



## Conservation and utilization of soft endosperm coconut accession from Andaman Islands

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### Abstract

The recent genetic resources explorations undertaken in Andaman Islands revealed the occurrence of coconut palms yielding soft endosperm among the natural coconut population called *Thairu thengai* or *Nei thengai*. The characterization of *Thairu thengai* accession from Andaman Islands using the *in situ* observations on seven palms revealed that the palms belong to tall group of coconut. The palms of this type bear fruits with both normal and soft endosperm. About 16 to 27 per cent of the fruits per bunch were observed to be with soft endosperm and the remaining ones were with normal firm endosperm. The normal nuts of the identified palms produced poor quality copra indicating some degree of softness. The soft endosperm fruits are of three types with difference in the layers of soft endosperm, nut water and firm endosperm. The palms are found to occur sporadically in South Andaman. Although these palms appear morphologically looking similar to other coconut palms except for endosperm trait, differences could be observed for many morphological and fruit component traits. The morphological and fruit component traits of *Thairu thengai* coconut are compared with the other other coconut populations. The strategies for conservation and utilization of this novel type of coconut are proposed.

**Keywords:** Andaman Islands, characterization, coconut, soft endosperm, *Thairu thengai*

### Introduction

Coconut (*Cocos nucifera* L.) is an important multipurpose tropical palm of the humid tropics that supports millions of people in coastal and island ecosystems for their livelihood. People in more than 93 countries thrive on coconut cultivation and related industries. It has been traditionally used for its oil, and varied products from endosperm, nut water, tender nut water, husk, fiber and leaves. Emphasis on product diversification is considered important in increasing profitability. Coconut genetic resources conservation and utilization strategies in major growing countries have paved way for achieving the desired results in crop improvement and product diversification in coconut. India is considered as the leader in conservation and utilization of coconut genetic resources for development of improved coconut varieties for copra, oil, tender nut traits,

disease resistance and drought tolerance. The crop has been reported to exhibit wide variability for its fruits (Ashburner *et al.*, 1997), flowers (Ratnambal *et al.*, 2003), foliar traits (Arunachalam *et al.*, 2005) and other morpho-physiological traits (Zizumbo-Villarreal and Marin, 2001) which have been extensively used for breeding new varieties. Product diversification and adoption of improved varieties play a major role in improving the productivity and profitability. Coconut industries are currently facing challenges in the global scenario owing to the increased cost of production and lower prices. The status of coconut as an oilseed crop is being changed with emphasis as a food and nutrition crop in the recent times in order to increase profitability in coconut cultivation (CPCRI, 2010). In coconut, numerous phenotypic traits have been described to differentiate the diversity in coconut (Narayana and

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John, 1949). Among the different traits studied in coconut, fruit component traits were found to be the best for discriminating the varieties (Harries, 1978). Spontaneous useful mutations are reported in coconut for traits such as soft endosperm called *Makapuno* coconuts (Torres, 1937). This aberrant form of coconut isolated and purified from natural coconut populations is now a highly priced crop in Philippines (Nunez and de Paz, 1990). In India, occurrence of such palms have been reported earlier (Menon and Pandalai, 1958) in populations of West Coast Tall, East Coast Tall and in a conserved germplasm accession, Philippines Lono Tall (Satyabalan, 1953). But consistent efforts have not been made to characterize, isolate and purify those types for any commercial exploitation. The present report is the first in India describing the palms of the *Thairu thengai* type among the natural populations of Andaman Islands. Such soft endosperm types have been reported from almost all the major coconut growing countries (Arunachalam and Rajesh, 2008) and named differently such as *Makapuno* (Philippines), *Dikiri-Pol* (Sri Lanka), *Kelapa Kopyor* (Indonesia), *Maphrao Kathy* (Thailand), *Coco Gra* (Seychelles), *Niu Garuk* (Papua New Guinea), *Pia* (Polynesia), *Dong Kathy* (Cambodia) and *Dua Sap* (Vietnam). Conservation and utilization of such selected diversity in crop improvement are expected to yield promising results as the soft kernels provide opportunities for product diversification. The identification and characterization of such types among indigenous populations give a scope for further development of this population with higher proportion of *Thairu thengai* nut bearing palms through *in situ* conservation and participatory breeding efforts. Considering the importance of this novel type, the present study was conducted to characterize the novel type for aiding further conservation and utilization.

### Materials and methods

The study area is situated in South Andaman Island of India where the terrain is generally hilly with spurs and ridges enclosing narrow valleys with sea on the southern side. The palms studied are located between 11° 31' 23.60" and 11° 36' 24" N latitudes and 92° 40' 31" and E 92° 44' 40.99" E

longitudes, known to be the original and subsequent progenies of coconuts brought and planted from Nicobar Islands. The archipelago of the Andaman and Nicobar (A&N) Islands stretches over 800 km in the Bay of Bengal, approximately 1220 km south-east of the coast of West Bengal and 1190 km east of Chennai. It comprises 572 islands, reefs and rocks, of which 38 islands are inhabited. A deep 10° channel, a wide gap of 155 km with heavy tidal flows, separates the Andaman Island group from Nicobar Island group. These islands have a luxuriant evergreen tropical rainforest canopy reported to contain about 2100 varieties of plants, out of which 11 per cent is endemic and 1300 varieties do not occur in the mainland of India. A major part of the island flora is either of the Indo-Myanmarese–Thailand order or the Malaysian–Indonesian order (Balakrishnan and Ellis, 1996).

Germplasm exploration in Andaman Islands, targeting special coconut types during the year 2009-2010, revealed the presence of *Thairu thengai* bearing palms. In such palms, a proportion of nuts exhibited soft endosperm ranging from butter consistency to curd consistency and other nuts being normal with firm kernel (CPCRI, 2010). The A & N Islands were selected for this targeted exploration as it was suggested to have the widest variable coconut populations among Indian coconut populations in a small geographical area without much human intervention and the area was suggested to be the part of original Indo-Pacific home of *Cocos nucifera* (Balakrishnan and Nair, 1979). Recent studies in the natural coconut populations of A & N Islands through microsatellite markers revealed rich diversity preserved over generations and rare alleles were found to be present in tall accessions of Nicobar Islands (Rajesh *et al.*, 2008). The explored coconut population in Andaman Islands was reported to be the secondary and tertiary progenies of coconut originally brought from Nicobar Islands and multiplied for generations. The palms with soft endosperm are locally called as *Thairu thengai* or *Nei thengai* and the nuts of which are generally rejected by the growers during nut selection and sorting in copra making process as they are not suitable for copra making due to the soft endosperm. The *Thairu thengai* bearing palms in the population were identified through farmer's

participatory appraisal and individual testing of identified palms. Out of about 9000 palms, seven palms were identified with this trait. The morphological and nut component traits were recorded on the *in situ* *Thairu thengai* palms as well as the palms in the same population for characterizing the accession in comparison with general coconut population of Andamans. Morphological and fruit component traits were observed as per the standard coconut descriptors (IPGRI, 1995). Observations were made on all the seven palms along with fifteen representative palms each in the other categories of coconut palms in the population. The mean values were compared with standard deviation for all the traits observed in different groups.

## Results and Discussion

The morphological, inflorescence and nut component traits observed in Andaman Tall Thairu Thengai (ATTT) palms compared with other types *viz.*, Andaman Ordinary Tall (ADOT), Andaman Giant Tall (ADGT) and Andaman Micro Tall (ADMT) are presented in Tables 1, 2 and 3. The range for most of these parameters are in similar line with the earlier report by Balakrishnan and Nair (1979) who have listed the range of diversity in wild coconut populations of these Islands. However, the *Thairu thengai* type has not been reported in the earlier exploration, probably due to the low occurrence of such palms in the population. Earlier, a type of coconut called *Makapuno* has been reported

**Table 1. Morphological traits of ATTT compared with other Andaman coconut populations**

Trait/Accession	ATTT			ADOT			ADGT			ADMT		
	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD
Height (cm)	1465.00	1145 to 1700	287.10	1312.13	1150 to 1525	173.47	1347.67	1215 to 1565	189.74	1097.50	1010 to 1185	123.74
Girth of trunk at 50 cm (cm)	106.83	98 to 115	8.52	116.00	98 to 130	15.80	112.67	96 to 130	17.01	119.50	99 to 140	28.99
Girth of trunk at 100 cm (cm)	91.17	86 to 97	5.53	95.00	88 to 105.5	9.28	102.50	87.5 to 120	16.39	103.00	96 to 110	9.90
Girth of trunk 150 cm (cm)	86.33	85 to 89	2.31	87.63	81 to 98.5	7.65	94.83	84.5 to 110	13.42	98.00	92 to 104	8.49
Total number of leaves	40.17	34 to 50	8.61	31.75	25 to 43	7.84	37.50	35 to 40	2.29	37.50	35 to 40	3.54
Fronnd tip	Erect		Intermediate				Erect			Intermediate		
Length of petiole (cm)	109.33	109 to 110	0.58	98.50	91 to 105	7.55	109.58	103 to 115.75	6.39	120.50	120 to 121	0.71
Length of leaflet bearing portion (cm)	317.33	305 to 325	10.79	335.63	280 to 387.5	47.63	348.75	330 to 361.25	16.54	321.00	282 to 360	55.15
Petiole girth (cm)	17.63	16 to 20.5	2.49	18.69	13 to 22	3.95	18.98	17.75 to 20.2	1.23	19.00	19	0.00
Number of leaflets	111.33	94 to 121	15.04	112.00	92 to 121	13.44	124.00	120 to 132	6.93	119.50	117 to 122	3.54
Breadth of leaflets (cm)	5.65	5.2 to 6.05	0.43	5.90	4.5 to 7.4	1.19	5.58	5.2 to 6.03	0.42	5.70	4.9 to 6.5	1.13
Length of leaflets (cm)	113.33	111 to 117	3.21	112.50	92 to 131	16.58	114.25	93 to 131	19.40	124.50	116 to 133	12.02
Length of 10 internodes (cm)	62.67	58 to 65	4.04	64.00	44 to 84	17.59	69.83	61.5 to 75	7.29	54.00	50 to 58	5.66
Number of leaf scars in 1m	17.33	15 to 21	3.21	17.13	12.5 to 21	3.52	15.33	13 to 19	3.21	19.50	19 to 20	0.71

**Table 2. Inflorescence traits of ATTT compared with other Andaman coconut populations**

Trait/Accession	ATTT			ADOT			ADGT			ADMT		
	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD
Length of inflorescence (cm)	84.17	79 to 90	5.53	105.50	100 to 118	8.48	89.83	85 to 96.5	5.97	108.50	100 to 117	12.02
Length of spikelet bearing portion (cm)	32.33	29 to 36	3.51	34.75	25 to 48	9.60	34.17	30 to 37.5	3.82	36.00	32 to 40	5.66
Length of stalk (cm)	35.50	35 to 36	0.50	44.50	30 to 53.5	10.82	38.25	38 to 38.75	0.43	42.00	38 to 46	5.66
Inflorescence stalk girth (cm)	9.25	9 to 9.5	0.25	7.31	6 to 8.25	0.94	12.67	12 to 14	1.15	7.75	7.5 to 8	0.35
Length of spikelet (cm)	36.00	30 to 41	5.57	38.88	32 to 42.5	4.84	36.25	32 to 38.75	3.70	41.50	40 to 43	2.12
Number of spikelets	43.17	30.5 to 62	16.63	36.63	29 to 42	5.56	33.92	26 to 38.75	6.91	40.50	39 to 42	2.12
Number of female flowers	41.00	25 to 65	21.17	37.13	32 to 41	3.88	26.83	9 to 52.5	22.78	76.50	25 to 128	72.83
Number of bunches	12.50	9 to 16	3.50	13.38	11.5 to 16	1.89	12.50	10 to 17.5	4.33	12.50	12 to 13	0.71
Number of nuts	9.67	2 to 16	7.09	8.75	7 to 10	1.50	10.75	8 to 14.25	3.19	36.00	12 to 60	33.94
Bunches with buttons	4.33	3 to 5	1.15	4.75	3.5 to 7	1.55	4.42	3 to 7.25	2.45	1.50	1 to 3	0.71
Bunches with nuts	5.17	2 to 7.5	2.84	8.63	8 to 9	0.48	7.08	6 to 8.25	1.13	11.00	10 to 12	1.41

**Table 3. Fruit component traits of ATTT compared with other Andaman coconut populations**

Trait/Accession	ATTT			ADOT			ADGT			ADMT		
	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD
Quantity of tender nut water (ml)	257.00	215 to 300	42.51	428.13	200 to 580	166.10	485.42	276.25 to 600	181.42	100.00	78 to 128	18.32
Sweetness of water	Very good			Very good			Good			Good		
Sweetness of meat	Good			Good			Good			Good		
TSS	6.17	5.5 to 6.8	0.65	5.65	5 to 6.6	0.79	5.88	5.8 to 6	0.11	5.65	5.5 to 5.8	0.21
Colour of fruit	Green			Green			Green			Green		
Shape of fruit	Oblong			Oblong			Round			Oval		
Fruit weight (g)	788.00	646 to 936	145.09	1093.50	724 to 1294	252.44	1365.00	1075 to 1762	355.78	515.75	500 to 531.5	22.27
Fruit length (cm)	22.33	18 to 25	3.79	20.91	19.37 to 22.5	1.46	21.25	18.75 to 26	4.12	20.63	17.2 to 24.3	4.77
Fruit breadth (cm)	12.50	12 to 13.5	0.87	15.44	13.5 to 16.5	1.36	17.25	14.75 to 18.5	2.17	11.00	10.4 to 11.6	0.71
Husk thickness (cm)	6.50	5 to 8.5	1.80	4.41	3 to 5.5	1.10	4.00	3.45 to 4.55	0.50	7.50	3.75 to 11.25	5.30
Husk weight (g)	336.33	301 to 379	39.51	432.19	345 to 508.25	75.89	722.00	471 to 973	354.97	224.75	177.5 to 272	66.82
Nut weight (g)	451.67	345 to 557	106.01	661.31	379 to 793	194.26	696.50	604 to 789	130.81	291.00	228 to 354	89.10
Nut length (cm)	9.83	6.5 to 11.5	2.89	11.88	10.5 to 14	1.49	12.50	11 to 14	1.26	9.88	9 to 10.75	1.24
Nut breadth (cm)	9.17	9 to 9.5	0.29	10.56	8.5 to 12	1.48	11.56	10.8 to 16	2.61	8.38	7.25 to 9.5	1.59
Nut weight without water (g)	320.50	261 to 380	84.15	534.19	268 to 745	197.53	519.00	471 to 567	67.88	302.25	211.5 to 393	128.34
Shell thickness (cm)	0.40	0.31 to 0.46	0.14	0.43	0.36 to 0.45	0.04	0.42	0.33 to 0.50	0.12	0.31	0.30 to 0.32	0.01
Endosperm thickness (mm)	11.00	10 to 11.6	1.56	11.19	8.66 to 12.6	1.86	9.83	8 to 11.6	2.59	10.50	9.6 to 11.3	1.18
Cavity volume (ml)	160.00	106 to 204	58.20	353.75	230 to 470	98.10	385.00	377 to 389	7.01	150.00	90 to 210	84.85
Shell weight (g)	118.00	78 to 154	77.28	172.31	102 to 203	47.98	197.00	185 to 209	16.97	83.25	61.5 to 105	30.76
Copra weight(g)	128.00	101 to 172	37.56	227.81	104 to 341	97.56	200.5	180 to 255	40.31	133.25	90.5 to 176	60.46

in Philippines which is a mutant coconut with jelly like endosperm having great potential in confectionary industry and is caused by recessive alleles (*mm*) of a single gene (Torres, 1937). While conforming this single recessive mutation, it was described that the endosperm becomes buttery hence the embryos cannot germinate under natural conditions (Zuniga, 1953). The deficiency of  $\alpha$ -D-glucosidase in the *Makapuno* endosperm and embryos has been attributed to the non-germination of these nuts in nature (Mujer *et al.*, 1984). The palms heterozygous for the makapuno mutation (*Mm*) produced both normal (*MM* or *Mm*) and *Makapuno* (*mm*) fruits based on the pollen received. In the present investigation also, the identified palms produced both normal and soft endosperm nuts suggesting they are similar to the *Makapuno* type and possibly controlled by recessive genes. In Philippines, the soft glutinous meat that almost fills the cavity of the mature nut of makapuno coconut are often consumed as sweetened confectionary or used for flavouring ice cream, candies and pastries. The naturally occurring *Thairu Thengai* trees in Andaman are tall, occur sporadically in the natural population, and bear a maximum of 5 or 6 soft endosperm nuts out of 20 to 25 nuts in a bunch. This is similar to *Makapuno* bearing trees of

Philippines as reported by Nunez and de Paz (1990). A similar type of coconut called *Dikiri-Pol* was reported from Sri Lanka among tall coconut populations by Peries (1995).

The ATTT palms observed in Andaman could be classified into three types based on the following nut kernel characteristics.

Type 1. Nuts with cavity filled with water and endosperm soft and buttery (kernel and water separated) (Fig. 1). Type 2. Nuts with entire cavity filled with the mixture of endosperm and water (Fig. 2). Type 3. Nuts mostly without water, with very small cavity, endosperm soft and buttery on the inner surface but little harder adjoining the shell. Three types of *Makapuno* have also been described in literature based on the number of layers of soft, liquid and hard kernel (Andriano and Manahan, 1937).

The morphological traits showed that ATTT palms are taller than the general population comprising Ordinary, Giant and Micro types of the Andaman coconut population. The higher number of leaves on the crown of *Thairu thengai* palms may be due to the absence of regular harvesting in those palms, as the climbers generally do not harvest nuts

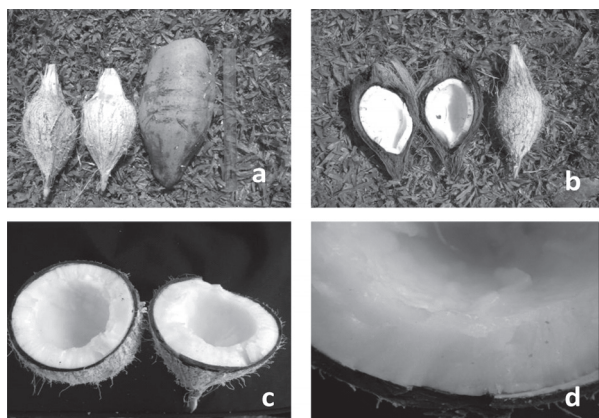


Fig. 1. Fruit characteristics of ATTT type 1. (a. Dehusked and whole fruit; b. Nuts with normal endosperm; c. Nut with soft endosperm; d. Close-up view of soft endosperm)

from those palms, identified as *Thairu thengai* palm. However, the leaf retention in the ATTT palms needs to be further observed with regular harvesting of bunches over longer periods to find out the possibility of its significance. The number of leaflets were higher in ADGT (124) whereas it is almost similar in ATTT and ADOT palms (Table 1).

ATTT palms produce shorter inflorescence among the other palms in the population with higher inflorescence stalk girth than ADOT and ADMT. ADMT palms can be easily identified with their large number of small nuts. Identification of ATTT palms using this trait needs further observations with more number of palms. The number of spikelets appeared higher in ATTT palms followed by ADMT whereas, the number of female flowers was higher in ADMT followed by ATTT. The number of bunches on the crown, number of nuts and buttons revealed that the ATTT palms are similar to normal palms, except



Fig. 2. Fruit Characteristics of ATTT Type 2 with soft endosperm completely mixed with nut water

that they produce a few abnormal nuts with soft endosperm (Table 2).

The tender nut water quantity was lower in ADMT whereas it was higher (>400 ml) in ADOT and ADGT (Table 3). ATTT has moderate tender nut water quantity indicating medium sized nuts when compared to ADOT and ADGT. The copra data on ATTT palms represent the observation in the normal nuts of ATTT palms as copra could not be processed with *Thairu thengai* nuts. The fruit weight was higher in ADOT and ADGT and lower in ADMT whereas it was medium in ATTT. The husk content was higher in ADGT and lesser in ADMT followed by ATTT. Though the nut traits of ATTT are superior to ADMT, the copra content was lowest among the four types indicating that even the normal nuts of ATTT are incapable of producing good copra and some amount of softness may be present which could not be easily identified on visual observation.

The number of soft endosperm nuts per bunch were recorded in seven ATTT palms (Table 4) based on identification of nuts by shaking. The normal nuts produce a water splashing sound whereas the *Thairu thengai* nuts produce a dull or no sound when the nuts are shaken. The observation was recorded over 12 months in which the *Thairu thengai* nuts ranged from about 16 to 27 per cent of the total nuts produced. Considering the recessive trait and single gene inheritance, it could be presumed that pollen from heterozygote palm for this trait need to pollinate same or other heterozygote palm to produce *Thairu thengai* nut. Hence, the proximity of other ATTT palms may have influence on the percentage of *Thairu thengai* nuts. However, more observations over years would be required to find out any possible seasonal influence on the nut set and also the pollen effect for this trait. The similar varied proportion of

Table 4. *Thairu Thengai* nut yield in the ATTT palms

Palm number	Bunches yr <sup>-1</sup>	Total nuts yr <sup>-1</sup>	<i>Thairu Thengai</i> nuts yr <sup>-1</sup>	<i>Thairu Thengai</i> nuts (%)
1	11	128	32	25
2	9	120	22	18.33
3	12	87	24	27.58
4	11	110	18	16.36
5	8	69	11	15.94
6	9	97	16	16.49
7	13	112	20	17.85

*Makapuno* nuts from the total number of nuts was earlier reported by Nunez and de Paz (1990). Results indicate that the production of *Thairu thengai* nuts within bunches, varied with palms and the percentage is dependent on the number of nuts produced per bunch. Hence, palms which are giving more *Thairu thengai* nuts with higher nut yield potential are to be selected for further exploitation.

The experiences and reports from Philippines with *Makapuno* type would be of much use in making a plan to utilize the ATTT palms at Andaman. The *Thairu thengai* nuts are not capable of normal germination due to the soft nature of endosperm and disposition of embryos inside the nuts. In the initial years of *Makapuno* breeding, the few *Makapuno* bearing trees in Philippines were categorized as heterozygotes (*Mm*) for the trait since it produced a few homozygous (*mm*) type nuts. In order to develop homozygous *Makapuno* bearing trees, the embryos of these nuts were cultured to produce plantlets and further evaluated. Further, selection was also made in the progenies for purification (Nunez and de Paz, 1990). From the studies, it was reported that the embryo-cultured *Makapuno* coconut trees were pure *Makapuno*-bearing and homozygous for the traits and it was proved through controlled pollination. Similar studies on artificial pollination also indicated the influence of pollen on the manifestation of type of endosperm (Cedo *et al.*, 1984). Hence, the ATTT palms of Andaman could be utilized for embryo culture of selected nuts produced through artificial controlled pollination for developing a homozygous population of ATTT palms could be producing all *Thairu thengai* nuts. Another approach could be to use pollen of existing ATTT palms for making crosses with selected superior dwarf cultivars to exploit the hybrid vigour with the desirable traits of dwarfness and soft endosperm. The latter approach may take more years for field evaluation, but the result will be highly useful to the farming community as it would combine more desirable traits. Considering the success by Nunez and de Paz (1990) in which *Makapuno* bearing Dwarf x Tall hybrids trees were observed to exhibit nut characteristics of dwarf female parents combined with the *Makapuno* trait, the scope for producing dwarf *Thairu thengai* palms appears promising.

Hence, the available palms *in situ* are to be conserved for artificial pollination amongst themselves, collection of embryo and pollen could be useful for embryo culture and production of new hybrid combinations in order to develop a pure *Thairu thengai* bearing population. Considering the reported double recessive nature of the trait as an assumption in the present case and identification of few palms, a strategy for conservation and utilization of this unique type of coconut is proposed (Fig. 3). In order to hasten the breeding programme, more number of such palms need to be identified in Andaman Islands as the present explored area was confined to only South Andaman. Exploration in the original coconut populations of Nicobar Islands would also help in identification of more such palms in addition to further more diversity within this soft endosperm type. The new food products from soft endosperm may increase the consumption of coconut products among traditional and non-traditional consumers and also contribute to nutritional security.

Although A & N Islands were reported to have diverse coconut population (Balakrishnan and Nair, 1979) with array of major coconut types within tall and dwarf coconut populations, the sporadic occurrence of *Thairu thengai* palms has not been reported earlier. Rajesh *et al.* (2008) has reported high level of population differentiation and observed majority of rare alleles in coconut populations collected by Jerard *et al.* (2000) from many uninhabited places or naturally growing coconut groves in various A & N Islands and concluded that rich genetic diversity exist among coconut populations of A & N Islands. Abraham *et al.* (2008) have also reported a few promising coconut types of these Islands and suggested that further exploration is needed in unexplored areas to collect new diversity. Rare coconut populations with rare gene sources could be possibly found in these islands as many uninhabited and remote islands are situated in Nicobar group of Islands such as Car Nicobar, Tillangchang, Chowra, Teresa, Trinket, Kamorta, Katchal, Pulo Milo, Kondul and Great Nicobar where coconut is mostly grown without any selection for many decades. In order to effectively combine the available information for possible use of *in situ* palms of such rare and novel types available in remote Islands such as A & N Islands in coconut

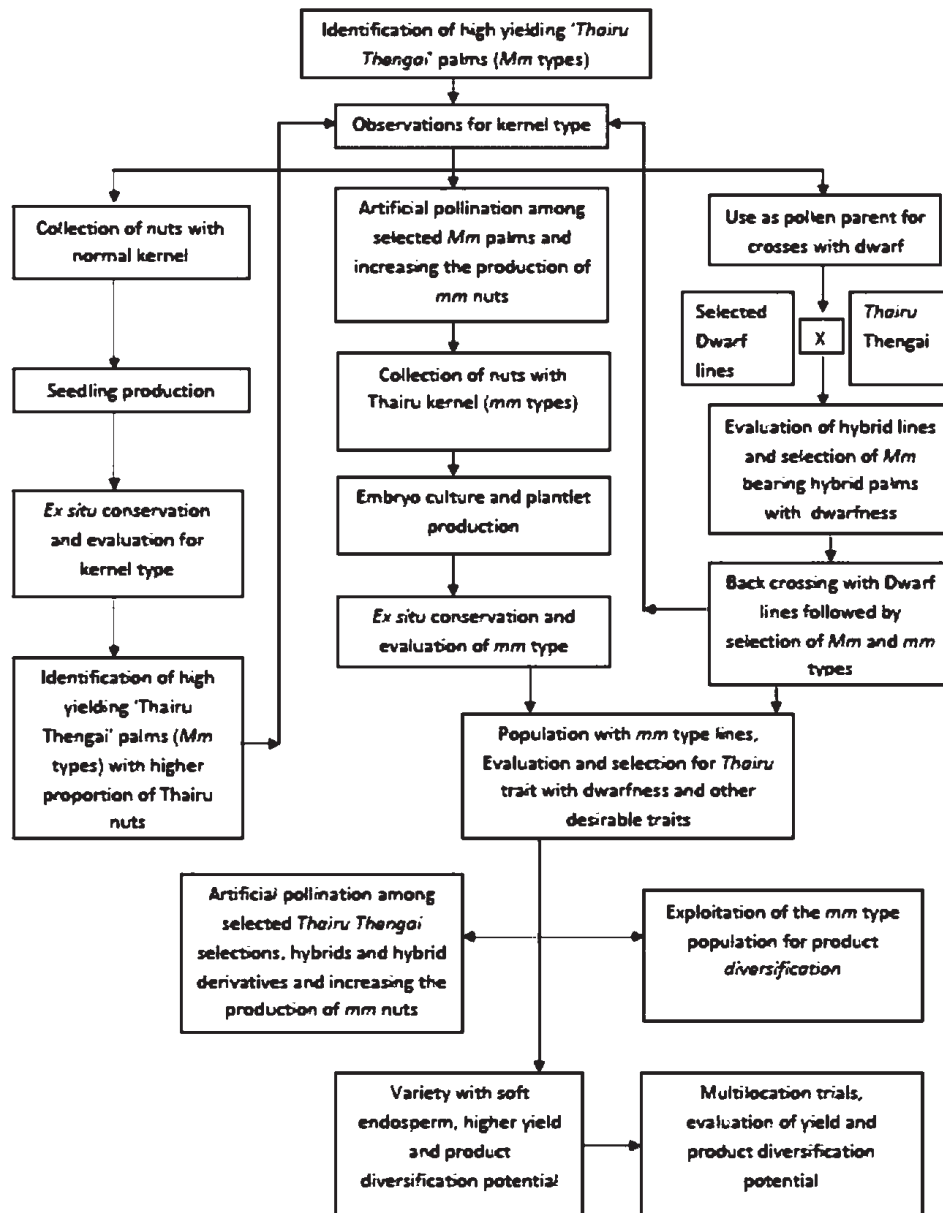


Fig. 3. Proposed strategies for conservation and utilization of *Thairu Thengai* palms

breeding, *in situ* conservation of documented types and participatory breeding programme would be ideal as the time taken for the breeding could be reduced.

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