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Review

# Role of medicinal plant gardens in pharmaceutical science education and research: An overview of medicinal plant garden at Kumamoto University, Japan

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**ABSTRACT**

Medicinal plants have played an important role in human healthcare as the essential ingredients of traditional medicines for thousands of years. Botanical gardens worldwide play a crucial role in the conservation, cultivation and utilization of plant species, and research activities related to ecology, taxonomy, systematics, biotechnology, etc. Medicinal plant gardens have played a significant role in education and research of plant species used for medicinal purposes. Botanical gardens and medicinal plant gardens are also actively involved in organizing of educational programs/events to students and the general public. This article will provide an overview of the educational and research activities of Medicinal Plant Garden at the School of Pharmacy, Kumamoto University, Japan.

**Key words**: Pharmacy education, medicinal plants garden, medicinal plants, herbal medicine, research

## 1. Introduction

Medicinal plants have played an important role in human healthcare as the essential ingredients of traditional medicines for thousands of years. It is reported that more than 80% of the world population still relies on medicinal plants as a source of primary healthcare (Fitzgerald et al., 2019; Kunwar and Bussmann, 2008). Natural products isolated from medicinal plants have also played an important role as a source of modern drug discovery and development (Atanasov et al., 2015; Newman and Cragg, 2020). Medicinal and aromatic plants are widely used as foods, spices, and also used in cosmetics, aroma, perfumes. Phytochemicals isolated from plants have more extensive applications as food preservatives, colourants, sweeteners, etc. (Negi, 2012; Pawar et al., 2013; Sarkic and Stappen, 2018; Voon et al., 2012). Out of more than 460,000 plant species worldwide, at least 28,187 plants species were documented to be used for medicinal purposes (Willis, 2017). Out of these medicinal plants, only 4,478 were mentioned in regulatory publications (Willis, 2017). However, with the decreasing number of plants worldwide due to climate change and anthropogenic disturbances, many medicinal plants are on the verge of extinction. The extinction of plants was also compounded by unsustainable collection and trade coupled with land use and sociocultural changes.

Botanical gardens worldwide play an important role in the conservation, cultivation and utilization of plant species along with research activities related to ecology, taxonomy, systematics, biotechnology, etc. (Chen and Sun, 2018; Gaio-Oliveira et al., 2017; He and Chen, 2012; Heywood, 2017; Mounce et al., 2017). Botanical gardens also play a central role in citizen science programs and science communication through educational activities, observational tours and organizing various events (Chen and Sun, 2018). It is estimated that there are about 2500 botanical gardens around the world and these gardens collectively cultivate more than 6 million plants belonging to about 80,000 species (Chen and Sun, 2018). Such *ex-situ* cultivation activities of botanical gardens will be of increasing importance in future with declining biodiversity and effects of global warming and climate change.

Medicinal plant gardens are primarily focused on the conservation, cultivation, research and educational activities related to plant species known for medicinal purposes. However, these gardens also equally provide services related to other plant species whose primary use is not for therapeutic practice. In this article, we aim to provide a comprehensive

outline of the activities of Medicinal Plant Garden at the School of Pharmacy, Kumamoto University, Japan related to pharmaceutical science education and research and its implications for conservation of medicinal plants.

## 2. History and current status of medicinal plant garden at Kumamoto University

Medicinal Plant Garden (Figure 1) currently situated inside the School of Pharmacy at Kumamoto University was established in 1927 AD as the Medicinal Plant Garden of Kumamoto Pharmaceutical College (established in 1885), the predecessor of the current School of Pharmacy. However, the actual history of the garden dates back to more than 260 years as five medicinal tree species, i.e. *Crataegus cuneata* Siebold et Zucc. ("Sanzashi" in Japanese), *Cornus officinalis* Siebold et Zucc. ("Sanshuyu"), *Vitex negundo* L. var. *cannabifolia* (Siebold et Zucc.) Hand.-Mazz. ("Ninjinboku"), *Lindera aggregata* (Sims) Kosterm. ("Tendaiuyaku") and *Koelreuteria paniculata* Laxm. ("Mokugenji") (Figure 2) were transferred from the historical medicinal plant garden, 'Banjien'. 'Banjien' was founded in 1756 by Lord Hosokawa of the Higo Province and it is referred to as the origin of the School of Pharmacy (https://ewww.kumamoto-u.ac.jp/en/about/history/outline/). After the formation of Kumamoto University in 1949, the medicinal plant garden is serving as a center of excellence for education and research activities related to medicinal plants at Kumamoto University. From April 2019, it has been affiliated to the Global Center for Natural Resources Sciences, Faculty of Life Sciences, Kumamoto University. The Director of Global Center for


**Figure 1. School of Pharmacy and Medicinal Plant Garden along with some photographs of different zones in the garden.**

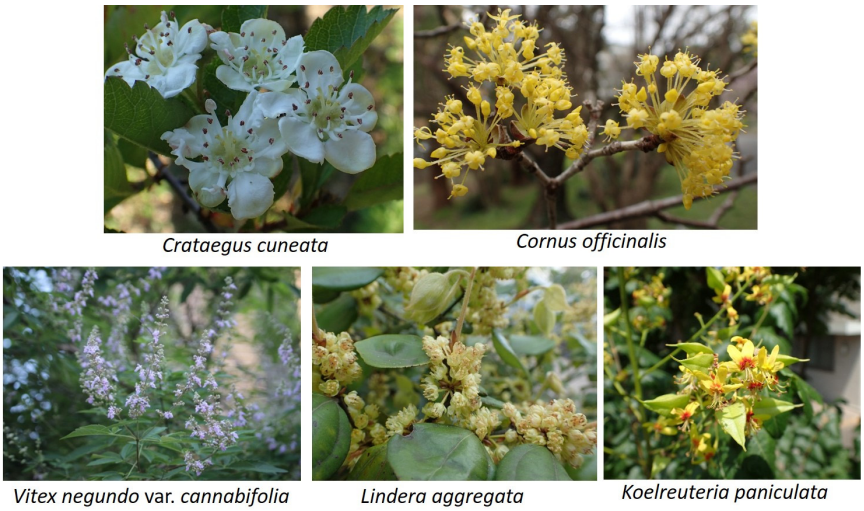


**Figure 2. Photographs of five medicinal plant species obtained from historical "Banjien."**


(a) (b)

**Figure 3. An example of medicinal plant label for *Curcuma longa* L. (a) and the page for it in Medicinal Plant Database (b) that is accessible by scanning the QR code in label.**

Natural Resources Sciences also serves as the Director of Medicinal Plant Garden. The overall activities related to plant conservation and cultivation are managed by two Technical Officers. Educational and research activities of the garden are supported by other academic and technical staffs of the University.

About 1500 plant species are cultivated in the exhibition garden, medicinal tree garden and other 10 different cultivation areas. It covers an area of more than 6000 $m^2$. One greenhouse (59 $m^2$) and two small separate green conservatories for plants of Zingiberaceae family and ferns are also located inside the garden. Medicinal and other plants are cultivated in different zones based on their nature (aquatic plants, *Citrus* plants, medicinal trees, plants used in folk medicines, etc.).

More than 600 medicinal plants have been appropriately labelled with their family name, Japanese name, scientific name, English name, plant parts used as a medicine, medicinal uses, photos and structures of main chemical constituents. An example of the label can be found in Figure 3a. Each label also contains an individual QR code which when scanned will direct to the individual plant information of the Kumamoto University Medicinal Plant Garden Database (http://www.pharm.kumamoto-u.ac.jp/yakusodb/), that provides the detailed information on each medicinal plant (Figure 3b). This database is currently available only in Japanese language and English version is now under preparation.

Medicinal Plant Garden is open to the students, the general public and any person interested to visit at any time. Currently, there is are no gates or any other physical barriers, so that interested people can come and make the observation at any time point of the year. From 2015, a new initiative, named as “Medicinal Plant Park Initiative” has been started which aims to convert the whole area of School of Pharmacy into medicinal plant park that can be freely used by the general public. Interested people can also make donations to the “Medicinal Plant Park Initiative” through Kumamoto University Fund, which is utilized for the maintenance of the garden. One output of this initiative was the publication of “A Guidebook of Medicinal Plant Garden” in 2018 which covers the general information about medicinal plants, the history and organization of medicinal plant garden and detailed information about 360 medicinal plants (Watanabe et al., 2018a).

## 3. Conservation and cultivation of medicinal plants used in Kampo medicines, folk medicines and other rare and endangered plants

Kampo medicines, sometimes also referred to as Japanese traditional medicines is an integral part of the healthcare system in Japan (Arai and Kawahara, 2019; Maegawa et al., 2014; Motoo et al., 2009). Kampo medicine formulations usually contain the standard mixtures of few to tens of crude drugs originated from the plant, animal or mineral sources. They are officially approved, and 148 Kampo are covered by the National Health Insurance System of Japan, and many are also sold as over-the-counter (OTC) medicines. According to Arai and Kawahara (2019), the market of Kampo medicines in Japan accounted for about 2.5% of the total pharmaceutical market. The Japanese Pharmacopoeia covers many crude drugs used in Kampo formulations along with their different forms (e.g. powders, extracts) and few most common Kampo formulations (Kameyama et al. 2019; The Ministry of Health Labor and Welfare of Japan, 2016). Along with the Kampo formulations, medicinal plant-based folk medicines

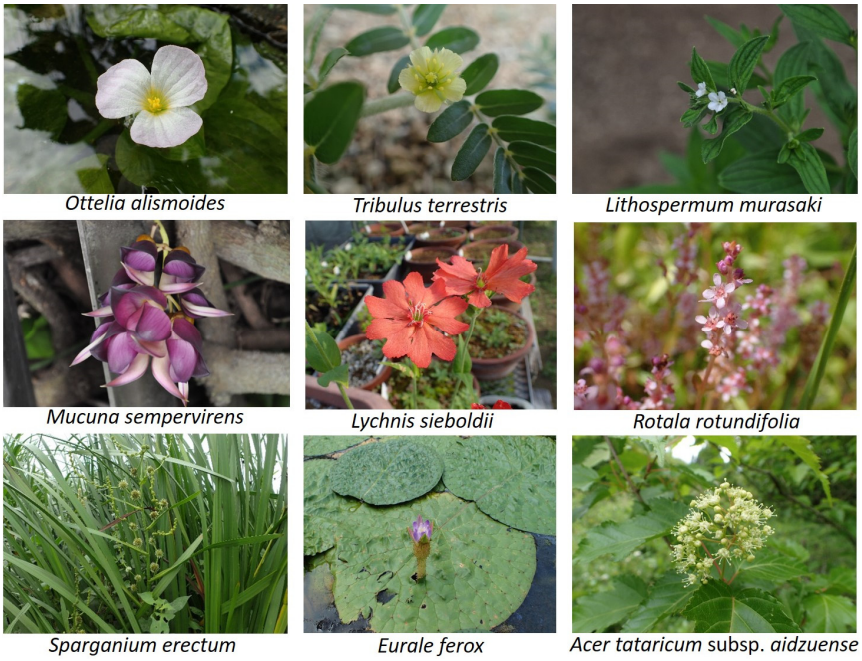


**Figure 4. Some examples of rare and endangered plants cultivated in Medicinal Plant Garden.**

("Minkan-yaku" in Japanese), herbal products, functional foods and food supplements are also quite popular among Japanese people and are widely available in the market.

Kumamoto University Medicinal Plant Garden has a plan to collect and cultivate as many medicinal plants as possible that are included as biological sources for the crude drugs covered in Japanese Pharmacopoeia. As of July 2020, among many medicinal plants cultivated in garden, 180 medicinal plants are those which are listed as biological sources for collectively 148 plant-based crude drugs included in Japanese Pharmacopoeia. This makes the current coverage about 90% for the plant-based crude drugs included in Japanese Pharmacopoeia.

Medicinal Plant Garden at Kumamoto University is selected as one of the leading center for the conservation of rare and endangered plants by the Japan Association of Botanical Gardens (JABG) in 2006. Currently, about 50 such rare plant species are conserved inside garden. Few examples are *Ottelia alismoides* (L.) Pers., *Tribulus terrestris* L., *Lithospermum murasaki* Siebold, *Mucuna sempervirens* Hemsl., *Lychnis sieboldii* Van Houtte, *Rotala rotundifolia* (Buch.-Ham. ex Roxb.) Koehne, *Sparganium erectum* L., *Euryale ferox* Salisb., and *Acer tataricum* L. subsp. *aidzuense* (Franch.) P.C.de Jongetc. (Figure 4). Some of these medicinal plant seeds and seedlings are shared among other botanical gardens in Japan as part of activities of JABG.

Various field research for rare and endangered plants are also performed on a regular basis. For example, *Acer tataricum* subsp. *aidzuense* was rediscovered in Kumamoto after 30 years (Watanabe et al., 2014; Watanabe and Devkota, 2017). Similar research is also performed for many other plants, including medicinal and useful ferns (Nakato et al., 2020; Watanabe et al., 2018b). Various activities related to the conservation and documentation of traditional knowledge about medicinal plants are also performed. For example, starch from the roots of *Pueraria lobata* (Willd.) Ohwi root (known as Kudzu-denpun in Japanese) was traditionally used as food and also as an ingredient in the preparation of medicines and snacks in Japan. However, as the traditional process is not commonly used nowadays, such knowledge is declining. Thus, by performing the field works and practice along with students, a complete step-by-step process was documented and reported (Watanabe et al., 2018c).

## 4. Contribution in Pharmacy education

In 2006, the undergraduate clinical pharmacy curriculum in Japan was extended from four years to six years program for students who want to appear in National License Examination (Kubota et al., 2018). Thus, current undergraduate pharmacy education is divided into two types, a) 6 year undergraduate clinical pharmacy course (including 22 weeks internships in a community pharmacy and a hospital pharmacy in fifth year) and b) 4 year undergraduate pharmaceutical sciences course (Okuda 2015; Kubota et al. 2018). Students completing 4 year course do not participate in internships in pharmacies and cannot participate in National License Examination in general. In graduate schools, students who completed 6 year course can directly enroll into 4 year doctoral course and students who completed 4 year course can enroll into 2 year master course plus 3 year doctoral course (Okuda, 2015).

The English version of the Model Core Curriculum for Pharmaceutical Education for 6 year course can be accessed from the website of The Pharmaceutical Society of Japan


**Figure 5. Events for the general public and students.**

(https://www.pharm.or.jp/eng/curriculum.html). The Model Core Curriculum includes the major part (70%) of the pharmacy curriculum that every pharmacy schools in Japan should follow and the rest 30% of the curriculum can be designed by each pharmacy school. It includes course related to medicinal plants such as Pharmacognosy (Naturally Derived Drugs) and Kampo Medicine.

In Japan, Schools of Pharmacy must have Medicinal Plant Garden as one of the facilities (https://www.mext.go.jp/b_menu/shingi/chousa/koutou/053/gijiroku/__icsFiles/afieldfile/2012/10/30/1325943_02_3_1.pdf). At Kumamoto University School of Pharmacy, Medicinal Plant Garden is actively involved in the education of medicinal plants, crude drugs, Kampo medicine and natural products to undergraduate and gradute course students. As part of Pharmaceutical Chemistry Practical, students are required to participate in medicinal plant garden observation tour, sketching medicinal plants, preparation of Kampo formulations and basic phytochemical techniques, among others. As the garden is located inside the School of Pharmacy, students can visit it anytime if they are interested and can learn about medicinal plants through the specified labels, handbooks and by discussing with academic and technical staffs. From the last few years, short seminars for undergraduate and graduate students (Figure 5) are organized almost every Friday, in which, about 2 medicinal plants flowering during that particular period are explained in detail.

## 5. Seminars/events for the general public and pharmacists

University-community collaboration is essential for the proper outcome of community-based projects to improve the regional economy through locally based product development and commercialization. Various seminars, plants observation tours and related events are organized throughout the year targeted for the general public. From 2003 to 2015, Medicinal Plant Garden Observation Tour was organized once in a month, where about 30–40 people (pharmacists, students, general public) joined each time. From 2016, these events were reorganized and a 3 hours' event of combined medicinal plant seminar and observation tour is organized 4 times a year. In average, about 50 people of different age group join these events (Figure 5).

School of Pharmacy at Kumamoto University started "Medicinal Plant Park Initiative" in FY 2015 to promote better utilization of Medicinal Plant Garden. To expand this initiative to local communities in Kumamoto Prefecture, a community-based project "Medicinal Herb Caravan" was started to promote the use of local herbs for beneficial health effects and product development using them through proper conservation, cultivation and utilization. In the initial phase, programs such as medicinal plant survey, public lectures, observational tours and medicinal herb-based food recipe design in Yamato Town, Kamimasiki Gun and Minami-Oguni Town, Aso Gun were organized in collaboration with Local Woman Association and local enterprises. Such events are now expanded to other communities.

From 2018, a new event targeted for licensed pharmacists termed as "Kampo Forum" was started in collaboration with Kumamoto Kampo Research Association. In this event, pharmacists who are interested in Kampo medicine can participate and listen to the lectures provided by experienced physicians, pharmacists and other professionals.

Events targeted for elementary school, junior high school and high school students, are also organized on a regular basis inside the pharmacy campus/medicinal plant garden or as part of other events in different schools/communities. In such events, the importance of medicinal plants, their conservation,


**Figure 6. Activities related to Medicinal Herb Village Project of Hyuga City**


**Figure 7. Kawachi Satellite Farm of Kumamoto University, School of Pharmaceutical Sciences.**

cultivation and impact on human health are explained to the young students.

## 6. Collaboration with local governments and companies

Medicinal Plant Garden as an affiliated facility of the School of Pharmacy is also involved in collaboration with local governments, communities and enterprises. For example, a Memorandum of Understanding was signed between Hyuga city, Miyazaki Prefecture and School of Pharmacy, Kumamoto University for a project called "Medicinal Herb Village Project" funded by Hyuga city. School of Pharmacy provided technical support for the project through plant cultivation, organizing different events such as seminars and observation tours (Figure 6), formulation of herbal products, etc. *Citrus* 'Hebesu', a local cultivar of *Citrus* plant in Hyuga city was also further analyzed for its chemical constituents and biological activities at Kumamoto University as a part of the project (Adhikari-Devkota et al., 2019b; Miyashita et al., 2018).

Medicinal Plant Garden has also collaborated with many local enterprises. For example, in collaboration with Orange Blossom Co., Ltd., Kawachi, Kumamoto, a satellite garden was established at the orchard of the company for the utilization of medicinal plants for further research (Figure 7). One of the outputs of this project was the chemical analysis and biological activity analysis of flowers of Satsuma mandarin (*Citrus unshiu* (Yu.Tanaka ex Swingle) Marcow.) (Adhikari-Devkota et al., 2019a).

## 7. Contribution to medicinal plant research/ International collaborations

Medicinal Plant Garden has supported research activities inside Kumamoto University and outside to different research organizations/universities by sharing the samples of medicinal plants and technical support/collaborations. A lab associated with the garden has also devoted its research activities to the elucidation of chemical constituents and evaluation of biological activities of materials from medicinal plants, genetic analysis and studies related to ecology and conservation. In recent years, many plants cultivated inside the garden have been utilized for scientific research (Chaudhary et al., 2019; Devkota et al., 2015, 2019).

Academic and technical staffs associated with Medicinal Plant Garden have also contributed to the scientific study of medicinal plants of many countries in collaboration with


**Figure 8. Museum of Traditional Medicines at the School of Pharmacy, Kumamoto University.**

domestic research organizations in Japan and research institutes/universities in respective countries. From 2002, Medicinal Plant Garden has contributed to the research of Nepalese medicinal plants through joint field surveys, documentation of medicinal plants (Adhikari et al., 2019), publication of handbooks (Watanabe et al., 2005, 2013) and chemical and biological analyses of various medicinal plants (Adhikari et al., 2016; Cong et al., 2015; Devkota et al., 2010a, b, 2012a, b, 2013a, b, 2014, 2018; Hori et al., 2018; Joshi et al., 2013, 2014a, b, 2015). In the recent years, various medicinal plants from other Asian countries such as Bangladesh (Hassan et al., 2019), Bhutan (Iwashina et al., 2019), Myanmar (Zar Wynn Myint et al., 2019) and African countries such as Sudan and Egypt (Dirar et al., 2019a, c, b; Elbashir et al., 2018) are also studied for their chemical constituents and biological activities in collaboration with universities/research institutions in these countries and Japan. Such collaborations are now being expanded to other countries for strengthening scientific research on traditional medicines and medicinal plants.

## 8. Museum of Traditional Medicines

A Museum of Traditional Medicines has also been established inside the School of Pharmacy (Figure 8). Here, plant-based crude drugs used in various traditional medicines all over the world are collected and displayed. The current collection has different forms of more than 100 crude drugs used in Kampo medicines and other crude drugs commonly used in India, Nepal, Sri Lanka, Myanmar, Cambodia and Sudan. In collaboration with the local authorities in different countries, the Museum collection is being expanded. Students and the general public can visit the museum and learn about various traditional medicines of the world through guided tours and available information booklets, posters and videos.

## 9. Conclusions

Medicinal plant gardens are integral parts of the School of Pharmacy facilities to teach about the various aspects of medicinal plants in human healthcare. The general public can also get benefited from the medicinal plant gardens by participating in various educational and training events/ activities. Medicinal Plant Garden of School of Pharmacy, Kumamoto University has contributed to the various aspects of pharmaceutical science education and research not only in Japan but also in foreign countries. In future, wide sharing of scientific knowledge among multiple stakeholders could generate larger stewardship for conservation of traditional knowledge and medicinal plants. Medicinal plant gardens are appropriate tools for conservation of medicinal plants and preservation of traditional knowledge that help collaborate more local communities, academicians, students, researchers and pharmacists for generating greater conservation benefits and promote science communication.

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