Biodiversity wealth forging well-being: a case of institutional herbal garden consolidating the biodiversity citizen science

Tara Singh Mehra, D. K. Pandey and Shantanu Kumar Dubey*

The institutional herbal garden for North East region (NER) of India was established in 2014 wherein medicinal and aromatic plant (MAPs) species were brought from different ecologies experienced differential survival. This triggered the participation of local citizens in developing the science of herbal biodiversity in this region. Consequently, MAPs were collected from the forest and farmers' fields in different parts of NER. This resulted in better survival of the species from tropical to subtemperate conditions of NER. Over eight years, 164 MAPs have been conserved in the herbal garden representing 60 families comprising herbs (84), shrubs (45), climbers (15), trees (15) and grasses (5). The herbal garden at Pasighat conserves over 50% of the species documented nationwide including nine of the threatened species of India. Thus, the herbal gardens endorsing citizen science is instrumental for the widespread sharing of scientific expertise and stewardship on healing herbs.

Keywords: Biodiversity, citizen science, indigenous materials, institutional herbal garden, traditional resource.

CITIZEN science has emerged as a promising format in environmental and sustainability education as well as science education. It has been, though greater recognition in environmental sciences, particularly gaining acceptance in biodiversity management-related programmes[1]. Citizen science enables researchers to include the general public in biodiversity-related studies, thereby facilitating the data gathering that otherwise could not have been obtained[2,3]. Medicinal and aromatic plants (MAPs) contribute to human well-being through health and economic benefits. Globally, more than 28,000 plant species have been recorded having medicinal use[4] and one in every nine species (approximately 3000) is in the trading system at local, regional and global levels[5]. MAPs have more than 25% share among all the newly marketed drugs derived from natural products. For example, 70% of anticancer drugs are extracted from MAPs[6,7]. For people living in Africa and Asia, MAPs constitute their primary source of medicine[8]. Of late, the increased demand for natural health products and herbal drugs has given a boost to the trading of MAPs globally[9]. This is also evident from the fact that while in 2003, the annual global market for herbal medicines was estimated at US$ 60 billion, within ten years (2012), the global industry in traditional Chinese medicine (TCM) alone captured the global market worth US$ 83 billion[4,10]. MAPs also offer employment to rural dwellers across the globe through collecting and gathering from uncultivated environments and increasing their income by selling these materials[11]. MAPs are treasured for their herbal and bioactive product formulations. However, they are at risk of extinction because of overexploitation, inappropriate harvesting and utilization[12]. They are also being affected by climate change and development policies[13]. As a consequence, a large share of the global population relies on natural medicines and offering alternative to new medicinal compounds[10,14]. Hence, it has been recently emphasized to devise and encourage multiplication and cultivation strategies for MAPs[15]. In general parlance, conservation may be conceptualized as the process of managing the biosphere to derive maximum benefits for the present generation without impairing its potential for the future. This may involve multipronged actions for the conservation and sustainable use of MAPs. As a sequel, the National Medicinal Plants Board (NMPB), Ministry of AYUSH, Government of India has initiated the getting up of institutional herbal gardens across the country in programme mode. This initiative is in agreement with the National Biodiversity Action Plan-2008 and the United Nations Convention on Biological Diversity, both of which have provided the standard protocol for managing biodiversity. NMPB works for the development of herbal gardens to preserve MAPs for use by future generations as well as to propagate and multiply them for industrial use.

The richness of India's MAP resources is largely bestowed in the Indian Himalayan region, contributing 1748 species

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Table 1. Inventory of MAPs in the herbal garden, Pasighat, Arunachal Pradesh, India

Botanical name	Common name	Family	Habit
Abelmoschus moschatus	Musk dana	Malvaceae	Shrub
Abrus precatorius	Ratti	Fabaceae	Climber
Abutilon indicum	Indian mallow, atibala	Malvaceae	Shrub
Achillea millefolium	Common yarrow	Asteraceae	Herb
Achyranthes aspera	Latjira	Amaranthaceae	Herb
Acorus calamus	Sweet flag	Acoraceae	Herb
Adhatoda vasica	Malabar nut, vasaka	Acanthaceae	
Agave americana	Century plant	Agavaceae	Herb
Aloe barbadensis	Ghritkumari	Liliaceae	Herb
Alpinia calcarata	Smaller galangal	Zingiberaceae	Herb
Alpinia galanga	Greater galangal	Zingiberaceae	Herb
Alpinia officinarum	Lesser galangal	Zingiberaceae	Herb
Amaranthus spinosus	Spiny amaranth	Amaranthaceae	Herb
Ammi majus	Bishop's weed	Apiaceae	Herb
Amomum subulatum	Large cardamom	Zingiberaceae	Herb
Andrographis paniculata	Kalmegh	Acanthaceae	Herb
Angelica glauca	Chora	Apiaceae	Shrub
Annona reticulata	Custard apple	Annonaceae	Tree
Anthium graveolens	Dill	Apiaceae	Herb
Argemone Mexicana	Prickly poppy, Satyanashi	Papaveraceae	Herb
Argyreia nervosa	Elephant creeper	Convolvulaceae	Climber
Artimisia annua	Sweet worm wood, babuna	Asteraceae	Shrub
Arundina graminifolia	Bamboo orchid	Orchidaceae.	Herb
Asclepias curassavica	Tropical milkweed, Kaknasha	Asclepiadaceae	Shrub
Asparagus adesence	Yellow satavar	Asparagaceae	Herb
Asparagus officinalis	Garden asparagus	Asparagaceae	Herb
Asparagus racemosus	Satavar	Liliaceae	Herb
Bacopa monnieri	Brahmi	Scrophulariaceae	Herb
Bauhinia purpurea	Purple bauhinia	Fabaceae	Tree
Berberis asiatica	Rasanjan, daruharidra	Berberidaceae	Shrub
Bixa orellana	Sinduri	Bixaceae	Tree
Boerhaavia diffusa	Punarvava	Nyctaginaceae	Herb
Butea monosperma	Palash, dhak	Fabaceae	Tree
Canavalia gladiata	Sword bean, maha simbi	Fabaceae	Climber
Cardiospermum halicacabum	Balloon vine	Sapindaceae	Herb
Cassia alata	Candle bush	Fabaceae	Shrub
Cassia sophera	Kasunda, baner	Fabaceae	Shrub
Catharanthus roseus	Sadabahar	Apocyanceae	Herb
Centella asiatica	Mandookparni	Apiaceae	Herb
Chlorophytum arundinaceum	Musli	Liliaceae	Herb
Cissus quadrangularis	Asthisamharaka, hathjor	Vitaceae	Herb
Clerodendrum colebrookianum	East Indian glory	Verbenaceae	Shrub
Clerodendrum indicum	Tube flower, bharangi	Verbenaceae	Shrub
Clerodendrum serratum	Bharangi	Lamiaceae	Shrub
Clitoria ternatea	Aparajita	Fabaceae	Herb
Coleus aromaticus	Pathar choor	Lamiaceae	Herb
Commiphora wightii	Guggul	Burseraceae	Shrub
Costus speciosus	Crape ginger, Kuekand	Costaceae	Herb
Curcuma caesia	Kali haldi	Zingiberaceae	Herb
Curcuma longa	Haldi	Zingiberaceae	Herb
Cymbopogon martini	Palmarosa	Poaceae	Grass
Cymbopogon winterianus	Java citronella	Poaceae	Grass
Cymbopogon flexuosus	Lemongrass	Poaceae	Grass
Cyperus scariosus	Nagarmotha	Cyperaceae	Grass
Datura metel	Kala datura	Solanaceae	Herb
Dactylicapnos scandens	Yellow bleeding heart	Papaveraceae	Climber
Desmodium gangeticum	Dirghamoola, salaparni	Fabaceae	Herb
Dioscorea floribunda	Yam	Dioscoreaceae	Herb
Dioscorea pentaphylla	Five leaf yam	Dioscoreaceae	Herb
Echinacea purpurea	Purple coneflower	Asteraceae	Herb
Eclipta alba	Bhringraj	Asteraceae	Herb

(*Contd*)

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Botanical name	Common name	Family	Habit
Eryngium foetidum	Mexican coriander	Apiaceae	Herb
Eucalyptus globulus	Blue gum	Myrtaceae	Tree
Euphorbia hirta	Duddhi	Euphorbiaceae	Herb
Foeniculum vulgare	Sweet fennel	Apiaceae	Herb
Gloriosa superba	Glory lily	Colchicaceae	Herb
Goodyera procera	Slim goodyera	Orchidaceae	Herb
Gymnema sylvestre	Gurmar	Asclepiadaceae	Herb
Hedychium coronarium	Butterfly ginger lily	Zingiberaceae	Herb
Hedychium gardenerianum	Kahili ginger, ginger lily	Zingiberaceae	Herb
Hemidesmus indicus	Indian sarsaparilla	Asclepiadaceae	Climber
Hibiscus sabdariffa	Rosella	Malvaceae	Shrub
Homalomena aromatica	Sugandhmantri	Araceae	Herb
Houttuynia cordata	Chameleon	Saururaceae	Herb
Kaempferia galanga	Chandramula	Zingiberaceae	Herb
Kalanchoe pinnata	Clapperbush, patharchur	Crassulaceae	Herb
Lipidium sativum	Chandrashoor	Cruciferae	Herb
Leucas aspera	Dronpushpi	Lamiaceae	Herb
Macuna pruriens	Cow hedge	Fabaceae	Climber
Melia azedarach	Persian lilac	Meliaceae	Tree
Mentha arvensis	Menthol mint	Lamiaceae	Herb
Mentha piperita	Peppermint	Lamiaceae	Herb
Mentha spicata	Spearmint	Lamiaceae	Herb
Messua ferra	Nagkeshar	Clusiaceae	Tree
Mimosa pudica	Touch me not, laajvanti	Fabaceae	Herb
Mirabilis jalapa	Four o'clock plant	Nyctaginaceae	Herb
Moringa oleifera	Sahijan	Moringaceae	Tree
Murraya koenigii	Curry leaf	Rutaceae	Shrub
Murraya paniculata	Kamini	Rutaceae	Shrub
Ocimum canum	Amritanjan	Lamiaceae	Shrub
Ocimum citriodorum	Lemon basil	Lamiaceae	Herb
Ocimum gratissimum	Ram tulsi	Lamiaceae	Shrub
Ocimum kilimandscharicum	Camphor basil, African blue basil	Lamiaceae	Shrub
Ocimum tenuiflorum	Big tulsi	Lamiaceae	Shrub
Ocimum viride	Clove basil	Lamiaceae	Shrub
Oenothera biennis	Evening prime rose	Onagraceae	Shrub
Operculina turpethum	Indian jalap, turpeth	Convolvulaceae	Climber
Paederia foetida	Gandal	Rubiaceae	Climber
Panax assamicus	Ginseng	Araliaceae	Herb
Paris polyphylla	Satuwa	Melanthiaceae	Herb
Peperomia pellucida	Baby rubber plant	Piperaceae	Herb
Phlogacanthus pubinervius	Orange nongmangkha	Acanthaceae	Shrub
Phlogacanthus thyrsiflorus	Ram basak, lal basak, teetapool	Acanthaceae	Shrub
Phyllanthus amarus	Bhumi amla	Euphorbiaceae	Herb
Pimenta dioca	All spice	Myrtaceae	Shrub
Piper longum	Pipali	Piperaceae	Herb
Piper mullesua	Hill pepper	Piperaceae	Herb
Piper nigrum	Black pepper	Piperaceae	Climber
Plumbago zeylanica	Chitrak	Plumbaginaceae	Shrub
Pogostemon benghalensis	Bengal pogostemon	Laminaceae	Herb
Pogostemon cablin	Patchouli	Laminaceae	Herb
Pouzolzia hirta	Urticahirta, blume	Urticaceae	Herb
Pouzolzia zeylanica	Oyik	Urticaceae	Herb
Psoralea coryfolia	Babchi	Fabaceae	Herb
Pterocarpus santalinus	Red sandal wood	Fabaceae	Tree
Rauvolfia serpentina	Sarpaghandha	Apocyanceae	Herb
Ricinus communis	Castor bean	Euphorbiaceae.	Shrub
Ruta graveolens	Rue, herb of Grace	Rutaceae	Herb
Saraca ashoka	Sita Ashok	Fabaceae	Tree
Sansevieria trifasciata	Snake plant	Asparagaceae	Herb
Santalum album	Sandalwood	Santalaceae	Tree
Sauropus androgynus	Katuk, star gooseberry	Phyllanthaceae	Shrub

(*Contd*)

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Botanical name	Common name	Family	Habit
Scoparia dulcis	Sweet broom weed, mithipatti	Scrophulariaceae	Herb
Sida acuta	Broom weed	Malvaceae	Shrub
Sida cordifolia	Bala, country mallow	Malvaceae	Herb
Sida rhombifolia	Cuban jute	Malvaceae	Shrub
Silybum marianum	Milk thistle	Asteraceae	Herb
Smilax ovalifolia	Kumarika, jangliaushbah	Smilacaceae	Climber
Smilax spp.	Catbriers, sarsaparilla	Liliaceae	Climber
Solanum indicum	Indian nightshade	Solanaceae	Shrub
Solanum khasianum	Nightshade	Solanaceae	Shrub
Solanum nigrum	Makoi	Solanaceae.	Herb
Solanum spirale	Brush nightshade	Solanaceae	Shrub
Solanum surattense	Kantakari	Solanaceae	Shrub
Solanum turvum	Turkey berry	Solanaceae	Shrub
Spilanthes acmella	Akakara	Asteraceae	Herb
Spilanthes paniculata	Phakphet	Asteraceae	Herb
Stemona tuberosa	Stemona root	Stemonaceae	Climber
Stephania japonica	Tape vine, snake vine	Menispermaceae	Climber
Stevia rebaudiana	Stevia, madhupatri	Asteraceae	Shrub
Swertia chirata	Chirayata	Gentinaceae	Herb
Syzygium aromaticum	Clove, laung	Myrtaceae	Tree
Talinum triangulare	Ceylon spinach	Portulacaceae	Herb
Tecoma stans	Yellow bells	Bignoniaceae	Shrub
Tegetus minuta	Jangli gainda	Asteraceae	Shrub
Terminalia arjuna	Arjuna, Arjun tree	Combretaceae	Tree
Terminalia belerica	Beleric myrobalan	Combretaceae	Tree
Terminalia chebula	Chebulic myrobalan	Combretaceae	Tree
Thevetia peruviana	Yellow oleander	Apocyanceae,	Shrub
Tinospora cordifolia	Giloy	Menispermaceae	Climber
Tinospora crispa	Faribel, patawali	Menispermaceae	Climber
Urena lobata	Bur mallow	Malvaceae	Shrub
Trichopus zylenicus	Jeevni	Dioscoreaceae	Herb
Ureria picta	Prishnaparni, dabra	Fabaceae	Shrub
Valeriana jatamansi	Valerian	Valerianaceae	Herb
Vernonia anthelmintica	Kalijiri	Asteraceae	Herb
Vetiveria zizanioides	Khus grass	Poaceae	Grass
Viola odorata	Garden violet	Violaceae	Herb
Vitex negundo	Chaste tree, nirgundi	Verbanaceae.	Shrub
Widelia chinensis	Pilabhangara	Asteraceae	Herb
Withania somnifera	Ashwagandha	Solanaceae	Shrub
Xanthium strumarium	Banokra, chotagokhru	Asteraceae	Shrub
Zanthoxylum armatum	Winged prickly ash, timroo	Rutaceae	Shrub
Zanthoxylum rhetsa	Prickly ash onger	Rutaceae	Shrub

to the herbal wealth of the country[16]. The diverse traditional knowledge systems of the ethnic groups dwelling in this area help provide them with food, housing and healthcare[17]. However, ongoing cultural changes, particularly the influence of modernization, and the lack of interest shown by the younger generations are a threat to the current understanding and use of traditional medicinal plants[18]. Hence, to preserve biodiversity and safeguard MAPs that are in danger of extinction, the farming community should be encouraged to engage in their systematic cultivation[19]. Indeed, there is a possible threat to the local medicinal flora as a result of the dwindling forests and landscape changes, indicating the need for serious efforts to raise public awareness so that necessary actions are taken to conserve the suitable environments needed to protect MAPs in the natural ecosystems of the north eastern region (NER)[20].

Overview of the institutional herbal garden

A herbal garden for NER was established in 2014 to accommodate important medicinal plants used by the indigenous people of that region as part of their folk tradition. The herbal garden is maintained at the College of Horticulture and Forestry, Pasighat – the oldest town of Arunachal Pradesh – a constituent college of the Central Agricultural University, Manipur, has commercially used medicinal plants as well as plants used in folk tradition by the people of NER. The herbal garden was established by a collection of materials from different parts of NER. The climate in Pasighat is warm and temperate. Compared to winter, there is more rainfall in summer with an average annual temperature of 22.8°C and average annual rainfall of 3898 mm. The collected materials from different parts of NER have

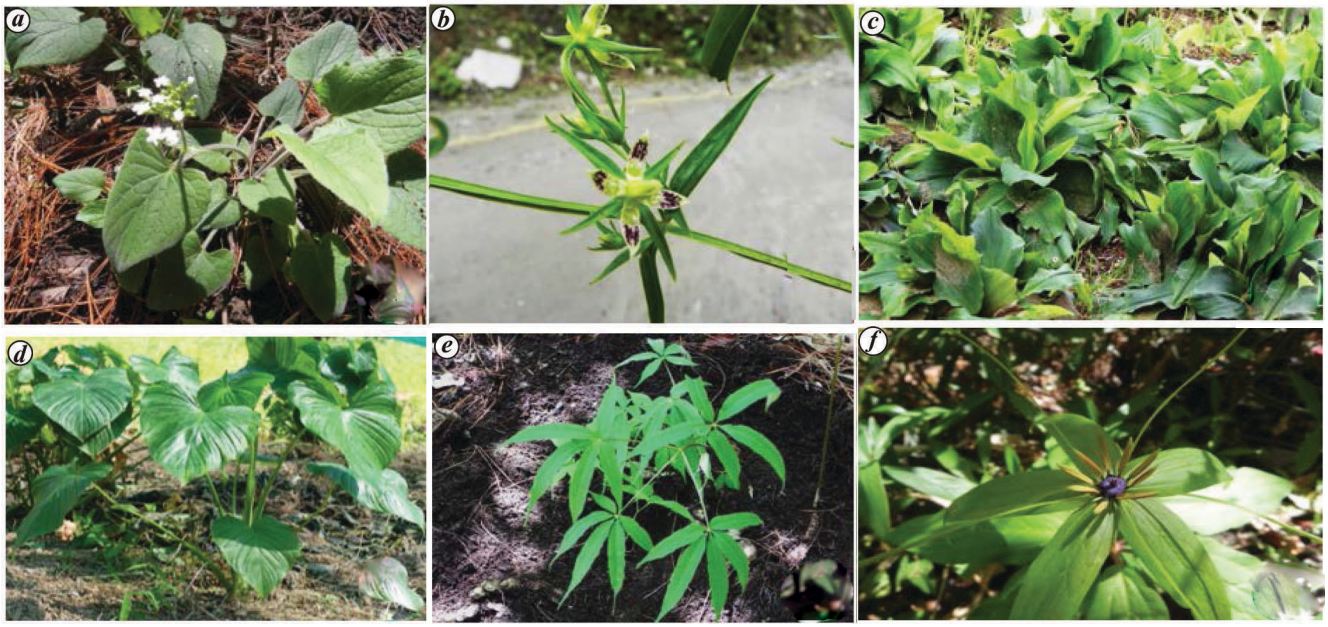

Figure 1. *Ex-situ* conservation of some threatened species in the herbal garden. ***a***, *Valeriana jatamansi*; ***b***, *Swertia chirata*; ***c***, *Kaempferia galangal*; ***d***, *Homalomena aromatica*; ***e***, *Panax assamicus*; ***f***, *Paris polyphylla*.

been planted in the herbal garden and further propagated, conserved and used for research purposes. Initially, there was only a small block of about 20 medicinal plants. However, after the sanction of the proposal and allocation of funds from NMPB in 2014 for the establishment of 'herbal gardens for NER', MAPs were also brought from institutions in different parts of India. Soon it was realized that the species brought from Gujarat, Rajasthan, Madhya Pradesh, Chhattisgarh and other drier regions of the country did not survive in the agro-climatic condition of Pasighat. MAPs were collected from the forests and farmers' fields located in different parts of NER. It was observed that the species adapted to tropical to sub-temperate conditions of NER had established well, with some exceptions. To date, over 160 MAPs have been conserved in the herbal garden. Table 1 gives the inventory of MAPs in the herbal garden at Pasighat.

As can be seen from Table 1, over 160 MAPs are maintained in the herbal garden, representing 60 families. The majority of them are herbs (84) followed by shrubs (45), climbers (15), trees (15) and grasses (5). Further, it is worth mentioning that out of 300 MAPs established in various institutional herbal gardens in India[21], the one at Pasighat conserves over 50% of species. Nine threatened species, as enlisted in the *Red Data Book of India,* are also conserved in this garden. Figure 1 depicts some of them.

Consolidation of the biodiversity citizen science

Citizen science has great potential not only for science but also for education. Biodiversity is currently being eroded at faster rates[22,23]. A crucial step in biodiversity conservation is raising society's awareness of its value and importance[24,25]. In addition to this, changing people's attitudes and behaviour is of utmost importance for biodiversity protection[26,27]. Various studies across similar environments have also established that the younger generations gain more by learning if they are made responsible for using natural resources in the future. This approach may be operationalized by emphasizing biodiversity protection and personal responsibility among the local people for protecting the environment[28]. By incorporating formal information, the herbal garden actively creates public awareness of the herbal biodiversity heritage and conservation. Since its establishment (2014–15) till February 2020, around 2500 people, including students, farmers, researchers and unemployed youth, have benefited from the herbal garden with increased awareness and knowledge on the biodiversity of MAPs beside pro-environmental behaviour-actions aimed at avoiding harm to and/or safeguarding the environment.

Apart from exchanging planting materials with numerous indigenous people of NER, the institutional herbal garden has also supplied/exchanged germplasm to many educational and research institutions in India. The COVID-19 pandemic-related lockdown and restrictions to human movement have had severe negative impacts on the biodiversity of the MAP in this herbal garden and have also restricted people's participation. Thus, sincere efforts are being made to recover and restore biodiversity in the garden. In addition, the institution is trying various activities to consolidate biodiversity citizen science.

Conclusion

In addition to enhancing the survival of rare and endangered plant species and other priceless plant genetic resources, the institutional herbal garden at Pasighat, developed with

NMPB funding, plays a significant role in conserving ecosystems. Additionally, the herbal garden serves as a training ground for fields like horticulture, agriculture, botany, forestry, landscaping, *ex-situ* conservation and environmental awareness. On the basis of the underlying core concept and topic, the institutional herbal garden is also fostering familiarity with the local biodiversity and assisting in forging the instant connection with higher credibility. The herbal garden also aids in the implementation of national strategies, plans and programmes for the conservation of biological diversity and its sustainable use. Thus, the future widespread sharing of scientific expertise with numerous stakeholders shall increase stewardship for traditional resource preservation related information on healing herbs. Gardens with medicinal plants are ideal for their conservation and the collaborative preservation of traditional knowledge with neighbour organizations, academia, students, researchers and pharmacists for harnessing more benefits and encourage the sharing of scientific information.

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