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किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

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Vision 2050

भाकृअनुप
ICAR

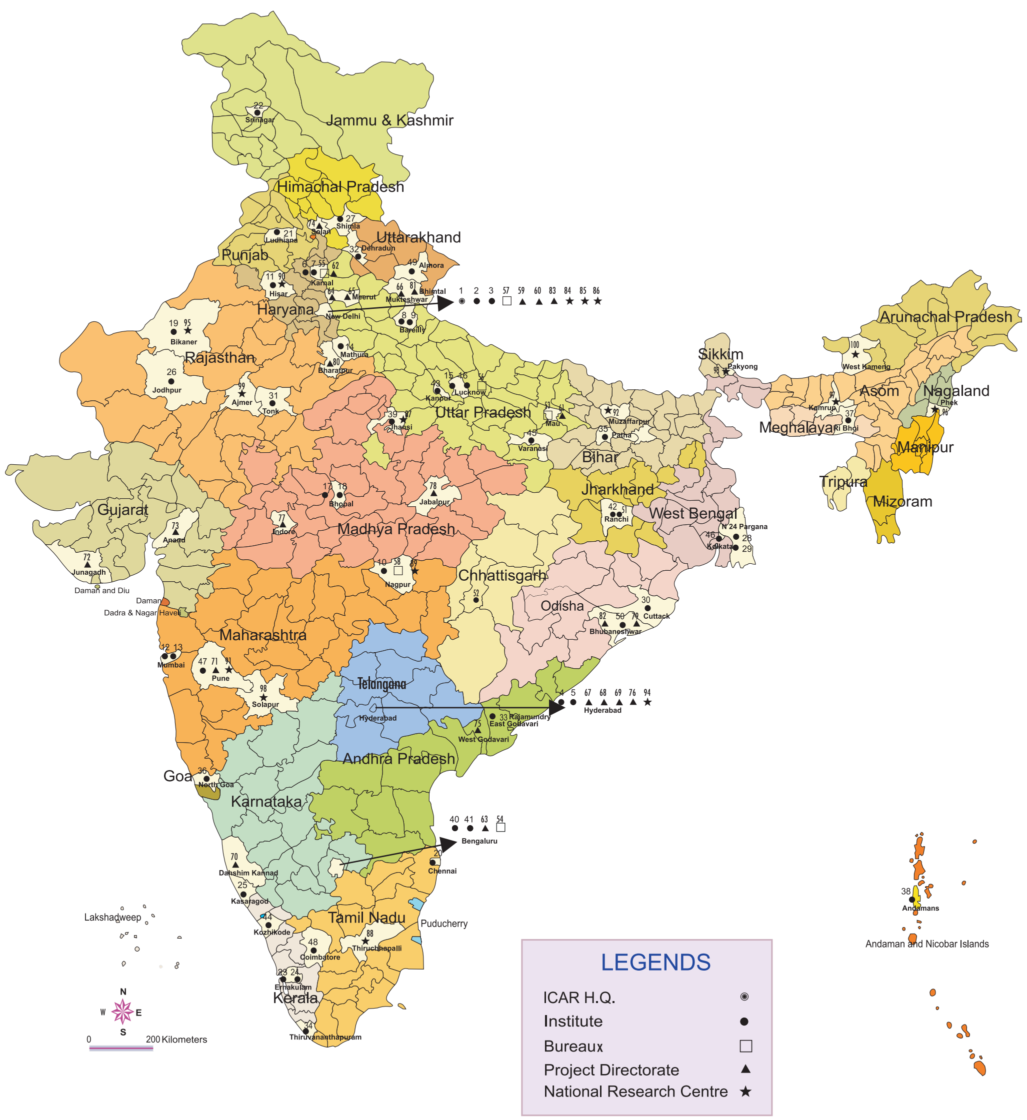
Indian Institute of Oil Palm Research

Indian Council of Agricultural Research

INDIAN INSTITUTE OF OIL PALM RESEARCH

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Institutes, Bureaux, Directorates and National Research Centres



● 64 Research Institutes ● 6 Bureaux ● 15 National Research Centres ● 15 Project Directorates

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Agricultural Universities

LEGENDS

- State Agricultural Universities ○
- Central Universities with Agricultural faculties ■
- Central Agricultural Universities ☆
- Deemed Universities ●

Vision 2050

INDIAN INSTITUTE OF OIL PALM RESEARCH

Indian Institute of Oil Palm Research
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संदेश

भारतीय सभ्यता कृषि विकास की एक आधार रही है और आज भी हमारे देश में एक सुदृढ़ कृषि व्यवस्था मौजूद है जिसका राष्ट्रीय सकल घरेलू उत्पाद और रोजगार में प्रमुख योगदान है। ग्रामीण युवाओं का बड़े पैमाने पर, विशेष रूप से शहरी क्षेत्रों में प्रवास होने के बावजूद, देश की लगभग दो-तिहाई आबादी के लिए आजीविका के साधन के रूप में, प्रत्यक्ष या अप्रत्यक्ष, कृषि की भूमिका में कोई बदलाव होने की उम्मीद नहीं की जाती है। अतः खाद्य, पोषण, पर्यावरण, आजीविका सुरक्षा के लिए तथा समावेशी विकास हासिल करने के लिए कृषि क्षेत्र में स्थायी विकास बहुत जरूरी है।

पिछले 50 वर्षों के दौरान हमारे कृषि अनुसंधान द्वारा सृजित की गई प्रौद्योगिकियों से भारतीय कृषि में बदलाव आया है। तथापि, भौतिक रूप से (मृदा, जल, जलवायु), बायोलोजिकल रूप से (जैव विविधता, हॉस्ट-परजीवी संबंध), अनुसंधान एवं शिक्षा में बदलाव के चलते तथा सूचना, ज्ञान और नीति एवं निवेश (जो कृषि उत्पादन को प्रभावित करने वाले कारक हैं) आज भी एक चुनौती बने हुए हैं। उत्पादन के परिवेश में बदलाव हमेशा ही होते आए हैं, परन्तु जिस गति से यह हो रहे हैं, वह एक चिंता का विषय है जो उपयुक्त प्रौद्योगिकी विकल्पों के आधार पर कृषि प्रणाली को और अधिक मजबूत करने की मांग करते हैं।

पिछली प्रवृत्तियों से सबक लेते हुए हम निश्चित रूप से भावी बेहतर कृषि परिदृश्य की कल्पना कर सकते हैं, जिसके लिए हमें विभिन्न तकनीकों और आकलनों के मॉडलों का उपयोग करना होगा तथा भविष्य के लिए एक ब्लूप्रिंट तैयार करना होगा। इसमें कोई संदेह नहीं है कि विज्ञान, प्रौद्योगिकी, सूचना, ज्ञान-जानकारी, सक्षम मानव संसाधन और निवेशों का बढ़ता प्रयोग भावी वृद्धि और विकास के प्रमुख निर्धारक होंगे।

इस संदर्भ में, भारतीय कृषि अनुसंधान परिषद के संस्थानों के लिए विजन-2050 की रूपरेखा तैयार की गई है। यह आशा की जाती है कि वर्तमान और उभरते परिदृश्य का बेहतर रूप से किया गया मूल्यांकन, मौजूदा नए अवसर और कृषि क्षेत्र की स्थायी वृद्धि और विकास के लिए आगामी दशकों हेतु प्रासंगिक अनुसंधान संबंधी मुद्दे तथा कार्यनीतिक फ्रेमवर्क काफी उपयोगी साबित होंगे।

(राधा मोहन सिंह)

केन्द्रीय कृषि मंत्री, भारत सरकार

Foreword

Indian Council of Agricultural Research, since inception in the year 1929, is spearheading national programmes on agricultural research, higher education and frontline extension through a network of Research Institutes, Agricultural Universities, All India Coordinated Research Projects and Krishi Vigyan Kendras to develop and demonstrate new technologies, as also to develop competent human resource for strengthening agriculture in all its dimensions, in the country. The science and technology-led development in agriculture has resulted in manifold enhancement in productivity and production of different crops and commodities to match the pace of growth in food demand.

Agricultural production environment, being a dynamic entity, has kept evolving continuously. The present phase of changes being encountered by the agricultural sector, such as reducing availability of quality water, nutrient deficiency in soils, climate change, farm energy availability, loss of biodiversity, emergence of new pests and diseases, fragmentation of farms, rural-urban migration, coupled with new IPRs and trade regulations, are some of the new challenges.

These changes impacting agriculture call for a paradigm shift in our research approach. We have to harness the potential of modern science, encourage innovations in technology generation, and provide for an enabling policy and investment support. Some of the critical areas as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy, and technology dissemination need to be given priority. Multi-disciplinary and multi-institutional research will be of paramount importance, given the fact that technology generation is increasingly getting knowledge and capital intensive. Our institutions of agricultural research and education must attain highest levels of excellence in development of technologies and competent human resource to effectively deal with the changing scenario.

Vision-2050 document of ICAR-Indian Institute of Oil Palm Research (IIOPR), Pedavegi has been prepared, based on a comprehensive assessment of past and present trends in factors that impact agriculture, to visualise scenario 35 years hence, towards science-led sustainable development of agriculture.

We are hopeful that in the years ahead, Vision-2050 would prove to be valuable in guiding our efforts in agricultural R&D and also for the young scientists who would shoulder the responsibility to generate farm technologies in future for food, nutrition, livelihood and environmental security of the billion plus population of the country, for all times to come.

(S. AYYAPPAN)
Secretary, Department of Agricultural Research & Education (DARE)
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Preface

Vegetable oils are highly responsive to income growth and are usually one of the cheapest protein sources available. The remarkable growth in vegetable oil consumption in India over the past three decades was driven by income growth. Rapid growth of food demand in the developing countries, in conjunction with the high calorie content of oil products, have been a major component of the increases achieved in food consumption (kcal/person/day) in these countries. This trend is set to continue, as vegetable oils still have significant scope for increased consumption in most of the developing countries. The second major driving force on the demand side has been non- food industrial use of vegetable oils, with China and European Union being major contributors to this growth. If petroleum prices remain high, the biofuel sector would likely to grow in importance as a market outlet for oils and fats, just as the growing market for bioethanol provides outlets for sugarcane (mainly in Brazil), maize (mainly in the USA) and to a much smaller extent for other crops (sugar beet, wheat, sorghum, eventually cassava, etc).

India is one of the major producers and consumers of vegetable oils. Despite production of over 9.64 million tonnes of vegetable oils during 2013-14 in the country, the domestic availability of edible oil continues to remain inadequate to meet the demand. The gap between demand and availability of edible oils is met by imports and palm oil constitutes bulk of these imports. During 2013-14, India has imported 11.72 million tonnes of edible oils valued at US $ 7.58 billion. In terms of volume, it was 54.86 per cent of domestic availability.

Oil palm satisfies 30 per cent of the world edible oil and fat requirements with little fewer than seven per cent of the area planted to oil crops. At the global level, 52 million tonnes of palm oil was produced in 2012 from 13.5 million hectares and demand is expected to reach 77 million tonnes in 2050 to feed world's growing population and the increased affluence of emerging economies like India and China, which consume 16 and 12 per cent of global palm oil, respectively. To meet the increasing per capita consumption of vegetable oils along with the population growth, there was an urgent need to increase the production and productivity of vegetable oils in India. Oil palm is known to be the highest edible oil yielding perennial crop. Oil palm is the crop that has a greater advantage in terms of productivity that is much higher than that of other oil seed crops. Oil palm produces 5.00 tonnes of crude palm oil per ha and 0.50 tonnes of palm kernel oil from fourth to thirtieth year of its productive life span. The fresh fruit bunch yields obtained by progressive farmers of Andhra Pradesh and Karnataka, under optimum cultural and irrigated conditions as per the schedules recommended by Directorate of Oil Palm Research, are between 20 and 25 tonnes of FFB per ha per annum i.e. 4-5 tonnes of oil per ha per annum from fourth year onwards. The highest yield of 30-35 tonnes FFB per ha during the seventh year was also recorded in many plantations. One of the farmers' in Karnataka could achieve a record yield of 53.2 tonnes FFB per ha per annum.

Oil palm is an introduced crop in India and through intensive research and development efforts; we could bring an area of 2.62 lakh ha under oil palm cultivation. Oil palm sector in India is at the "take off" stage that needs adequate support from research system in the form of new hybrids and crop management technologies along with the required policy support. Fortunately, a well established research system with the required infrastructural facilities is available in the country for oil palm research. Research in oil palm is being strengthened remarkably to provide the technology back up for the development plan. The new technologies are expected to play a critical role in improving oil palm production and increasing the efficiency of oil palm sector in the country.

Long term planning of pathways of research for oil palm is highly critical as the crop takes a longer gestation period to show the results and still longer duration for the results to be converted as technologies for further use in commercialization. For example, it takes about three decades of research to enable the farmers to reap the benefit from any of the new initiatives in crop improvement. Any wrong step taken at any point of time in the schedule or any missing link in this chain would result in wastage of vast resources including precious time. Hence it is highly essential that long term plans should be prepared and properly monitored for mid course corrections for ensuring better results. With land, water and labour resources becoming increasingly scarce, our main target shall be to achieve better Resource Use Efficiency. It is estimated that a four-fold increase in land productivity, threefold increase in water productivity, doubling of energy-use-efficiency and a six fold increase in labour productivity are to be aimed at, so as to remain competitive in the emerging global scenario. To achieve this objective, the present Document on "**Vision 2050**" has been prepared. The programmes have been formulated to initiate need based and action based research for meeting the future targets and challenges. New programmes are identified mainly in the areas of development of improved oil palm hybrids with high yield potential, efficient nutrient and water management technologies, integrated farming system models for enhancing the returns from oil palm gardens, use of bio-control agents for pest and disease management in oil palm and harvest and processing technologies for effective utilization of oil palm products. Emphasis is also given on achieving self sufficiency in quality planting material production of improved hybrids from different centres.

It could be optimistically expected that the well established oil palm research system along with intensive efforts through Oil Palm Development Programme as well as research and development efforts in annual oil seed crops and other sources, India would be able to achieve self sufficiency in vegetable oil production at the earliest.

We take great pride in presenting the **'Vision - 2050'** of oil palm sector in India that harmonizes multi-disciplinary teams' problem solving approaches, with focus on small farmers' issues, sustainability and profitability. I would like to place on record my grateful appreciation to all my colleagues presently working at IIOPR and those who have retired from this Institute after rendering meritorious service. Everyone at the Institute has contributed inputs for the preparation of this document. I would especially like to thank my fellow editors Dr. K. Suresh, Dr. R.K. Mathur, Dr. B.N. Rao, Dr. M.V. Prasad and other Scientists for facilitating to bring out this document in an abridged form. The initiative, encouragement and suggestions received from Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR, Dr. N.K. Krishna Kumar, Deputy Director General (Hort. Sc.) and Dr. T. Janakiram and Dr. S. K. Malhotra, Assistant Director General (Hort. Sc.) from time to time are gratefully acknowledged.

Director
IIOPR, Pedavegi

Contents

Context

Oil palm (*Elaeis guineensis* Jacq.) is a native of West Africa and is grown extensively in South-East Asian countries (Malaysia, Indonesia and Papua New Guinea), African countries (Nigeria, Cote de'Ivoire, Ghana, Liberia, Sierra Leone, Cameroon, Republic of Congo and Zaire) and South American countries (Costa Rica, Panama, Columbia, British Guyana, Peru, Ecuador, Venezuela and Brazil). Malaysia, Indonesia and Nigeria are the leading producers of oil palm in the world.

Oil palm is known to be the highest edible oil yielding perennial crop that produces two distinct oils, i.e., palm oil and palm kernel oil, which have culinary and industrial uses. Palm oil is derived from the fleshy mesocarp of the fruit, which contains about 45-55 per cent of oil. The palm kernel oil, obtained from the kernel of stony seed, is a potential source of lauric oil. Oil palm is the crop that has a greater advantage in terms of productivity that is much higher than that of other oil yielding crops. Oil palm produces 5.00 tonnes of crude palm oil per ha annually and 0.50 tonnes of palm kernel oil from 4th to 30th year of its productive life span.

Oil palm is the crop of the present and future vegetable oil economy of the world as well as for India. Palm oil has good consumer acceptance as a cooking medium because of its price advantage. It is a good raw material for manufacturing oleochemicals used in preparing cosmetics, pharmaceuticals, nutraceuticals etc. Broadly, it could be mentioned that palm oil is a source of improving health and nutrition, value addition, waste utilization, eco-friendly, source of diversification, import substitution, co-generation and sustainability.

Why 2050?

The world is experiencing unprecedented technologically aided changes leading to broad based growth and development. Over the next four decades, global population is expected to reach nine billion and the Indian population would reach 1.6 billion.

Vegetable oils are highly responsive to income growth and are usually one of the cheapest vegetable protein and fat sources. The remarkable growth in per capita consumption of vegetable oil in India over the past three decades was driven by income growth.

Long term planning of pathways of research on perennial crops is highly critical as the crop takes a longer gestation period to show the results and still longer duration for the results to be converted into technologies for further use in commercialization. Thus, for example, if a scientist initiates a dura improvement activity in oil palm during 2013, the time schedule for the benefits to accrue to the farmers could be as follows:

S. No	Activity	Tentative year of completion
1	Selection of potential dura mother palms	2013
2	Inter se crossing/selfing of selected palms	2014
3	Seed processing and Development of nursery	2015
4	Initiation of Field Trial	2016
5	Selection of promising progenies	2025
6	Multiplication of promising types through selfing or Tissue culture and Planting in seed gardens	2027
7	Production of hybrid seed for commercial planting	2036
8	Seed processing and Development of nursery	2037
9	Planting in farmers' fields	2038
10	Harvesting starts at commercial scale	2042

Any wrong step taken at any point of time in the above schedule or any missing link in this chain would result in wastage of vast resources including precious time. Hence, it is highly essential that, to remain competitive in oil palm sector, long-term plans should be prepared and properly monitored for mid course corrections for ensuring better results.

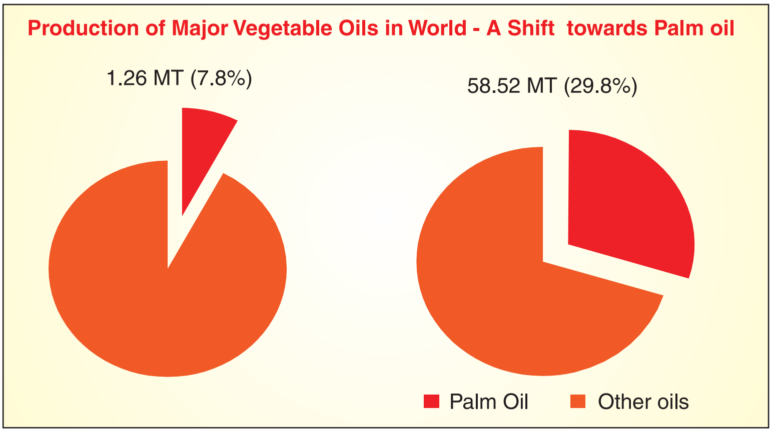
Global Vegetable Oil Scenario

Oil Crops, Vegetable Oils and Products: The oil crops sector has been one of the most dynamic components of world agriculture in recent decades. In two decades up to 2001, it grew at 4.1 per cent per annum, compared to an average of 2.1 per cent per annum for overall agricultural growth. Its growth rate exceeded by a good margin, even to that of livestock products. In the recent years, the major driving force on the demand side has been the growth of food consumption in developing countries, mostly in the form of oil but also direct consumption of soybean, groundnut, etc., as well as in the form of derived value-added products other than oil. Food demand in the developing countries accounted for one half of the increase in world output for the last two decades, with output measured in oil equivalent content. China, India and a few other countries represented the bulk of this increase in consumption. No doubt, the strong growth in demand for protein products for animal feed was also a major supporting factor for the buoyancy in vegetable oil sector. The rapid growth of oil crops sector reflects the synergy of two fast rising components of the demand for food – food demand for oils favouring all oil crops that had the potential for rapid expansion of production e.g. the oil palm, and that for livestock products favouring oil crops with high protein oil meals for feed e.g. soybean. The oil palm and soybean provided 57 per cent of the total increment in world edible oil production during the last two decades.

Growing Contribution to Food Supplies and Food Security: Rapid growth of food demand in the developing countries, in conjunction with the high calorie content of oil products, has been a major component of the increase achieved in food consumption (kcal/person/day) in these countries. This trend is set to continue, as vegetable oils still have significant scope for increased consumption in most of the developing countries with concurrent increase in population.

Non-Food Uses: The second major driving force on the demand side has been non-food industrial use of vegetable oils, with Brazil, China and The European Union being major contributors to this growth. In terms of actual oil produced and used (rather than of oil equivalent of oil crops), the world is apparently utilizing 25 million tonnes for non-food industrial uses out of the total production of 91 million tonnes. Two decades earlier, the comparable figures were 8 and 41 million tonnes, respectively. The existing data do not permit us to draw even a partial balance sheet of the non-food industrial products for which, significant quantities of vegetable oil products are used as inputs. The main industrial products involved (paints, detergents, lubricants, oleo chemicals in general and, increasingly, biodiesel) are commodities for which world demand could be expected to grow much faster than the demand for food. If petroleum prices remain high, the biofuel sector would grow in importance as a market outlet for oils and fats, just as the growing market for bioethanol provides outlets for sugarcane (Brazil), maize (USA) and to a much smaller extent for other crops (sugar beet, wheat, sorghum and eventually cassava etc). The European Union had a target of achieving 5.75 per cent market share of biofuels in the petrol and diesel market in 2010 (European Commission, 2005).

At the global level, 58.52 million tonnes of palm oil was produced in 2013 and demand is expected to reach 77.2 million tonnes in 2050 to feed world's growing population and the increased affluence of emerging economies like India and China, which consume 16 and 12 per cent of global palm oil, respectively. About 60 per cent of palm oil consumption is concentrated in China, India, Europe, Indonesia and Malaysia.



Production of Major Vegetable Oils in World (in million tonnes) – A Shift towards Palm oil

Vegetable oil	1960	2010	2013*
Palm oil	1.26	45.87	58.52
Palm kernel	0.42	5.22	6.50
Soybean	3.30	40.18	43.78
Rapeseed	1.09	23.77	25.69
Sunflower seed	1.78	12.42	15.64
Groundnut	2.58	4.07	4.11
Cotton seed	2.32	4.60	4.86
Coconut	1.94	3.62	3.21
Olive	1.33	3.33	3.44
Total	16.07	143.12	196.43

*Source – Oil World Annual (2014)

According to World Bank estimates, the Trade and Competitiveness will determine the future global trade resulting in net export of cereals to triple; net export of oil seeds and vegetable oil to more than triple and net export of sugar to double. Biofuel has potential to alter trade prospects and there would be heavy pressure on all the countries to reduce subsidies, improve efficiency and reduce carbon emissions. In such a scenario, oil palm production and consumption at global level are bound to grow very fast.

Influence on Biodiversity: In South East Asian countries like Malaysia and Indonesia, oil palm is reported to be the greatest immediate threat to biodiversity as forests are being converted into oil palm plantations. Oil palm is a rapidly expanding profitable crop that is, to a large degree, grown in and exported to countries with weak environmental regulations. In the case of oil palm and tropical deforestation, the two most notable examples of financial incentives have been the Roundtable on sustainable Palm Oil (RSPO) certification programme and payments for Reducing carbon Emissions from Deforestation and forest Degradation (REDD). REDD payments have attracted a great deal of attention from the environmental community as they hold the promise of re-directing large sums of money from developed countries to developing countries for the purpose of protecting forests and other carbon-rich ecosystems. The growing demand for biofuels, coupled with higher overall energy prices, could make oil palm more profitable than carbon trading and undermine the financial incentives of REDD. However, if REDD becomes recognized as a legitimate emissions reduction activity by the United Nations Framework Convention on Climate Change for the second commitment period of the Kyoto Protocol (2013–17), carbon credits generated from REDD schemes would be tradable in Kyoto-compliance markets, which could make REDD economically competitive with oil palm. In addition, oil palm is a prime candidate for storing carbon in the tropical countries, where it is grown and is also eligible for the Clean Development Mechanism (CDM). The annual biomass productivity of oil palm amounts to 50 tonnes during its 30 year life span, which could serve as an effective carbon sink.

Oil palm Requirement for Biodiesel Production: It is estimated that, though the demand for vegetable oil may not increase as fast as in the recent past, the demand for biodiesel would increase manifold. Global biodiesel production was reported as 29.07 million tonnes during 2013-14. The International Energy Agency (IEA) expects biofuels to generate $11-13 trillions in production between 2010 and 2050 and global share of biofuel in the total transport fuel to grow from 2 per cent (2012) to 27 per cent (2050). With world population growing at more than 30 per cent to 9 billion people (in 2050), and food demand increasing by 70 per cent (estimates by Food and Agriculture Organization), competition of biofuel production for land with food, fodder as well as fibre production needs to be carefully addressed to avoid negative impact of biofuel expansion on food security.

Palm oil, like other vegetable oils, could be used to produce biodiesel. First generation biodiesel production from palm oil is in demand globally. A study conducted in 2009 at Malaysian Science University concluded that palm oil, compared to that of other vegetable oils, is a healthy source of edible oil and at the same time, available in quantities that can satisfy global demand for biodiesel. Oil palm planting and palm oil consumption circumvents the Food vs. Fuel debate because it has the capacity to fulfil both demands simultaneously. It is to be noted that Indonesia produced 3.90 million tonnes of biodiesel from palm oil (2013-14) with the adoption of B10 Policy in Indonesia. By 2050, a British scientist estimates that the global demand for edible oils would probably be around 240 million tonnes (nearly twice the 2008 consumption). Most of the additional oil might be palm oil, which has the lowest production cost among the major oils, but soybean oil production also would probably increase. An additional 120 lakh hectares of oil palm may be required, if average yields continue to rise as in the past to supply the oil demand required for edible purposes in 2050.

India is one of the major producers and consumers of vegetable oils, accounting for 12 to 15 per cent of the area under oilseeds and 6 to 7 per cent of the production of vegetable oils in the world. Despite production of over 9.64 million tonnes of vegetable oils during 2013-14 in the country, the domestic availability of edible oil continues to remain inadequate to meet the demand. The domestic consumption *vis-a-vis* production of edible oils is depicted in Fig. 1.

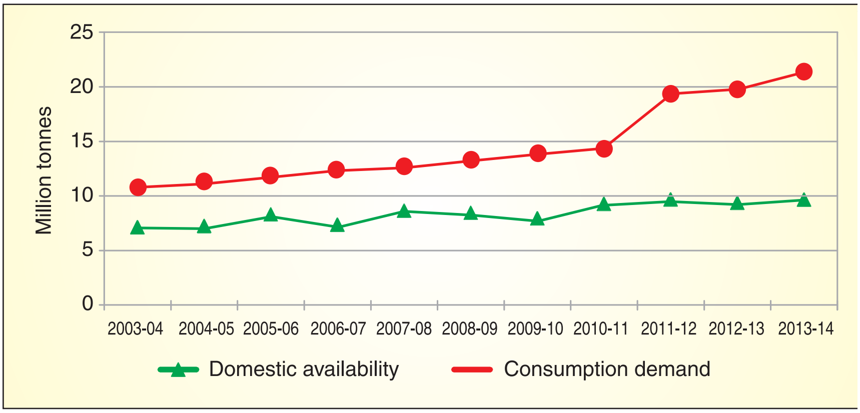


Fig. 1 Consumption and availability of edible oils in India from 2003-04 to 2013-14

The gap between demand and availability of edible oils is met by imports and palm oil constitutes bulk of these imports. During 2013-14, India has imported 11.72 million tonnes of edible oils valued at US $11.32 billion. In terms of volume, it was 56 per cent of domestic availability of edible oils. The quantity of edible oils imported along with its value from 2005-06 to 2013-14 are shown in Fig. 2. The quantum of import is likely to go up due to increased per capita consumption and population pressure, resulting in higher future demand.

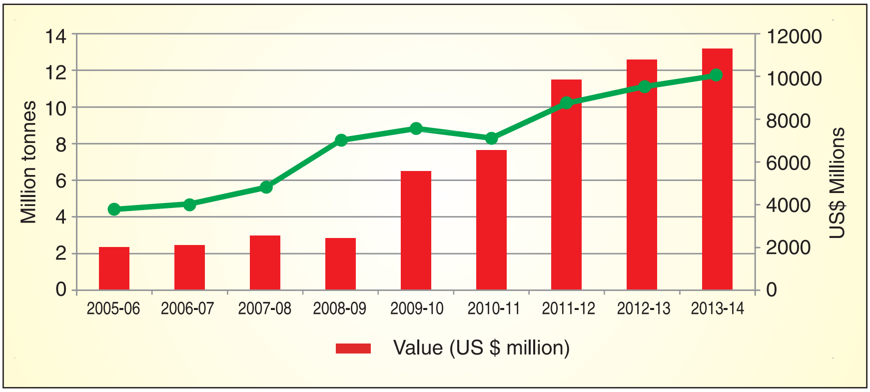


Fig. 2 Import of edible oils by India from 2005-06 to 2013-14

The Govt. of India and National Agricultural Research System are giving adequate emphasis for improving productivity of oilseed crops through the release of high yielding varieties and adoption of technology. During the last two decades, efforts have also been made to introduce and exploit a number of new oil bearing crops. However, among the recently introduced crops, only oil palm has shown promise for commercial cultivation under Indian conditions.

Oil Palm Scenario in India

Oil palm was first introduced to India at National Royal Botanical Gardens, Kolkata during the year 1886. The Maharashtra Association for Cultivation of Sciences (MACS), Pune later introduced African dura palms along canal bunds, home gardens and, to some extent, in forest lands near Pune during 1947 to 1959. Large scale planting of oil palm was launched from 1971 to 1984 in Kerala by Plantation Corporation of Kerala Ltd. (subsequently taken over by Oil Palm India Ltd.) and Andaman Forest and Plantation Development Corporation Ltd., in Little Andaman Islands of Andaman and Nicobar Islands during 1976 to 1985. Oil palm has been established as a successful crop in a number of states in the country and productivity levels of 4-6 tonnes oil per ha could be achieved. The Technology Mission on Oilseeds and Pulses (TMOP) implemented by Government of India looks after development of oil palm in the country through Oil Palm Development Programme (OPDP) along with other nine annual oilseed crops.

Though Oil Palm Development Programme in the country is progressing well, area coverage is not taking place as per targets envisaged. Various Expert Committees constituted by Ministry of Agriculture, Government of India have identified a total of 19.33 lakh hectares in 18 states of the country as suitable for oil palm cultivation. So far, an area of 2.62 lakh ha only has been covered under oil palm. Production of palm oil in India continues to be at a meagre level with respect to its actual requirement. The FFB yields obtained by progressive farmers of Andhra Pradesh and Karnataka, under optimum management conditions, are between 20 and 25 tonnes per ha per annum i.e., 4-5 tonnes of oil per ha per annum from fourth year onwards. High yields of 30-35 tonnes FFB per ha from seventh year onwards was also recorded in many plantations. One of the farmers' in Karnataka could achieve a record annual mean yield of 53.20 tonnes of FFB/ha.

❑

Challenges

Utilization of Natural Resources for Better Agricultural Gross Domestic Product

Land, water and energy are the major resources which are to be managed in an integrated way for sustainable development, since India has only 2 per cent of the global land, 4 per cent of water but 16 per cent of the population of the world. At present, land use is very poorly regulated and both Government Departments as well as private agencies are acquiring land wherever possible and using it for their limited purpose without considering any integrated planning and use of land. Management of human and financial resources is also critical for sustainable and inclusive growth. The natural resources are being developed and used at a comparatively faster rate during the last decade due to increased economic activity. It is only through careful and integrated management of these resources that one can provide livelihood for all and prosperity to the nation.

At present, the Gross Domestic Product (GDP) growth of 8 per cent during the previous 5 to 6 years has been mainly contributed by the services and industry sectors. Agriculture currently contributes 13.7 per cent to the GDP (2012-13) while supporting 51 per cent of the population, which cannot be sustained, if those dependent on agriculture are to be moved out of poverty. At present, the population living on agriculture is being sustained through subsidies in the form of cheaper water, energy and fertilizer besides fixing a minimum support price. Almost half the country's population is below the poverty line. The contribution of agriculture to GDP has fallen from 56 per cent in 1950-51 to 13.70 per cent in 2012-13 and there have been corresponding increases in the share of industry and services sector.

Indian agriculture is currently among the lowest category in the world in terms of productivity. During the eleven-year period (1994-2005), the rate of increase in per worker GDP in agriculture was only 2.24 per cent per annum as compared to 4.35 per cent per annum. In view of the emphasis on high-value floriculture and horticulture for export, between 1990 and 2005, the respective cropped areas under cereals and pulses fell from 103.3 m ha and 24.7 m ha to 97.7 m ha and 22.5 m ha. Agricultural holdings also declined from 1991 to 2011. The falling productivity in agriculture is being caused by several interlinked factors - low productivity of land due to imbalanced use of chemical fertilizers and pesticides over long periods, soil and water pollution, inefficient use of land and water resources, poor extension and advisory services, declining public investment in agricultural research, development and infrastructure, absence of land redistribution and emphasis on modern seed technology. In fact, according to the report of International Assessment of Agricultural Science and Technology for Development (IAASTD), progress in agriculture has been achieved in many cases at a high social and environmental cost, making poor people vulnerable to high food prices amid extremely low incomes.

Irrigation Requirement: According to estimates of National Commission on Integrated Water Resources Development (NCIWRD), the demand for irrigation is 557 bcm during 2010 and would go up higher by 511 bcm (2025) and 807 bcm (2050).

Land Requirement: The efficiency of water use for irrigated agriculture is 35-40 per cent at present, which could be increased to at least 60-70 per cent with better management and operation. If the net irrigated area is restricted to 65 million ha and the cropping intensity increased from 135 to 150 per cent, then a production of about 280 million tonnes of food grains with an average productivity of 4 tonnes/ha could easily be achieved. In rainfed areas, which at present have a productivity of about 1 tonne per ha, this could be increased to 2.5 tonnes per ha with the production of 175 million tonnes. Thus the total production could be 455 million tonnes in 2050. The area sown at present is 142 million ha, which should not be allowed to be decreased. ❑

Operating Environment

3.1 Oil Palm Research

Oil palm research in India started with the establishment of a Research Station at Thodupuzha by Department of Agriculture, Kerala during 1960. Indian Council of Agricultural Research (ICAR) started oil palm research at Central Plantation Crops Research Institute Research Centre at Palode in 1975. Oil palm was included as one of the crops in the All India Coordinated Research Project on Palms during VII Five Year Plan period with the establishment of four Coordinating Research Centres at Vijayarai (Andhra Pradesh), Mulde (Maharashtra), Aduthurai (Tamil Nadu) and Gangavathi (Karnataka). ICAR established the National Research Centre for Oil Palm at Pedavegi in Andhra Pradesh in 1995, which was later renamed as Directorate of Oil Palm Research in 2009 and subsequently upgraded as Indian Institute of Oil Palm Research (IIOPR) during the year 2014. Two more Coordinating Centres for oil palm research were established in 2009 at Pasighat (Arunachal Pradesh) and Madhopur (Bihar) representing North East and Eastern Regions. Thus, a well established research system with the required infrastructural facilities is available in the country for oil palm research.

Mandate

- To conduct mission oriented research on all aspects of oil palm with an objective to improve the productivity and quality.
- To serve as a national repository for oil palm germplasm and clearing house for all research information on oil palm and to coordinate national research programmes.
- To act as centre for training in research methodology and technology of oil palm.
- To generate nucleus planting material for the establishment of seed gardens.

Vision

By 2050, India will have adequate, nutritious, safe and healthy vegetable oil within the limits of natural ecosystem.

Main Targets of Vision

With land, water and labour resources becoming increasingly scarce, our main target shall be to achieve better Resource Use Efficiency. A four-fold increase in land productivity, three-fold increase in water productivity, doubling of energy use efficiency and a six fold increase in labour productivity are to be aimed at so as to remain competitive in the emerging global scenario.

Mission

- To ensure technology led development of oil palm for food and industrial purposes and make it available to the citizens at affordable price.
- To ensure the availability of new hybrids and production technology to the farmers that can provide better profitability and withstand biotic and abiotic stresses.
- To develop technologies that are socially compatible, politically feasible and ecologically sustainable and to provide environmental services.

Cutting Edge Research Themes for Oil Palm

- Development of hybrids with higher oil yield potential with resistance to biotic and abiotic stresses.
- Achieve self sufficiency in quality planting material production.
- Efficient nutrient and water management technologies.
- Promote effective use of bio-control agents for pest and disease management.
- New harvesting tools and machineries for oil palm cultivation.
- Processing technologies for effective utilization of oil palm products.

The new technologies are expected to play a critical role in improving oil palm production and increasing the oil palm sector efficiency in the country.

Significant Research Achievements of IIOPR

The significant research achievements made in oil palm could be summarised as follows:

Genetic Resources Management: Oil palm germplasm has been collected from different oil palm growing countries with wide variability for different characteristics. Presently, IIOPR has an assemblage of 128 accessions. High yielding cross combinations have been identified and mother palms for production of new hybrids were planted in seed gardens. Intensive evaluation of African germplasm resulted in the identification of a few remarkably high yielding accessions that could play a major role in oil palm crop improvement programme in India. Explant samples were collected for tissue culture of these valuable palms. Twenty best performing tenera hybrids have been identified for use in crop improvement programmes at Palode. Screening of 240 African dura palms for drought tolerance based on physiological and biochemical characters have been completed. With a view to develop dwarf and compact palms and to facilitate planting more palms per unit area and easy harvesting, inter-specific hybrids were developed which are being evaluated. Evaluation of inter-specific hybrids at Palode resulted in identification of three promising dwarf palms that can be used for further improvement. Work on developing an *in vitro* regeneration protocol of oil palm using explants from mature palms has entered into the commercialization phase. Somatic embryogenesis and regeneration could be standardized and found repeatable with inflorescence as explants and planted in field.

Production and Processing System Management: Results from irrigation experiments have indicated that when irrigation was restricted to replace evaporation losses by 100 per cent either with drip or micro jet system, crop growth and yields were superior to that of basin irrigation. Sap flux studies in oil palm were studied in relation to evapo-transpiration and vapour pressure deficit as they could give vital leads in developing an approach for monitoring the environmental responses in oil palm. Fertigation trial indicated that palms applied with 1200:600:1200 g NPK/palm/year through soil application recorded the lowest FFB yield (18.43 t/ha) and bunches (6.43/palm) while the highest FFB yield (24.15 t/ha) and bunches (8.37/palm) was obtained with application of 1200:600:2700g NPK/palm/year. Annual carbon sequestered by oil palm was 11.73 and 5.51 t ha^{-1} y^{-1} under irrigated and rainfed conditions respectively. The standing biomass of a ten year old oil palm plantation was of the order of 59.62 and 36.53 t ha^{-1} under irrigated and rainfed conditions. Oil palm based cropping systems with heliconia, red ginger, bush pepper, guinea grass and cocoa have been standardized in adult oil palm plantations. Diagnosis and Recommendation Integrated System norms and optimum leaf nutrient concentration ranges have been developed for Karnataka and Goa States for routine diagnostic and advisory purposes. The technique of vermicomposting has been perfected for oil palm plantation wastes. Based on the nutrient equivalence value, it was found that almost 90% of N, 50% of P and 75% of K requirement of palms could be met through composting process. Height adjustable hydraulically elevated platform to reach up to a height of 5 metres has been designed and developed for harvesting FFB from tall palms. A low cost ablation tool was designed and developed during the year, that received great appreciation from the farming community. Back pack mounted and trolley mounted motorized sickles were developed. Three models (DOPR - 1, 5 and 6) of improved sickles with light weight high strength poles were found to be promising. Standardized technology of mushroom cultivation on oil palm factory wastes. Isolated and identified various microorganisms from Palm Oil Mill Effluent and developed POME based animal and fish feed formulations. Carotenoids were extracted using different adsorbants and developed a cost and time saving indirect method for oil estimation. Studies on the effect of low temperature on FFA content in the oil after harvesting of the FFB indicated that the increase in FFA content was steady up to seven days and hence, there is no possibility of storing FFB at lower temperature before processing.

Plant Health Management: Roving survey on the pests of oil palm in various states of India revealed that rhinoceros beetle is the most frequently observed pest in oil palm plantations. Leaf eating caterpillar damage was observed to be very severe in some of the gardens. Management measures for rhinoceros beetle have been standardized. Infestation of rhinoceros beetle was brought down from 8.25 per cent to 1.8 per cent by release of baculovirus-infected beetles. A wild boar scaring devise was developed for oil palm nurseries and young plantations. Use of bamboo noose traps was found to reduce the burrowing rat population. Oil palm is an entomophilous crop and pollinating weevil *Elaeidobius kamerunicus*, introduced from Malaysia has established well in all agro-climatic zones of oil palm in India. Integrated disease management package for the management of basal stem rot has been found to be successful. Molecular diagnostic kit for rapid detection of basal stem rot pathogen in oil palm has been developed.

Social Sciences: Technological gaps, adoption and constraints faced by the farmers in oil palm production were studied. Training needs of stakeholders in oil palm were assessed and need based training programmes were conducted at regular intervals. A digital video film on oil palm cultivation “The Golden Palm” was brought out in nine languages. Oil Palm Kisan Mobile Message Services in the form of text messages as well as voice messages were sent to oil palm growers belonging to Andhra Pradesh, Arunachal Pradesh, Chhattisgarh, Goa, Gujarat, Karnataka, Maharashtra, Meghalaya, Mizoram and Nagaland in four languages.

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New Opportunities

Oil palm crop offers great opportunities to all the stakeholders involved in oil palm sector. Oil palm is a high yielding crop (more than 5 tonnes of oil per hectare per year) as compared to other oil yielding crops that are yielding around one tonne of oil per hectare. There are ample opportunities for the development of oil palm in India which has diversified agro-climatic conditions and vast stretches of land with untapped underground water potential. The oil palm crop, though recently introduced in India, comes up well in many regions and 1.93 million ha. in 19 states could be brought under oil palm cultivation. Oil palm farmers are assured with a remunerative price, as decided by Government of India/State Governments. Payment for the produce is made to farmers within 15 days as per the Oil Palm Act. To meet the increasing per capita consumption of vegetable oils as well as population growth, there is an urgent need to increase the production of vegetable oils in the country. Thus, the farmers as well as the processing units in India would not face any constraint with reference to the marketing of the produce. Government of India supports Oil Palm Development Programme with high budget allocations to improve the production of vegetable oils for import substitution. The sector also offers vast employment potential in rural areas for oil palm cultivation and in processing industries that include product diversification and value addition enterprises. The crop has an appreciable level of carbon sequestration potential that makes the crop attractive with reference to climate change management.

A large number of germplasm are available in the country that include the different fruit types (dura and tenera) identified recently in commercial plantations, incidentally introduced through the import of planting materials from different countries over a period of four decades. IIOPR could identify germplasm yielding upto 52.00 tonnes of FFB per ha. Recent identification of a germplasm with 30.6 per cent oil to bunch ratio enlarges the scope of oil palm crop improvement in the years to come for enhancing oil productivity in the country. Indian Institute of Oil Palm Research has excellent facilities including scientific manpower in major disciplines for pursuing oil palm research, laboratory facilities with state of the art equipments and day-to-day support from ICAR for strengthening its research programmes. Multi-locational trials could be carried out through All India Coordinated Project on Palms (AICRP) Centres, located in six States representing various agro-climatic regions of the country, to identify location- specific technologies.

Based on intensive research at IIOPR and AICRP Centres, package of practices for oil palm cultivation could be finalized, that enabled the farmers to record high yields. A farmer could record 53.20 tonnes FFB per ha in Karnataka State, which indicates the opportunities available for scientists and development managers (to prove their excellence) in terms of production potential as well as the extent of Research and Extension gaps available at present. Key technologies on soil and water conservation, irrigation management, pest and disease management etc., could be availed from the experience already gained in other crops and expertise from the relevant ICAR Institutes could be availed for strengthening oil palm research.

IIOPR serves as the "Technology Source" for the preparation and implementation of various oil palm development programmes in India. This helps the Institute to transfer its technologies including the high yielding planting materials, instantaneously to the farming community with adequate support in terms of incentives from Government of India. The major advantage in oil palm is that the policy managers and research system, through proper coordination, could ensure rapid transfer of technology especially with reference to new cross combinations with higher productivity potential being evolved in the research system through the establishment of adequate number of seed gardens with these planting materials. It is to be noted that each seed garden, to be planted with advanced breeding materials (to be provided by IIOPR) in an area of 20.00 ha, would have the production potential of one million sprouts per annum which is sufficient to cover about 5000 ha per annum. Thus, we may require 27 state-of-the art seed gardens to be established in different locations to meet the planting material requirements of the country from the indigenous sources with high productivity potential. It is expected that, with the present pace of Research and Development, we would be able to achieve self-sufficiency for planting material requirement by 2027-28.

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Goals and Targets

Projected oil Palm Production by 2050

Year	Per capita consumption (kg)	Area (million ha)	FFB Yield (t/ha)	Oil Yield t/ha	OER (%)	FFB Production (million tonnes)	Oil Production (million tonnes)
2020	16.43	0.50	17	3.74	22	8.50	1.87
2030	17.52	1.50	20	5.76	24	30.00	7.20
2040	18.62	1.80	22	6.25	25	39.60	9.90
2050	19.16	2.00	26	7.02	27	52.00	14.04

FFB: Fresh Fruit Bunches; OER: Oil Extraction Ratio

Oil Yield at Research Stations is projected to reach 12.00 tonnes/ha by 2050

To remain competitive in the emerging global scenario, a four-fold increase in land productivity, three-fold increase in water productivity, doubling of energy use efficiency and a six fold increase in labour productivity are to be envisaged for the future. In India, for a population of 1200 million during 2013-14, 21.36 million tonnes of vegetable oil was utilized. However, the current per capita consumption of 16.71 kg is lower than our nutritional needs as defined by FAO. The country is currently producing 0.785 lakh tonnes of palm oil only. In the years to come, oil palm is likely to play a major role in augmenting the supply of vegetable oil in the country. As against the potential area of 19.30 lakh hectares spread over 19 states in the country, hardly 2.62 lakh ha was planted upto March 2014. Among the major tree crops, oil palm exhibits the high potential prospective as a long-term source of edible oil, which is expected to contribute significantly towards meeting the growing edible oil demand in the country. By 2050, with an area of 2.00 million ha covered under oil palm, the country must be able to produce about 14.04 million tonnes of oil from oil palm, as against the 31.03 million tonnes of vegetable oil required for feeding 1620 million population at a per capita requirement of 19.16 kg. Oil palm sector would be contributing 45% of the vegetable oil requirements of the country by 2050 and import of vegetable oil would be almost negligible from 2030 onwards. (Table). There is an urgent need for proper policy back-up for sustaining the long-term commitment of the farmers, researchers and policy managers towards oil palm sector.

Demand projections of vegetable oilseeds and oils in India

(in million tonnes)

	2020	2030	2040	2050
Projected population (billion)	1.32	1.43	1.55	1.68
Projected Availability of vegetable oils (million tonnes)				
Total Vegetable oil availability from annual oilseed crops	13.33	15.30	18.1	20.3
Vegetable oil availability from oil palm	1.87	7.2	9.9	14.0
Vegetable oil availability from secondary sources	5.05	5.89	6.85	7.18
Total Vegetable oil availability from primary and secondary sources	20.25	28.39	34.9	41.5
Total vegetable oil requirement	23.81	29.05	34.3	39.1
Surplus/Deficit (million tonnes)	-3.56	-0.66	0.56	2.42

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Way Forward

Strategies for Oil Palm Research

The role of Indian Institute of Oil Palm Research is of crucial importance in the emerging vegetable oil scenario in India. To enable the Institute to remain competitive and relevant, research planning is to be done on a systematic basis along with continuous monitoring of progress for on-course corrections, if any, by focusing attention on the development of cutting edge technologies. An interdisciplinary mode of research would be encouraged. Innovation will be the key driving force for sustainable productivity growth and other changes for Green Revolution 2.0 by changing our strategy from input intensive to knowledge intensive mode. Efficiency is the "core path" to be achieved through the advent of new hybrids, improved agricultural practices, improved planting materials, frontier technologies including biotechnology & nanotechnology, without any associated increase in demand for additional resources.

Road Map for Action

With the present level of rapid increase in the per capita consumption of vegetable oils in the country, it is expected that the estimated population of 1620 million in 2050 may need 31.03 million tonnes of vegetable oils at the estimated per capita consumption of 19.16 kg. It would be ideal, if the country could become self-reliant in the vegetable oil production sector by sparing the required additional land for oil palm development.

In the recent report on the potential area for oil palm cultivation in India, IIOPR recommended that an area of 1.93 million ha from 19 States could be utilized for oil palm cultivation. With its intensive research efforts and active implementation of Oil Palm Development Programme by Govt. of India, it is estimated that the oil palm productivity levels in the country could be enhanced to 7.02 tonnes of oil per ha, thus producing a total quantity of about 14.04 million tonnes of palm oil by 2050. Thus, oil palm could contribute towards the vegetable oil requirements of the country by 45 per cent. The balance demand for vegetable oil could be met from the traditional oilseeds like groundnut, sunflower, rice bran, sesame, mustard, rape seed, etc. It is estimated that with the "Mini-Mission Programme on Oil Palm" to be implemented from XII Five Year Plan onwards, an additional area of 1.25 lakh ha could be brought under oil palm cultivation. The additional area is to be increased to 1.50 lakh ha per annum so as to increase the total production as well as to meet the replanting schedule.

Productivity Targets

Narrowing Gap Between Potential and Realised Yields

A potential yield of 18.5 tonnes oil/ha/year from oil palm should be possible based on the combination of maximum levels observed for the individual yield components in oil palm and additional considerations of dry matter portioning within the bunch. A more realistic estimate of 10-12 t/ha/year has been obtained in private plantations of Karnataka and Andhra Pradesh, which are on par with the maximum yields obtained with the advanced genetic materials produced in India. In general, the average yields of commercial plantations range from 5-6 t/ha/year with good planting materials, soil conditions and best management practices.

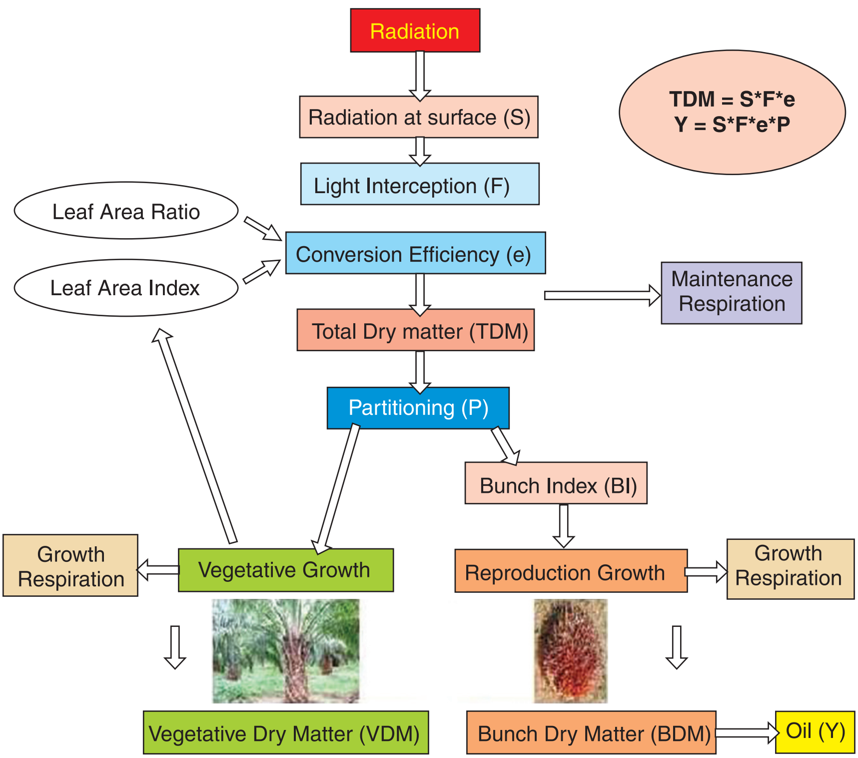

Fig. 3 Components of oil palm productivity for narrowing the yield gap in oil palm

The challenge is therefore to narrow the gap between the national average/commercial yield and the yield potential, both through crop improvement and management. The key components of productivity for narrowing the yield gap in oil palm are presented in Fig.3.

The following physiological and breeding approaches are to be considered for reducing the gap between potential and realized yields in oil palm under Indian conditions:

- **Improving the Extinction Coefficient**: In oil palm, the leaves on the crown are not randomly distributed but clamped around few widely spaced growing points. This non-random distribution will also lead to a low extinction coefficient and its 0.34 for oil palm (tend to have vertical leaflet distribution than coconut). Thus the extinction coefficient should be improved for better light interception in oil palm.
- **High Leaf Area Index:** Leaf Area Index (LAI) of 7.0 is required for achieving 95 per cent interception of Photosynthetically Active Radiation (PAR) and between 8.0 and 10.0 for achieving 99 per cent interception. Identification of palms, where leaf area expands more rapidly than normal and reaches a maximum LAI earlier during 8-10 years after planting should be preferred. Such palms give higher total dry matter production during the stage of leaf area increase, but also a more favourable partitioning of assimilates between vegetative and reproductive growth after canopy closure.
- **Increasing Conversion Efficiency**: The efficiency of canopy in converting intercepted radiation to dry matter can be expressed in terms of total weight of dry matter produced per unit solar energy intercepted or energy fixed per unit energy intercepted. The conversion efficiency in oil palm ranges from 1.0-1.6 g MJ^{-1} PAR intercepted. Any factor that affects the rate of either photosynthesis or respiration may alter conversion efficiency.
- **More Erectophile Canopy Architecture**: Canopy of oil palm does not provide an effective intercepting surface considering the amount of foliage it contains. This is due to non-random distribution of leaflets and leaflet angles. Hence oil palm leaves are considered more as an indication of good light penetration than of poor interception. Leaves are erectophile during nursery stage with more than 70 per cent having 45° leaf angle and further leaves tend to less erectophile in the young palms to adult plantations (8 years old) and hence poor interception.
- **Better Partitioning of Assimilates**: Harvest index in oil palm has two components – the proportion of total dry matter in fruit bunches

and proportion of oil in fruit (latter component can be increased by breeding). Considerable variation in harvest index exists in oil palm and there is obvious scope for further improvement by selection. Partitioning of assimilates between leaves and non-photosynthetic organs are important. Selection of parent palms for high leaf area ratio (LAR) is an effective method of improving progeny yield. Fertilizers play a vital role in the partitioning of assimilates in oil palm. Fractional interception, conversion efficiency and partitioning ratios are highly correlated with yield with application of fertilizers. The greatest fertilizer response has been conversion efficiency – N, P and K increased the conversion efficiency by 26 per cent, 16 per cent and 12 per cent.

- **Breeding approaches** like reducing leaf production, high bunch weight (bunch number should not be too high), reduced trunk growth and high oil to bunch ratio should be considered for narrowing yield gap in oil palm.

Ideotype of oil palm for Indian Conditions

a. Extinction Coefficient of more than 0.4
b. Leaf area index - greater than 7
c. More erectophile canopy (45° angle)
d. Early leaf area expansion (< 8 years)
e. Conversion efficiency of more than 1.6 g MJ-1
f. High Bunch Index
g. Bunch dry matter should be more than 53 per cent
h. High leaf area ratio

Though the present yield levels in progressive districts like West Godavari in Andhra Pradesh is about 4.00 tonnes of oil per ha (on par with Indonesia and Malaysia), other districts in Andhra Pradesh as well as remaining oil palm growing states continue to record productivity levels of less than 2.00 tonnes per ha. Thus, the productivity improvement through better planting materials and efficient management of water, nutrients and labour would be of crucial importance for achieving the targets. The research activities at IIOPR, especially, the crop improvement programmes are to be strengthened and hastened up to meet the productivity targets. A schematic presentation on the Action Plan for oil palm crop improvement programme at IIOPR till 2050 in the form of "Road map for 2050" is presented in centre page-spread.

When the area coverage target is 60,000 ha per annum, more than 70 per cent of the planting material requirements of the country are imported from different sources. Trials laid out in different locations indicated that productivity of oil palm sprouts imported from other countries is equal to that of the planting materials produced indigenously. However, with the enhanced productivity targets for indigenous source of planting material as envisaged in the previous paragraphs, the planting materials, if continued to be imported may not have the equivalent productivity potential. Hence, it would be ideal and imperative to enhance the indigenous planting material production through conventional breeding and *in vitro* methods.

Six seed gardens were available in India by the end of XI Five Year Plan. The number of seed gardens would be enhanced to 14 by the end of XII Five Year Plan with four seed gardens planted during 2012-13 and additional four seed gardens with a production potential of 250 kg per palm per annum (35.00 tonnes FFB per ha i.e. 7.00 tonnes of oil/ha) to be established by 2015-16. Thus, it is envisaged that, by 2027-28, 27 seed gardens would be available in the country. Subsequently, with development of new cross combinations with better yielding potential, old seed gardens would be replanted with new materials, thus keeping the total number of seed gardens as 27. The planting materials to be produced in the seed gardens would be supplemented with sprouts to be produced from the National Seed Gardens concurrently to be established in Horticulture Farms of Mizoram, Karnataka and Andhra Pradesh as well as from the Tissue Culture Laboratories proposed to be established in public and private sectors. Any additional seed materials that would be available in India (after 2027-28) could be exported to other countries especially to the SAARC countries and African countries, where the agro-climatic conditions are similar to that of India and are also eager to import oil palm planting materials from India.

Genetic Enhancement in Oil Palm

Breeding objectives: The primary breeding objectives for oil palm would be to achieve higher FFB yield with better oil content (oil to bunch ratio) – Ideal selection criteria could be 15:20 (15 bunches per year with an average bunch weight of 20 kg) yielding about 300 kg FFB per palm per year (42.90 tonnes/ha) and ultimately to 350 kg FFB per palm per year (50.05 tonnes/ha). This would ensure better oil content in all the fruits in a bunch resulting in better oil/bunch ratio. There is a need to increase the oil to bunch ratio to 27 per cent that would ensure the Oil Extraction Ratio in the Processing Mills to a minimum of 25 per cent. Thus, we have to aim at achieving a genetic potential of 12.00 tonnes of oil/ha.

Search for New Genes: Breeding in oil palm would aim at development of new planting materials that have the capability for better oil yields with high quality, slow height increment and larger kernels. These traits could be improved through breeding and biotechnology. The oil palm genome has been sequenced and is approximately 1.8 billion base pairs in size, about four times the size of the rice genome and two thirds the size of the maize genome. Shell thickness marker which is very important to identify the fruit type at an earlier stage, gene for increasing the mono unsaturated fatty acids for edible purpose, introduction of dwarfing gene into oil palm are some of the important areas of oil palm genomics research.

IIOPR has initiated molecular research in oil palm mainly for analyzing the genetic diversity of the existing germplasm and also attempted to identify the marker for shell thickness. IIOPR has been successful in raising a mapping population for shell thickness. IIOPR has also succeeded in identifying RAPD and SSR markers to distinguish the two species, *E. guineensis* and *E. oleifera*. Sequencing of oil palm genome may facilitate the in-depth understanding of genes encoding for several traits including plant height, shell thickness, disease or pest resistance, plant yield, oil quality etc., and this shall foster the development of an improved oil palm cultivar in future. The work could be taken up by utilizing the DNA sequencing facilities and the bioinformatics expertise available at other ICAR Institutions.

Breeding programme: It is to be noted that there are few germplasm available in India with high oil yield potential. By utilising these base materials and through repeated crossing and selection programmes, higher oil yields could be achieved. In each cycle, an improvement of 15-20 per cent yield could be aimed at. Concurrently, planting materials (dura) could be taken from selected parental palms from better yielding families for the establishment of new seed gardens. The success in oil palm crop improvement depends on the large number of Progeny Evaluation Trials to be conducted with the selected cross combinations and selection of promising combinations and utilization of results for establishment of new seed gardens with the active participation of Public and Private Sector Entrepreneurs. AICRP Centres also would be actively involved in this task.

There is an urgent need to strengthen the oil palm crop improvement programmes in the country. The strengthening process could be initiated with the germplasm resources available at Palode (Kerala), Pedavegi (Andhra Pradesh), Thodupuzha (Kerala) and other germplasm evaluation centres at Athirapalli (Kerala), Adilabad (Andhra Pradesh), Mohitnagar (West Bengal), Mulde (Maharashtra) and Gangavathi (Karnataka) as well as in commercial plantations recently identified at Little Andamans, Goa, Tamil Nadu, Maharashtra, Andhra Pradesh and Karnataka. Concurrently, efforts also would be intensified for the import of base germplasm from different sources (especially from the Centre of Origin in West Africa) as well as advanced breeding materials from the countries conducting oil palm research for more than five decades.

Progeny Evaluation Trials shall be completed within 9 years (3 years of pre-bearing stage i.e., initial stage and 6 years of yielding phase). Crop management schedules shall be appropriately modified to achieve the peak yield by 6th year after planting in the experimental fields. Based on the performance recorded during the 4 years of peak yield period (6th to 9th year), elite selections could be made. The adult palms are to be used in the production of planting materials for seed gardens and also for future crop improvement programmes. Selection shall always be made based on family and individual performance. However, for further use in seed gardens or advancement of breeding cycles, better yielding palms of the selected families shall be used. For evaluation of any cross combination, 54 seedlings are to be selected for laying the Progeny Evaluation Trial (to be planted in RBD with 18 palms per plot in 3 replications). As the molecular markers for high yield (to enable early screening) could not be identified so far, stringent screening could be done at nursery level based on early splitting of leaves, stem girth and avoiding plants with any morphological symptoms of deficiencies.

Criteria for screening germplasm accessions for special characters could be (i) height increment of less than 15 cm per year with 100 kg FFB yield (if the height increment criterion is raised to 20 cm per year, yield parameter shall be increased to 200 kg FFB per palm). (ii) selection criterion for better oil content could be fixed at 30 per cent oil to bunch ratio. Evaluation programme for the identification of core collections for important traits is to be strengthened especially for height increment and oil to bunch ratio. Methodology for *in vitro* screening of oil palm accessions and progenies for biotic and abiotic stresses as well as early selection of progenies with better yielding potential are to be evolved. Possibility of exploiting wider genetic distances using inter-specific hybridization along with embryo rescue technique is to be explored.

A 'Pollen Bank Repository' needs to be established to facilitate storage and exchange of freeze dried viable pollen for increasing the domestic production potential of oil palm planting materials. Pollen selection (gametophytic selection) methods for evaluation of germplasm for abiotic and biotic stresses would be attempted. As a part of germplasm conservation programme, all the basic germplasm as well as high performance palms at various stages of crop improvement are to be taken up for long term conservation. Thirty embryos per type could be collected after selfing the selected palms and preserved at -80°C for long term conservation. When high yielding dura palms are located, *inter se* crossing between these high yielding duras are to be attempted and the progenies selected for progeny evaluation trials (in RBD with 18 palms per cross combination in 3 replications). High yielding dura palms thus selected in the dura improvement programmes are to be multiplied clonally through tissue culture for planting in seed gardens.

Pisifera improvement: High yielding tenera palms are to be inter-crossed for the development of pisifera palms and by the sixth year, 4 to 5 potential pisifera palms are to be selected and each palm is to be crossed with 20-25 proven dura palms for Progeny Evaluation Trials for selecting the best cross combinations by 15th year – leading to the selection of pisifera palms with better General Combining Ability and Specific Combining Ability. These pisifera palms could be further utilized for the commercial production of sprouts for the next 15 years. Multiplication of pisifera palms through tissue culture for use in seed gardens is to be avoided. High potential pisifera palms shall be fully utilized by collection of pollen in different months and stored for regular use in different seed gardens. Recent studies at IIOPR have indicated that pollen could be stored up to one year (without any loss of germination) under low temperatures.

Tissue culture: In the recent years, tissue culture protocol is transferred to public and private sector entrepreneurs for the establishment of Tissue Culture Laboratories for refinement and commercialisation through production of location-specific planting materials. As the first step, field performance of the plants is to be confirmed and the protocol is to be refined to make it more cost-effective. Concurrently, planting material production level at IIOPR Tissue Culture Laboratory could be gradually enhanced to 20,000 plants per annum at the earliest. Care should be taken to remove 5-10 per cent of plants showing malformations within the first four years. These materials are to be replanted with good planting materials. Tissue culture methodology could be used more frequently for the multiplication of dura and tenera palms.

Other Biotechnology Programmes: Studies on the identification of molecular markers for shell thickness are to be strengthened at IIOPR to enable early identification of pisifera palms in seed gardens. Research Programme for the decoding of oil palm genome is to be initiated in collaboration with relevant ICAR Institutes and oil palm research institutions of other countries. Concurrently, studies for the evolution of transgenics could also be initiated – Malaysia has reported success in transgenics in oil palm. Development of transgenic plants in oil palm for higher bunch number and low height increment would receive greater attention in the future. "Association mapping" procedure will be used for oil content and bunch number as an aid for crop improvement programme. Scope for utilising the "Determinate Gene" available (free of cost) in the public domain for restricting the palm height thereby increasing the productive period of oil palm by one or two decades more would also be explored.

Production System Management

Characterization of Basic Genetics of Biotic Tolerance: A precise genetic analysis for resistance to Ganoderma wilt disease and stem wet rot disease is to be carried out. Studies on genetic variation in disease causing pathogens using molecular markers are important. Large number of isolates of the pathogen would be collected for further studies.

Agrotechniques Modulation: Studies on "Induced Systemic Resistance against diseases" using *Pseudomonas* and other antagonists will be strengthened. Antagonists that have been found to be effective against diseases are to be field tested on a large scale.

Early Diagnostics using Nano-Biotechnological Applications: Nanotechnology could be used for combating the plant diseases by controlled delivery of functional molecules and also as a diagnostic tool for disease detection. The endophytes from oil palm will be isolated and screened *in vitro* and *in vivo* for their field tolerance potential against important oil palm diseases like basal stem rot, bud rot and stem wet rot. The association of endophytes with oil palm through nano fabricated pillared assay will be studied. Early detection of incidence of *Ganoderma* wilt disease in oil palm by using molecular techniques would be strengthened. Use of nanotechnology for early diagnostics would also be attempted. Detection of the disease and exact interactions between *Ganoderma* pathogen and oil palm host would help in the better management of the disease. Methodology for diagnosing basal stem rot disease caused by *Ganoderma* sp through quantum dots by SILAR method would also be standardized.

Influence of Bio-control Agents: Studies on identification and utilization of bio-control agents, development of bio-pesticides, bio-efficacy of botanical pesticides and kairomonal influence of bio-control agents would be strengthened. Pheromones are to be developed for combating the rhinoceros beetle in oil palm by using electrophysiological techniques. Further refinement is required for better dispensing systems for the pheromones. Developing temperature tolerant strains of bio-control agents for improving the bio-efficacy of natural enemies would be another major area of research.

Pest Risk Analysis and SPS measures assume importance in view of the globalization process and prevalence of catastrophic pests and diseases in palms in other countries and large scale import of oil palm planting materials from these regions.

Role of Pollinators: In view of the low fruit yield as compared to the number of female flowers produced in oil palm, studies on pollinators are to be strengthened on priority. Pollination in oil palm is carried out by various means including wind and several species of insects, of which the weevil *Elaeidobius kamerunicus* Faust. is the predominant species. In the absence of the native pollinating weevils in countries, where oil palm was an introduced crop, *E. kamerunicus* was introduced from Cameroon to Malaysia and subsequently, to other oil palm growing tracts of South East Asia and South Pacific Islands, resulting in a significant increase in fruit set and other bunch characters. However, there have been concerns regarding periodic occurrence of poor pollination, bunch failure and yield loss in certain locations due to insufficient weevils or no weevil population and less abundant male inflorescences. It is also observed that population density of weevil and fruit set vary from place to place and season to season due to climatic conditions and various other factors. Hence studies are to be intensified to assess the genetic diversity of pollinating weevil by morphological and molecular analysis, study the effect of climatic conditions on pollination efficiency of the weevil, screen the existing pollinating weevil populations for evidence of infection by parasitic nematodes and other biotic factors, develop high and low temperature tolerant weevil populations to suit extreme agro climatic conditions and to screen effective pesticides for their selectivity against pollinating weevil and their pollination efficiency.

Management of Abiotic Stresses: As “water” would become critical factor for agricultural prosperity, and “water availability” situation often varies in different seasons and years, for perennial crops like oil palm, emphasis would be given on soil moisture deficit management. Evolving an Integrated Water Management Technology package for higher water-use-efficiency would receive priority attention. Similarly, nutrient deficiency management and role of low temperature on floral initiation in oil palm and oil quality would also receive adequate attention.

Management of Adverse Effects of Climate Change: It is generally accepted that there is a link between increase in average temperature and higher concentration of green house gases, particularly CO_2 and water vapour. The impact of climate change on oil palm is witnessed in Malaysia, Indonesia, Colombia and other oil palm growing nations of the world. Being grown as an irrigated crop in India, oil palm is likely to be more vulnerable due to excessive use of natural resources particularly water with poor adaptive mechanisms. Oil palm is highly sensitive to moisture stress and is strongly affected by climatic anomalies such as *El Nino* in South East Asia. Under such extreme climatic situations, when FFB yield level in oil palm decreases, small and marginal growers would be affected most. Hence, consequences of climate change on oil palm could be severe on livelihood security of poor in the absence of proper mitigation strategies. Study on climate resilient oil palm is very much essential for ensuring livelihood security of oil palm growers in the context of climate change. The study involves (a) Screening of oil palm germplasm for drought, salinity and high temperature tolerance using physiological and biochemical markers; (b) Assessing and quantifying impact of CO_2 and temperature in oil palm (CO_2 enrichment studies); (c) Studying the effect of environmental variables on seasonal and annual variations in growth, phenology and yield and (d) Understanding sap flow dynamics and quantifying CO_2 flux, energy budget and water transfer in oil palm canopies (Eddy Covariance studies).

Climate resilient technologies would be evolved especially to manage high temperature conditions prevailing for 3-4 months in East Coast region, high rainfall received in short spells causing flooding of oil palm gardens in several States, low temperature conditions prevailing for 2-3 months in Eastern and North-Eastern regions, low rainfall received in specific districts in certain years causing moisture stress resulting in poor yield in the subsequent 2-3 years, sudden incidence of frost for a short spell in Eastern region. AICRP Centres also would be involved in this task.

Diversification of Cropping Systems: Methods of higher crop intensification with oil palm as the base crop would be evolved. Crop – livestock integration with reference to ecology, crop and season would also be attempted.

Integrated Soil Health Management: New agronomic practices based on precision farming with new crop geometries, zero tillage and micro irrigation techniques are to be strengthened. Total Factor Productivity studies would be intensified to ensure better Resource Use Efficiency for land, water, fertilizers, chemicals and micronutrients. Technologies for optimum use of macro and micronutrients in combination with organics and microbes would be evolved.

Converting Waste into Wealth: Oil palm generates huge amounts of biomass equivalent to 10.3 tonnes per ha per annum on dry matter basis, which in turn provides 108 kg N, 10 kg P, 139 kg K, 26 kg Ca and 17 kg Mg. However, it is difficult to manage the biomass as it decomposes very slowly under normal field conditions. Presently, fronds/leaves in oil palm gardens are heaped in columnar space and left for natural decomposition which not only takes very long time for decomposition but also adds back very little quantity of nutrients. Considering the nutrient potential of oil palm biomass, shortage of labour and high cost of fertilizers, there is an immediate need to standardize *in situ* composting of oil palm leaves and male inflorescences in the basin itself.

Precision Farming: Precision farming identifies the critical factors which limit yield and determines intrinsic spatial variability. In general, oil palm plantations are managed by conventional technology wherein uniform application of inputs without considering spatial and temporal variability is practiced, which results in under/over utilization of resources. Precision farming offers a comprehensive approach to enhance the productivity of oil palm by using the inputs to full extent as it identifies the site specific critical factors based on soil, crop, weather and prior management across space and over a period of time. Precision farming would help in developing site specific farming systems, so that it could help in enhancing oil palm productivity and improve economic status of the farmers.

Agriculturally Important Microbes and their Utilization in Oil Palm: Studies on diversity of microbes, their identification, characterization, conservation and utilization in oil palm would be initiated. Substrate dynamics and rhizosphere engineering studies would be conducted on the use of a consortium of agriculturally important micro-organisms *viz.,* nitrogen fixers, phosphate solubilizers, plant growth promoting rhizobacteria (PGPR), mycorrhizae, organic matter decomposers and microbial pesticides to enhance Nitrogen Use Efficiency and Water Use Efficiency.

Farm Mechanization: Fabrication of harvesting devices and spraying equipments would receive priority attention, in view of severe shortage and high cost of labour (climbers) for bunch harvest.

Processing and Value Addition: Though research on oil palm processing and value addition are not included in the mandate of Indian Institute of Oil Palm Research, research on the following lines could be initiated by appropriate research organizations for the benefit of oil palm sector in the country. Oil extraction ratio in India needs to be improved through the use of optimum mill management practices. Major emphasis is to be given for using crude palm oil for the production of value addition materials that includes oleo derivatives such as pharmaceuticals, nutraceuticals and cosmetics. In oil palm processing units, no waste or effluent is to be permitted to go outside the factory and the entire quantity of by-products should be used through a number of value addition enterprises and all the final wastes including palm oil mill effluents (POME) from the processing units are to be utilized to produce methane, which can be captured and stored to generate electricity, that could be sold to the national grid. These additional enterprises would enable us to considerably reduce the cost of crude palm oil, concurrently increasing the price of FFB being offered to the farmers.

Social Sciences

Policy studies on technology, investment and credit, pricing, marketing and trade and agri-business are some of the areas which needs attention. The Institute could serve as a hub for generation and analysis of socio-economic intelligence in oil palm sector and increasingly involve in Policy Advocacy role. Intensification of participatory technology assessment should be promoted through refinement, dissemination and strengthening of production capabilities. Documentation of indigenous technical knowledge, use of information technology for TOT and impact analysis on technologies needs additional focus.

Integrated Development of Oil Palm in North Eastern Region: Research programmes are to be strengthened especially on the combined utilization of soil and water conservation technologies in oil palm cultivation for ensuring large-scale cultivation of oil palm in the region. This programme would ensure better utilization of land, labour and water in the region resulting in better prosperity.

Road Map at a Glance

S.No	Goal	Approach	Performance measure
1	To effectively manage, enrich and evaluate oil palm genetic resources for different traits.	Enrichment of oil palm genetic resources through germplasm exchange, procurement and collection from centres of diversity. Documentation of performance indicators in the available genetic resources.	Broadening of oil palm genetic base.

S.No	Goal	Approach	Performance measure
2	To develop improved hybrids with high yield, quality and tolerance to biotic and abiotic stresses.	Evaluation of germplasm for higher oil yield and better performance under biotic and abiotic stress, slow vertical growth, compact canopy and superior oil quality by conventional and molecular methods. Development of high yielding hybrids with dwarf stature along with high iodine value and resistance to biotic and abiotic stresses. Augment nursery evaluation studies to evolve sound criteria and Identification of palms with unusually high yield potential and Pre-Potent palms. Crossing programmes to be taken up based on FFB yield, oil yield, molecular characterization and combining ability of diverse pisiferas and duras. Laying out multi-location trials with new promising cross combinations utilizing the facilities under All India Coordinated Research Project on Palms.	Oil palm hybrids with high yield and better oil quality and tolerance to biotic and abiotic stresses.
3	Strengthening of oil palm hybrid seed production with advanced generation materials to achieve self sufficiency in domestic planting material requirement.	Strengthening of existing oil palm seed gardens by way of selection of more parental palms with high combining ability. Establishment of new seed gardens with advanced selection cycle materials from indigenous sources. Conducting DxP progeny evaluation trials on a large scale to base future seed production programmes.	Production of adequate planting materials to achieve self sufficiency.
4	Development of *in vitro* regeneration protocol for multiplication of elite palms.	Refinement of tissue culture protocol for mass multiplication of elite oil palm. Public-Private Partnership programmes to be strengthened for refinement and commercial exploitation of tissue culture technology.	Rapid multiplication of elite palms.
5	Develop agro techniques and system for productive use of water to get 'more crop per drop' by increasing the water and nutrient use efficiencies.	Development of suitable production technologies for maximization of yield under irrigated conditions. Water and nutrient management studies to improve Water and Nutrient Use Efficiencies. Integrated Plant Nutrient Management (IPNM) for oil palm based cropping system with major emphasis on bio-waste recycling process. Basic studies to know biochemical and physiological basis for growth and yield of oil palm under irrigated conditions.	Improved resource use efficiency. Developing suitable agro techniques for improved cultivation.

6	Impact of climate change on the metabolism of the crop and its productivity.	Effect of climate change on growth, metabolism and yield of oil palm. Climate resilient technologies to be developed for ensuring better oil palm productivity. Carbon sequestration studies in relation to different age groups	Development of climate resilient technologies and management practices.
7	Develop suitable harvesting tools for improved labour efficiency and post- harvest technologies to improve product quality and minimize environmental impact.	Development of efficient harvesting tools and machineries for mechanization in oil palm plantations. Developing maturity standards for harvesting FFB at right stage. Development of techniques for product diversification and by-product utilization Development of advanced treatment systems for palm oil mill effluent	Development of tools/techniques and processed products.
8	Develop integrated pest management and improve pollination efficiency for better productivity.	Develop eco-friendly IPM practices for major pests Studies on conservation of the pollinating weevils and enhancing their activity during different seasons. Studies on impact of pheromones in attracting the weevils to the female inflorescence. Scope for using new types of honey bee as a pollinating agent.	IPM technology for oil palm pests. Improved pollination efficiency in oil palm.
9	Development of new innovative diagnostic techniques for rapid, accurate and cost effective detection of high impact diseases.	Development of early diagnostics for major diseases. Management of important diseases like basal stem rot, stem wet rot and bud rot. Development of techniques to forecast disease outbreak and suggesting suitable prophylactic measures.	Integrated disease management for major diseases.
10	Understand social needs of communities and build their capabilities for practicing the change for effective utilization of resources and adoption of technologies and respond to emerging needs.	Development of decision-support system as a tool for precision farming. Human resource development programmes for farmers, officers, youth, Self Help Groups, women and unemployed youth in oil palm production and allied industries associated with oil palm. Promoting Information Technology enabled services like video conference and other cyber extension tools. Participatory extension mechanism to generate, evaluate and refine technologies. Application of statistical and computerized tools for research and development. Impact evaluation studies on oil palm technologies.	Better knowledge and skill levels among clients for improved efficiency.

Human Resources Development

Since oil palm is an introduced crop in this country, it is very much essential to train scientists on important areas at different oil palm growing countries of the world. Training will be imparted in the following priority areas at the institutions mentioned against each:

a. Oil Palm Breeding - MPOB, Malaysia, IOPRI, Indonesia, ASD, Costa Rica
b. Molecular studies - Univ. of California, Dept. of Horticulture, Karetsort Univ., Bangkok, Thailand
c. Seed Production - MPOB, Malaysia, ASD, Costa Rica
d. Biotechnology - IDEFOR, Ivory Coast, United Plantations, Berhard, Malaysia, MPOB, Malaysia
e. Water Management - Centre for International Agril. Development and Cooperation (CINADCO), Israel, CIRAD-CP, Montpelier, France
f. Nutrient Management - IRHO, Montpelier, France
g. Climate change - Kansas State Univ, USA, Utrecht Uni., Netherlands, Univ. of Basel, Switzerland, Colorado State Univ., USA
h. Nutrient Management - IRHO, Montpelier, France
i. Integrated Pest Management. - International Agril. Centre, Wageningen, Netherlands
j. Pollinating Weevils - IDEFOR, Ivory Coast
k. Disease Management - CIRAD-OP, France, IDEFOR, Ivory C oast
l. Post Harvest Technology - MPOB, Malaysia

Interaction and Linkages

Indian Institute of Oil Palm Research has collaboration with different institutions for educational, research and infrastructural facilities. IIOPR is linked with State Agricultural Universities and other Universities and their Research Centres. Eligible Scientists of IIOPR have registered themselves as bonafide Research Guides at these Universities. Selected Post Graduate students from colleges of different states are provided space for doing their project work at IIOPR. IIOPR conducts research work in collaboration with CIAE, Bhopal, CPCRI, Kasaragod, IIHR, Bangalore, IIOR, Hyderabad and State Agricultural Universities. For the purpose of dissemination of technology, the Institute is linked with Krishi Vigyan Kendras, processing units and Local Government Institutions. It is proposed to establish/strengthen linkages with the following organizations:

Prioritized Topic	Foreign Institute
Collaborative research particularly inter country varietal trial and training; Getting expertise in Processing Technology; High yield potential genetic resources	MPOB, Malaysia; NIFOR, Nigeria
High yield potential genetic resources	MPOB, Malaysia; Palm Oil Research Institute. Indonesia; DAMI, PNG; IDEFOR, Ivory Coast
Seed garden establishment with high yield potential genetic resources; Getting parental seeds of *E. guineensis* and *E. oleifera* - especially for dwarfness and compactness	ASD, Costa Rica
Collaborative efforts in germplasm exploration	NIFOR, Nigeria
Areas of collaboration	**National Agency**
Genomics, Seed research, Hybrid varieties, Planting material production, Bio-technological research and training, Climate change, Fibre utilization, Precision farming, Farm mechanization, Nanotechnology, Water management, Waste management, E-Extension and Agricultural Knowledge Management	Other ICAR Institutes
Processing and product development, By-product utilization and Nutritional studies	CIPHET, Ludhiana, CFTRI, Mysore, NIN, Hyderabad and State Agricultural Universities
Strengthening Training programme, Front-line demonstrations and adaptive research	TMOP, Govt. of India; various stakeholders of oil palm sector

Physical and Infrastructure Facilities Proposed to be Developed

The following infrastructural facilities in the Institute are to be strengthened with respect to the emerging challenges and research gaps in oil palm:

a. At present, land for undertaking new experiments is a major constraint at the Institute. Being a perennial crop, large areas of land is required for undertaking research particularly on progeny evaluation trials, fertilizers, irrigation, fertigation, precision farming, etc.

b. Construction of a new building for housing a common equipment facility is very much required so that all the scientists could use the facilities.

c. Water shortage is very acute during summer and arrangements need to be done for creating adequate irrigation facilities at IIOPR main campus.

d. Development of a repository for pollen for short term storage of pollen of all the existing pisiferas so as to aid in hybrid seed production in all seed gardens of the country.

e. Image analysis system with rhizotrons and canopy analyzer will help in simulation and modelling oil palm based cropping system in juvenile and adult phases.

f. Radio isotope laboratory will be very useful for understanding nutrient uptake and estimation of photosynthetic enzymes in oil palm.
g. Inductive coupled plasma analyzer will be useful for elemental analysis and could boost the existing leaf analysis laboratory in saving time.
h. Procurement of advanced software for simulation modelling will help in undertaking advanced physiological studies for growth and yield.
i. With respect to studies on climate change in oil palm, flux towers need to be installed for undertaking Eddy Covariance studies and FACE/FATE facilities for CO_2 enrichment studies.
j. Establishment of a pheromone laboratory with GC and EAG facilities for pheromone identification coupled with evaluation of synthesized pheromone.

Enabling Policy Environment

Honourable Prime Minister of India in his address in the Foundation Day Programme of ICAR held during July, 2014 emphasized that adequate steps are to be taken to ensure that the country becomes self sufficient in pulses and oilseeds production by 2030. In this task, oil palm could play a major role in view of its high productivity potential. For achieving the target, it shall be ensured that the Oil Palm Area Expansion programme is adequately strengthened along with measures for improving productivity in different parts of the country. The present area expansion target could be enhanced from 25,000 ha per year to 1.50 lakh hectares per year so that the entire potential area of 2.00 million hectares could be covered before 2024. Concurrently, efforts for improving the productivity of oil palm as well as from annual oilseed crops are also to be intensified. Thus, by 2030, out of the total vegetable oil requirement of 29.05 million tonnes, 7.20 million tonnes (about 25%) would be contributed by oil palm and the balance quantity could be made available through annual oilseed crops and other sources. In addition, the following non-price recommendations of CACP, submitted to Govt. of India in 2012, could also be considered for implementation:

I. It is recommended to keep the import duty trigger at US$ 800/MT, i.e. if and when the import price falls below US$800/MT, immediately the import tariffs need to go up and it be counter-cyclical to international prices.
II. As OER varies a great deal from one garden to another and average OER de-motivates efficient farmers, it is recommended that FFB

Testing Centre be established in each oil palm industry, test every consignment of FFB for their Oil content (OER) and then industry may arrive at the consignment-specific price of the FFB, based on such test reports. These Testing Centers may be managed jointly by cultivators, processors with a nominee of the concerned state Government. This will induce and incentivize cultivators to adopt better farming practices and invest in modern technology.

III. Given that India is land scarce country, and the domestic production of edible oils from direct oilseed sources in the country is just 6.48 million MT with area coverage under oilseeds of more than 25.60 million ha., oil palm could be a hugely land saving strategy. Through the current mix of oilseeds, it implies that about 4 million MT of oil is being produced in the country by using 15.80 million ha. of land. This much quantity of palm oil could be produced from just 1 million ha. Thus, one million hectares under oil palm is akin to more than 15 million hectares under other mix of oilseeds. Currently, the country has only 1.7 lakh hectares under oil palm, while the potential identified for it is one million hectares. If additional 8 lakh ha. of area is brought under oil palm cultivation (to make it approximately one million ha.) by scaling up incentives in a big way, together this one million hectares of oil palm can produce 4 million MT of palm oil, which could result in savings of imports to the tune of Rs. 22,458 crore at current prices. Since the fruit bearing life of oil palm is roughly 27 years, cumulated over this period, the foreign exchange savings at current prices will be worth about Rs. 6,06,360 crores (i.e., US $ 117 billion). Given this potential saving in foreign exchange, the country needs to invest to reap this potential benefit through customized public investment strategy as indicated in para (vi) hereunder.

IV. Two important constraints that seem to impede area expansion programme under palm oil are opportunity cost of land of farmers and high cost of irrigation. Compensating farmers for opportunity cost of their land @ Rs. 30,000 per annum per hectare during lock-in period of three years and providing one time subsidy for irrigation system @ Rs. 36,000 per hectare, which would have a financial implication of the order of Rs.10,080 crores (less than US $ 2 billion) in next six years, would bring additional 8 lakh hectares of area under oil palm. And in return it can save the foreign exchange outgo worth US $117 billion. Based on sound economic principle of rationality and long term vision, it is strongly recommended that the Government should earmark Rs. 10,080 crores (less than US$2 billion) for providing subsidy/support to compensate cultivators for opportunity cost of their land and one time irrigation investment so as to expand the oil palm programme in a big way. Out of this outlays, Rs. 9,480 crores would be required in the XII Five Year Plan and the remaining Rs. 600 crores would spill over to the first year of XIII Five year Plan. This public policy would not only serve as a strategy for import substitution in a cost effective manner but also augment farmers' incomes and thus would be in the best interest of the country's agriculture sector.

V. Since the underlying basis of pricing formula rests in the relative costs of production of FFBs and their processing into oil, a more robust scientific survey of costs needs to be undertaken on priority basis, and on annual basis. For this purpose, collection of quality data in a structured form based on sound statistical sampling design is inescapable. This database should have four important ingredients *viz.* transparency, timeliness, reliability and adequacy. The current mode of collecting the cost data through DES (for other crops) does not fully satisfy these criteria, and therefore sometimes is mired in controversy. An alternative way to collect requisite data through an outside agency of repute on outsourcing basis under the overall supervision and monitoring of price recommending authority (such as CACP in this case, which is the prime user of this cost data) is the need of the hour. Besides, senior officers of the Commission may be drafted to other major oil palm producing countries to deepen the understanding of dynamics of this crop in its entirety. All this would help evolve "efficiency norms" in the production and processing of FFBs. Accordingly, suitable adjustments can be done in the formula where efficient producers and processors are rewarded.

VI. Looking at the global experience in oil palm, especially in Indonesia and Malaysia, where both the household farmer model as well as corporate model of oil palm farming are practiced, it would be good for India too to experiment with both models. For the corporate sector to enter oil palm, we suggest that oil palm be declared as a plantation crop so that corporates can lease in land on longer term basis, and internalize costs of production and processing of FFBs. This would give them better cushion to weather external shocks of global prices. Given the financial and managerial strength of the corporate sector, and higher capacity to undertake risks, this model may take off even faster than the household model alone.

Expected Outcome

Strengthening of oil palm research at IIOPR and other related organizations in India would lead to the following:

- Development of hybrids with higher yield potential, resistant to biotic and abiotic stresses.
- Self sufficiency in quality planting material production.
- Efficient nutrient and water management technologies.
- Effective use of bio-control agents for pest and disease management.
- New harvesting tools and machineries.
- Processing technologies for effective utilization of oil palm products.
- New technologies are expected to play a critical role in improving oil palm production and increasing the sector efficiency in the country.

The programmes have been formulated to initiate need based research for meeting the future targets and challenges. New programmes are identified mainly in the areas of development of improved oil palm hybrids with high yield potential, efficient nutrient and water management technologies, integrated farming system models for enhancing the economic returns from oil palm gardens, use of bio-control agents for pest and disease management in oil palm and harvest and processing technologies for effective utilization of oil palm products. Emphasis is also given on achieving self sufficiency in quality planting material production of improved hybrids from different centres. The new technologies to be developed from the proposed programmes are expected to play a pivotal role in overall improvement of oil palm production in the country.

The agricultural paradigm is already undergoing a shift with focus from cereal production to diversified farming. Oil palm besides improving biological productivity and nutritional standards also has enormous scope for enhancing profitability as well as employment potential. Past investment in oil palm research has been rewarding in terms of increased production and productivity of oil palm. However, challenges confronting oil palm sector are still many. Although, the country's vegetable oil consumption level is still continuing to be below the dietary requirements, with increase in per capita income and accelerated growth of a health conscious population, demand for vegetable oil will increase progressively and is expected to further accelerate, which will call for more production. But the production has to be competitive both in terms of quality and price. Thus, the potentialities, which exist, need to be harnessed and gains have to be sustained. Development of improved hybrids with high productivity, quality characteristics, resistance to pests and diseases and tolerance to abiotic stresses need prime attention. The technologies must improve the efficiency of water and nutrients and reduce variability in yield fluctuations and quality and also reduce post harvest losses. Efforts will also be needed to ensure self sufficiency in production of quality hybrid seed and planting material. Consequently, oil palm development has to be seen as an integrated approach, addressing the important gaps, in harnessing the potential through targeted research with focus on enhancing efficiency. Thus, technology driven oil palm development is expected to address the concern for complimentary and nutritional security leading ultimately to economic prosperity.

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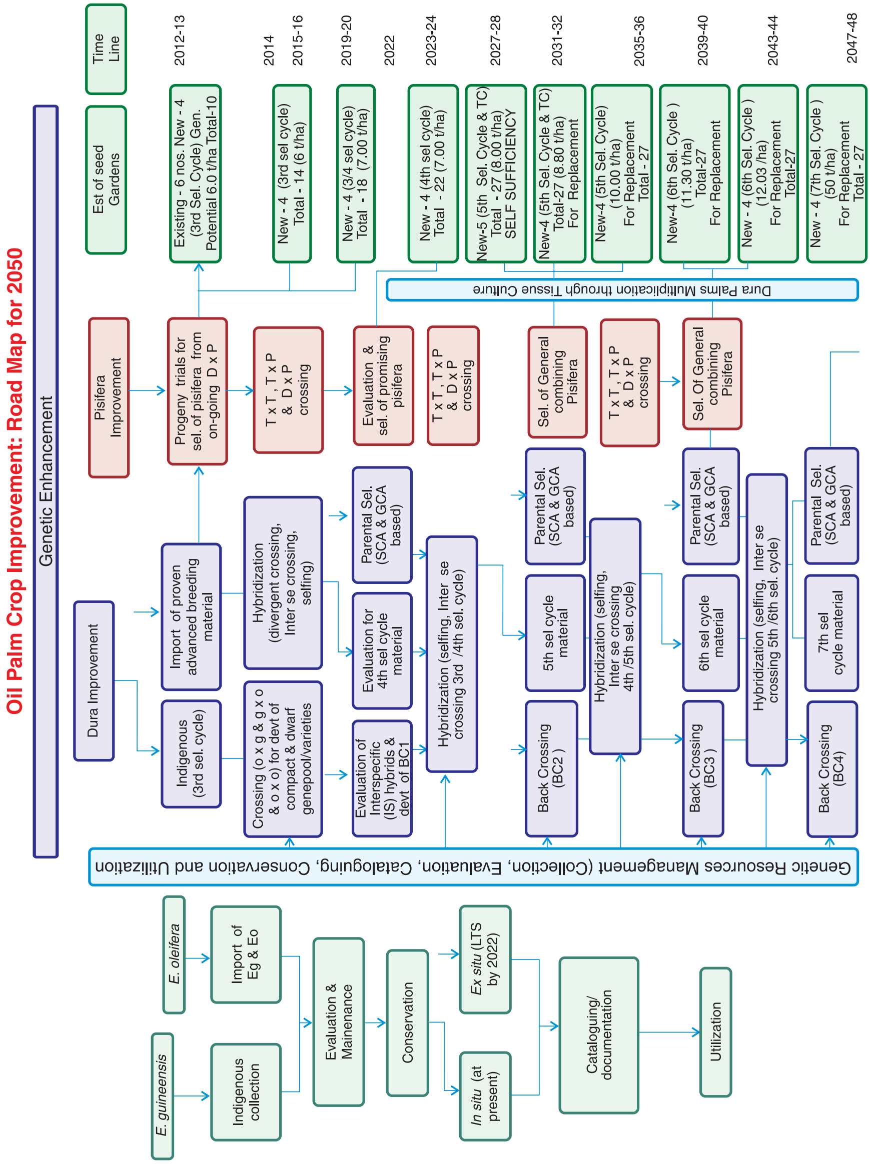
Oil Palm Crop Improvement: Road Map for 2050
Genetic Enhancement
Est of seed Gardens
Time Line
Dura Improvement
Pisifera Improvement
Indigenous (3rd sel. cycle)
Import of proven advanced breeding material
Progeny trials for sel. of pisifera from on-going D x P
Existing - 6 nos. New - 4 (3rd Sel. Cycle) Gen. Potential 6.0 t/ha Total-10
2012-13
Crossing (o x g & g x o & o x o) for devt of compact & dwarf genepool/varieties
Hybridization (divergent crossing, Inter se crossing, selfing)
T x T , T x P & D x P crossing
New - 4 (3rd sel cycle) Total - 14 (6 t/ha)
2014
2015-16
Evaluation of Interspecific (IS) hybrids & devt of BC1
Evaluation for 4th sel cycle material
Parental Sel. (SCA & GCA based)
Evaluation & sel. of promising pisifera
New - 4 (3/4 sel cycle) Total - 18 (7.00 t/ha)
2019-20
2022
Hybridization (selfing, Inter se crossing 3rd /4th sel. cycle)
T x T , T x P & D x P crossing
New - 4 (4th sel cycle) Total - 22 (7.00 t/ha)
2023-24
Dura Palms Multiplication through Tissue Culture
New-5 (5th Sel. Cycle & TC) Total - 27 (8.00 t/ha) SELF SUFFICIENCY
2027-28
Back Crossing (BC2)
5th sel cycle material
Parental Sel. (SCA & GCA based)
Sel. of General combining Pisifera
New-4 (5th Sel. Cycle & TC) Total-27 (8.80 t/ha) For Replacement
2031-32
Hybridization (selfing, Inter se crossing 4th /5th sel. cycle)
T x T , T x P & D x P crossing
New-4 (5th Sel. Cycle) (10.00 t/ha) For Replacement Total - 27
2035-36
Back Crossing (BC3)
6th sel cycle material
Parental Sel. (SCA & GCA based)
Sel. Of General combining Pisifera
New-4 (6th Sel. Cycle) (11.30 t/ha) Total-27 For Replacement
2039-40
Hybridization (selfing, Inter se crossing 5th /6th sel. cycle)
New - 4 (6th Sel. Cycle) (12.03 /ha) For Replacement Total-27
2043-44
Back Crossing (BC4)
7th sel cycle material
Parental Sel. (SCA & GCA based)
New - 4 (7th Sel. Cycle) (50 t/ha) For Replacement Total - 27
2047-48
Genetic Resources Management (Collection, Evaluation, Cataloguing, Conservation and Utilization
E. guineensis
E. oleifera
Indigenous collection
Import of Eg & Eo
Evaluation & Mainenance
Conservation
In situ (at present)
Ex situ (LTS by 2022)
Cataloguing/ documentation
Utilization

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