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Research perspectives on Coconut, Arecanut and Cocoa

Coconut (*Cocos nucifera* L.) and arecanut (*Areca catechu*) are intrinsic to India's culture and civilization which is evident from the description of their use in ancient texts and epics. Cocoa (*Theobroma cacao* L.) was introduced to India in the 1930s, for establishing the plantations (Criollo type) in the Nilgiris, but was found to be the best companion crop in coconut and arecanut gardens. Over the time, these crops have become the most widely cultivated small-holder plantation crops in India and support the livelihoods of over 25 million people. The contribution of these crops to the Nation's Gross Added Value is estimated to be ₹14,200 crores.

THE inability of small and marginal farmers to invest adequately for achieving sustainable production is a major challenge to be reckoned with, at the policy level. Among these crops, coconut is cultivated in varied agro-climatic zones spread across 20 states/union territories of the country. It is also economically more vulnerable and experiences violent price fluctuations. Selective government interventions in terms of minimum support price (MSP) and regulating tariff rates are not enough to infuse growth and price stability in coconut. Development of appropriate technologies for small holdings, faster and wider technology adoption, and synergy from the developmental efforts of various institutions are to be channeled through better institutional linkages and cross-disciplinary approaches to integrate the sector with the global economy.

Global and national status of production

Coconut: The global coconut production is estimated at 67,698 million nuts from an area of 12.56 million ha. The world productivity stands at 5397 nuts/ha. Notably, 70% of the total area and production is concentrated in three countries, viz. India, Indonesia, and the Philippines. In productivity, India is much ahead of the major coconut producers' with an average yield of 9346 nuts/ha.

Coconut is the most important cultivated crop in large parts of India's east and west coasts. In the year 2020-21, the four southern states of Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh accounted for 89% of the area under coconut cultivation and 90% of the production. The productivity of the crops varies widely among the coconut growing zones. For instance, it was only 6892 nuts/ha in Karnataka, which is 26% less than the national average. On the other hand, several regions have productivity levels that are 50% higher than the national average. Various biotic and abiotic stressors affecting coconut productivity were investigated, but weather extremes experienced in the past are a matter of serious concern for the prospects of coconut in the country.

Table 1. Area, production and productivity of coconut in the world

Country	Area ('000 ha)	% share	Production (million nuts)	% share	Productivity (nuts/ha)
Indonesia	3413	27.2	13994	20.7	4120
The Philippines	3652	29.1	14491	21.4	3969
India	2173	17.3	20309	30.0	9346
Sri Lanka	444	3.5	3086	4.6	6623
Brazil	216	1.7	2331	3.4	11923
Papua New Guinea	221	1.8	1483	2.2	6709
Thailand	124	1.0	645	1.0	4859
Others	2325	18.5	11359	16.8	5195
Total	**12568**	**100.0**	**67698**	**100.0**	**5397**

Source: ICC (2021), Statistical year book-2019.

Table 2. State-wise production statistics of coconut

State/UT's	Area ('000 ha)	% share	Production (million nuts)	% share	Productivity (nuts/ha)
Tamil Nadu	437.57	20.1	5373.21	26.5	12280
Karnataka	624.03	28.7	4300.69	21.2	6892
Kerala	760.78	35.0	6980.30	34.4	9175
Andhra Pradesh	111.38	5.2	1555.82	7.7	13969
Others	221.40	11.0	1718.96	10.3	---
All India	**2173.28**	**100.00**	**20308.70**	**100.00**	**9345**

Source: Horticulture Division, Department of Agriculture and Cooperation, Ministry of Agriculture and Farmers Welfare, Government of India.

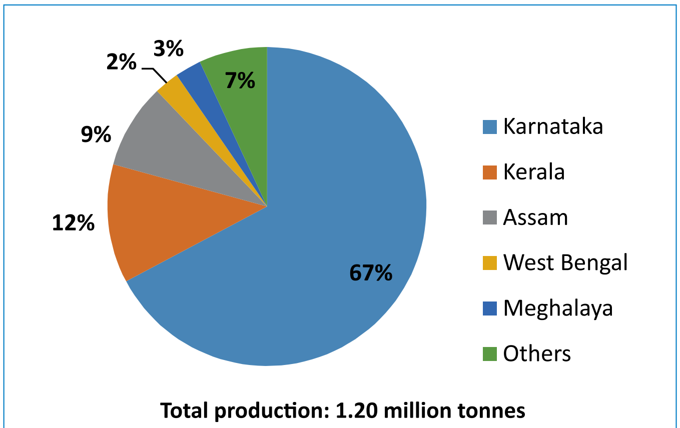
Table 3. Production statistics of arecanut in the world

Country	Area ('000 ha)	Production ('000 T)	% Share (Area)	% Share (Production)
Bangladesh	405.01	328.61	28.33	15.64
Bhutan	1.77	17.45	0.12	0.83
China	40.18	98.57	2.81	4.69
India	730.82	1208.94	51.12	57.56
Indonesia	138.23	132.60	9.67	6.31
Myanmar	70.06	203.22	4.90	9.67
Nepal	2.65	8.78	0.19	0.42
Sri Lanka	18.21	63.99	1.27	3.05
Thailand	22.66	38.20	1.58	1.82
Others	0.01	0.13	0.00	0.01
World	**1429.61**	**2100.48**	**100.00**	**100.00**

Source: FAOSTAT (2022).

Arecanut: The current world production of arecanut is about 2.1 million tonnes from an area of 1.42 million ha. India ranks first in both the area (51.12% of global share) and production (57.56% of world's share) of arecanut. Karnataka, Kerala, Assam and West Bengal are the major arecanut producing states in India.

Cocoa: It is grown in 58 countries around the world in 10 million hectares with an estimated production of 4.7 million tonnes during 2019-20. The four West African countries, viz. Côte d'Ivoire, Ghana, Cameroon and Nigeria together contribute to 73.6% of worldwide cocoa production. India is a little player with a minuscule share of 0.31% in production. In India, cocoa is cultivated mainly in Tamil Nadu, Andhra Pradesh, Kerala, and Karnataka. India produced 27,072 tonnes cocoa from 97,563 ha with a productivity of 669 kg/ha in the year 2021 (DCCD, 2021). Tamil Nadu has the highest area under cocoa (33%), followed by Andhra Pradesh (32%); however, in production, Andhra Pradesh has a significant share (41%), followed by Kerala (38%). The contribution of cocoa to the national income is ₹2000 million. The cocoa industry in the country has expanded considerably since more than 15 industrial entrepreneurs and firms are in the field demanding nearly 40,000 tonnes of cocoa beans, of which the current domestic availability is only about 42%.



State-wise production of arecanut in India
(*Source:* DASD, 2021)

Foreign trade

Coconut: India, of late, has been making a concerted effort to penetrate its products in the high-value export segments. The data of Directorate General of Commercial Intelligence and Statistics (DGCIS), reveals that the value of exports of coconut products (excluding coir and coir products) significantly increased about 30.2% from ₹1,762 crore in 2019-20 to ₹2,295 crore in 2020-21, while imports decreased by about 5.3% from ₹1,196 crore to ₹1,132

Coconut-Chandrakalpa

Areca-Dwarf-hybrid-VTLAH-2

crore during the same period. Total exports of coconut and coconut products have increased at CAGR of 2.7% over the last five years but with large inter-year variations. Activated carbon accounted for 66% of total exports of coconut products, followed by refined coconut oil (11%), coconut fresh (8%), coconut dried (5%), copra (1.4%), shell charcoal (1.4%) and desiccated coconut (1.2%). Exports of coir and coir products increased significantly from ₹2,758 crore in 2019-20 to ₹3,779 crore in 2020-21, which is an increase of 37%. The major coir products exported are coir pith (49%), tufted mats (21%), and coir fibre (17%). Exports of coir and coir products have increased at CAGR of 13.4% over the last five years.

India's imports of coconut and coconut products have been on an upward trajectory in the recent years; increasing from ₹495.5 crore in 2016-17 to ₹1,196.1 crore in 2019-20. However, in 2020-21, these imports declined by 5.3% to ₹1,132.5 crore. With respect to the composition of imports, copra oil cake accounted for 45.7%, followed by activated carbon (34.3%) and copra (8.5%) in 2020-21. The Gulf countries constitute the major export destination of India's coconut products wherein more than 85% of fresh coconuts and about 80% of the coconut oil are exported to these regions.

Arecanut: During 2020-21, India has exported 2640 tonnes of arecanut worth ₹700 million and the major export destinations are Maldives, Sri Lanka and UAE, which together account for 75% export value share. Arecanut is not an export-oriented crop, as the internal demand has always remained high. Stagnating market prices and increasing cost of production, especially the skilled labour charges, in the recent times have generated livelihood concerns of arecanut farmers in India. Surging imports, which is around 12% of the domestic production, certainly has a significant role in price stickiness.

Cocoa: India imports large quantity of cocoa beans and powder to meet the demands of domestic market. Considering the food consumption patterns and growth of confectionary industry in India at around 20%, the demand for cocoa is likely to increase in coming years. The import of cocoa and cocoa products to India has increased at a CAGR of 17% during 2012-21. It shows a surging domestic demand of cocoa and cocoa products and surplus processing capacity in the country. It is noteworthy that the import of cocoa in the year 2021 was 89,060 tonnes, while the export was a meagre 28,929 tonnes accounting for a negative trade balance of 60,131 tonnes. With the projected supply (121 thousand tonnes), there would be a demand-supply gap of 90 thousand tonnes of cocoa beans in 2050. To bridge this gap, production should increase at an annual growth rate of 7.68%.

Trade barriers: One of the reasons for non-realization of large-value export of coconut, arecanut and cocoa is the huge domestic demand. In the past, the country relied on imported machineries for establishing processing facilities but has gradually moved to indigenous manufacturing and even exports. The challenge then shifted to globally competitive production, which is highest in India compared to other major countries. The regional trade agreements such as the ASEAN-India Free Trade Agreement (AIFTA) have compelled the fixation of import tariffs at an extremely low level (especially for palm oil, the major competitor for coconut oil) and have made the commodity price in India more vulnerable, which in turn affected the production also. It is also noteworthy that

Cocoa-Nethra Centura

Shatamangala plantlet

the primary processing of coconut to copra is not done by many farmers, and they sell fresh coconut. Therefore, a large share of farmers do not benefit from the market intervention by the government in the form of MSP. Consequent to this, the desired influence of MSP on market price regulation is also not materialized in the case of coconut.

Despite no promotion of arecanut cultivation, the area under the crop has increased tremendously. There are many instances of the import of arecanut from other countries through different means, which is detrimental to the interests of our farmers. Arecanut sector in India is also facing a crisis owing to conflicts of interest at the policy level. On one hand, the possible huge social cost of growing arecanut (in terms of public health due to chewing of arecanut especially with tobacco) with all the existing institutional support for the crop, and on the other hand, the possible marginalization of millions of farming communities in the event of threats of a partial or complete ban on the cultivation and allied activities of the crop are major issues to contemplate.

Cocoa is an important commodity traded on international stock exchanges. India imports a large quantity of cocoa beans and cocoa powder to bridge the demand-supply gap in the domestic market. International cocoa prices are soaring high and the likely impact of the current price rally may be reflected in the Indian market soon, as the importers usually book orders in advance. It is observed that the primary processing of cocoa often does not meet industry standards. Capacity building on fermentation practices and the drying of cocoa beans should be a priority in the wake of area expansion programmes.

Impact of varieties on production

Development of improved varieties has continued to be the most important focal theme from the very beginning of coconut and arecanut research in the country. From different germplasm expeditions conducted within and outside the country during the past several decades, large number of distinct accessions could be collected for these crops and were conserved in the field gene banks.

The world's largest coconut germplasm assemblage is with ICAR-CPCRI having 455 accessions, of which 132 are exotic. Out of 18 field coconut gene banks in the country, four are under ICAR-CPCRI and 14 under different AICRP (Palms) centers. By utilizing these germplasm, 21 varieties and 11 hybrids were released for cultivation in different coconut growing regions.

Among the released coconut varieties, 16 were for copra yield and five for tender nut purpose. The copra yield varies between 2.15 to 5.01 t/ha (i.e. one-and-a half to three times more than the local cultivars). Highest copra yield is recorded in the variety Kalpa Shatabdi (5.01 t/ha) followed by Kalpa Pratibha (4.07 t/ha). Two varieties are suitable for production of ball copra viz. Kalpatharu and Kalpa Haritha with yield 3.59 and 3.72 t/h, respectively. Screening for moisture stress tolerance helped identify seven varieties, viz. Chandra Kalpa, Kalpa Pratibha, Kalpa Dhenu, Kalpa Mitra, Kalpatharu, Kerakeralam, and Kalpa Ratna for cultivation in drought prone areas.

Exploitation of hybrid vigour in coconut was first reported from CPCRI in 1932. The copra yield of released hybrid varieties varies between 2.56 to 6.28 t/ha. But the demand for hybrid seedlings could not be met fully owing to many constraints such as non-availability of mother palms, low reproductive rate, and requirement of skilled labourers. Towards reducing the labour deployment for hybridization, a pollination device to avoid multiple climbing during the period of fertilization for facilitating pollination from ground itself was developed recently.

Over the years, the supply of quality planting material in the country has improved. It bears a positive influence on coconut production in the country as evident from the fact that despite a relatively stagnant area under the crop, the production showed 2% compound growth rate in the past decades mainly due to increase in yield. At present, nearly half of the annual demand of 13 to 14 million planting material is met from released varieties produced either from ICAR-CPCRI or other governmental agencies including AICRP (Palms) centers. Utilization of improved varieties for planting in a single year will thus result in an additional life-time return of 14,500 million rupees to the growers.

Field planting of hardened coconut plantlet

In the case of arecanut too, CPCRI maintains the world's largest germplasm collection with 169 accessions of four species, viz. *Areca catechu, Areca triandra, Areca normanbyii* and *Areca concinna.* Eleven varieties and two hybrids were released for cultivation in *Areca catechu.* Their yields (dry kernel) vary from 3.0 to 4.6 kg/palm. The two hybrids released in arecanut are VTLAH1 and VTLAH2 having yield of 2.54 and 2.64 kg/palm. The relatively low yield of dwarf arecanut hybrids are compensated with high plant density and easy field operations. The Institute is supplying 5.1 lakh arecanut seeds and 1.5 lakh seedlings every year.

Cocoa germplasm was enriched in the National Active Germplasm Site (NAGS) for cocoa at Vittal over a period of time and at present holds 530 collections of which 444 are exotic. Following the method of selection, three varieties and following hybridization (between self incompatible lines) and progeny evaluation, five cocoa hybrids were released. The dry bean yield varies between 1.3 to 1.5 kg/tree/year. Planting material for released varieties are made through soft wood grafting and hybrid seeds from the bi- or poly-clonal orchards. Annually 40,000 to 70,000 cocoa planting materials are produced from the Institute. Private agencies are also producing and supplying cocoa planting material to the farmers.

Biotechnology protocols

Developing a clonal propagation technique for coconut was the primary objective of the biotechnology lab at CPCRI. Though it is still not achieved, many tissue/organ culture protocols were standardized from this lab that include coconut zygotic embryo culture protocol for germplasm exchange, immature inflorescence tissues culture in arecanut and cryopreservation of coconut embryo and pollen. FAO/Bioversity International had recommended the CPCRI embryo culture protocol for safe movement of coconut germplasm between countries. Recently, plantlet development directly from immature inflorescence tissues of coconut has been reported.

Molecular markers: The genome of the Chowghat Green Dwarf cultivar, possessing enhanced resistance to coconut root (wilt) disease, has been deciphered, and the repertoire of resistance gene analogues (RGAs) has been unearthed. Transcriptome analysis of the response of coconut to root (wilt) disease and somatic embryogenesis has been undertaken using RNA-sequencing (RNA-seq). Sequence characterised amplified regions (SCAR) markers have been developed to confirm the hybridity at the seedling level in both coconut and arecanut. A panel of SSR markers has been identified for confirming the hybridity of D × T hybrids (CGD × WCT) which will ensure the supply of genuine hybrid material to farmers.

Cropping systems

Scientific studies on coconut based cropping systems were started in ICAR-CPCRI during 1972 which led to the identification of compatible annual/biennial/perennial crops suitable to specific growth stage of coconut. Some of the most commonly cultivated crops in coconut garden are cassava, elephant foot yam, colocasia, ginger, turmeric, banana, pineapple and vegetables. Cocoa, black pepper, clove, and nutmeg are some of the perennial crops successfully introduced as a mixed stand under coconut. Recent studies have suggested the feasibility of growing ground nut, soybean, cowpea, millets, cinnamon, fruit tree crops, dragon fruit, and floriculture in coconut gardens. Possibility of growing fodder grass in the interspaces of coconut paves way for incorporation of livestock component in the system. The coconut based integrated farming system (IFS) models developed at ICAR-CPCRI involving dairy, poultry, goats, and fisheries along with black pepper, banana, fodder grass provide more system productivity and income; this IFS model has provided a net income of ₹7,67,568/ha during 2020-21. The economic impact of research and extension on coconut based cropping systems is worked out to be ₹5910 crores a year.

Similar to coconut, arecanut also accommodates many intercrops such as black pepper, cocoa, banana, vegetables and selected medicinal plants.

Organic farming

Coconut is highly amenable for organic farming mainly because of large quantity of recyclable biomass (16-20 t/ha) and availability of biocontrol measures to manage pests and diseases in the coconut ecosystem. Recycling of organic matter in the garden especially in the form of vermicompost; basin management with leguminous crops at the beginning of South-West monsoon and incorporating the biomass to the soil before flowering; adoption of soil moisture conservation measures such as mulching in the basin with coconut leaves, raising half-moon bund around the basin reinforced with pineapple, and trenches filled with husks in the interspace; and application of *Trichoderma* enriched neem cake are the key components in organic cultivation of coconut. However, in the long run, potassium in soils was observed to be deficient while following organic cultivation. Potassium nutrition can be managed organically by husk burial in the interspaces and judicious application of sulphate of potash. The annual yield of organically maintained coconut in the Institute for the past 18 years suggests that productivity can be sustainable at 17,500 nuts/ha, which is nearly double the national average. The vermicomposting technique standardized at the Institute is found to be most effective for the composting of lignin-rich coconut leaves.

Other organic inputs developed at the Institutes include Kera Probio® (*Bacillus megaterium*), a PGPR-based bioinoculant which produces plant growth hormones and enzymes, and improves root growth in seedlings, thereby promoting growth and health of plants. The antagonistic fungi *Trichoderma* is found to be effective in controlling the bud rot, stem bleeding and ganoderma diseases of coconut. The 'cake' formulation of *Trichoderma* developed by the Institute is most suitable for disease infected areas of the palm. Another beneficial fungus is *Metarhizium* which is effective in destroying the grubs of Rhinocerous beetle, a major pest of coconut.

Many other technologies have been developed for organic production of coconut and arecanut. ICAR-CPCRI had published a complete package of practices for organic cultivation of coconut. Feasibility of zero tillage and *in situ* vermicomposting were also reported. However, experimentation on natural farming has been initiated and results will be available within a couple of years.

Strategies to cope with climate change

The phenomenon of climate change is being experienced in different coconut growing regions in terms of extreme weather events such as prolonged dry spell along with increased temperature, changes in quantity and intensity of rainfall, rise in sea levels, and frequent cyclones. The long term effect is described in terms of increasing atmospheric temperature and CO_2. Adopting scientific practices such as cultivation of most adaptive varieties, soil and water conservation, rationalizing water use through drip irrigation, and integrated nutrient management will mitigate the ill effects of climate change to a greater extent. However, there is no way to avoid yield/crop loss due to extreme weather except to bring more farmers under crop insurance schemes.

Rise in temperature and CO_2 may leave some traditional coconut growing areas not suitable in future as observed in simulation studies conducted at ICAR-CPCRI. One such scenario is that south interior parts of India, eastern coast and north eastern region may become less suitable for coconut. More than coconut, arecanut cultivation may be affected in the event of rise in temperature. However, *in situ* screening for tolerant cultivars may lead to the development of more adaptive varieties to suit such situations.

Another perceived change is in the incidence and spread of pests and diseases. Adaptive mechanism of crop will add further complexities in this regard which thus calls for studies on unpredictability of pest incidence, preparation of contingency plans, developing robust cropping systems, and dissemination and skill development of crop protection techniques. The long term strategies to deal with climate change should also be taken into account for the country's commitments in COP26, specifically on reduction of carbon emission by one billion tonnes by 2030 and achieving net-zero emissions by 2070. Tree crop plantations like coconut, arecanut and cocoa have a significantly high carbon sequestration potential and are able to sequester carbon for longer periods of 30 years or more. Coconut can sequester quite a high amount (15 tonnes) of CO_2/ha/year. In arecanut, it is 7 t/ha and 1 t/ha in cocoa. By adopting high density multiple cropping systems further, more CO_2 can be sequestrated.

Value-addition and product diversification

Primary processing and community level value-addition are the two steps for upgrading commodity value chains for better price realization for the farmers. Well established value chains are in operation for coconut and arecanut in the traditionally cultivated regions. The concerted efforts of ICAR-CPCRI and other research organizations, and Coconut Development Board paved way for development/refinement of protocols for many coconut products leading to establishment of novel value chains.

Processing protocols for certain novel coconut products developed at the Institute are: (i) coconut chips, which is a ready-to-eat snack prepared by osmotic dehydration of thinly sliced coconut kernel; (ii) virgin coconut oil (VCO): two protocols were developed for obtaining VCO from coconut milk (hot- and fermentation processing); (iii) low fat desiccated coconut and Kalpa Krunch®, an extrudated product using coconut milk residue; (iv) Kalparasa®, the unfermented coconut inflorescence sap collected using the coco-sap chiller; (v) coconut sugar from Kalparasa®; (vi) foam mat dried coconut milk powder; (vii) vegan frozen delicacy which is made from coconut milk, coconut sugar, tender coconut water and pulp; (viii) trimmed tender coconut; (ix) snow ball tender coconut; (x) carbonated tender coconut water; and (xi) value added products from coconut water such as natural vinegar, squash, carbonated drink, and jelly. The gadgets and machinery required for these products were also designed and developed at ICAR-CPCRI. Nearly 70% of the technology licensing agreements from

ICAR-CPCRI are in this area revealing the reception of Institute led technologies by the entrepreneurs.

Futuristic technology prospects

Agriculture all over the world is undergoing unparalleled technology-based reformation, chiefly due to the developments in computation biology, sensor applications, image processing, robotics, and unmanned aerial vehicles supported by artificial intelligence and Internet of Things. Thus, the present scenario warrants convergence of these technology enabled solutions in attending to the problems of plantation sector.

Generation of appropriate planting material will remain one of the major short- and long-term strategies for cultivation of coconut, arecanut and cocoa. Unlocking the genomics of these crops and manipulating at gene level for developing trait-specific and climate-resilient varieties could be a top priority. Seamless rapid changes are expected in the field of precision agriculture.

There is a global demand for plant-based functional molecules which are in abundance in these crops. Agribusiness on commercial exploitation of such molecules is a priority area of research.

Against mounting dependence of technology driven agriculture, a tendency to go back to natural farming is also an emerging trend. This is especially seen with adoption of eco-friendly technologies for plant protection and a strive to achieve a balance on technology utilization and environmental impact.

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