

Biodiversity, social adoptability, and preference toward managing medicinal plants in homegardens across elevations in the Menoreh Mountains, Kulonprogo District, Indonesia

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Abstract. Budiadi, Irwan SNR, Lestari LD, Madjid MIN, Arifin HS, Nurhayati, Kaswanto, Faisal B, Dahlan MZ, Nadhiroh SR, Wahyuni TS, Ali MS. 2025. Biodiversity, social adoptability, and preference toward managing medicinal plants in homegardens across elevations in the Menoreh Mountains, Kulonprogo District, Indonesia. *Biodiversitas* 26: 1316-1324. *Pekarangan*, or "homegarden" is an agroforestry system that provides various products, including low-cost medicinal plants for maintaining family and community health. The Menoreh Mountains in Yogyakarta province, Central Java, is a center of production for medicinal plants that have been utilized by local people for generations. This research was conducted at three elevation levels—100-200 masl (lowland), 400-500 masl (mid-elevation), and >800 masl (highland)—in the Menoreh Mountains, to measure the biodiversity of homegardens, to predict adoption level of and people's preference toward medicinal plants, and to discuss pharmacological activity of the plants against potential epidemics. It involved direct observation of 30 homegardens, and interviews with 45 respondents using 22 close-ended questions from the ADOPT Tool framework. Diversity indices among locations were compared using one-way ANOVA and Tukey HSD post-hoc test, and results from the interviews were analyzed using the ADOPT Tool. The pharmacological activities of the medicinal plants were analyzed through a literature study. The results showed that plant species in the homegardens had five main functions, i.e., food-producing, medicinal, fodder, estate crops, and ornamental plants. A total of 22 species from 13 families of medicinal plants deeply rooted in the local culture were cultivated in the homegardens. Peak adoption of medicinal-plant management in lowland, mid-elevation, and highland communities was predicted at 17%, 98%, and 98% within a period of ten, five, and two years, respectively. Highland people can more easily adopt the cultivation system of medicinal plants than mid-elevation and lowland communities. Turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*) were the two most preferred medicinal plants in all locations, that increase immunity via antiviral, immunomodulatory, anti-inflammatory, and antioxidant. This suggests people in the Menoreh Mountains have good resilience to potential epidemics. Still, future research to increase the diversity and characterization of specific compounds of medicinal plants is needed.

Keywords: Agroforestry, pandemic, pharmacological activity, rural people, watershed

INTRODUCTION

The *pekarangan* or "homegarden" is a traditional agroforestry system used on Java Island, Indonesia (Budiadi et al. 2021) that has various functions, including ecological, social, and cultural ones (Mekonen et al. 2015; Masriah et al. 2019; Abdoellah et al. 2020). Other types of traditional homegardens are also practiced by the people in other regions of Indonesia, e.g., *kebun talun* in West Java and *dusun* in the Moluccas (Budiadi et al. 2021). Homegardens generally have a functional relationship with their owners and, therefore, exhibit multipurpose characteristics with a

multispecies composition to meet the daily needs of the household (Galhena et al. 2013). Homegardens usually have a multistory vegetation structure that provides food, medicine, fuelwood, fodder, construction wood, other commercial goods, and ornaments. Such diverse plant composition offers multiple services to the owner even on a relatively small piece of land (Martin et al. 2019; Castañeda-Navarrete 2021; Seid and Kebebew 2022).

The homegarden acts as a source of medicinal plants that are easily and quickly accessible by the owner (Panyadee et al. 2019), especially for recurring mild symptoms of a disease, such as a cough and fever, as well as enhancing

immunity (Kandowanko et al. 2018; Nahdi and Kurniawan 2019; Arifin et al. 2021; Ramadhani et al. 2021). Research on homegardens in some locations has reported a relatively high diversity of medicinal plants (Panyadee et al. 2019; Khadka et al. 2021; Ramadhani et al. 2021). This is especially evident in rural and peri-urban areas, where plant diversity and the utilization of medicinal plants are significantly higher than in urban areas (Furlan et al. 2016). Scientific evidence indicates that medicinal plants in homegardens have natural compounds with anti-inflammatory, antioxidant, and antiviral activity, thus facilitating improved immunity (Kamoka and Elengoe 2024). A positive trend for consuming and cultivating medicinal plants in homegardens was reported during the Covid-19 pandemic because some species are believed to cure symptoms related to Covid-19, while others are used as supplements for post-Covid-19 recovery (Khadka et al. 2021; Kamoka and Elengoe 2024).

The problem of limited access to proper health services and the topographical complexities of the hill areas of the Menoreh Mountains in Central Java has led the local people to rely on the living medicinal plants surrounding them to treat mild illnesses. The tradition of consuming these medicinal plants through simple preparation methods has been practiced for generations (Junaidah et al. 2015; Hadi et al. 2016). A study by Hani and Suryanto (2014) reported that the people in Menoreh cultivate medicinal plants producing rhizomes and cloves in different kinds of agroforestry systems. The Menoreh Mountains consist of an area with an elevation of more than 1,000 masl, and there is, therefore, biophysical and socio-economic variation among the localities. This variation is predicted to affect the social adoptability of and preference toward medicinal-plant management among the farmers, especially in their homegardens. In line with Swamila et al. (2020) stated that farmer adoptability of a new farming practice is affected by combinations of biophysical factors and other resources.

Species selection for homegardens (including medicinal plants) is affected by several factors, namely climate type, site feasibility, and socio-cultural aspects of societies (Widyastuti et al. 2018). There is a tendency for rural or highland societies that are far from and have difficulty accessing health facilities to be more receptive than urban or lowland societies to adopting the cultural habit of

utilizing medicinal plants in homegardens (Hadi et al. 2016). Several studies have explored the biodiversity of plants in homegardens (Idohou et al. 2014; Korpelainen 2023). However, none have combined an analysis of plant species diversity with a comparison of farmers' peak acceptance levels for managing medicinal plants. This study is, therefore, crucial for addressing this knowledge gap. The research was conducted to measure species diversity—with a special interest in medicinal plants—in the homegardens of people living at different elevations, to predict the adoption rate and preferences toward medicinal-plant management, and to observe people's resilience to potential future epidemics based on a pharmacological study of the existing cultivated medicinal plants.

MATERIALS AND METHODS

Study area

Medicinal plants are managed traditionally in homegardens of Menoreh Mountains communities and utilized simply by means of direct consumption, boiling, or use as seasoning (Hadi et al. 2016). The variety of medicinal products from the area, encompassing ginger, turmeric, clove, cardamom, and so on, confirms the region as a center of spice production in Yogyakarta province (Yudhana et al. 2023). According to some references, the diversity of species in homegardens is affected by elevation and factors such as commercialization, urbanization, and ecosystem fragmentation (Kehlenbeck et al. 2007). Area zonation—i.e., urban lowland, peri-urban mid-elevation, and rural highland—has been predicted to affect homegarden management by people (Balzan et al. 2018). Based on the reference and direct observation, the urbanization/elevation level of the research locations were divided into lowland (elevation 100–200 masl, represented by Purwoharjo Village, and representing an urban area), mid-elevation (400–500 m asl., Gerbosari Village, representing a peri-urban area), and highland (>800 m asl., Sidoharjo Village, representing a rural area) (Figure 1). All the locations are distributed in Progo watershed, in the Kulonprogo District, Yogyakarta Province in the center of Java Island, Indonesia (Figure 1).

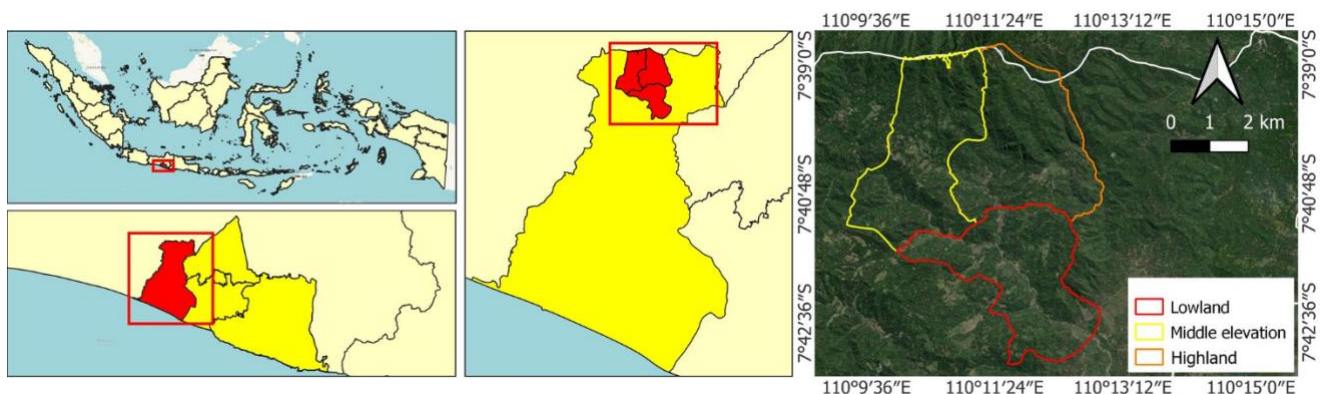


Figure 1. Map of study sites in the Menoreh Mountains, Kulonprogo District, Yogyakarta Province, Indonesia

Procedures

Data collection was conducted by direct observation and household interviews during the Covid-19 pandemic in August-September 2021. Direct observation was performed in ten homegardens for each elevation, or a total of 30 homegardens in the Menoreh Mountains, Kulonprogo region. It was conducted to identify and measure species composition-with a special focus on medicinal plants-by using respondents' and researchers' knowledge (e.g., Mekonnen et al. 2014). Verification of the name and taxonomy of the species was performed using The Plant List, a comprehensive and user-friendly online database of plant nomenclature (Kalwij 2012).

Household interviews were conducted by asking 22 close-ended questions within the ADOPT Tool framework by Kuehne et al. (2017) that were modified for innovation in developing and managing medicinal plants. ADOPT analysis has a role to predict the level of innovation acceptance within a certain time span (Dhehibi et al. 2018). ADOPT Tool framework provides information on the prediction of the numbers of farmers who adopt the cultivation of medicinal plants in homegarden, determined based on the variables of relative advantage for farmers and relative advantage of the adoption. Meanwhile, the prediction of adoption time is determined based on the variables of farmers' learning ability and ability to learn medicinal plants cultivation in the homegardens. The participants for household interviews were selected purposively, with 15 farmers at each elevation, or 45 respondents in total, including the leaders, members, and non-members of farmer groups. The proposed variables were based on the innovation diffusion theory by Rogers (2003), by which innovations introduced in an area require time for dissemination and determination prior to adoption decisions by farmers, as adoption units.

Data analysis

Data analysis involved classifying the plants by their function, including food-producing (i.e., fruit and vegetable), medicinal, fodder, other estate crops, and ornamental plants. Species diversity was analyzed using the Shannon-Wiener Index (Keylock 2005), and differences between the indices were compared using one-way ANOVA and Tukey HSD post hoc test in RStudio software (Gerbing 2023). The results of the interviews were analyzed using ADOPT Tool software in the smallholder version (e.g., Madjid et al. 2023) by counting the most frequent answer to each question. ADOPT analysis provides a prediction of the peak adoption of medicinal plant development and of the time required to reach the peak adoption. Preferences toward medicinal plant management were studied by comparing the number of respondents interested in a certain medicinal plant to the total number of respondents, using the following classification: high (75-100% preference), moderate (50-75% preference), low (25-50% preference), and not-applicable (<25% preference). Classification of immunity-boosting pharmacological activities of the medicinal plants was performed using a literature search of the Google Scholar database, and a total of 24 peer-reviewed English-language articles were consulted.

RESULTS AND DISCUSSION

Diversity of plant species in homegardens

The plants grown in homegardens in the Menoreh Mountains were classified, based on the main function of each, as food-producing (including fruit and vegetable), medicinal, fodder, other estate crops, and ornamental plants. The lowland area showed the highest diversity values in terms of fruit-producing species, while the mid-elevation and highland areas had the highest diversity of vegetable-producing species. The diversity of fruit-producing species differed significantly between the locations ($F = 5.36$, $p = 0.011$), while that of the other functions did not ($p > 0.05$). The highest diversity index was found for vegetable-producing species in all locations (Table 1).

Field observations identified 22 species of medicinal plants from 13 families: Acanthaceae, Acoraceae, Apiaceae, Basellaceae, Euphorbiaceae, Leguminosae, Myrtaceae, Melastomataceae, Pandanaceae, Piperaceae, Poaceae, Talinaceae, and Zingiberaceae, in Menoreh Mountains homegardens. Zingiberaceae was the most dominant family at all locations and elevations. At the species level, *Pandanus amaryllifolius*, *Piper betle*, *Cymbopogon citratus*, *Alpinia galanga*, and *Zingiber officinale* were found in all locations. The most dominant medicinal plant in lowland areas was *A. galanga*, with 97 individuals per hectare. At the same time, *Z. officinale* was generally found in mid-elevation and highland homegardens, with 257 and 223 individuals per hectare, respectively. The highest diversity of medicinal plants was found in homegardens in the highlands, with at least five dominant species, namely *Z. officinale*, *Curcuma* spp., *Syzygium aromaticum*, *Kaempferia galanga*, and *A. galanga* (Table 2). In the study, *Curcuma* spp. could not be identified up to the species level because it usually comes from two species, namely *Curcuma longa* or *C. xanthorrhiza*. Note that the observations were conducted during the dry season, which caused the absence of aboveground organs of some rhizome species.

Table 1. Shannon-Wiener diversity index based on the main function of each plant species in homegardens across elevations in the Menoreh Mountains, Kulonprogo District, Yogyakarta Province, Indonesia

Main function	Locations		
	Lowland	Middle elevation	Highland
Food-producing, fruit	0.80±0.31 ^a	0.45±0.31 ^b	0.53±0.24 ^{ab}
Food-producing, vegetable	0.58±0.42 ^a	0.97±0.38 ^a	0.99±0.36 ^a
Medicinal	0.37±0.14 ^a	0.36±0.17 ^a	0.47±0.24 ^a
Fodder	0.21±0.16 ^a	0.04±0.04 ^a	0.11±0.07 ^a
Other estate crops	0.36±0.03 ^a	0.20±0.09 ^a	0.32±0.14 ^a
Ornamental plants	0.56±0.57 ^a	0.76±0.57 ^a	0.42±0.22 ^a

Note: Different characters in the same row indicate significant differences at $\alpha = 0.05$

Table 2. Medicinal plants in homegardens across elevations in the Menoreh Mountains, Kulonprogo District, Yogyakarta Province, Indonesia (number of individuals per ha)

Local name	International name	Scientific name	Family	Locations		
				Lowland	Middle elevation	Highland
<i>Wungu</i>	Caricature plant	<i>Graptophyllum pictum</i> (L.) Griff.	Acanthaceae	10		
<i>Keji beling</i>	Keci beling	<i>Strobilanthes</i> sp.	Acanthaceae			17
<i>Dingo bawang</i>	Sweet flag	<i>Acorus calamus</i> L.	Acoraceae			17
<i>Adas</i>	Fennel	<i>Foeniculum vulgare</i> Mill.	Apiaceae	5		
<i>Binahong</i>	Madeira vine	<i>Anredera cordifolia</i> (Ten.) Steenis	Basellaceae		13	
<i>Yodium</i>	Coral plant	<i>Jatropha multifida</i> L.	Euphorbiaceae		13	
<i>Telang</i>	Butterfly pea	<i>Clitoria ternatea</i> L.	Leguminosae			17
<i>Dadap</i>	Indian coral tree	<i>Erythrina variegata</i> L.	Leguminosae	5		
<i>Parijoto</i>	Showy Asian grapes	<i>Medinilla speciosa</i> (Reinw. ex Blume) Blume	Melastomataceae		4	17
<i>Salam</i>	Bay leaf	<i>Eugenia polyantha</i> Barb.Rodr.	Myrtaceae	10	4	
<i>Cengkeh</i>	Clove	<i>Syzygium aromaticum</i> (L.) Merr. & L.M.Perry	Myrtaceae		88	172
<i>Pandan</i>	Pandan	<i>Pandanus amaryllifolius</i> Roxb. ex Lindl.	Pandanaceae	10	17	26
<i>Sirih</i>	Betel leaf	<i>Piper betle</i> L.	Piperaceae	24	67	9
<i>Sirih merah</i>	Red betel leaf	<i>Piper crocatum</i> Ruiz & Pav.	Piperaceae	10		17
<i>Merica</i>	Pepper	<i>Piper nigrum</i> L.	Piperaceae		46	
<i>Sereh</i>	Lemongrass	<i>Cymbopogon citratus</i> (DC.) Stapf	Poaceae	39	84	69
<i>Ginseng</i>	Ginseng	<i>Talinum fruticosum</i> (L.) Juss.	Talinaceae		4	9
<i>Jahe</i>	Ginger	<i>Zingiber officinale</i> Roscoe	Zingiberaceae	19	257	223
<i>Lengkuas</i>	Galangal	<i>Alpinia galanga</i> (L.) Willd.	Zingiberaceae	97	21	86
<i>Kunyit and temulawak</i>	Turmeric	<i>Curcuma</i> spp.	Zingiberaceae	14		180
<i>Kapulaga</i>	Cardamom	<i>Elettaria cardamomum</i> (L.) Maton	Zingiberaceae			9
<i>Kencur</i>	Aromatic ginger	<i>Kaempferia galanga</i> L.	Zingiberaceae	14		172

Observation by Hadi et al. (2016) reported 28 understory crops in the Menoreh Mountains with predicted medicinal function, while the present study found only 22 medicinal plant species in the locations. The tendency of the people to cultivate vegetables may have resulted in the decreasing variability and number of medicinal plants in homegardens. A similar trend was reported in homegardens in Citarum watershed (Abdoallah et al. 2020). Another study reported an increased abundance of understory plants with the increase in elevation level of rural-urban development in the Menoreh Mountains. However, the number of species tended to decrease (Widyastuti et al. 2018). The most common types of medicinal plants grown are location-specific, corresponding to certain environmental conditions and the local traditions of the societies, thus resulting in variations of dominant medicinal plants among the locations (Nahdi and Kurniawan 2019). On the other hand, the higher distribution of certain species planted in homegardens across sites reflects the richness of local culture, as well as the tendency of the people to conserve or develop the species (Roy et al. 2022). In the Menoreh Mountains, members of the Zingiberaceae family are often used as ingredients for local medicine (Hadi et al. 2016; Rahayu et al. 2020) and most commonly as condiments in cooking (Sholekha et al. 2023).

Adoption level of managing medicinal plants

The results of the household interviews showed that farmer groups or communities in lowland, mid-elevation, and highland areas had different levels of adoption of

medicinal-plant management in homegardens. The ADOPT analysis predicted that peak adoption of medicinal plants in lowland, mid-elevation, and highland communities was 17%, 98%, and 98% achieved within a 10-, 5-, and 2-year period, respectively (Figure 2). The high adoption levels for medicinal plants among mid-elevation and highland communities were probably affected by the high dependency of the people on medicinal plants. The medicinal plants in the mid-elevation and highland communities were utilized for household consumption, to be sold to other people, or as cash crops.

The results from ADOPT, shown in Figure 2, describe the differences in adoption levels and required time to adopt medicinal plant management in the three different locations (elevations). A similar result has been reported by Swamila et al. (2020), i.e., that adoption of certain commodities is determined by biophysical factors and labor availability. Hence, the adoption of a particular technology is determined by socio-economic factors and, therefore, results in different peak adoption levels (Ochieng et al. 2022). Farming is a risky land-management system for farmers, with its technical difficulties and low benefits; in short, profit orientation is the main factor affecting adoption (van Wyk and Prinsloo 2018), in addition to the effect of local traditions (Feintrenie et al. 2010). The adoption of medicinal plants is simply affected by the availability of resources and local skills to manage them at minimum cost (Rao et al. 2014). Therefore, the adoption level of a land-based management system will be relatively high when it provides short-term economic benefits (Pifheiro et al. 2020).

The variables of current economic benefit and long-term ecological value highly influence the level of adoption of medicinal plant management by lowland or urban areas. This aligns with a study by Venkatesan et al. (2022) stated that agricultural crops with high current economic value will result in high adoption levels compared to lower-value crops. The low adoption level of medicinal plant management in the lowland community was probably related to the complexity of cultivating crops. Still, it might be positively driven by accessibility to proper health facilities in urban areas. The time to reach peak adoption of medicinal-plant management in homegardens in the lowland area was driven by variables of the possibility of the innovation to be tested and the complexity of the innovation. The possibility of the innovation to be tested was affected by the ease by which the lowland people could adopt medicinal plants on a limited scale or with a small land size. Hence, the complexity of innovation was related to the need to improve the capability of cultivating crops during the adoption of the innovation. The time to reach peak adoption of medicinal-plant management for the lowland community can be accelerated through capacity building of the people in terms of cultivation techniques.

Preference toward medicinal plants

Turmeric (*C. longa*) and ginger (*Z. officinale*) were the two kinds of medicinal plants most preferred by people in all study locations in the Menoreh Mountains. In general, the medicinal plants preferred by the people in the locations—namely *A. galanga*, *C. citratus*, *C. longa*, *K. galanga*, and *Z. officinale*—also functioned as additional ingredients in daily food and were easy to cultivate. In addition, in the mid-elevation and highland areas, the people also preferred *C. xanthorrhiza*, *E. cardamomum*, and *S. aromaticum*, which were not cultivated in the lowland area. In short, the highland and mid-elevation communities grow a higher number and variety of medicinal plants compared to the lowland community (Table 3).

Turmeric is the most common commodity sold in many traditional markets in Yogyakarta province, accounting for 93.10% of the *Curcuma* spp. group (Jalil et al. 2021). The

main function of medicinal plants in homegardens was sometimes combined with other functions, for instance, as ornamental plants, additives to many local cuisines, or to support cultural events, therefore possibly affecting the diversity of the species in the homegardens across sites (Panyadee et al. 2019). In fact, most of the medicinal plants are deliberately cultivated in homegardens (Igustita et al. 2023). Intensive farming of such a commodity in homegardens is highly related to the role of the commodity in people's daily life, with the same preference among adjacent locations indicating a high rate of knowledge exchange between the locations (Panyadee et al. 2019; Pauletto et al. 2023). In the Menoreh Mountains, galangal, turmeric, and ginger have been utilized widely for traditional remedies as they are easy to obtain and have a low cultivation cost (Igustita et al. 2023).

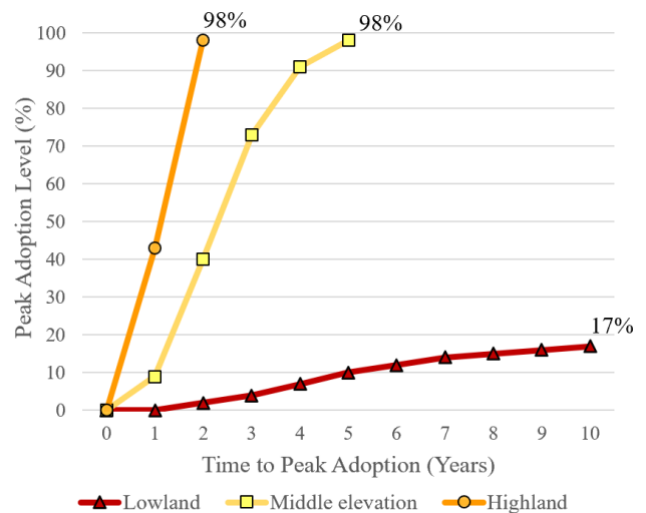


Figure 2. Prediction of communities' required time to adopt, and level of adoption of, medicinal-plant management in homegardens in the Menoreh Mountains, Kulonprogo District, Yogyakarta Province, Indonesia

Table 3. People's preference toward medicinal plants in homegardens across different elevations in the Menoreh Mountains, Kulonprogo District, Yogyakarta Province, Indonesia

Name	Scientific name	Abbr.*	Locations		
			Lowland	Middle elevation	Highland
Galangal	<i>Alpinia galanga</i>	Ag	Low	Moderate	High
Lemongrass	<i>Cymbopogon citratus</i>	Cc	Low	Low	Low
Turmeric	<i>Curcuma longa</i>	Cl	High	High	High
Javanese turmeric	<i>Curcuma xanthorrhiza</i>	Cx	-	Low	Low
Cardamom	<i>Elettaria cardamomum</i>	Ec	-	Low	High
Kencur	<i>Kaempferia galanga</i>	Kg	Low	Low	Low
Pepper	<i>Piper nigrum</i>	Pn	-	-	Low
Cubeb pepper	<i>Piper cubeba</i>	Pc	-	-	Low
Betel leaf	<i>Piper betle</i>	Pb	-	Low	-
Clove	<i>Syzygium aromaticum</i>	Sa	-	High	High
Ginger	<i>Zingiber officinale</i>	Zo	High	High	High

Notes: Abbr.: Abbreviations of scientific names used in this study; High: 75-100% preference; Moderate: 50-75% preference; Low: 25-50% preference; -: Not applicable (<25% preference)

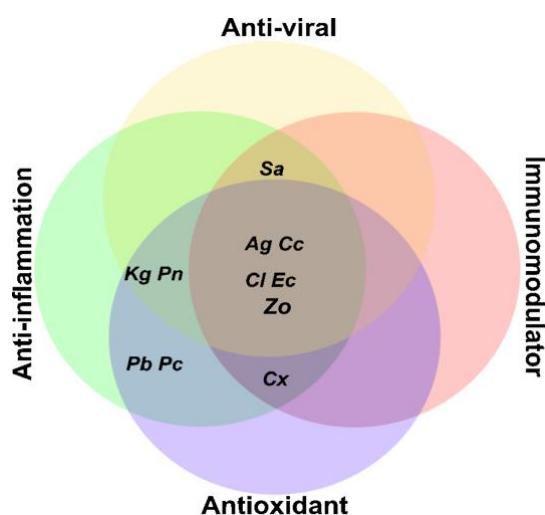


Figure 3. Pharmacological activities of medicinal plants potentially managed in homegardens in the Menoreh Mountains, Kulonprogo District, Yogyakarta Province, Indonesia. Reference: (Kim et al. 2009; Dao et al. 2012; Chang et al. 2013; Tasleem et al. 2014; Bao et al. 2015; Ekpenyong et al. 2015; Amri and Touil-Boukoffa 2016; Das et al. 2016; Priya and Kumari 2017; Chouni and Paul 2018; Munda et al. 2018; Pillai et al. 2018; Ashokkumar et al. 2020; Batiha et al. 2020; Deng et al. 2020; Garza et al. 2021; Haro-González et al. 2021; Kumar 2021; Vicidomini et al. 2021; Wani et al. 2021; Yuandani et al. 2021; Dibha et al. 2022; Sangeetha et al. 2022)

Pharmacological activity related to immunity

The essential contents of medicinal plants in dealing with a pandemic or epidemic are related to their pharmacological roles as immunomodulators, anti-inflammatory agents, antioxidants, and antivirals (Mrityunjaya et al. 2020; Zhang et al. 2020; Bahari et al. 2021; Fazio et al. 2022). Such pharmacological activity has been reported for galangal, lemongrass, turmeric, cardamom, and ginger (Figure 3), of which four—galangal, lemongrass, turmeric, and ginger—were highly preferred by the people in Menoreh Mountains communities. All of the species have dual functions, i.e., as medicine and seasoning, and are therefore called "cheap kitchen medicines" (Deng et al. 2020; Sholekha et al. 2023). More variation in preference toward medicinal plants was observed in mid-elevation and highland communities, reflecting these communities' higher resilience to potential epidemics or even pandemics than the lowland community. Specifically, the people in the highland and mid-elevation areas had a high preference for clove and a moderate preference for cardamom, neither of which was observed for the people in the lowland area. Overall, the people at all elevation levels and of all urban-rural statuses in the Menoreh Mountains had a high preference for turmeric and ginger, which exhibits the four aforementioned pharmacological activities. This suggests that people in the Menoreh Mountains potentially have good immunity to future epidemics or pandemics.

Homegardens can function as sources of natural therapeutics during and post-pandemic, as locations facilitating physical exercise and emotional equilibrium through gardening, and as sources of edible plants to

maintain family food security, as well as of medicinal plants (Lal 2020; Zhang et al. 2021). The consumption of traditional remedies has been inherited from countless past generations and, at some stage, was eliminated by the influence of Western health treatments, then rose again during the Covid-19 pandemic (Bagus and Triratnawati 2021; Novriyanti et al. 2021). In Indonesia, public awareness of and interest in medicinal plants significantly increased during the pandemic, as indicated by an increasing trend of internet searches using the keywords "*jahe*" (ginger), "*kunyit*" (turmeric), and "*menanam jahe*" (planting ginger) (Rokhmah et al. 2020). The pandemic re-stimulated cultivation of medicinal plants in accessible areas surrounding houses, i.e., in homegardens, which was also influenced by an increase in the price of medicines in the market at this time (Girsang et al. 2021; Khadka et al. 2021).

Many medicinal plants contain secondary metabolites with antiviral, antioxidant, and anti-inflammatory functions that are used to maintain health in the face of inflammatory and hemotoxic symptoms and contain immunomodulators for preventing infection by new pathogens, thus naturally enhancing human immunity (Hooda et al. 2024; Kamoka and Elengoe 2024). For example, a mix of galangal, turmeric, and ginger extract can relieve respiratory inflammation, while mix of turmeric and ginger has shown immunoregulatory and anti-inflammatory activity against SARS-CoV-2 infection (Dongre et al. 2015; Adrianta and Somantara 2023). Curcumin is the main component of turmeric and has strong immunomodulatory activity, while 6-gingerol from ginger acts as an anti-inflammatory, antiviral, antioxidant, and immunomodulator that helps treat Covid-19 symptoms (Deng et al. 2020; Islam et al. 2021; Hooda et al. 2024). Active constituents of turmeric, such as curcumin and Zedoary Turmeric Oil (ZTO), can block entry of the virus into cells and inhibit viral replication, including for SARS-CoV-2 and influenza (Wu and Tong 2023). Furthermore, ginger has a warming effect on the human body that improves blood circulation and also has a strong antiviral response against many kinds of DNA and RNA viruses that cause influenza and inflammation (Islam et al. 2021).

In conclusion, in general, plant diversity in homegardens in the Menoreh Mountains is relatively high and covers various functions. However, the diversity of medicinal plants is still relatively low, compared to other species functions. The adoption of medicinal plants in the lowland (urban) community is low due to the complexity of farming techniques and a lower dependency on traditional remedies compared to the communities at higher elevations, i.e., mid-elevation (peri-urban) people and highland (rural) people. In mid-elevation and highland areas, the adoption of further medicinal plant management in homegardens is predicted to be successful. In addition, there are enough sources of medicinal plants to maintain the health of these communities.

More specifically, all the communities manage medicinal plants for multifunctional purposes, such as turmeric and ginger, for household consumption or commercial purposes. These two commodities also have anti-inflammatory, immunomodulatory, antioxidant, and antiviral functions. Diversification of medicinal plant species is necessary

because some viruses are constantly mutating and have a high probability of causing a future epidemic or pandemic. Therefore, the characterization of the specific roles of medicinal plants with these four disease-preventing functions must be accelerated. The utilization of their products both directly as medicine and within food supplements can also be further promoted. In this case, promoting integrative approaches—combining the utilization of medicinal plants in homegardens with formal healthcare systems—can enhance community resilience and ensure that individuals have access to both traditional and modern medical resources. In terms of plantation management, almost all the studied medicinal plant species grow and adapt well as understory crops in agroforestry systems, including homegardens. Research to increase the productivity of these systems must be initiated to improve people's resilience against diseases at a low cost.

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