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NOTES ON NEGLECTED AND UNDERUTILIZED CROPS

Conservation and sustainable utilization of horticultural biodiversity in tropical Andaman and Nicobar Islands, India

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Abstract Tropical region representing 36 % of the Earth's surface and 20 % of its land mass is characterized by warm to hot and moist climate with lush green vegetation. Andaman and Nicobar Islands, India harbour over 2650 species of flowering plants, of which 223 species are endemic and 1300 do not occur in the mainland India. Horticultural crops occupy about 70 % of the total cropped area in the islands. Plantation crops (63 %) are dominant component, while vegetables, fruits and tuber crops are known to contribute in livelihood and nutrition of native tribes and settler population. Continuous introductions of non-native crops and domestication of wild plants expended the list of horticultural crops since the Penal Settlement Process in nineteenth century. Presently, about 150 species of vegetables, 120 of fruits, 132 of orchids, 120 of ferns and 300 of medicinal plants have been reported from the islands. By utilizing the diversity in potential species, 18 improved varieties have been developed in various crops apart from identification of 20 breeding lines, registration of seven unique germplasm and conservation of about 187 germplasm at National gene banks. However, overemphasis on commercial exotics, ignorance of native bioresources, introduction of pests, habitat degradation and changing climatic factors could lead to loss of potential horticultural germplasm. Present article highlights efforts made and challenges involved in the conservation and sustainable utilization of horticultural resources for development of the tropical archipelago in the era of changing climate.

Keywords Climate change · Habitat enrichment · Horticulture genetic resources · Indigenous crops · Indigenous tribes · Tropical region

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Introduction

The tropical region (23°26′16″N; 23°26′16″S) representing 36 % of the Earth's surface and 20 % of its land mass is characterized by warm to hot and moist climate with lush green vegetation. This climate favours higher diversification rate during evolution

process due to factors such as reproductive isolation, faster molecular evolution and increased biotic interactions (Mittelbach et al. 2007), and hence these regions are commonly known as 'biodiversity paradise'. The Andaman and Nicobar Islands (ANI) is one of the archipelagos in tropical region, which is considered as a veritable storehouse of plant diversity (Balakrishnan and Ellis 1996). Geographically, the islands are a part of the long Island Arch extending from the Arakan Yoma hill range of Myanmar to the Sumatran range of Indonesia (Basic Statistics 2011). The islands are positioned between two major biodiversity areas (Zeven and Zhukovsky 1975), which endows them with an unmatched distribution of plant diversity with representatives from the Indian, Burmese, Thai, Malaysian and Indonesian floras (Balakrishnan and Ellis 1996; Pandey and Diwakar 2008; Singh et al. 2014c). The ANI has about 34 mangrove species, which cover 12 % of its geographical area; few of them having culinary uses (Goutham-Bharathi et al. 2014).

About 86.2 % of geographical area of the islands is occupied by forests and only 6 % of the land is available for agricultural purpose (Basic Statistics 2011). Nine national parks, 96 sanctuaries and one biosphere reserve are being maintained in different parts of the islands i.e. 19.6 % of total geographical area is dedicated for the conservation of wild plants in forest ecology (ENVIS-WII 2012; Singh et al. 2014a). But, a number of factors contribute to the degradation of natural habitats of the endemic and horticulturally important wild crop relatives. Natural catastrophes such as Tsunami (December 2004) in the Indian Ocean, tropical cyclones viz. Leher (2013) and Hud hud (2014), frequent occurrence of prolonged wet (May–November) and dry spells (January–April); and unregulated anthropogenic activities have been responsible for loss of the pristine island biodiversity (Padalia et al. 2004; Arisdason and Lakshminarasimhan 2013).

The horticulture sector has a major role to play in the nutritional as well as economic security (Irungu 2011; Singh et al. 2013; 2015) in the island ecosystem even during stresses imposed by climate change and resource scarcity (Keatinge et al. 2011). The sector has shown its utility in livelihood and food security besides playing pivotal role in moral boosting and life-saving for farmers during post-Tsunami (2004) rehabilitation programmes. Local germplasm with unique traits are vulnerable to loss by climate change or habitat degradations. Although, the Supreme Court of India banned deforestation and local administration is strictly implementing the regulations to protect the island ecology, climate change factored increase in average air temperature by 1.4–5.8 °C, enrichment of atmospheric CO_2 concentration and variations in rainfall pattern (Houghton et al. 2001) will certainly affect island ecosystem including genetic resources (Bellard et al. 2012). In this context, the present article envisages efforts towards conservation and utilization of horticultural diversity in the ANI for its use in sustainable development of the region.

Study locale

The Andaman and Nicobar Islands encompasses 572 islands in the Bay of Bengal, India with geographical area of around 8249 km^2. It stretches between 6°N to 14°N and 92°E to 94°E. The Andaman and Nicobar groups of Islands are separated by the 10°N Channel (about 90 miles/145 km wide), with the Andaman group lying towards the north while the Nicobar group towards the south (Fig. 1). Geographically, the landmass could be divided into five groups of islands, namely North and Middle Andaman, South Andaman, Car Nicobar, Nancowry and Campbell Bay. It is located at 1255 km from Kolkata, 1200 km from Visakhapatnam and 1130 km from Chennai, the nearest cities in mainland India. About 90 miles to the southwest of Great Nicobar lies the north-western tip of Sumatra, Indonesia. Like other tropical islands, the climate of ANI is similar to maritime climate with two distinct cropping seasons, mainly based on the rainfall pattern viz. rainy season (May–December) and dry season (January–April). Rainy season is characterized by plentiful rains (400–600 mm/month), average temperature of 23–27 °C and predominant cloud cover. Relative humidity remains higher (≥80 %) during rainy season and lower (65–75 %) in dry season. Dry season is rain-free (except incidental rains during February–March months) and comparatively cooler (21–24 °C) during December–February than March–April (28–33 °C). Low-land soils are clayey and silty in nature, while upland soils are predominantly gravely clay loam, weak, sub angular blocky, friable, slightly sticky with moderately rapid permeability. The *C*/*N* ratio ranges from 16 to 21 (Pandey

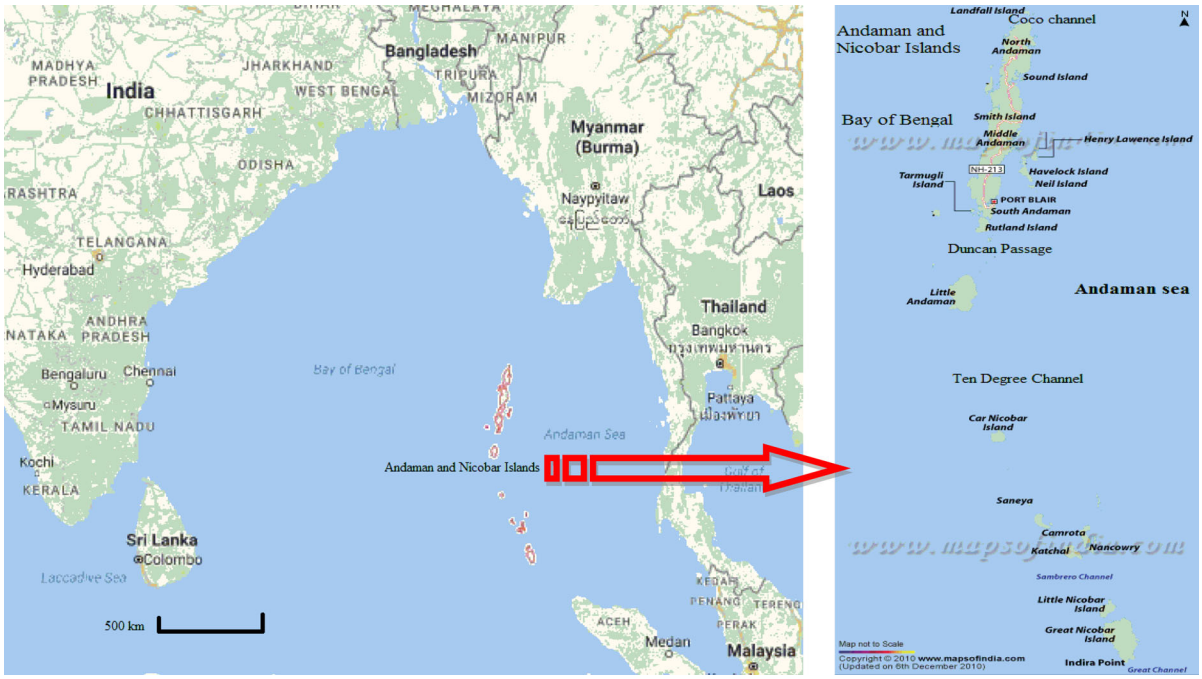

Fig. 1 Andaman and Nicobar Islands: geographical location in Bay of Bengal in the Indian Ocean. *Numbers* indicated in the map signify the distance (km) of the islands from different countries and places

et al. 2007). Major share of cropped area lies in North, Middle and South Andaman Islands, while very little area is under cultivation in Nicobar group of islands. Land resources are limited and climatic condition are not much favourable for introduced crop plants, hence there is a great challenge to meet the food demand of 0.38 million local population from only 50,000 ha of cultivated lands, which is scattered across the 38 inhabited islands.

Further, the archipelago houses six native tribes including the Nicobarese, the Jarawa, the Shompen, the Onges, the Sentinels and the Great Andamanese, which constitutes 7.5 % of total island population (Basic Statistics 2011). Settlers have maximum share in island population, which arrived in the islands during nineteenth and twentieth century as a result of British imprisonment and settlement, independent India's Penal settlements and immigration from adjacent regions (Majumdar 1975). This heterogeneous population in true sense represents the 'Mini India' for culture, religion, festivals and food diversities. Some islands have emerged as commercial production centres for agri-horticultural crops due to differences in food and cultural preferences, technological interventions, input supply and market opportunities, which had impact on local diversity in these islands of ANI (Singh et al. 2012).

Horticultural crops in the islands

Coconut and arecanut based farming system dominates the upland agriculture, while paddy-vegetable system is predominant in low land situation in the islands. About 70 % of total cropped area (50,000 ha) in the islands is covered by horticultural crops and plays important role in livelihood and nutritional security. Coconut (21,768 ha), rice (9081 ha), arecanut (4152 ha) and fruits (3160 ha) are major crops in the ANI. Vegetable crops are grown on 6890 ha area but mostly as post-paddy crop in dry season. Although, tropical climate of ANI favours cultivation of roots and tuber crops, vegetable crops and fruit crops but, very slow increment in productivity and no expansion of area are matters of concern to meet their projected local demands of 37, 42 and 25 thousand tones, respectively (Srivastava and Ambast 2011). Climate change and continuous increase in

tourist inflow call for measures to ensure adequate local production in the islands (Singh et al. 2015; Chand et al. 2015). High yielding crop varieties are the potent and eco-friendly tools to minimize the yield gaps and for this, the local genetic resources having genes for tolerance against high humidity, salinity, diseases and pests and increased CO_2 and temperature levels (de la Peña and Hughes 2007; Singh and Bainsla 2015) need to be explored.

Horticultural diversity

Vegetables and tuber crops

Vegetables are rich sources of dietary micronutrients and antioxidants (Singh et al. 2011a) and their regular intake counters the risk of non-contagious diseases of cardiovascular, digestive, respiratory and nervous systems. Hence, these are useful tools for food-based approach in combating anemia, blindness and other immunity associated diseases for attaining the millennium development goals (Keatinge et al. 2011; Thompson and Amoroso 2014). Vegetables are integral component of agriculture and generate livelihood opportunity for more than 50 % of island population, which depends on agricultural activities (Basic Statistics 2011; Singh et al. 2015). Unlike cereal staples, the kind of vegetables in local diet changes with region, traditional preferences, farming situations, socio-economic condition and prevalence of local diversity of culinary herbs (Rai et al. 2009). Around 150 species of vegetable crops are reported in the islands and family-wise distribution of which has been presented in Fig. 2. Of them, perennial vegetables constitute 18 % of reported vegetables followed by less-used-leafy vegetables (15 %), local legume vegetables (10 %), tuber crops (9 %), less known cucurbits (7 %) and wild related vegetables (5 %). The remaining part is shared by commercial vegetables (18 %) and new exotics (11 %). Indigenous vegetables are easily available to tribal and rural communities (FAO/WHO 2002; Chadha and Oluoch 2003; Maroyi 2011). Further, low incidence of diseases and pests minimize indiscriminate use of pesticides, which otherwise would deteriorate the quality of soil and water bodies (Swarnam and Velmurugan 2013). However, local production of commercial vegetables in dry season lowers the prices and ensures supply of dietary microelements indicating their role in island economy and public health. Hence, both indigenous and exotic commercial vegetable crops are crucial for regular supply.

The islands are rich in diversity of underutilized legume vegetables such as *Mucuna pruriens* (L.) DC., *M. monosperma* Wight, *M. gigantea* (Willd.) DC., *Canavalia ensiformis* (L.) DC., *Canavalia gladiata* (Jacq.) DC., *Canavalia stocksii* Dalz. et A. Gibson, *Parkia roxburghii* G. Don., *Vicia sativa* L. var. *nigra* L., *V. faba* L., *Atylosia cajanifolia* Haines, *A. scarabaeoides* (L.) Baker, *A. grandiflora* Benth. ex Baker, *A. nivea* Benth., *Cicer microphyllum* Benth., *Abrus precatorius* L., *Acacia andamanica* I.C. Nielsen, *Psophocarpus tetragonolobus* (L.) DC. and *Centrosema pubescens* Benth. Of these, *Mucuna* spp., *Vicia* spp., *Dolichos* spp. and *Atylosia* spp. have a centre of diversity in the islands (Arora and Nayar 1984; Singh et al. 2013; 2015).

Besides, a number of introduced vegetable crops got commercial status in the islands, which include chilli (*Capsicum annuum* L.), okra (*Abelmoschus esculentus* L.), brinjal (*Solanum melongena* L.), tomato (*Solanum lycopersicum* L.), bitter gourd (*Momordica charantia* L.), bottle gourd [*Lagenaria siceraria* (Mol.) Standl.], cucumber (*Cucumis sativus* L.), radish (*Raphanus sativus* L.), cauliflower (*Brassica oleracea* L. var. *botrytis* L.), cabbage (*B. oleracea* L. var. *capitata* L.), knol khol (*B. oleracea* L. var. *gongylodes* L.), ridge gourd [*Luffa acutangula* (Roxb.) L.], sponge gourd (*Luffa aegyptiaca* Mill.), ash gourd [*Benincasa hispida* (Thunb.) Cogn.], muskmelon (*Cucumis melo* L.), palak (*Beta vulgaris* L. var. *bengalensis* (Hort.) Burm. f.), dolichos bean (*Dolichos lablab* L.), French bean (*Phaseolus vulgaris* L.), cowpea (*Vigna unguiculata* (L.) Walp.), cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.] and sweet potato [*Ipomoea batatas* (L.) Lam.]. The observed diversity in these vegetable crops is evolved due to segregation of selfed hybrids, natural mutations and introductions from other parts of the mainland India. Tree vegetables such as *Artocarpus heterophyllus* Lam., *A. altilis* (Parkinson) Fosberg, *Murraya koenigii* (L.) Spreng. and *Tamarindus indica* L. are prevalent in home gardens in the ANI (Abraham et al. 2008; Pandey et al. 2006). *Cycas rumphii* Miq. and *Calamus andamanicus* Kurz are eaten in the form of stew, soup, pickle, chutney or curry (Singh and Singh 2012). The islands are rich in wild relatives of cultivated

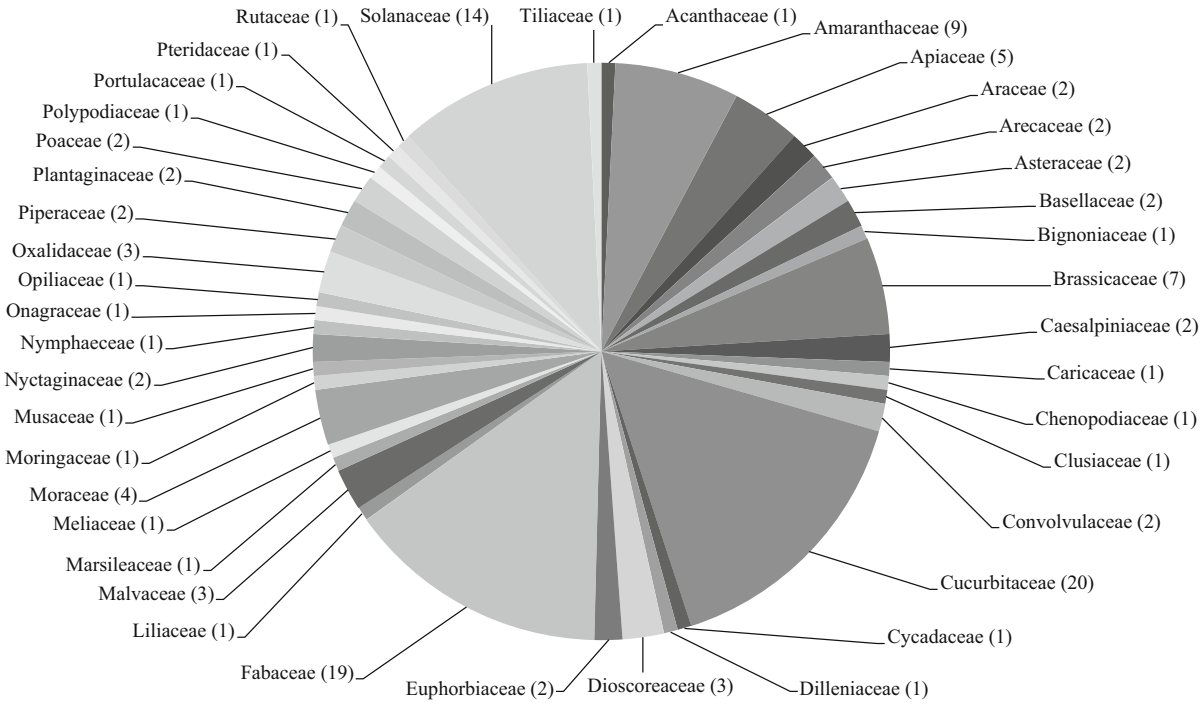

Fig. 2 Family-wise distribution of vegetable crops in Andaman and Nicobar Islands, India. *Numbers* indicated in the parentheses signifies total number of vegetable species of each family present in the islands

vegetable species viz. *Solanum melongena*, *Capsicum annuum* L., *Amaranthus viridis* L., *Luffa aegyptiaca* Mill., *Cucumis melo* L. and *Ipomoea batatas* (L.) Lam. (Abraham et al. 2008). Wild relatives of *Ipomea batatas* (L.) Lam. were observed near sea shore area, indicating their tolerance to salinity and water-logging situations.

Root and tuber crops are the third important food crops of mankind after cereals and grain legumes, and constitute as staple or subsidiary food for about one-fifth of the world population. In ANI, tubers and aroids are secondary foods for settlers but constitute important part of diets of native Nicobari, Jarawas and Onges tribes (Edison et al. 2006; Swarnam et al. 2015). Major edible aroids are represented by two botanical tribes and five genera including Lasioideae (*Cytosperma* and *Amorphophallus*) and Colocasiodeae (*Alocasia*, *Colocasia* and *Xanthosoma*). All parts of the plants including corms, cormels, rhizome, stalks, leaves and flowers are edible. Major tuber crops in the islands are *Manihot esculenta* Crantz, *Ipomoea batatas*, *Dioscorea alata* L., *Colocasia esculenta* (L.) Schott, *Xanthosoma sagittifolium* and *Amorphophallus paeniifolius* (Dennst.) Nicholson. Out of 22 species of *Amorphophallus* in India, five are present in the islands. Of these, *Amorphophallus campanulatus* (Roxb.) Blume ex Decne has attained commercial status. Prevalent diversity in tuber vegetables could be due to isle effect and introduction of species from mainland India (Balakrishnan and Ellis 1996; Singh et al. 2014a).

Plantation and spice crops

Plantation and spice crops are the important cash crops of the islands. The palm family is represented by four horticulturally important species viz. coconut (*Cocos nucifera* L.), areca palm (*Areca catechu* L.), wild areca palm (*A. triandra* Roxb.) and oil palm (*Elaeis guineensis* Jacq.). Coconut and arecanut have been cultivated on commercial scale and are considered as the major sources of income, food, fuel and shelter. Apart from being used as stimulant (Sharief 2007), arecanut has multifaceted uses in the life of tribal communities. Leaves are used for preparing the floors and thatching of huts, whereas spathes are used as utensils. Nuts of *A. triandra* are commonly used as stimulants by the local tribes (Elanchezhian et al.

2007). The Jarawa tribes use the stem of *A. triandra* for sitting during menstruation and after parturition (Sharief 2007).

Among the Anacardiaceae family, *Anacardium occidentale* L., *Semecarpus kurzii* Engler (endemic to ANI), *S. kurzii* Engler var. *elongata* D. Chandra et S.K. Mukerjee (endemic to Nicobar), *S. prainii* King and *S. subpanduriformis* Wall. ex Hook. f. (endemic to ANI) are reported in the islands (Pandey and Diwakar 2008). Leaf juice of *S. kurzii* is commonly used by the tribes for treating wounds and malarial fever (Das et al. 2006). One unique type of *S. kurzii* (IC547016) has been registered in the ICAR-National Bureau of Plant Genetic Resources, New Delhi (Singh 2006).

According to the International Organization for Standardization (ISO), Geneva, spices are described as the 'vegetable products or mixtures thereof, free from extraneous matter, used for flavouring, seasoning and imparting aroma in foods'. They have multiple uses namely in flavour, fragrance, aromatherapy, as insect repellants, radio-protecting agents and anti-microbial agents (Waman and Karanjalker 2010). India is known as "the land of spices" as it is one of the major producers and exporters of important spices in the world (Nirmal Babu et al. 1998). In the ANI, spices mainly belonging to seven botanical families viz. Lauraceae, Myristicaceae, Myrtaceae, Orchidaceae, Piperaceae, Rutaceae and Zingiberaceae have been reported (Pandey and Diwakar 2008). *Piper* (Piperaceae), is one of the important genera comprising of about 2000 species occurring in the tropical and subtropical regions of the world (Airy Shaw 1973). Of these *Piper nigrum* L. (black pepper), *P. betle* L. (betel vine), *P. longum* L. (long pepper), *P. miniatum* Bl., *P. pedicellosum* Wall. ex DC., *P. ribesioides* Wall., *P. flavimarginatum, P. clypeatum* Wall. ex Hook. f., *P. colubrinum* Link., *P. chaba* Hunt and *P. sarmentosum* Roxb. have been reported in the islands, which can be explored for breeding for stress tolerance (Mathew et al. 2004; Pandey et al. 2005; Pandey and Diwakar 2008). It has been assumed that, these islands could probably be one of the centres of origin for these species (Mathew et al. 2004). Black pepper is common in every home garden in ANI (Pandey and Singh 2010) and *P. colubrinum* and *P. chaba* are its potential rootstocks. *Piper sarmentosum* is known to possess antioxidant activity (Vimala et al. 2003) and anti-tuberculosis and anti-spasmodial activities (Thitima et al. 2004), while *P. longum* is effective as anti-bacterial, anti-allergic, anti-tumour and is used in hepatitis and respiratory disorders (Manoj et al. 2004) due to rich content of microelements (Singh et al. 2011a). Different wild forms of betel vine have also been reported from these islands (Sreekumar and Ellis 1990), which need further investigation. Both intra-specific and inter-specific diversity need to be studied in these species for identification of useful types for future use. *Murraya koenigii* (L.) Spr. (Rutaceae) possess anti-diabetic, vaso-dialating, hypo-cholestrolemic, anti-diarrheal and many other medicinal properties (Handral et al. 2012) and stem of its related species *M. paniculata* (L.) Jack. is used by the native Jarawa tribe in the preparation of arrow shaft and spears (Sarkar 2008).

Clove (*Syzygium aromaticum* (L.) Merr. et Perry; Myrtaceae) is a commercial crop in the islands (Pandey and Diwakar 2008) and vast diversity in genus *Syzygium* in ANI could be explored for possible use as rootstocks. Considerable diversity of family Myristicaceae has been reported from the islands (Pandey and Diwakar 2008). Species such as *Knema andamanica* (Warb.) de Wilde subsp. *andamanica, K. andamanica* (Warb.) de Wilde subsp. *nicobarica* (Warb.) de Wilde and *Myristica andamanica* Hook. f. are endemic to the Islands, apart from the natural populations of *M. elliptica* Wall. ex Hook. f. et Thoms. Recently, *Knema andamanica* (Warb.) W. J. de Wilde subsp. *peninsularis* W. J. de Wilde has been reported from Little Andaman (Rasingam and Upadhyay 2013). Systematic studies on drought tolerance (Krishnamurthy et al. 2008) could help in identification of promising rootstocks for nutmeg (Rema et al. 2006). *M. elliptica* is used for curing skin infections by the Shompen tribe (Elanchezhian et al. 2007), *K. andamanica* by the Jarawa tribe for cough and throat pain and *M. andamanica* to treat sickness and coagulation (Sharief 2007). The islands have *Cinnamomum verum* L. (cinnamon), *C. tamala* L. (Indian bay leaf) and *C. bejol-ghota* (Buch.-Ham.) Sweet in Lauraceae (Pandey and Diwakar 2008). Carambola (*Averrhoa carambola*) and bilimbi (*A. bilimbi*) of Oxalidaceae, and *Garcinia gummi-gutta* of Clusiaceae are not uncommon in backyards. *Vanilla albida* Blume, *V. andamanica* Rolfe (endemic to the islands) and *V. sanjappae* Rasingam, Pandey, Wood and Srivastava (endemic to Andaman group of islands) are the wild relatives of cultivated species (*V. planifolia* Jacks. ex Andrews) and may contain certain

useful genes for crop improvement for characters such as self-pollination, resistance to root rot and viruses, better beans size, superior aroma profile and pod indehiscence (Sasikumar 2010). White and pink flowering types of *V. andamanica* were self-compatible and their crosses with commercial vanilla were successful (ICAR 2005). In Zingiberaceae, *Curcuma longa* L. and *Zingiber officinale* Rosc. are grown commercially, while *Curcuma mangga* Val. et Van Zijp. and *Curcuma amada* Roxb. occur in wild habitats. Hence, magnificent diversity in spices highlights great opportunity for breeding for biotic and abiotic stress tolerance.

Fruit crops

The islands host a wide range of diversity of genetic resources in fruit crops (Singh et al. 2012), some of these being native to the region, while many were introduced species. Important fruits in islands are banana (51.7 %), papaya (10.0 %), mango (9.1 %), pineapple (8.7 %), sapota (5.0 %), while other underutilized fruits share 6.2 % of total recorded fruit coverage (3241 ha) (Basic Statistics 2011). Annual fruit production in islands is 37,150 MT. So far, about 25 families of fruit crops have been reported in the islands (Fig. 3) and predominant are Clusiaceae, Anacardiaceae, Myrtaceace, Moraceae, Musaceae and Rhamnaceae. In Anacardiaceae, six species of the genus Mangifera are found in Bay Islands, including *Mangifera indica* L. (common mango), *M. andamanica* King (small, yellowish orange fruits), *M. griffithi* Hook. f. (crimson red fruits) and *M. camptosperma* Pierre (compressed fruits). Two species of hog plum viz. *Spondias pinnata* (L. f.) Kurz and *Spondias cytherea* Sonner. also occur in cultivated as well as wild state (Singh et al. 2002). *Dracontomelon dao* (Blanco) Merr. et Rolfe is another species in this family, which yields edible pink colour fruits. In Annonaceae, *Annona squamosa* L. (sugar apple), *A. muricata* L. (soursop), *A. reticulata* L. (bullock's heart) and *A. glabra* L. (pond apple) exist with high level of inter-specific but low intra-specific diversity (Ahmad et al. 2010). *Annona glabra* has been reported to tolerate salinity (Singh et al. 2005), fruits of *A. squamosa* and *A. muricata* are rich in natural antioxidant (Singh et al. 2011b), while seeds in unsaturated fatty acids (Singh et al. 2005).

Karonda or pickle berry is an introduced fruit crop and has *Carissa carandus* L., *C. spinarum* L. and *C. andamanensis* L.J. Singh species in the ANI (Singh and Murugan 2012). The genus *Phoenix* has one endemic species *Phoenix andamanensis* S. Barrow and three other species viz. *P. sylvestris* (L.) Roxb., *P. rupicola* and *P. paludosa* Roxb. are also found in seashores areas (Pandey and Diwakar 2008). Carambola (*Averrhoa carambola* L.) and bilimbi (*A. bilimbi* L.) are two known fruits of Averrhoaceae family. These fruits are rich in oxalic acid and adapted well in the islands (Singh et al. 2002). Papaya has spread all across the islands and natural crossing and 'tropical isle effect' favoured evolution of 'local types' (Sudha et al. 2013). *Garcinia* (Clusiaceae) has 18 species in the islands and six of them are endemic viz. *Garcinia andamanica* King var. *andamanica*, *G. cadeliana, G. dhanikhariensis* S.K. Srivast., *G. kingii* Pierre ex Vesque, *G. kurzii* Pierre and *G. microstigma* Kurz (Pandey and Diwakar 2008). An anti-obesity compound 'hydroxy citric acid' in *Garcinia* fruits highlights its potential in pharmaceutical industry. Considering the potential of *Garcinia* species, these could be screened for their nutritional and phytochemical contents. In *Dillenia*, the reported species with edible fruits are *D. andamanica* C. E. Parkinson, *D. indica* L. and *D. pentagyna* Roxb. (Pandey and Diwakar 2008). Velvet apple (*Diospyrous blancoi* Willd.), mangosteen (*Garcinia mangostana* L.) and dragon fruit (*Hylocereus undatus* Haworth) are potential fruit crop. *Diospyros andamanica*, a wild relative of velvet apple is found in the forests. In Euphorbiaceae, *Phyllanthus emblica* L., *P. acidus* (L.) Skeels, *Baccaurea sapida* Müll. Arg. and *B. ramiflora* Lour. bear edible fruits and are found in the islands. *Baccaurea sapida* Müll. Arg. fruits are highly nutritive and are rich source of vitamin C, protein and iron (Singh et al. 2011b). *Haematocarpus validus* (Miers) Bakh. f. ex Forman or *khoon phal* (Menispermaceae) occurs in wild state in North and Middle Andaman Islands, which bears β-carotene and anthocyanin rich red edible fruits (Singh et al. 2014a).

In ANI, Moraceae is a rich family having genus *Ficus* (49 species) and *Artocarpus* (7 species) (Pandey and Diwakar 2008). *Ficus carica* L. and *F. racemosa* L. produce edible fruits. In *Artocarpus* genus, jackfruit (*A. heterophyllus*), breadfruit (*A. altilis)*, monkey jack (*A. lakoocha* Buch.-Ham.) and cham pedak (*A. chaplasha* Roxb.) are common in backyards. This

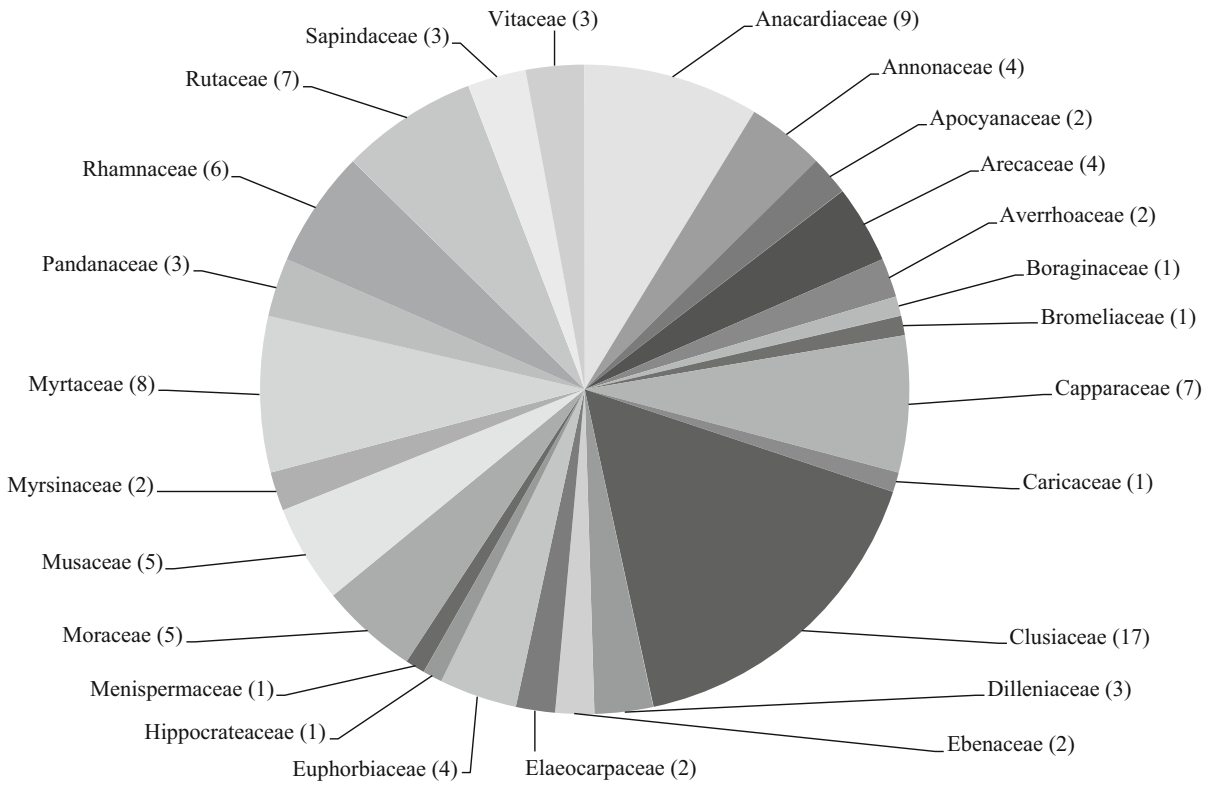

Fig. 3 Family-wise distribution of fruit crops in Andaman and Nicobar Islands, India. *Numbers* indicated in the parentheses signifies total number of fruit species of each family present in the islands

region has wide diversity of *Musa* having *Musa acuminata* Colla, *M. balbisiana* Colla and *M. paradisiaca* L. and wild relatives *Musa balbisiana* Colla subsp. *andamanica* Singh et al., *Musa textilis* Nees, *Musa sabuana* and *Musa indandamanensis* L. J. Singh (Singh 2014b). Abundance of seeds in wild species limits their immediate use but their stress tolerance can be used for banana improvement.

Khaariphal (*Ardisia solanacea* Roxb. and *A. andamanica* Kurz) of Primulaceae family is found to grow luxuriantly in sea water affected soils, which is a common problem of the ANI in post-Tsunami *era*. In Myrtaceae family, *Syzygium cuminii*, *S. claviflorum, S. samarangense, S. aqueum, S. jambos* and *S. malaccense* are found in backyards and semi-wild state (Pandey and Diwakar 2008). *S. jambos* bears rose flavoured fruits suggesting use in beverages. Fruits of Pandanus or *Kewra* form an essential part of Nicobari diets and medicines (Elanchezhian et al. 2007). *Pandanus lerum* Jones ex Fontane var. *lerum*, *P. lerum* var. *andamanensium* (Kurz) D.C. Stone and *P. tectorius* Soland are found in coastal and forest areas. Here, *Ziziphus andamanica* Bhandari et Bansali, *Z. mauritiana* Lam., *Z. nummularia* (Burm. f.) Wight et Arn., *Z. rugosa* and *Z. oenoplia* (L.) Mill. var. *oenoplia*, *Z. oenoplia* (L.) Mill. var. *pallens* Bhandari et Bhansali of Rhamnaceae are common. *Aegle marmelos* (L.) Correa, *Atalantia spinosa* (Willd.) Yu. Tanaka, *Citrus grandis* (L.) Osbeck, *C. hystrix* DC., *C. medica*, *C. nobilis* Lour. var. *limonellus* Kurz. and *Limonia acidissima* L. of Rutaceae family have been used as fresh or in medicinal preparations. *Litchi chinensis* Sonn. was introduced but lack of chilling temperature in the ANI limits its flowering. However, *Dimocarpus longan* (longan) and *Nephelium uncinatum* Radlk. ex Leench (hooked rambutan) of this family are noticed in the islands. Wild relatives of grapes (Vitaceae) viz. *Ampelocissus barbata* (Wall.) Planchon, *A. helferi* (Lows) Planchon and *A. polystachya* (Wall.) Planchon could be used as source of valuable genes.

Other important flora

Apart from the commercially exploited and exploitable species discussed above, a number of species of ornamental and medicinal value have been reported from the ANI. Orchids and ferns are the important species, which could be explored for their economic potential. A unique endemic species ground orchid viz. *Eulophia andamanensis* has been known to produce longer green spikes. Considering the potential of this species, an improved selection has been released for the benefit of the island farmers (Singh et al. 2014a).

Medicinal plants are commonly being employed by the native tribes for primary health care needs. More than 600 species including 71 endemic have been employed by the native tribes for various healthcare purposes (Dagar and Dagar 1991). Documentation of ethno-medicinal knowledge about such species have been carried out in native tribes such as Shompen, Jarawa, Onge, Nicobarese and Great Andamanese tribes (Dagar 1989; Gupta et al. 2004; Elanchezhian et al. 2007; Sharief 2007; Verma et al. 2010. A large number of medicinally important species are being threatened due to indiscriminate harvesting for meeting the growing demands for herbal drugs. Adoption of biotechnological techniques such as in vitro secondary metabolite production could help in production of drugs from potential species without further destruction (Waman et al. 2015).

Noni (*Morinda citrifolia* L.; Rubiaceae) is an important underutilized species of medicinal importance found distributed in the ANI. It has climate resilient characters such as tolerance to salinity, frequent water logging and partial shade conditions (Singh and Singh 2013). Two species *Morinda citrifolia* and *M. pubescens* are distributed in ANI (Singh et al. 2011c) and extent of diversity in *M. citrifolia* was reported to be 55–61 % (Singh et al. 2012). 'CIARI Rakshak' is developed as a new variety of Noni having tolerance to salinity and 'CIARI Sanjivini' and 'CIARI Samridhi' have partial shade tolerance and suitable for intercropping in coconut (Singh and Singh 2013).

Threats to island biodiversity

Island agriculture changed from nomadic to subsistence and then towards commercialization. Over the years, the islands harbour rich diversity of horticultural plants (Arora and Chandel 1972; Arora and Nayar 1984; Singh 2014a). These indigenous horticultural crops contribute in livelihood and food and health needs of the native tribes and settler communities in the islands (Fig. 4). However, the earlier efforts on documentation and conservation were limited to botanical explorations (Pandey and Diwakar 2008; Rasingam and Parthasarathy 2009; Manohara et al. 2010) or short-term conservation activities (Singh et al. 2003, 2014b; Sharma et al. 2006, 2009; Frison et al. 2006). Immense pressure on biodiversity has been created due to habitat degradation, introduction of invasive alien species, habitat change, over-exploitation, climate change and pollution (Denslow 2003; Daehler 2006). In 1947, Island population was just one-fourth of present day, which has increased enormously to approximately 0.38 million (Basic Statistics 2011) and indiscriminate activities during the settlement process have played a major role in degradation of local bioresources. Further, consistent increase in tourist population without adequate environment sensitive measures increased vulnerability of island ecosystem and plant diversity (Gossling et al. 2002; Chand et al. 2013). High level of endemism was concentrated in smaller areas of ANI, which rendered them vulnerable to the loss caused by natural calamities (Porwal et al. 2012). Local fruits, vegetables and flowers are marginalized by exotic introductions in lure of high price offered by tourism sector (Gossling 2003). Natural disasters such as Tsunami (26 December, 2004), cyclones (Leher 2013; Hud hud 2014) and frequent flooding in low lands and drought in uplands constitute the major threats to island biodiversity (Pandey and Diwakar 2008). During Tsunami in 2004, smaller islands like Trinket Island washed out by seawater and caused huge destruction of its biodiversity. Besides, a large portion of coastal region was permanently inundated by seawater, which submerged the existing plant diversity in this region. Islands of Nicobar group were affected more severely than those in the Andaman group of islands due to subduction of landmass by Tsunami. It has been estimated that about 56.3, 27.6 and 63.8 % area under coconut was affected in Car Nicobar, Central Nicobar and Great Nicobar, respectively (Porwal et al. 2012). Impact of Tsunami was great enough to cause as high as fifty times higher damage to the forest cover than the usual

Fig. 4 Indigenous horticulture commodities—Indispensible for tribal and rural lives in Andaman and Nicobar Islands. **A** Indigenous vegetables—better option for consumer's pocket; **B** indigenous vegetables—tool of women empowerment; **C** indigenous vegetable—employment for youth; **D** fruits and vegetables being sold in a local market at Middle and North Andaman; **E** indigenous crops—medicine for tribals

anthropological activities (Prasad et al. 2009). However, predicted threat from climate change and tectonic movements of earth increase vulnerability of this hot spot for possible seawater ingression and habitat destruction. Further, even with strict international rules, the 'Gene Rush' has surfaced to explore new genes using biotechnological interventions (Akurugoda 2013). Modern practices in agriculture are also affecting population of pollinators either as direct killing by pesticides in fields and adjoining areas or influencing their food chain (Isenring 2010). Shift in environmental factors due to climate change will influence reproductive behavior of indigenous germplasm, which would ultimately lead to change in their genetic make-up or extinction from natural habitats.

Tapping horticultural biodiversity

The genetic resources from these islands have been utilized at different research institutes in mainland India for breeding of varieties with higher yield, tolerance to biotic and abiotic stresses and quality traits. Risk factors to horticultural diversity in the islands are described in Fig. 4 along with feasible options and practices for mitigating their impact in conservation of resources. The host institute Indian Council of Agricultural Research-Central Island Agricultural Research Institute (ICAR-CIARI), Port Blair took a lead and deposited about 187 important germplasm of horticulture crops at ICAR-National Bureau of Plant Genetic Resources (NBPGR), New

Delhi. In medicinal plant, germplasm of *Zingiber* spp. (IC362619, IC370699), *Z. spectabile* (IC370700, IC370701, IC422476), *Z. odoriferum* (IC422392), *Ocimum tenuiflorum* (IC 371812), *Curcuma longa* (IC 401732), *C. longa* (IC 401735) and *Murraya koenigii* (IC 405586) are being conserved at the Bureau. Unique germplasm such as INGR No. 03041 (*Eulophia andamanensis),* INGR No. 04060 (*Mangifera griffithi),* INGR No. 04122 (*Mangifera andamanica*), INGR No. 05028 (*Morinda citrifolia*), INGR No. 06022 (*Semecarpus kurzii*), INGR No. AG01 (*Annona glabra*) and INGR No. 12015 (CARI Brinjal-1) have also been registered. Unique types in coconut such as soft endosperm mutant (*Macapuno* coconuts) (Devakumar et al. 2014), Andaman Horned Cocos (IC 0598221: INGR 13067) with horny nuts (Jerard et al. 2014a), Niu Lekha green dwarf (EC0415218; INGR13065) having short statured palm (Jerard et al. 2014b), Chowghat Green Dwarf (IC296656) with very early flowering and tolerance to root wilt, Andaman Giant Tall (IC296657) with high copra content and Kenthali Orange Dwarf (IC296658) with tender nuts have also been registered from the islands and conserved at ICAR-NBPGR. Recently, vivipary in Andaman Green Dwarf has also been reported by Sankaran et al. (2012). In tuber crops, germplasm of few species such as *Manihot esculenta* Crantz (10), *Ipomoea batatas* (L.) Lam. (10), *Amorphophallus paeoniifolius* (Dennst.) Nicolson (4), *Dioscorea alata* L. (10), *Colocasia esculenta* var. *antiquorum* (L.) Schott (8), *Colocasia esculenta* var. *stoloniferum* (L.) (2), *Coleus* (4), *Maranta arundinacea* L. (1), *Xanthosoma sagittifolium* (L.) Schott (4), *Dioscorea* spp. (2) and *Typhonium* spp. (10) are conserved in field genebanks (Sankaran et al. 2012), suggesting the need for more efforts to tap diversity from unexplored regions.

Local germplasm was employed in breeding of new varieties in *Morinda citrifolia* L. (CIARI Sanjivini, CIARI Sampada, CIARI Samridhi, CIARI Rakshak), *Ipomoea batatas* (CIARI-SP-1, CIARI-SP-2), *Cocos nucifera* (CIARI Surya, CIARI Anapoorna, CIARI Omkar, CIARI Chandan), *Eulophia andamanensis* (CARI Pretty Green Bay), *Basella alba* L. (CARI Poi Selection), *B. rubra* L. (CIARI Shan), *Amaranthus viridis* L. (CIARI Harita), *Amaranthus tricolor* L. (CIARI Lal Marsha), *Eryngium foetidum* L. (CARI Broad Dhaniya), *Dioscorea* spp. (CARI Yamini) and bacterial wilt resistant *Solanum melongena* L. (CARI Brinjal 1) (Gautam et al. 2016). Varieties 'CIARI Sanjivini' and 'CIARI Samridhi' have tolerance to partial shade and 'CIARI SP-1' and 'CIARI SP-2' have tolerance to diseases and pests. 'CARI Poi Selection' and 'CIARI Shan' are suitable for round the year cultivation and have tolerance to heavy rains. Similarly, Amaranthus varieties have high yielding potential even in excess rains and drought conditions. The collected germplasm of horticultural crops are conserved in Germplasm Block at ICAR-CIARI, Port Blair. Extent of diversity in germplasm of Noni, Colocasia, Chilli, Orchids, Mango, Bael, Jatropha, Arecanut and Coconut has been analyzed using morphological traits and molecular markers. Noni is a native crop of the islands and systematic experiments on this newly domesticated plant resulted into development of scientific production technology. The identified superior genotypes of Ground Orchid, culantro, noni and mango were also characterized using DNA markers (RAPD and ISSR). The genetic resources were documented through publications and databases using bioinformatics software. Varietal evaluation trials were conducted under All India Coordinated Research Project (Vegetable Crops) and significant number of promising entries were identified for cultivation under island conditions such as in French bean (Contender, IIHR-909, Arka Anoop), Cowpea (Shwetha, Indira Hari, Swarna Harita), Dolichos bean (Gomuchi Green, Ankur Goldy, IIVR Sem-8, IIVR Sem-11), Hybrid okra (Arka Anamika, Shakti, HOKE 152), Chilli (LCA-353, Arka Lohit, CARI-Sel-1, KA-2) and Brinjal (CARI Brinjal-1, PB-69, PB-60) (Singh and Bainsla 2015). Custodian farmers conserving unique germplasm in the ANI have also been identified and documented (Gautam et al. 2014).

Biodiversity of tropical regions, particularly developing countries, is getting importance during deliberations at international fora such as Convention on Biological Diversity (1993), the Cartagena Protocol on Biosafety to the Convention on Biological Diversity (2003), the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity (2014), Trade-Related Aspects of Intellectual Property Rights (1995) etc. for equitable share of benefits. Besides, appropriate laws exist at national level to check the biopiracy of the unique genetic resources. Already, a lot of damage has been caused to the island biodiversity; therefore,

attention should be focused on balanced approach of sustainable development of the region, while conserving local bioresources (Pattullo 1996).

The way forward

Food preservation can meet the demand of present generation but gene conservation is must for survival of future generations. While considering the importance of biodiversity, various national and international agencies are engaged in conservation and sustainable utilization of genetic resources. Although, the initiatives are taken in this direction but there are other thrust areas, which need urgent attention viz. (1) in situ and ex situ conservation of unique germplasm and recognition of custodian farmers, (2) establishment of field gene bank/germplasm repositories, (3) develop DNA signatures of important germplasm/species, (4) development of database on island biodiversity using geospatial mapping, geographic information system (GIS) and global positioning system (GPS) along with ground-truthing, (5) characterization of genetic resources for traits of economic importance to utilize in breeding programmes, (6) adequate protection measures for genetic resources against unpredictable climatic vagaries, (7) regular survey and monitoring of changes in crop species in geographically fragmentized islands with reference to continental locations for understanding the adaptive changes, (8) consumer's acceptance of directly domesticated local/indigenous vegetables, fruits and mushroom is poor due to their poor quality which need adequate attention, (9) collaboration and effective coordination amongst related institutions such as Botanical Survey of India, Directorate of Agriculture, ICAR, and Forest Survey of India is necessary for long-term conservation and utilization of bioresources, (10) adequate strategies are required for search of climate resilient genes to transfer them in commercial crops using high throughput tools and techniques, (11) systematic evaluation and documentation of indigenous vegetables, ferns, orchids and fruits is necessary to protect them from possible natural or anthropogenic threats and, (12) genetic enhancement and pre-breeding of indigenous horticultural crops for yield, quality and stress tolerance are also important areas of research. Recently, a major initiative by ICAR-CIARI, Port Blair to establish a bio-security and quarantine facility will also go a long way to protect the island biodiversity from the exotic pests and pathogens. Tropical islands are spread across the tropical region of the world and harbor rich diversity of flora, which highlights for an international institute to deal with researchable issues pertaining to agro-biodiversity in tropical regions. Frequent interaction events are suggested to sensitize the actual stakeholders, recognize the custodian farmers and communities involved in biodiversity conservation, and bring new ideas from researchers and policy makers.

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Compliance with ethical standards

Conflict of interest No conflict of interest among the authors.

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