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Research article

# Medicinal plants used by rural Thai people to treat non-communicable diseases and related symptoms

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ABSTRACT

Non-communicable diseases (NCDs) are becoming more common in remote regions, whereas previously they were more common in middle-class to wealthy societies. The rising prevalence and severity of NCDs has increased the demand for medical innovation in this space. In this regard, knowledge of traditional medicines used in the treatment of NCDs, by people in the remote communities of Thailand, represents an innovation opportunity.

This study aims to use data on ethnomedicinal plants used by local Thai people to identify plant candidates for study of safety and efficacy against a range of specified NCDs.

Data were taken from both the literature and interviews from 230 locations in Thailand. The consulted literature was published in the years from 1990 to 2020. Ethnomedicinal field observations were made in person, in villages in Nan and Chiang Rai provinces, in 2021. Data includes names of plants used to target NCDs, and names of target diseases. Important plant species were identified based on the number of use reports and use values together with results from Bayesian approach. A total of 766 plant species were recorded in the treatment of NCDs. Most of the species that were described by informants were used to target diabetes, hypertension, chronic respiratory and renal diseases. This study proposes several plant species that have potential as treatments against NCDs. Many of these important species have insufficient scientific data to support their uses. The study suggests that assessment of efficacy and safety should be the next logical steps.

## 1. Introduction

The world's cultures still depend on wild medicinal plants as their primary form of health care. This includes societies in developed nations that view medicinal plants as an alternative form of a treatment [1]. However, traditional knowledge of medicinal plants is also used in the development of modern medicines that become primary in developed nations [2,3].

Unfortunately, traditional knowledge around the world is eroding dramatically [4,5,6]. The erosion of traditional knowledge not only reduces opportunities to develop new allopathic medicines, but it also poses a health threat to people living in remote areas who

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have limited access to public healthcare centers. Preserving knowledge of medicinal plants ensures that we still have options for new medicines, in meeting the challenge of recurring and new infectious diseases, like Covid-19, and non-communicable diseases, that affect societies over the world.

Non-communicable diseases (NCDs) are non-infectious diseases affecting patients as chronic diseases. Cause of NCDs is a single or combination of genetic, physiological, environmental, and behavioral factors [7]. NCDs kill over 41 million of the world population, which accounts for 71% of the world's deaths. Of those 41 million deaths, 77% were reported in low- and middle-income countries. The major types of NCDs are cardiovascular diseases, cancers, respiratory diseases, and diabetes [7]. These are projected to rise in the next few decades [8,9]. Like any other country, the people of Thailand are now confronted with an increasing prevalence of NCDs [10]. Currently, the economic burden of NCDs to the Thai people is high. Allopathic medicines are associated with logistical burdens, such as financial obstacles, transport and waiting times at clinics. Natural products become popular among NCD patients, especially for cancer treatments, due to multitargeting efficacy, ease in availability, high potential of chemo-sensitization, cost-effectiveness, low toxicity, and drug resistance [11]. Thailand is rich in ethnomedicinal plant knowledge, which serves as a valuable resource for use in modern drug development.

After ethnobotany was officially introduced to the Thai academic system in 1990, several of the remote locations in Thailand were systematically studied. Many studies focused on uses of medicinal plants. The knowledge extracted from informants regarding medicinal plants is increasing in each decade [12]. In this large body of knowledge, a total of 2187 medicinal species were recorded, accounting for over 20% of the Thai flora [13]. Moreover, one study shows that the traditional knowledge of each village in the country is unique [14]. Not only does this unique knowledge guide in the selection of plant candidates for drug development [15], but it also highlights the possibility for there to be geographical specificity in relation to medicinal plant selection. This latter point may be significant in the selection of therapeutic chemotypes, if any, prior to scientific assessment for safety and efficacy.

A study summarized the ethnomedicinal plants reported during 1990–2014 in Thailand that are used in the treatment of diabetes [16]. However, it was found that the numbers of ethnomedicinal reports increasing sharply in each decade [12]. Moreover, diabetes is only one of many NCDs that threaten the world population. In many cases, diabetes develops many associated symptoms making diabetic patients feel more suffering. It is necessary to include symptoms and/or sicknesses associated or developed after having NCDs. Therefore, a comprehensive study of Thai ethnomedicinal plants used to treat NCDs and other related symptoms is needed.

In Thailand, the increasing problem of NCDs is a relatively recent phenomenon, and it is projected to get worse [17]. Furthermore, many of the types of NCDs were defined only a few decades ago, with the aid of measurement technologies to identify the symptoms, i.e., the level of blood sugar, blood pressure, and so forth. Evidently, traditional healers have never relied on instrumental or analytical technologies to diagnose. Rather, observations of the patterns of symptoms were utilized to diagnose a patients' condition. For this reason, the study of traditional knowledge related to NCDs is difficult, unless informants directly mention the names of NCDs. The current study focuses on medicinal plants that treat symptoms that are consistent with NCDs, or symptoms of an NCD.

Thus, signs and symptoms associated with cardiovascular disease are hypertension, hypotension, heart attack, heart disease, stroke and neurologic problems, kidney disease (adults with high blood pressure have higher risk of developing chronic kidney disease than those without the condition). Symptoms of diabetes include excessive urination (often at night: nocturia), excessive thirst, unexpected weight loss, excessive appetite, numb or tingling hands or feet, overly tired, blurry vision, very dry skin, sores that heel slowly, and more infections than usual. Chronic respiratory disease symptoms may include asthma, chronic cough, breathlessness, and excessive sputum production [7,18,19].

The current study aims to list ethnomedicinal plant species used in the treatment of NCDs by people in Thailand and identify important medicinal plants which may have potential for NCD treatment. The specific research questions are: 1) How many plants are used to treat NCDs in Thailand? 2) Which species are the most important species for the treatment of specific NCDs? 3) Based on scientific evidence, should those important species be recommended for the treatments?

## 2. Methods

### 2.1. Ethnomedicinal plant data

Names and uses of ethnomedicinal plants were compiled from two main data sources, which were firstly the published literature, and secondly field interviews conducted by the authors. Ethnomedicinal plants were recognized as used against NCDs when informants mentioned any of the symptoms related to cardiovascular diseases, diabetes, chronic respiratory diseases, and various kind of cancers.

The published ethnobotanical reports that were used for the current study included academic books, journal articles, scientific reports, and post graduate theses published in both Thai and English. The sources of data were from PubMed, Scopus, Google Scholar, and Thai university databases and libraries. The studies were chosen based on adherence to the following criteria: 1) Use of the accepted standard for conducting ethnobotanical studies [20] preferably with details of voucher specimens, 2) Use of scientific names of plants, 3) Locations restricted to Thailand, 4) Plants must be used to treat any of the NCDs and related symptoms mentioned above, and 5) If a study, published in the years from 1990 to 2020. Any data that were repeated across publications (e.g., journal articles and theses) is reported as a single entry.

Translation of terminology to denote types of illness was translated from traditional to modern definitions by following a careful process. Common terms from original research, (coughing, fingertip numbness, insomnia, etc.) were directly translated to modern terms. Complicated terms of illness were carefully classified by authors based on experience obtained when visiting and interacting in villages of several ethnic groups in Thailand. Some illnesses that challenged the authors in translation were solved by consulting with colleagues who had more experience of ethnobotanical studies in Thailand. Many modern terms of illnesses, such as hypertension, high

blood sugar/diabetes, cancers, and so forth were directly translated from original research.

The data from field observations were collected from villages in Chiang Rai and Nan provinces, Thailand. Ethical approval was obtained from the Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, Institutional Review Board. The certificate's reference number is COA MU-DT/PU-IRB 2021/037.0704. The study was conducted in the localities shown in Fig. 1 during the period from April 2021 to March 2022. The studied villages were visited at least three times a year in different seasons. To select only local healers (unspecific genders) from each studied village, key informants (traditional healers) who were able to share traditional knowledge and present examples of the plant species, were selected for interview using purposive sampling and snowball sampling. The selected informants were informed of their rights to consent as detailed in the COA. The method involved a walk-in-the-woods (including home gardens) approach. Then, the selected informants were asked for information about local plant names, part used, and treated diseases/symptoms via semi-structured interviews. The plants were collected for making voucher specimens and identified by the authors using taxonomic keys, the literature of Thai plants and the neighboring floras. The plant voucher specimens were deposited at the Queen Sirikit Botanic Garden Herbarium (QBG) and the herbarium of the Department of Pharmaceutical Botany, Mahidol University (PBM). This part of the study listed only plants mentioned by informants that were used for illnesses or symptoms related to NCDs. Informants were asked to give details of each illness or symptom treated by a mentioned plant to make sure that traditional and modern terms of illness/symptom were accurately interpreted by the authors.

### 2.2. Combination of the data

The data from both sources (literature and the field interviews) were combined. All plant family and species names were updated following the database in the World Checklist of Vascular Plants (www.wcvp.science.kew.org). The data from the literature generally was not as detailed a specific use with a cited informant as the field data collected by the authors. Published data showed only the numbers of interviewed informants and the list of plant species. This led to some difficulty of using an ethnobotanical index to analyze the data. The current study combined all information of all informants from a single studied location as a single unit to represent an informant cited all uses of plants reported in a studied area. The term "use report" represents a single mention by all informants mention a use of a species for a treatment from a single studied location. Finally, the index for a species use report was calculated to identify important species using the following equation.

$$UV = \sum U_{is}/n_{is}$$

where $U_{is}$ is the number of use reports mentioned by each informant i for a given species "s" and $n_{is}$ is the total number of use reports mentioned by informants from studied location I [21]. Therefore, the higher number of use reports for a species implies a higher

**Fig. 1.** Location of studied villages in Thailand.

number of locations where that one species was used. In the current study the plants with higher UVs are regarded as more important than plants that have lower UVs in the context of a specific ailment. This study also used Bayesian approach to support results of species had high UVs. The Bayesian statistics were calculated using BETAINV function in Excel described in Ref. [22]. However, the number of use reports were used as a parameter instead of the number of species, and the family level in Ref. [22] was replaced by species level in this study. Only plant species had high UVs and were estimated as highly used for NCD treatments were identified as potential plants.

## 3. Results

### 3.1. Uses of medicinal plants in the treatment of NCDs

The current study collected names of plants used against NCDs from 230 locations, which included 224 villages from the published literature and 6 villages from field observations (28 key informants, 12 men and 16 women, 54–72 years were interviewed). While the current study identified over 700 sicknesses and symptoms for all ethnomedicinal plant use reports in Thailand from those locations, only 63 are related to NCDs. In total, the study gathered 2100 medicinal plant use reports for NCDs.

Most studied villages mentioned low proportion of plants used against NCDs compare to the number of all medicinal plants uses in the villages (Fig. 2). During interviews, some informants mentioned that NCDs are modern diseases that have not appeared according to their ancestors' knowledge. Most knowledge was developed from plants used to treat similar symptoms of NCDs while some uses were developed from trial and error.

### 3.2. Use reports, use values (UVs), and Bayesian approach

Out of those use reports that we classify as relevant to NCDs, the majority were for cardiovascular diseases – including kidney diseases – (707 use reports), chronic respiratory diseases (637 use reports), and diabetes or associated symptoms (632 use reports) (Table 1).

More than half of the uses reported for chronic respiratory diseases were for the treatment of sputum, and around one-third for asthma. With regards to cardiovascular diseases, hypertension represented the highest number of mentions in that category (259 use reports) while there were 110 use reports focused on the improvement of blood flow. Out of symptoms associated with diabetes, plants that were directly targeted at diabetes represented approximately 75% (468) of the use reports in that group. With regards to cancers, out of the 164 use reports, the majority were for unspecified cancers (Table 1).

#### 3.2.1. Thai medicinal plants used to treat NCDs and related symptoms

This study listed 873 medicinal plants that people in Thailand use to treat NCDs and related symptoms. These species were from 179 vascular plant families (Table S1 and S2, Supplementary data). Fabaceae was the top ranked family, with 205 use reports for all NCDs and related symptoms. This was followed by Asteraceae (95), Rubiaceae (89), and Lamiaceae (88). The other families in the top 15 were listed in descending order according to the numbers of use reports, which were Poaceae, Acanthaceae, Phyllanthaceae, Zingiberaceae, Euphorbiaceae, Rutaceae, Apocynaceae, Menispermaceae, Solanaceae, Piperaceae, and Malvaceae. Each of these families were represented by more than forty species.

Fabaceae also had the highest number of use reports in three groups of NCDs, which were chronic respiratory diseases, diabetes and related symptoms, and cardiovascular diseases. For the other families, Rubiaceae showed an outstanding number of use reports for treatments of symptoms related to diabetes. Euphorbiaceae is strongly represented in the treatment of chronic respiratory diseases. Asteraceae, Lamiaceae and Poaceae had high numbers of use reports for cardiovascular diseases and diabetes and related symptoms. Among the sicknesses and symptoms treated by members of the family Menispermaceae, diabetes and related symptoms stood out, while species in Zingiberaceae were most frequently used to treat cardiovascular and respiratory systems. All families except Asteraceae presented plants that were used against cancers but if all such families are considered individually, use reports for these diseases account for less than ten (Fig. 3).

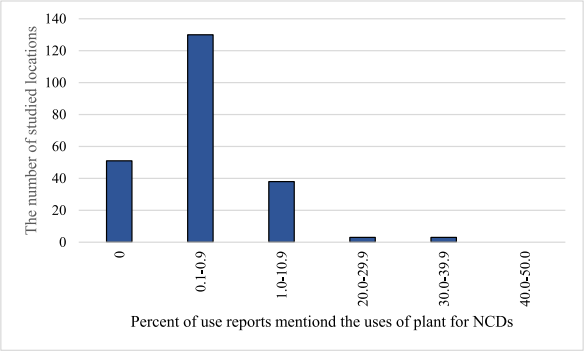


**Fig. 2.** Percent of use reports where NCDs are targeted, compared to overall use reports to treat all sicknesses and diseases of studied villages.

**Table 1**
The numbers of ethnomedicinal plant use reports of each NCD and related symptom.

| NCDs and related symptoms | No. of use reports |
|---|---|
| **Cardiovascular diseases** | |
| Blood circulation problems | 6 |
| Dyslipidemias | 2 |
| Heart diseases | 25 |
| Heart symptoms | 18 |
| Heart tonic | 77 |
| Heatstroke | 2 |
| High blood cholesterol | 18 |
| Hypertension | 259 |
| Improve blood circulation | 110 |
| Kidney diseases* | 142 |
| Tight chest | 48 |
| **Chronic respiratory diseases** | |
| Asthma | 205 |
| Asthma (in children) | 1 |
| Bronchitis | 30 |
| Choke | 2 |
| Chronic cough | 2 |
| Chronic respiratory symptoms | 3 |
| Emphysema | 1 |
| Lung diseases | 47 |
| Respiratory tract diseases | 4 |
| Sputum** | 342 |
| **Diabetes and related symptoms, and obesity** | |
| Anaesthesia | 2 |
| Beriberi | 73 |
| Blurred vision | 13 |
| Chronic wound | 28 |
| Diabetes | 468 |
| Finger tip numbness | 1 |
| High blood sugar | 13 |
| Overweight | 4 |
| Paresis | 22 |
| Pollakiuria | 1 |
| Reduce blood sugar level | 1 |
| Reduce body fat | 6 |
| **Cancers** | |
| Blood cancer | 1 |
| Bone cancer | 2 |
| Brain cancer | 1 |
| Breast cancer | 12 |
| Cervical cancer | 7 |
| Colon cancer | 1 |
| Intestinal cancer | 4 |
| Leukemia | 1 |
| Liver cancer | 9 |
| Lung cancer | 5 |
| Lymph cancer | 1 |
| Month cancer | 2 |
| Prostate cancer | 3 |
| Skin cancer | 10 |
| Unspecified cancers | 104 |
| Uterus cancer | 1 |

* Kidney disease is usually not classified as a cardiovascular disease, but the current study follows information from the WHO (2022) which lists kidney disease as a comorbidity of cardiovascular disease (or circulatory system disorders).

** The WHO explains that a significant component of chronic respiratory disease is "excessive sputum production." While informants are not specific about the amount of sputum, the current study infers sputum from knowledge of specific sicknesses where excess sputum is an accepted symptom.

Out of the top-ten highest used species against NCDs, according to the numbers of use reports and use values (UV), the top species in descending order included *Tinospora crispa* (L.) Hook. f. & Thomson, which had 31 use reports, followed by *Senna siamea* (Lam.) H.S. Irwin & Barneby, which had 28, *Andrographis paniculata* (Burm.f.) Nees, which had 21, and *Orthosiphon aristatus* (Blume) Miq., which also had 21. Again, in descending order, the other top species were *Heliotropium indicum* L., *Phyllanthus amarus* Schumach. & Thonn.,

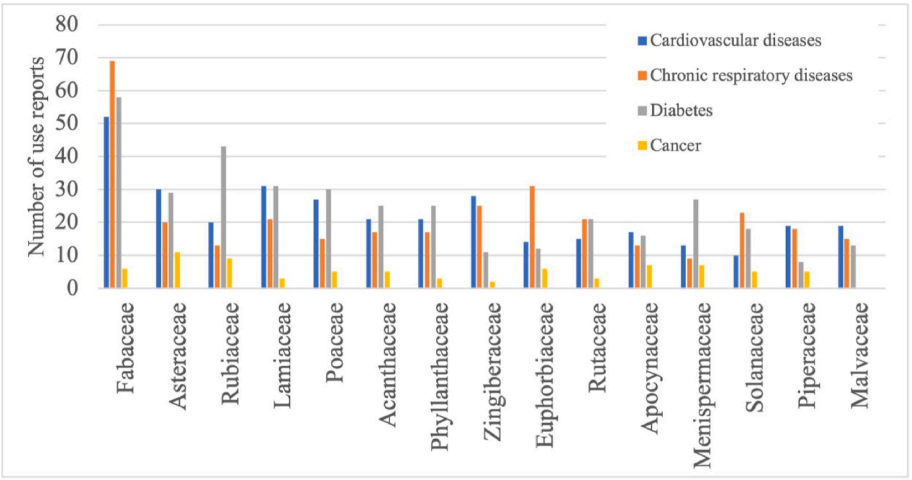


**Fig. 3.** The numbers of use reports from the top fifteen medicinal plant families used to treat each NCDs and related symptoms in Thailand.

*Phyllanthus emblica* L., *Physalis angulata* L., and *Cymbopogon citratus* (DC.) Stapf., which had numbers of use reports between 15 and 20 (Fig. 4 and Table S2, Supplementary data).

In the context of specific diseases, *Tinospora crispa* had the highest number of use reports and UV for treatments of diabetes and related symptoms followed by *S. siamea*, *P. amarus*, *A. paniculata*, and *O. aristatus*, which had more than 10 use reports. Furthermore, *Cymbopogon citratus*, *Phyllanthus emblica*, and *Piper sarmentosum* had a high number of use reports for chronic respiratory diseases (9–11 use reports). Cardiovascular diseases related to NCDs were mostly treated by *O. aristatus*, *S. siamea*, and *T. crispa*. Several plants were also used to treat cancers, but each of the species were mentioned infrequently (Fig. 4 and Table S2, Supplementary data).

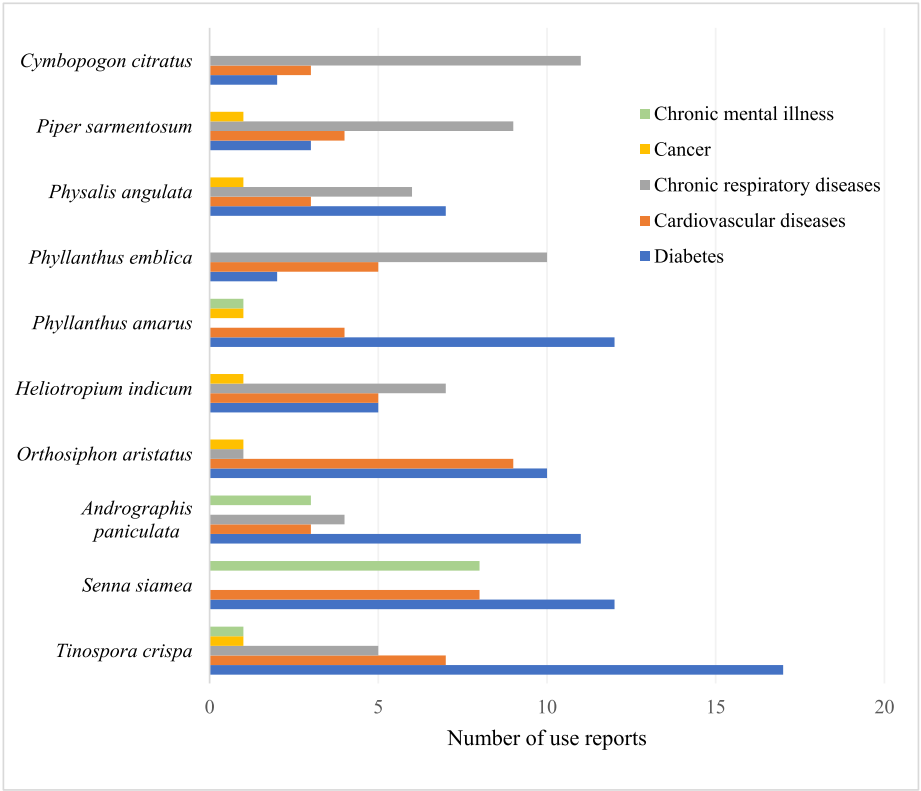


**Fig. 4.** The numbers of use reports from the top ten medicinal plant species used to treat each NCDs and related symptoms in Thailand.

### 3.2.2. Cardiovascular diseases and kidney problems

The current study listed 382 medicinal species that are used to treat cardiovascular diseases. Around 300 species had only one or two use reports, so the remaining 76 species had 3–9 use reports. The species with the highest UV were *Imperata cylindrica* and *Orthosiphon aristatus*, as both species are widely used against hypertension and kidney diseases. Other highly used species were *Aquilaria malaccensis*, *Centella asiatica*, *Senna siamea*, and *Salacia chinensis*. *Senna siamea* was the species most used to treat hypertension, followed by *Mimosa pudica*, *Piper nigrum*, *Rauvolfia serpentina*, *Moringa oleifera*, and *Thunbergia laurifolia*. *Thinospora crispa*, and *Biancaea sappan* were the species most used for improving blood circulation, while *Salaca chinensis*, *Dioecrescis erythroclada*, and *Orthosiphon aristatus* were the species most used to treat kidney problems (Table 2 and Table S1 and S2, Supplementary data).

### 3.2.3. Chronic respiratory diseases

There were 311 medicinal species identified as therapeutic against chronic respiratory diseases. Sputum and asthma were the most common symptoms treated, which were targeted using 186 and 133 species, respectively. *Phyllanthus emblica* and *Garcinia cowa* were the most frequently used species in the treatment of sputum, followed by *Piper sarmentosum*, *Albizia myriophylla*, and *Oxyceros horridus*. The most common species used to treat asthma was *Heptapleurum leucacanthum*, followed by *Cymbopogon citratus*. Some other species for asthma were *Acalypha indica*, *Millingtonia hortensis*, *Euphorbia hirta*, *Datura metel*, *Zingiber purpureum*, and *Clausena excavata*. Lung diseases and bronchitis were also mentioned, but the numbers of use reports were only 47 and 28, respectively. The plant that was most used to treat lung diseases is *Plantago major*, whereas the top species for bronchitis treatment is *Physalis angulata* (Table 3 and Table S1 and S2, Supplementary data).

### 3.2.4. Diabetes and related symptoms, and obesity

The study included 329 medicinal plants used to treat diabetes and related symptoms, including obesity. These species received 632 use reports, out of which 468 of them are specifically targeted toward diabetes treatments. For all symptoms in this category, *Tinospora crispa* is the most used showing the highest UV and the number of use reports. Furthermore, *Phyllanthus amarus* and *Senna siamea* received 12 use reports each (including related symptoms), and 11 of the use reports for *P. amarus* were for diabetes treatments alone, while *S. siamea* received only 7 use reports specifically for diabetes. Other species that were frequently mentioned in this category include *Andrographis paniculata*, *Ortosiphon aristatus, Tectona glandis*, *Momordica charantia*, *Physalis angulata*, *Drynaria quercifolia*, *Morinda elliptica*, and *Ziziphus oenoplia*, in descending order of use reports. All of these species received a high number of use reports for diabetes alone. *Senna siamea* had the highest number of use reports for patients who had beriberi (thiamine deficiency causing glucose metabolism problems) (Table 4 and Table S1 and S2, Supplementary data).

### 3.2.5. Cancers

Cancers were poorly represented compared to other categories mentioned earlier. Generally, non-specific types of cancers are targeted by 125 species. Out of those species, the highest use reports were associated with *Suregada multiflora*, *Capparis micracantha*, *Ficus hispida*, and *Stemona tuberosa*.

### 3.2.6. Highly used species to treat NCDs identified by Bayesian approach

The Bayesian approach identified 108 species as highly used species. Twenty-six species of them had total number of use report for treatments of both NCDs and non-NCDs over than ten use reports while 67 species had the total numbers of use reports less than five use reports. *Orthosiphon aristatus, Phyllanthus amarus, Physalis angulata, Heliotropium indicum,* and *Piper sarmentosum* were identify as important species for treatments similar to identifying important species using UVs (Table S3, supplementary data).

## 4. Discussion

Noncommunicable diseases are increasing in both the low and high socioeconomic areas of Thailand and have become more common in recent decades, appearing in younger people. Furthermore, traditional healers become familiar with medical terms through interaction with their patients who provide feedback, on occasions where experience with allopathic medicine can be shared.

**Table 2**
The numbers of use reports from the Thailand's top ten medicinal plant species in the context of cardiovascular diseases and related symptoms.

| Plant name | The number of use reports | | | | | | |
|---|---|---|---|---|---|---|---|
| | Hypertension | Kidney diseases | Improve blood circulation | Heart tonic | Kidney disease | Tight chest | Other |
| *Imperata cylindrica* | 3 | 4 | 0 | 0 | 1 | 0 | 1 |
| *Orthosiphon aristatus* | 4 | 3 | 0 | 0 | 2 | 0 | 0 |
| *Senna siamea* | 7 | 0 | 0 | 0 | 1 | 0 | 0 |
| *Aquilaria malaccensis* | 1 | 1 | 3 | 3 | 0 | 0 | 0 |
| *Centella asiatica* | 4 | 0 | 0 | 3 | 0 | 0 | 1 |
| *Salacia chinensis* | 0 | 5 | 2 | 1 | 0 | 0 | 0 |
| *Mimosa pudica* | 5 | 2 | 0 | 0 | 0 | 0 | 0 |
| *Kaempferia parviflora* | 0 | 0 | 3 | 2 | 0 | 2 | 0 |
| *Pluchea indica* | 3 | 3 | 0 | 0 | 0 | 0 | 1 |
| *Tinospora crispa* | 3 | 0 | 4 | 0 | 0 | 0 | 0 |

**Table 3**
The numbers of use reports from Thailand's top ten medicinal plant species used to treat chronic respiratory diseases.

| Plant name | The number of use reports | | | | |
|---|---|---|---|---|---|
| | Sputum | Asthma | Lung diseases | Bronchitis | Other |
| *Heptapleurum leucanthum* | 2 | 6 | 2 | 1 | 1 |
| *Cymbopogon citratus* | 5 | 5 | 0 | 0 | 1 |
| *Phyllanthus emblica* | 10 | 0 | 0 | 0 | 0 |
| *Garcinia cowa* | 10 | 0 | 0 | 0 | 0 |
| *Piper sarmentosum* | 7 | 2 | 0 | 0 | 0 |
| *Biancaea sappan* | 3 | 2 | 3 | 0 | 0 |
| *Albizia myriophylla* | 7 | 0 | 0 | 0 | 0 |
| *Oxyceros horridus* | 7 | 0 | 0 | 0 | 0 |
| *Heliotropium indicum* | 4 | 3 | 0 | 0 | 0 |
| *Flacourtia indica* | 2 | 2 | 1 | 2 | 0 |
| *Ocimum tenuiflorum* | 2 | 3 | 0 | 2 | 0 |
| *Millingtonia hortensis* | 1 | 4 | 1 | 0 | 1 |

**Table 4**
The numbers of use reports from Thailand's top eleven medicinal plant species used to treat diabetes and related symptoms.

| Plant name | The number of use reports | | |
|---|---|---|---|
| | Diabetes | Beriberi | Other |
| *Tinospora crispa* | 16 | 0 | 1 |
| *Phyllanthus amarus* | 11 | 0 | 1 |
| *Senna siamea* | 7 | 5 | 0 |
| *Andrographis paniculata* | 10 | 0 | 1 |
| *Orthosiphon aristatus* | 10 | 0 | 0 |
| *Tectona grandis* | 8 | 0 | 1 |
| *Momordica charantia* | 6 | 2 | 0 |
| *Physalis angulata* | 7 | 0 | 0 |
| *Drynaria quercifolia* | 6 | 0 | 0 |
| *Morinda elliptica* | 6 | 0 | 0 |
| *Ziziphus oenopolia* | 6 | 0 | 0 |

Nevertheless, most of the rural people prefer to use medicinal plants recommended by local healers, rather than allopathic medicines, because they believe that medicinal plants produce fewer side effects. To diagnose NCDs patients require scientific tools for testing. For example, to have knowledge of one's blood sugar level or blood pressure, it is necessary to use a glucose monitor or sphygmomanometer, respectively while traditional healers diagnose diseases from visible symptoms.

Traditional knowledge has been developed and transmitted from the older generation to the next generation based on the older generations' experiences. In the past, local healers could not measure blood pressure nor blood sugar level. Furthermore, these complaints were much less common and affected the elderly, rather than middle aged or youthful people. In this regard, from the perspective of the traditional healers, NCDs are modern diseases. Thus, it is possible that modern knowledge of medicinal plants used against NCDs is recently developed, after local Thai people understood definitions of NCDs and started seeing them more frequently.

The current study listed 766 plant species that can be used for treating NCDs. Most of those species belong to medicinal plant families that are recognized as important in Thailand's ethnobotanical tradition [23]. Although the number of plants used against NCDs accounts for almost 40% of Thailand's known medicinal plant species [13], these numbers are significantly reduced when consideration is given only to those with high numbers of use reports and use value (Fig. 2 and Table S2, supplementary data).

According to the modern understanding of NCDs, most are caused by personal habits and/or environmental conditions, for example dietary habits, pollution, insufficient physical activities, chronic caloric overload, and so forth. In the past, rural Thai people and ethnic minorities lived closer to nature and the environment (fresh foods, exercise, fresh water, intermittent fasting, less dietary fats, less sugar, and starch), which protected them from developing NCDs. But with increasing urbanization, the lives of the younger generations have changed, and are still changing, creating marked contrast to the lives of older aged people. The culture around plants is eroding and staple diets associated with cardiovascular disease are becoming more common.

NCDs are a modern phenomenon for rural people, in relativistic terms. It is therefore unsurprising that local people, particularly the ethnic minorities, demonstrate preference for their *materia medica* since the modern lifestyles that are associated with NCDs are also associated with allopathic medicines. In this regard, trust is a major barrier to allopathic medicinal use, as well as the evident financial obstacle.

Local Thai people living in rural areas, especially ethnic minorities, continue to utilize medicinal plant species that are available from the surrounding lands. They have been accumulating traditional knowledge from trial and error and transmitted this knowledge from the old to the young generation orally. In general, local healers diagnose illness from appearing symptoms. After that, they use plants to treat symptoms not diseases or illnesses. Based on the authors' experience from field studies, we found that most plants used by traditional healers mentioned symptoms rather than names or terns of sickness, for example, they describe having a cough, fever,

abdominal pain, and so forth, but they don't call it the flu or a cold, not even by a name in their own language.

NCDs (e.g. hypertension, diabetes) are new terms for local healers. Local healers are unable to use traditional knowledge to diagnose these diseases because they need modern tools to do this, or patients need to be diagnosed by modern doctors. It forces traditional healers to develop traditional knowledge on uses of plants to treat related symptoms of NCDs. Thus, it would say that traditional uses of plants by local healers in Thailand are in a process of knowledge development.

It was not surprising that over 700 medicinal plants are utilized for NCDs. It is surprising, however, that only a few species had scientific evidence to support their use. As an example, *Tinospora crispa* is regularly used for diabetes treatment. The species is also used in Bangladesh, Malaysia, India, and Guyana, also for diabetes treatment [24]. Several studies demonstrated that oral consumption of the plant's extract reduces blood glucose in mammals [25], and it increases glucose utilization, delays the development of insulin resistance, and enhances insulin sensitivity [26]. Furthermore, it increased the plasma insulin level in animal models [27]. However, in human studies, differences between type-2 diabetes patients and placebo were non-significant [28,29].

In another example, *Andrographis paniculata* also showed a high number of use reports for diabetes treatments (Fig. 2). The plant is known for a broad number of therapeutic uses in Indian, Chinese, and Thai traditional medicine [30]. The plant is listed in the Thai National List of Essential Medicines as a treatment for diarrhea (non-infection), common cold, sore throat, and fever, but has no report for diabetes, nor is there a recommendation for diabetes [31]. In animal models, a study shows that andrographolide and the ethanol extract of *A. paniculata* have potential to protect high-fat-diet (HFD) rats by reversing inflammation-driven impairment of insulin sensitivity [32]. Another study using rats found that the same extract could protect the kidney from damage in cases of induced diabetes [33]. In this regard, mounting evidence corroborates that improved glucose metabolism by *A. paniculata* ingestion is associated with prevention of oxidative damage to organs. This explains why there is minimal evidence for candidates in advanced levels of type 2 diabetes, because *A. paniculata* appears to confer protective effects, but does not act as an insulin replacement, rather it restores insulin sensitivity. Other studies indicated that combinations of extracts from *A. paniculata* and other plants, such as *Momordica charantia* L. [34] or *Caesalpinia sappan* Linn and *Syzygium cumini* (L.) Skeels [35] have additive or synergistic potential in treatment of diabetes in rat models.

The species that had the highest number of use reports and UV for cardiovascular diseases was *Orthosiphon aristatus*, specifically for hypertension and kidney diseases. This species is part of an antihypertension herbal formula known as '*formula jamu antihipertensi*' (FJA). The total composition of FJA is leaves of *Apium graveolens* L., *Orthosiphon aristatus* (Blume) Miq., *Centella asiatica* (L.) Urb., *Phyllanthus niruri* L., and rhizomes of *Curcuma xanthorrhiza* Roxb., and *Curcuma domestica* Val. A study of this composition demonstrated that it was as good as captopril in reducing both systolic and diastolic blood pressure [36]. In considering *O. aristatus* alone, the major active metabolite methylripariochomene (MRC), was able to decrease blood pressure in rat models [37] and reduce systolic and diastolic pressure in clinical trials [38,39].

*Phyllanthus emblica* and *Cymbopogon citratus* are the most popular species used for chronic respiratory diseases (Fig. 2). In the current study, both species are used in the treatment of sputum. Both species are accepted for both Thai traditional medicine and modern medicine systems for the treatment of cough and sputum. Currently, products containing these plants are sold in both pharmacies and supermarkets in Thailand.

Other suggested plants as *Phyllanthus amarus*, *Physalis angulata*, *Heliotropium indicum*, and *Piper sarmentosum* have poor scientific evidence to confirm their efficacy related to traditional uses. However, these plants have been reported for similar uses in other countries [40,41,42,43].

Species with highly used reports and UVs are candidates for further studies. Many of these plants have been studied in animal models but need to be confirmed by comprehensive clinical trials in either animals or humans. Furthermore, some of the plants were evaluated as having high potential as a treatment for NCDs but had no scientific backing.

The data show in this study were from literature sources and additional field observations by the authors. All studied used international standard methods to collect the data. However, all the data presented in this study are traditional uses which many of medicinal species have poor scientific evidence to support the uses or mention toxicity of the plants. In general, medicinal plants having long history of uses have high level of safety uses. Since NCDs are chronic diseases which patients must continuously take medicine for a long period of uses, it is a high risk that patient will accumulate plant toxicity that might harm body systems in long term. For a safety reason, this study strongly encourages more works to confirm efficacy and/or toxicity of the highly used medicinal species. We listed the recommended species as follow: *Imperata cylindrica*, *Orthosiphon aristatus*, *Aquilaria malaccensis*, *Centella asiatica*, *Senna siamea*, *Salacia chinensis*, *Mimosa pudica*, *Piper nigrum*, *Rauvolfia serpentina*, *Moringa oleifera*, *Thunbergia laurifolia*, *Thinospora crispa*, and *Biancaea sappan* for Cardiovascular diseases and Kidney symptoms, *Phyllanthus emblica*, *Garcinia cowa*, *Piper sarmentosum*, *Albizia myriophylla*, *Oxyceros horridus*, *Heptapleurum leucacanthum*, *Cymbopogon citratus*, *Acalypha indica*, *Millingtonia hortensis*, *Euphorbia hirta*, *Datura metel*, *Zingiber purpureum*, and *Clausena excavate* for chronic respiratory diseases, *Tinospora crispa, Phyllanthus amarus, Senna siamea*, *Phullanthus amarus*, *Andrographis paniculata*, *Ortosiphon aristatus, Tectona glandis, Momordica charantia*, *Physalis angulata*, *Drynaria quercifolia*, *Morinda elliptica*, and *Ziziphus oenoplia* for diabetes, obesity, and related symptoms.

## 5. Conclusion

Ethnomedicinal data from 230 studied locations in Thailand listed over 700 plant species for the treatment of NCDs. Many highly used medicinal plants had insufficient scientific data on the plant efficacy and safety. This study proposes a list of medicinal plants for future studies for efficacy and toxicity tests for the treatment of symptoms of NCDs. The study provides lists plants for each group of NCD, namely cardiovascular diseases and kidney symptoms, chronic respiratory diseases, and diabetes and related symptoms. This study also strongly suggests that comprehensive studies on the efficacy and toxicity of these highly used species needs to be performed.

## Declarations

### Author contribution statement

VN & MP: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper. MP & HB: Contributed materials, analysis tools. NJS & HB: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

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### Declaration of interest's statement

The authors declare that they have no competing interests.

### Ethics approval and consent to participate

Permission to carry out the study was approved by the Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, Institutional Review Board the certificate number COA MU-DT/PU-IRB 2021/037.0704.

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## Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.heliyon.2022.e12758.

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