reports for a category, and "Nt" denotes the number of taxa utilized in that category.

Statistical analysis

Graphical display and statistical analysis of the data were performed with OriginPro 8.5 software (Stevenson 2011). It is one of the most complete data analysis and graphics products because of its simplicity of use and remarkable array of features.

Results

Demographic profile of the respondents

The total number of informants was 116. The male informants were 71.55% and rest 28.44% of the total is female. The highest number of informants was found in the age group of 41-50 years (35.34%) and the lowest was in the age group beyond 70 years. Most of the informants were lacking of formal education (32.75%) or had only primary education (51.72%). Farming was the most common occupation among informants. Some informants also participated in other occupations in addition to farming (Table 1).

Table 1. Demographic description of the informants n= 116

Age group	Male	Female	Total	Percentage (%)	Occupation
30-40	14	4	18	15.51	Farming, small-scale business.
41-50	32	9	41	35.34	Farming, teaching, small-scale business.
51-60	23	12	35	30.17	Farming, office worker.
61-70	12	8	20	17.24	Farming, retired officials.
70 >	2	0	02	1.72	Farming.
No formal education	28	10	38	32.75	Farming.
Primary education	45	15	60	51.72	Farming, Office job.
Secondary education	10	8	18	15.51	Teaching, farming, office job.

Distribution of phytopesticidal species

In the study, 35 locally grown phytopesticidal or botanical pesticidal species belonging to 31 genera and 21 families were recorded. Asteraceae and Zingiberaceae have the highest number of species, 4 each, followed by Solanaceae and Lamiaceae with 3 species each. The Apocynaceae, Rutaceae, and Amaryllidaceae shared two species each. Acanthaceae, Caricaceae, Thelypteridaceae, Lauraceae, Araceae, Cucurbitaceae, Urticaceae, Saururaceae, Melastomataceae, Myrtaceae, Euphorbiaceae, Fabaceae, and Combretaceae have one species each (Table 4; Fig. 2). Among the species, 14 herbs, 10 trees, 9 shrubs, 1 climber, and 1 creeper were present.

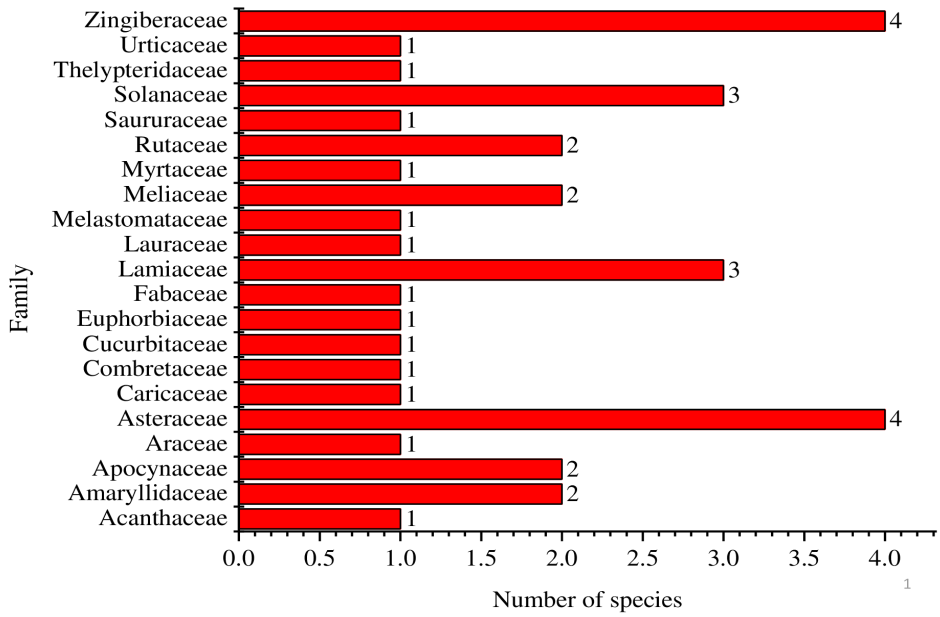

Figure 2. Distribution of number of pesticidal plants over different families

Diversity of pests

Twenty types of insect pests were reported in the study, which were repelled by using the plant species mentioned in Table 4. The insect pests manifested in the region were termites, stem borers, nematodes, jassids, aphids, grasshoppers, semiloopers, whiteflies, cutworms, armyworms, gundhi bugs, ants, caterpillars, thrips, leaf miners, leaf webbers, beetles, flies, boll weevils, and carrot flies. These pests manifest throughout the year and damage various species of vegetables. Twenty-eight locally grown vegetables and crops were damaged by these pests (Table 2). Vegetables were potato, maize, chickpea, teak, pumpkin, sugarcane, zucchini, tomato, cucumber, squash, okra, eggplant, beans, lettuce, spinach, carrot, cabbage, cauliflower, celery, green pea, beetroot, brassica, rice, cereals, radish, chilli, mustard and broccoli (Table 2).

Table 2. List of pests affecting vegetables in the study region and ICF value for the pests

Pests	Affected vegetables in the study region	Informant consensus factor
Termites	Potato, maize, chickpea, teak	0.97
Stem borers	Pumpkin, sugarcane, zucchini	0.96
Nematodes	Tomato, cucumber, squash, okra, eggplant	0.97
Jassids	Eggplant	0.96
Aphids	Tomato, beans, lettuce, spinach	0.96
Grasshoppers	Carrot, beans, lettuce	0.96
Semiloopers	Cabbage, cauliflower	0.97
Whiteflies	Beans, cucumber, eggplant, cabbage, tomato	0.95
Cutworms	Carrot, tomato, beans, celery	0.96
Armyworms	Peas, beans, beetroot, brassica, eggplant	0.94
Gundhi bug	Rice	0.98
Ants	Eggplant, tomato	0.95
Caterpillar	Cabbage, cauliflower	0.96
Thrips	Chilli	0.96
Leaf miners	Tomato, potato, cucumber, beans, squash	0.96
Leaf webbers	Cabbage, radish, mustard	0.96
Beetles	Cabbage, broccoli, potato, tomato, eggplant	0.96
Flies	Squash, tomato, carrot, potato	0.95
Carrot flies	Carrot, celery	0.95
Boll weevils	Mustard, tomato, potato	0.95

Plant parts used

Eight different parts of the plants were used to prepare pesticides. These were leaf, bark, bulb, seed, fruit, and skin of the fruit, rhizome, and stem. The most used plant part was the leaf with 80% (28 species). The lowest used part was the stem 2.85% (1 species). Bark, seed, fruit, and rhizome, each had 11.42% uses with 4 species individually. Both the bulb and the fruit skin had a use percentage of 5.71 each (2 species each) (Fig. 3).

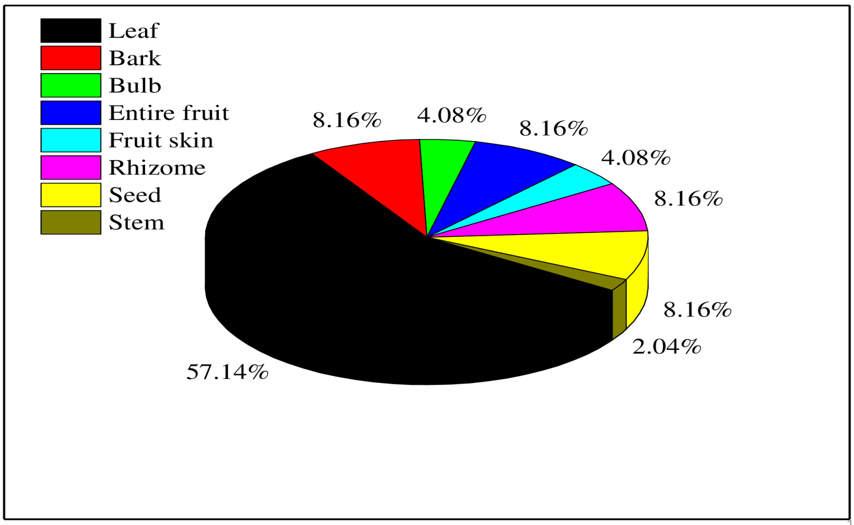

Figure 3. Use of plant parts as botanical pesticides

Formulation and application of traditional plant pesticides

Twelve different plant-based components were used in the development of traditional phytopesticides or plant-pesticides. These were leaf extract, bark extract, bulb extract, seed extract, crushed seed, fruit extract, physical admixture of plant parts, smoke, ash, rhizome extract, crushed rhizome and stem extract. The component most commonly used in the formulation was leaf extract (80%) followed by fruit extract (14.28%), physical admixture (14.28%), bark (11.42%), rhizome extract (11.42%), crushed rhizome (11.42%), seed extract (11.42%), bulb extract (5.71%), crushed seed (5.71%), smoke (5.71%), ash (5.71%), and stem extract (2.85%) (Table 4). The formulations were generally prepared by adding washing soap, detergents, kerosene, bleaching powder, and salt to the plant extract. Two modes of application from the studies were recorded, namely spraying of the formulated phytopesticides and blowing smoke over the infected plants (Table 3). Such traditional formulations of pesticides are cheap, easily affordable, and environmentally benign.

Table 3. Preparation and application of traditional pesticides by ethnic farmers

Formulation type	Preparation	Mode of application & doses
Insecticide-A	Plant extract (any of the reported species or mixture of them): Detergent: Water (200 ml: 300 ml: 500 ml).	Spray over the infected parts twice daily for 10 days or twice daily on every alternate day until the pests are repelled.
Insecticide-B	Plant extract (any of the reported species or mixture of them): Bleaching powder: Detergent: Water (200 ml: 50 gm: 200 ml: 500 ml)	Spray over infected parts for one week twice daily.
Insecticide-C	Plant extract (any of the reported species or mixture of them): Kerosene: Water (200 ml: 300 ml: 500 ml).	Spray over the infected parts twice daily for 10 days or twice daily on every alternate day until the pests are repelled.
Insecticide-D	Burning of plant parts (Ageratum conyzoides (L.) L. & *Christella*	Smoke explosion in the morning and evening daily for at least 10 days.

	parasitica (L.) H. Lev.) near the infected parts and blowing the smoke towards the pests.	
Insecticide-E	Burning of plant parts (*Ageratum conyzoides* (L.) L.; *Christella parasitica* (L.) H. Lev.; *Nicotiana tabacum* L.; *Mikania micrantha* Kunth.) to make ash and it is mixed with kitchen salts. (Half kg salt + half kg ash).	The mixture is applied over infected parts for at least 10 days.

Use value

Table 4 shows a diverse range of use values ranging from 0.06 to 0.56. *Azadirachta indica* A. Juss has shown the highest use value. The lowest use value was 0.06 which was recorded for *Tamarindus indica* L. and *Cucumis sativus* L. Species recorded with a higher use value were *Carica papaya* L. (0.52), *Adhatoda vasica* (L.) Nees (0.46), *Curcuma longa* L. (0.43), *Curcuma aromatica* Salisb (0.37), *Catharanthus roseus* (L.) G. Don (0.36), *Nicotiana tabacum* L. (0.34), *Curcuma zedoaria* (Christm.) Roscoe (0.34), *Melia azedarach* L. (0.30), *Capsicum frutescens* L. (0.20) and *Dendrocnide sinuate* (Bl.) Chew (0.20). Species with a use value in the range of 0.19 - 0.1 were *Ageratum conyzoides* (L.) L. (0.19), *Chromolaena odorata* (L.) R. M. King & H. Rob. (0.19), *Zingiber officlinale* Roscoe (0.18), *Bidens pilosa* L. (0.18), *Mikania micrantha* Kunth. (0.18), *Alstonia scholaris* (L.) R.Br. (0.18), *Christella parasitica* (L.) H. Lev. (0.17), *Ricinus communis* L. (0.16), *Allium cepa* L. (0.16) *Colocasia esculenta* (L.) Schott. (0.16), *Clerodendrum glandulosum* Lindl. (0.15), *Terminalia chebula* Retz. (0.14), *Houttuynia cordata* Thunb. (0.13), *Ocimum tenuiflorum* L. (0.12), *Melastoma malabathricum* L. (0.11), *Cinnamomum tamala* (Buch.-Ham) T.Nees & Eberm (0.10) and *Allium sativum* L. (0.10). Species with less than 0.10 use value were *Citrus grandis* Osbeck (0.09), *Solanum torvum* Sw. (0.09), *Psidium guajava* L. (0.09), *Vitex negundo* L. (0.08), and *Citrus sinensis* (L.) Osbeck (0.07).

Table 4. Plants used to control pests in the Dimapur district of Nagaland

Scientific name & Family	Vernacular name	Useful parts	Informants number (N= 116)	Target Pests	Use value	Mode of formulation	Mode of application
Adhatoda vasica (L.) Nees (Acanthaceae) UN-1	**kichanaro** (Ao)	Leaf	54	Stem borers, Cutworms, Nematodes, Jassids	0.46	Leaf extract	Spraying
Ageratum conyzoides (L.) L. (Asteraceae) UN-4	**imchenriza, tsuma za** (Ao)	Leaf	23	Termites, Semiloopers, Aphids, Whiteflies, Cutworms	0.19	Leaf extract	Spraying
Alstonia scholaris (L.) R.Br. (Apocynaceae) UN-3	**lazarongpang** (Ao)	Bark/ Leaf	21	Termites, Nematodes, Armyworms, Aphids	0.18	Bark extract/ leaf extract	Spraying
Allium cepa L. (Amaryllidaceae) UN-34	**piaz** (Nagamese/ Ao)	Bulb	19	Whiteflies, Stem borers, Caterpillars, Aphids	0.16	Bulb extract	Spraying
Allium sativum L. (Amaryllidaceae) UN-2	**losun / losen** (Nagamese/ Ao)	Bulb	12	Aphids, Ants, Jassids, Caterpillars, Whiteflies.	0.1	Bulb extract	Spraying
Azadirachta indica A. Juss (Meliaceae) UN-5	**neem** (Nagamese/ Ao)	Leaf/ Seed/ Bark	66	Termites, Aphids, Jassids, Stem borers, Caterpillars, Leaf miners, Thrips.	0.56	Leaf extract/bark extract/ crushed seed/ seed extract	Spraying
Bidens pilosa L. (Asteraceae) UN-35	**kure/ komo natzu** (Ao)	Leaf	22	Whiteflies, Stem borers, Grasshoppers	0.18	Leaf extract	Spraying

Capsicum frutescens L. (Solanaceae) UN-29	**meritsu** (Ao)	Fruit	24	Flies, Leaf webber, Aphids, Nematodes, Caterpillars, Leaf miners.	0.20	Fruit extract/ crushed seed	Spraying
Carica papaya L. (Caricaceae) UN-8	**mamali** (Ao)	Bark/ Leaf	61	Whiteflies, Semiloopers, Aphids, Termites, Caterpillars, Thrips, Gundhi bugs.	0.52	Leaf extract/bark extract/physical admixture	Spraying
Catharanthus roseus (L.) G. Don (Apocynaceae) UN-10	**tsuinlari-naro** (Ao)	Leaf	42	Leaf miners, Stem borers, cutworms, beetles, termites.	0.36	Leaf extract	Spraying
Christella parasitica (L.) H. Lev. (Thelypteridaceae) UN-19	**nambi jang** (Ao)	Leaf	20	Stem borers, Leaf miners, Whiteflies, Carrot flies, Ants.	0.17	Leaf extract /smoke/ash	Spraying/ blowing smoke
Chromolaena odorata (L.) R. M. King & H. Rob. (Asteraceae) UN-6	**langpa za** (Ao)	Leaf	23	Thrips, Boll weevils, Jassids, Stem borers, Aphids, Leaf miners.	0.19	Leaf extract	Spraying
Cinnamomum tamala (Buch.-Ham) T.Nees & Eberm (Lauraceae) UN-7	**sungsa** (Ao)	Leaf	12	Termites, Whiteflies, Carrot flies, Leaf webber, Leaf miners.	0.1	Leaf extract/ smoke	Spraying/ blowing smoke
Citrus grandis Osbeck (Rutaceae) UN-33	**narongsu** (Ao)	Leaf/ fruit skin	11	Nematodes, Stem borers, Flies, Termites.	0.09	Leaf extract/ fruit extract	Spraying
Citrus sinensis (L.) Osbeck (Rutaceae) UN-9	**chemben** (Ao)	Leaf/ fruit skin	9	Stem borers, Carrot flies, whiteflies.	0.07	Leaf extract/ fruit extract	Spraying
Clerodendrum glandulosum Lindl. (Lamiaceae) UN-11	**emmren** (Ao)	Leaf	18	Thrips, Leaf webbers, Beetles, Aphids, Stem borers, Leaf miners.	0.15	Leaf extract	Spraying
Colocasia esculenta (L.) Schott. (Araceae) UN-14	**ammi** (Ao)	Leaf	19	Ants,Stem borers, Thrips, Semilooper, Flies, Caterpillars, Beetles.	0.16	Leaf extract	Spraying
Cucumis sativus L. (Cucurbitaceae) UN-16	**matsusu** (Ao)	Leaf	8	Ants	0.06	Leaf extract	Spraying
Curcuma longa L. (Zingiberaceae) UN-12	**pangsalaphi** (Ao)	Rhizome	51	Stem borers, Nematodes, Jassids, Aphids, Termites.	0.43	Rhizome extract /crushed rhizome	Spraying
Curcuma aromatica Salisb (Zingiberaceae) UN-15	**pangsalaphi** (Ao)	Rhizome	43	Nematodes, Termites, Jassids, Aphids, Whiteflies, Carrot flies.	0.37	Rhizome extract /crushed rhizome	Spraying
Curcuma zedoaria (Christm.) Roscoe (Zingiberaceae) UN-17	**chentsunaro** (Ao)	Rhizome	40	Stem borers, Whiteflies	0.34	Rhizome extract/ crushed rhizome	Spraying

Dendrocnide sinuata (Bl.) Chew (Urticaceae) UN-18	**arem laklem**; **zaklu** (Ao)	Leaf	24	Beetles, Caterpillars, Ants, Grasshoppers, Termites, Gundhi bugs.	0.20	Leaf extract	Spraying
Houttuynia cordata Thunb. (Saururaceae) UN-13	**mokma** (Ao)	Leaf	16	Carrotflies, Whiteflies.	0.13	Leaf extract	Spraying
Melastoma malabathricum L. (Melastomataceae) UN-20	**imnaklaksu** (Ao)	Leaf	13	Grasshoppers, Cutworms, Armyworms, Caterpillars, Whiteflies.	0.11	Leaf extract	Spraying
Melia azedarach L. (Meliaceae) UN-25	**assa** (Ao)	Bark, Leaf/ Seed	35	Termites, Aphids, Flies, Ants, Cutworms, Jassids, Grasshoppers, Leaf miners, Leaf Webbers.	0.3	Leaf extract /bark extract/crushed seed/ seed extract	Spraying
Mikania micrantha Kunth. (Asteraceae) UN-26	**japanaza** (Ao)	Leaf/ Stem	22	Semiloopers, Flies, Ants, Cutworms, Jassids, Stem borers, Termites, Beetles.	0.18	Leaf extract/ stem extract	Spraying
Nicotiana tabacum L. (Solanaceae) UN-27	**moko tong** (Ao)	Leaf	40	Stem borers, Ants, Cutworms, Caterpillars, Termites, Aphids, Jassids.	0.34	Leaf extract/ physical admixture	Spraying/ Blowing smoke
Ocimum tenuiflorum L. (Lamiaceae) UN-28	**napa** (Ao)	Leaf	14	Whiteflies, Aphids, Stem borers, Leaf miners, Leaf Webbers.	0.12	Leaf extract /physical admixture	Spraying
Psidium guajava L. (Myrtaceae) UN-30	**motiram** (Ao)	Leaf	11	Whiteflies, Aphids, Ants, Nematodes.	0.09	Leaf extract/ ash	Spraying
Ricinus communis L. (Euphorbiaceae) UN-23	**eritu, latuwa** (Ao)	Leaf/ Seed	19	Termites, Cutworms, Aphids, Boll weevils, Carrot flies, Jassids.	0.16	Leaf extract/ seed extract	Spraying
Solanum torvum Sw. (Solanaceae) UN-21	**longkok, arem likok** (Ao)	Leaf/ Fruit/ Seed	11	Caterpillars, Whiteflies, Aphids, Thrips, Jassids, Stem borers, cutworms, armyworms.	0.09	Leaf extract /physical admixture/ fruit extract/ seed extract	Spraying
Tamarindus indica L. (Fabaceae) UN-22	**tedili** (Ao)	Fruit/ Leaf	8	Boll weevils, Cutworms, Armyworms.	0.06	Leaf extract /physical admixture/ fruit extract	Spraying/ blowing smoke
Terminalia chebula Retz. (Combretaceae) UN-31	**lingkha** (Ao)	Leaf/ Fruit	17	Cutworms, Stem borers, Termites, Caterpillars, Thrips, Leaf miners.	0.14	Leaf extract /fruit extract /crushed fruit	Spraying
Vitex negundo L. (Lamiaceae) UN-24	**N/A**	Leaf	10	Flies, Jassids, Thrips, and cutworms.	0.08	Leaf extract	Spraying

Zingiber officinale Roscoe (Zingiberaceae) UN-32	**assung, sungpak** (Ao)	Rhizome	21	Nematodes, Thrips, Stem borers, Armyworms, Leaf miners.	0.18	Rhizome extract /crushed rhizome	Spraying

Family use value

FUV provides insight into the family-wise use of phytomedicine for specific purposes. Among the recorded families, Caricaceae showed the highest FUV of 0.52, and Cucurbitaceae and Fabaceae showed the lowest FUV with FUV of 0.06 each. Families with moderate FUV were Acanthaceae (0.46), Meliaceae (0.43), Zingiberaceae (0.33), Apocynaceae (0.27), Solanaceae (0.21), Urticaceae (0.20), Asteraceae (0.18), Thelypteridaceae (0.17), Araceae (0.16), and Euphorbiaceae (0.16). The rest of the families have a FUV lower than 0.15 (Table 5).

Table 5. Family use value (FUV) and distribution of genera and species

Family	Number of genera	Number of species	FUV
Acanthaceae	1	1	0.46
Amaryllidaceae	1	2	0.13
Apocynaceae	2	2	0.27
Araceae	1	1	0.16
Asteraceae	4	4	0.18
Caricaceae	1	1	0.52
Combretaceae	1	1	0.14
Cucurbitaceae	1	1	0.06
Euphorbiaceae	1	1	0.16
Fabaceae	1	1	0.06
Lamiaceae	3	3	0.11
Lauraceae	1	1	0.10
Melastomataceae	1	1	0.11
Meliaceae	2	2	0.43
Myrtaceae	1	1	0.09
Rutaceae	1	2	0.08
Saururaceae	1	1	0.13
Solanaceae	3	3	0.21
Thelypteridaceae	1	1	0.17
Urticaceae	1	1	0.20
Zingiberaceae	2	4	0.33

Informant consensus factor (ICF)

The ICF indicates the homogeneity of the data gathered on the usage of the plant species for a particular therapy among plant users. The ICF value has been ranging from 0.94 to 0.98 for the pests (Table 2). The highest ICF value was recorded for gundhi bug (0.98) whereas the lowest ICF was recorded for armyworms (0.94). ICF was greater than 0.95 in 95% of the cases.

Pest management through plant-based pesticides: A correlation

Current study reveals the dependence of local farmers on traditional plant-based pesticides. This region is mainly depending on organic agriculture (Saikia & Jain 2007) and their traditional science has included the use of plants and their components as drugs (Jan *et al.* 2017). Nath & Puzari (2022) reported the use of various leaves as pesticides in the southwest part of Nagaland. Numerous studies have shown the use of pesticides generated from plants, which have been shown to have a range of negative effects on the neurological, respiratory, and endocrine systems as well as the water balance (Souto *et al.* 2021).

Discussion

One of the main challenges in agriculture in Northeast India is the infestation of a large number of pests. The climatic conditions are ideal for the growth and reproduction of insect species in the region (Kuotsu & Lalrinfeli 2019). There are around 653 species of Aphididae, divided into 208 genera reported in India, and 414 subspecies found in Northeast India

(Ghosh & Singh 2000). Similarly, termites stem borers, nematodes, jassids, aphids, grasshoppers, semiloopers, whiteflies, cutworms, armyworms, gundhi bugs, ants, caterpillars, thrips, leaf miners, leaf webbers, beetles, flies, boll weevils, and carrot flies are also abundantly found in the region. To control these insect pests, local farmers of the region adopt traditional plant pesticides in their organic farming.

Traditional plant medicine has been a very common practice among tribes. In the study, the older section of the society was found to be more familiar with traditional phytopesticidal plants (35.4% of the 41-50 year group; 30.17% of the 51-60 year group) than the younger generation (15.51% of the 30-40 year group). The younger and more educated members of the community treat ethnobotanical knowledge as outdated and unsuitable ancient information (Jamir *et al.* 2022). Traditional science has included the use of plants and plant components as medicines as well (Jan *et al.* 2017). Plant species such as *Azadirachta indica* A. Juss, *Zingiber officinale* Roscoe, *Carica papaya* L. and *Nicotiana tabacum* L. show a higher value as phytopesticides, which indicates the abundance of the plant and a well-versed knowledge of the farmers on its use in the study region. Plant parts such as barks, leaves, roots, flowers, fruits, seeds, cloves, rhizomes, and stems are utilized in the production of botanical insecticides. The intended bioactive chemicals and their quantity within that specific plant part determine which part of the plant is employed. Myrtaceae, Lauraceae, Rutaceae, Lamiaceae, Asteraceae, Apiaceae, Cupressaceae, Poaceae, Zingiberaceae, Piperaceae, Liliaceae, Apocynaceae, Solanaceae, Caesalpinaceae, and Sapotaceae are among the plant families whose plants have been reported to contain bioactive compounds with activity against significant crop pests (Vidyasagar & Tabassum 2013; Gakuubi *et al.* 2016; Jnaid *et al.* 2016; Ahmad *et al.* 2017). Families such as Asteraceae, Zingiberaceae, Solanaceae, and Lamiaceae were vigorously used as phytomedicine and phytopesticides in the study region. The presence of several secondary metabolites, such as alkaloid, flavonoid, phenol, saponin, tannin, and terpenoid, make some plant species very effective against a variety of crop pests (Nath & Puzari 2022). Some examples of mode of action of phytopesticides in insects include adherence to acetylcholine receptors and upsetting the neurological system, prevention of feeding, inhibition of oviposition, hatching, and moulting of eggs (*Azadirachta indica* A. Juss.) (Grdiša & Gršic 2013), preventing nematodes from hatching eggs, larval toxicity, and structural alteration (*Targates erecta* L.) (Feyisa *et al.* 2015).

Various species of the Asteraceae family have anti-inflammatory, antibacterial, antioxidant, and hepatoprotective properties (Achika *et al.* 2014), and this is due to some phytochemicals present in them. Most species of the Asteraceae family have therapeutic uses and have a long history in ethno- medicine; some have been grown for more than three thousand years for both edible and medicinal reasons (Rolnik & Olas 2021). In our study, species like *Ageratum conyzoides* (L.) L., *Bidens pilosa* L., *Chromolaena odorata* (L.) R. M. King & H. Rob., *Mikania micrantha* Kunth. were recorded with extensive use as phytopesticides. Almost 102 genera and 2460 species make up the Solanaceae family, which mainly grows in tropical regions. These plants including Capsicum frutescens L., *Nicotiana tabacum* L., *Solanum torvum* Sw. pose alkaloids with insecticidal action. AChE inhibition by a solanum alkaloid can disrupt an insect's cell membrane and impair respiration. These solanum alkaloids bind to the potassium channel of the mitochondria, reducing the potential function of the body. This leads to an increase in cytoplasmic calcium ions, which starts the process of cell death and damage (Nema *et al.* 2008). *Curcuma* Spp and *Zingiber officinale* Roscoe of Zingiberaceae were reported as one of the most effective phytopesticides in the study. Previous studies have also reported the insecticidal properties of these species against maize and rice weevils. Various chemicals in the family Zingiberaceae have demonstrated insecticidal, ovipositional, antifeeding, growth-regulating, fertilization-reducing, and repelling action against numerous insects (Abdulhay & Yonius 2019). The primary phytochemical of the Lamiaceae family (e.g *Vitex negundo* L., *Ocimum tenuiflorum* L., *Clerodendrum glandulosum* Lindl., etc), particularly monoterpenoid, has a variety of bioeffects and modes of action against several types of hazardous insects and mites and is believed to be a safe, readily accessible, and effective substitute for dangerous synthetic pesticides (Ebadollahi *et al.* 2020). The Euphorbiaceae family also shows immense insecticidal properties. *R. communis* L. has a highly toxic effect on leaf cutting ants, *Atta sexdens rubropilasa Forel* due to the phytochemical ricinine (Kensa & Yasmin 2011). There are more than 1400 species of insecticidal plants in the Meliaceae family. Most intriguingly, *Spodoptera littoralis* (Boisduval.), *Schistocerca gregaria* (Forskal), and *Myzus persicae* (Sulzer) were among the insects against which *Azadirachta indica* A. Juss performed best in agricultural testing. The species of this family have triterpenoids and limonoids that can affect the physiology of insects (Fowsiya & Madhumitha 2020). Apocynaceae family has larvicidal properties (Panneerselvam *et al.* 2013). *Catharanthus roseus* (L.) G. Don and *Alstonia scholaris* (L.) R. Br. have been some of the major plants used in the traditional formulation of pesticides. The presence of bioactive chemicals such as alkaloids, terpenoids, phenols, cardiac glycosides, and various proteins in the plants within Acanthaceae family makes them attractive resources for medicinal use. Many plant extracts are employed in the pharmaceutical and cosmetic sectors because they contain compounds like cyclopentane, acetaldehyde, and many more (Doss *et al.* 2017). In this study, *Adhatoda vasica* (L.) Nees has been reported as a very popular pesticidal plant with use value of 0.46.

For populations residing near forested regions, herbs serve as the main supply of medicine and other essentials (Giday *et al.* 2010, Yabesh *et al.* 2014). Local tribes in this area favor herbaceous plants as a source of ethnomedicine more frequently (Forest Survey of India, 2011). One of the primary causes of widespread use of herbs as plant insecticides may be their wide variety and accessibility. Local pest management was used prior to the use of chemicals for pest control. This knowledge-based management was site-specific and low cost. Using those methods, farmers could efficiently control pests without endangering the environment (Benjongtoshi *et al.* 2023). In the meantime, 17 chemical pesticide exposure-related symptoms from southwest Nagaland have been reported (Nath & Puzari 2024). In the current work, twenty different insect pests were recorded that were controlled by using six traditionally formulated plant-based pesticides. Smoke explosion of *Ageratum conyzoides* (L.) L. and *Christella parasitica* (L.) H. Lev. is one of the most unique types of traditional pest management practices found in some pockets of the North-eastern region of India (Nath & Puzari 2022).

Bhattacharjee & Ray in 2010 also reported traditional pest control measures in southwest Nagaland. Leaves were the most used plant parts in the region for pest management. This is because leaves are more accessible and abundant in the environment, and several ethnic groups prefer using leaves over other plant components. Thus, the leaf extract was the most popular way of formulating phytopesticides at the study site. Other studies have also reported the abundant use of leaf extract to control pests (Nath & Puzari 2022). The findings of this work reveal the use plant-based pesticides over modern pesticides which reduce pesticide-related pollution. Although, the local agriculture of Nagaland is based on traditional farming practices like shifting cultivation or Jhum cultivation but adoption of modern agriculture is quite common in Dimapur district. The results of this work show a clear indication of integrating traditional plant-based pesticides to contemporary agriculture practices.

Pesticides made from plants can be processed in a variety of ways, such as extracts or raw natural products that are formed into solutions or decoctions (Okwute 2012). However, the commercialization of botanical pesticides appears to be constrained by many factors, including difficulties with large-scale production, a lack of raw materials, a short shelf life, decreased residual toxicity in field settings, and difficulties with standardization and product improvement (Souto *et al.* 2021). One of the biggest issues facing the Indian herbal sector is standardization. The majority of the herbal medication enterprises have voiced concerns about the difficulties in obtaining and verifying raw materials as well as the issue of adulteration. Plants are known to be susceptible to contamination when being harvested, collected, and processed. Another issue that is noted at every stage of the process, from collecting to manufacture, is heavy metal contamination (Sahoo & Manchikanti 2013). The absence of adequate regulatory advice on quality concerns, proper farming and collecting procedures, and acceptable storage practices is another problem facing the herbal sector. The WHO-compliant GACP was created in 2009, although the majority of producers are not properly aware of these recommendations (Fong 2002). Sui generis laws are necessary for indigenous communities to safeguard their common natural resources and cultural legacy. Thus far, sui generis laws that preserve at least some components of traditional knowledge have been implemented by the USA, Brazil, Costa Rica, India, Peru, Panama, the Philippines, Portugal, Thailand, and the USA (WIPO 2005).

Marrone (2019) gave a summary of the condition of biopesticides and suggested some ways to increase their uptake, such as conducting demonstrations on farms and providing more instruction and training on how products function and how to include them in integrated pest management. The phytopesticidal plants recorded in the study have immense potential for easy adoption by farmers. Awareness and systematic study of such plants can add great possibilities to modern phytopesticide formulation. At the same time, the same plants can contribute to modern medical science.

Conclusions

The agricultural system fails to protect the environment, human health, and biodiversity due to the use of synthetic pesticides. The present study reveals that there are a variety of plants that may be used to isolate several phytochemical components that function as pesticides. The adoption of plant-based pesticides would reduce pesticide-related hazards and evolve an eco-friendly agricultural pest management system. The large amounts of plant material needed to produce botanical pesticides would require significant financial investment, preservation methods, and technology. At the same time, it can be challenging to formulate a phytopesticide, as a single plant can have a variety of active compounds with different chemical properties. Combining several plants with related compounds that cooperate to repel pests is one way to test this capability. The popularity of agricultural products in niche markets would increase with the increase in the use of organic pest control products in integrated pest management strategies, which would enhance global trade, promote food safety, preserve biodiversity, and preserve the environment and human health.

Declarations

List of abbreviations: ICAR- Indian Council of Agricultural Research; USA- United States of America; WIPO- World Intellectual Property Organization; WHO-World Health Organization.

Ethics approval and consent to participate: The data were collected with respect to confidentiality, anonymity and consent of the respondents who were informed about the objectives of the current study before the interview.

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Literature cited

Abate T, Huis AV, Ampofo JKO. 2000. Pest management strategies in traditional agriculture: an African perspective. Annual Review of Entomology 45: 631-659. doi: 10.1146/annurev.ento.45.1.631.

Abdulhay HS, Yonius MI. 2019. *Zingiber officinale* an alternative botanical insecticide against black bean aphid (Aphis fabae Scop). Bioscience Research 16 (2): 2315-2321.

Achika J, Arthur D, Gerald I, Adedayo A. 2014. A Review on the Phytoconstituents and Related Medicinal Properties of Plants in the Asteraceae Family. IOSR Journal of Applied Chemistry 7: 1-8. doi: 10.9790/5736-07810108.

Ahmad W, Shilpa S, Sanjay K. 2017. Phytochemical Screening and antimicrobial study of *Euphorbia hirta* extracts. Journal of Medicinal Plants Studies 2: 183-186.

Akhtar Y, Yeoung YR, Isman MB. 2008. Comparative bioactivity of selected extracts from Meliaceae and some commercial botanical insecticides against two noctuid caterpillars, *Trichoplusia ni* and *Pseudaletia unipuncta*. Phytochemistry Reviews 7:77-88.

AL-Rubae AY. 2009. The potential uses of *Melia azedarach* L. as pesticidal and medicinal plant, review. American-Eurasian Journal of Sustainable Agriculture 3(2): 185-194.

Altieri MA. 1993. Ethnoscience and biodiversity: key elements in the design of sustainable pest management systems for small farmers in developing countries. Agriculture, Ecosystems & Environment 46(1-4): 257-272. doi: 10.1016/0167-8809(93)90029-O.

Angioni A, Dedola F, Minelli EV, Barra A, Cabras P, Caboni P. 2005. Residues and half-life times of pyrethrins on peaches after field treatments. Journal of Agricultural and Food Chemistry 53: 4059-4063. doi: 10.1021/jf0477999.

Benjongtoshi , Kamni PB, Hammylliende T. 2023. Identification of the indigenous pest control methods adopted in jhum fields of Mokukchung district, Nagaland. Indian Journal of Traditional Knowledge 22(3): 491-495.

Bhattacharjee PP, Ray DC. 2010. Pest management beliefs and practices of Manipuri rice farmers in Barak Valley, Assam, Indian Journal of Traditional Knowledge 9: 673-676.

Caboni P, Sarais G, Angioni A, Garcia AJ, Lai F, Dedola F, Cabras P. 2006. Residues and persistence of neem formulations on strawberry after field treatment. Journal of Agricultural and Food Chemistry 54: 10026-10032. doi: 10.1021/jf062461v.

Compean KL, Ynalvez RA. 2014. Antimicrobial activity of plant secondary metabolites: A review. Research Journal of Medicinal Plant 8 (5): 204-213. doi=rjmp.2014.204.213.

Devanand P, Rani PU. 2008. Biological potency of certain plant extracts in management of two lepidopteran pests of *Ricinus communis* L. Journal of Biopesticides 1(2): 170-176.

Dimapur District Inventory of Agriculture, ICAR. 2015. https://icarzcu3.gov.in/district_agri_inventory/Dimapur.pdf. (Accessed on 23 December 2024).

Dominic R, Ramanujam SN. 2012. Traditional knowledge and ethnobotanical uses of piscicidal plants of Nagaland, north east India, Indian Journal of Natural Products and Resources 3 (4): 582- 588.

Doss A, Rukhshana MS, Rani KP. 2017. Identification and properties of *Asteracantha longifolia* (L.) Nees by GCMS analysis. Journal of Advancement in Medical and Life Sciences 5(1):1-6.

Dutta MP, Singh MK, Borah D. 2019. Piscicidal plants of Northeast India and its future prospect in aquaculture - A comprehensive review, Indian Journal of Natural Products and Resources 10 (3): 165- 174.

Ebadollahi A, Ziaee M, Palla F. 2020. Essential Oils Extracted from Different Species of the Lamiaceae Plant Family as Prospective Bioagents against Several Detrimental Pests. Molecules 25 (7): 1556. doi: 10.3390/molecules25071556.

Feyisa B, Lencho A, Selvaraj T, Getaneh G. 2015. Evaluation of some botanicals and *Trichoderma harzianum* for the management of tomato root-knot nematode (*Meloidogyne incognit*a (Kofoid and White) Chit Wood). Advances in Crop Science and Technology 1: 1-10.

Forest Survey of India, 2011. https://fsi.nic.in/forest-report-2011. (Accessed on 24 December 2024).

Fowsiya J, Madhumitha G. 2020. Review of Bioinsecticidal Activity and Mode of Action of Plant Derived Alkaloids. Research Journal of Pharmacy and Technology 13 (2): 963-973. doi: 10.5958/0974-360X.2020.00181.X.

Gahuubi MM, Wanzala W. 2012. A survey of plants and plant products traditionally used in livestock health management in Buuri district, Meru country, Kenya. Journal of Ethnobiology and Ethnomedicine 8: 39. doi: 10.1186/1746-4269-8-39.

Gahuubi MM, Wanzala W, Wagacha JM, Dossaji SF. 2016. Bioactive properties of *Tagetes minuta* L. (Asteraceae) essential oils: a review. American Journal of Essential Oils and Natural Products 2: 27-36.

Ghosh LK, Singh R. 2000. Biodiversity of Indian insects with special reference to aphids (Homoptera: Aphididae). Journal of Aphidology 14: 113-123.

Giday M, Asfaw Z, Woldu Z. 2010. Ethnomedicinal study of plants used by Sheko ethnic group of Ethiopia. Journal of Ethnopharmacology 132 (1): 75-85. doi: 10.1016/j.jep.2010.07.046.

Grdiša M, Gršic´ K. 2013. Botanical insecticides in plant protection. Agriculturae Conspectus Scientificus 2:85-93.

Fong HHS. 2002. Integration of herbal medicine into modern medical practices: Issues and prospects. Integrative Cancer Therapies 1(3): 287-293.

Heinrich M, Ankli A, Frei B, Weimann C, Sticher O. 1998. Medicinal plants in Mexico: Healers consensus and cultural importance. Social Science & Medicine 47: 1859-1871. doi: 10.1016/S0277-9536(98)00181-6.

Isman MB, 2000. Plant essential oils for pest and disease management. Crop Protection 19: 603-608. doi: 10.1016/S0261-2194(00)00079-X.

Isman MB. 2008. Botanical insecticides: for richer, for poorer. Pest Management Science 64: 8-11. doi: 10.1002/ps.1470.

Isman MB, Grieneisen ML, 2013. Botanical insecticide research: many publications, limited useful data. Trends in Plant Science 19: 140-145. doi: 10.1016/j.tplants.2013.11.005.

Isman MB, 2017. Bridging the gap: Moving botanical insecticides from the laboratory to the farm. Industrial Crops and Products 110: 10-14. doi: 10.1016/j.indcrop.2017.07.012.

Jamir K, Seshagirirao K, Meitei MD. 2022. Indigenous oral knowledge of wild medicinal plants from the Peren district of Nagaland, India in the Indo-Burma hotspot. Acta Ecologica Sinica 42 (3): 206-223. doi: 10.1016/j.chnaes.2021.04.001.

Jamir TT, Sharma HK, Dolui AK, 1999. Folklore medicinal plants of Nagaland, India. Fitoterapia 70: 395-401. http://dx.doi.org/10.1016%2FS0367-326X(99)00063-5.

Jan HA, Wali S, Ahmad L, Jan S, Ahmad N, Ullah N. 2017. Ethnomedcinal survey of medicinal plants of Chinglai valley, Buner district, Pakistan. European Journal of Integrative Medicine 13: 64-74. doi: 10.1016/j.eujim.2017.06.007.

Jnaid Y, Yacoub R, Al-Biski F. 2016. Antioxidant and antimicrobial activities of *Origanum vulgare* essential oil. International Food Research Journal 4: 1706-1710.

Kadir MF, Sayeed MSB, Mia MMK. 2012. Ethnopharmacological survey of medicinal plants used by indigenous and tribal people in Rangamati, Bangladesh. Journal of Ethnopharmacology 144 (3): 627-637. doi: 10.1016/j. jep.2012.10.003.

Kensa VM, Yasmin S. 2011. Phytochemical screening and antibacterial activity on *Ricinus communis* L. Plant Science Feed 1: 167-173.

Kuotsu K, Lalrinfeli R. 2019. Biodiversity of insect pests of major cereal crops in the mid hills of Meghalaya. Pharma Innovation 8 (8): 287-292.

Lehman AD, Dunkel FV, Klein RA, Ouattara S, Diallo D, Gamby KT, N'Diaye M, 2007. Insect management products from Malian traditional medicine-establishing systematic criteria for their identification. Journal of Ethnopharmacology 110: 235-249. doi: 10.1016/j.jep.2006.06.016.

Marrone P. 2019. Pesticidal natural product-status and future potential. Pest Management Science 75: 2325-2340. doi: 10.1002/ps.5433.

Misra HP. 2014. Role of botanicals, biopesticides, and bioagents in integrated pest management. Odisha Review 5: 62-67.

Muhammad BY, Awaisu A. 2008. The need for enhancement of research, development, and commercialization of natural medicine products in Nigeria: lessons from the Malaysian experience. African Journal of Complementary and Alternative Medicines 5: 120-130. http://www.ncbi.nlm.nih.gov/pmc/articles/pmc2816542/.

Mwine J, Damme PV, Kamoga G, K.udamba Nasuuna M, Jumba F. 2011. Ethnobotanical survey of pesticidal plants used in South Uganda: case study of Masaka district. Journal of Medicinal Plant Research 5 (7): 1155-1163. http://hdl.handle.net/1854/LU-1966602.

Nath U, Puzari A. 2022. Ethnobotanical study on pesticidal plants used in Southwest Nagaland, India for the development of ecofriendly pest control system. Acta Ecologica Sinica 42 (4): 274-288. doi: 10.1016/j.chnaes.2021.12.001.

Neeraj GS, Kumar A, Ram S, Kumar V. 2017. Evaluation of nematicidal activity of ethanolic extracts of medicinal plants to *Meloidogyne incognita* (kofoid and white) chitwood under lab conditions. International Journal of Pure & Applied Bioscience 5: 827-831. doi: 10.18782/2320-7051.2525.

Nema PK, Ramaya N, Duncan E, 2008. Potato glycoalkaloids: formation and strategies for mitigation. Journal of the Science of Food and Agriculture 88: 1869-1881. doi: 10.1002/jsfa.3302.

Okwute SK. 2012. Plants as Potential Sources of Pesticidal Agents: A Review. In: Soundararajan RP. (Ed). Pesticides—Advances in Chemical and Botanical Pesticides, IntechOpen; London, UK. pp. 207-232.

Panneerselvam C, Murugan K, Kovendan K, Kumar PM, Ponarulselvam S, Amerasan D, Subramaniam J, Hwang JS. 2013. Larvicidal efficacy of *Catharanthus roseus* Linn. (Family: Apocynaceae) leaf extract and bacterial insecticide *Bacillus thuringiensis* against *Anopheles stephensi* Liston. Asian Pacific Journal of Tropical Medicine 6(11): 847-53.

Rajalakshmi S, Vijaykumar S, Arulmozhi P. 2015. Ethnobotanical survey of medicinal plants in Thanjavur and its surroundings (Tamil Nadu-India). Acta Ecologica Sinica 39 (5): 380-397. doi: 10.1016/j.chnaes.2018.09.010.

Rates SMK. 2001. Plants as source of drugs. Toxicon 39 (5): 603-613. doi: 10.1016/S0041-0101(00)00154-9.

Rathi JM, Gopalakrishnan S. 2006. Insecticidal activity of aerial parts of *Synedrella nodifora* Gaertn (Compositae) on *Spodoptera litura* (Fab.). Journal of Central European Agriculture 7(2): 289-296.

Redfern J, Kinninmonth M, Burdass D, Verran J. 2014. Using Soxhlet Ethanol Extraction to Produce and Test Plant Material (Essential Oils) for Their Antimicrobial Properties. Journal of Microbiology & Biology Education 15 (1): 45-46. doi: 10.1128%2Fjmbe.v15i1.656.

Rolnik A, Olas B. 2021. The plants of the Asteraceae family as agents in the protection of human health. International Journal of Molecular Science 22 (6): 3009. doi: 10.3390%2Fijms22063009.

Sahoo N, Manchikanti P. 2013. Herbal drug regulation and commercialization: An Indian industry perspective. The Journal of Alternative and Complementary Medicine 19(12): 957-963.

Saikia SP, Jain V. 2007. Biological nitrogen fixation with nonlegumes: an achievable target or a dogma? Current Science 92: 317-322.

Sheng-Ji P. 2001. Ethnobotanical approaches of traditional medicine studies: some experiences from Asia. Pharmaceutical Biology 39: 74-79. doi: 10.1076/phbi.39.s1.74.0005.

Souto AL, Sylvestre M, Tölke ED, Tavares JF, Barbosa-Filho JM, Cebrián-Torrejón G. 2021. Plant-derived pesticides as an alternative to pest management and sustainable agricultural production: prospects, applications, and Challenges. Molecules 26 (16): 4835. doi: 10.3390/molecules26164835.

Stevenson KJ. 2011. Review of OriginPro 85. Journal of the American Chemical Society 133 (14): 5621. doi: 10.1021/ja202216h.

Stevenson PC, Isman MB, Belmain SR. 2017. Pesticidal plants in Africa: a global vision of new biological control products from local uses. Industrial Crops and Products 110: 2-9. doi: 10.1016/j.indcrop.2017.08.034.

Tewary DK, Bhardwaj A, Shanker A. 2005. Pesticidal activities in five medicinal plants collected from mid-hills of western Himalayas. Industrial Crops and Products 22: 241-247. doi: 10.1016/j.indcrop.2005.01.004.

Vidyasagar GM, Tabassum N. 2013. Antifungal investigations on plant essential oils; a review. International Journal of Pharmacy and Pharmaceutical Sciences 2: 19-28.

World Intellectual Property Organization. 2005. https://www.wipo.int/publications/en/details.jsp?id=123&plang=AR. (Accessed on 1 May 2024).

World flora online.2023. www.worldfloraonline.org (Accessed on 23 December 2024).

PestWorld.org. 2024. https://www.pestworld.org/pest-guide/ (Accessed on 24 December 2024).

Yabesh JEM, Prabhu S, Vijayakumar S. 2014. An ethnobotanical study of medicinal plants used by traditional healers in silent valley of Kerala, India. Journal of Ethnopharmacology 154 (3): 774-789. doi: 10.1016/j. jep.2014.05.004.

Yadav M, Chatterji S, Gupta SK, Watal G. 2014. Preliminary phytochemical screening of six medicinal plants used in traditional medicine. International Journal of Pharmacy and Pharmaceutical Sciences 6(5): 539-542.