6th

SOUVENIR

MS SWAMINATHAN AWARD 2015-16

Environment, energy and sustainable production

RETIRED ICAR EMPLOYEES' ASSOCIATION

HYDERABAD - 500 060 TELANGANA INDIA

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M S Swaminathan Award - An Overview

The Retired Indian Council of Agricultural Research Employees' Association (RICAREA) was formed in 1997 to promote and further the ideals and objectives of the Indian Council of Agricultural Research (ICAR) by providing services to Governmental Agencies, NGOs, Public & Private enterprises, and farming community. The association is also serving as a pool of resource persons for scientific and extension bodies, besides bringing awareness of developments in science and technology among the farming community and general public. At present the Association has a membership of 325.

As part of the activities, RICAREA in association with Nuziveedu Seeds Ltd., Hyderabad, Andhra Pradesh has instituted a prestigious National award in the name of the living legend Prof. MS Swaminathan. This award carries a Cash prize of Rs. 2.0 lakhs, a Medal and a Citation. This is an important recognition to the agricultural scientists for their lifetime achievements and contributions to Indian agriculture.

The first MS Swaminathan award for the biennium 2004-2005 was presented to the leading Poultry Scientist Dr Genda Lal Jain on 27th October 2005. The second M.S. Swaminathan award for the biennium 2006-2007 was presented to Dr B S Prakash, NDRI Scientist on 3rd November 2007. The third MS Swaminathan award for the biennium 2008-2009 was presented to Dr S Nagarajan, wheat pathologist and Former Director, Indian Agricultural Research Institute, New Delhi (ICAR-IARI) on 14th November 2009. The fourth MS Swaminathan award for the biennium 2010-2011 was presented to Dr S R Sai Kumar, Ex Project Director, Maize, New Delhi and Dr N Shobha Rani former Principal Scientist and Head Crop Improvement ICAR-IIRR (Formerly known as DRR) Hyderabad on 19th May 2012. The fifth M.S. Swaminathan award for the biennium 2012-2013 was presented to Dr. Surender Lal Goswami former Director, ICAR-NAARM, Hyderabad. In all the five occasions Souvenirs with articles from leading scientists of different crops, disciplines were released.

In response to our letters we have received twenty one nominations from eminent scientists from all over the country covering Agricultural sciences and Animal sciences for the 6th MS Swaminathan award for the biennium 2015-2016.

The Selection Committee under the Chairmanship of Dr EA Siddiq unanimously selected Prof. RR Hanchinal, Chairperson of Protection of Plant Varieties & Farmers' Rights Authority, GOI, New Delhi. This Souvenir, sixth in the series is brought out to mark the occasion of the Sixth MS Swaminathan award presentation function. This Souvenir is a collection of invited articles apart the article of the awardee Prof. RR Hanchinal with the theme "Environment, Energy and Sustainable Production"

The Office Bearers and the Executive Committee members sincerely thank Sri M Prabhakara Rao, MD Nuziveedu Seeds and all the RICAREA members who have extended their unstinted support and encouragement. The Souvenir contains articles presented by experts from different fields. They will be useful to the general reader as well as professionals in Agriculture.

Editors

About Retired ICAR Employees' Association (RICAREA)

Retired Indian Council of Agricultural Research Employees' Association (RICAREA) was formed on 13-09-1997 with 22 members including 5 office bearers with Dr. E A Siddiq as its President. The Association was registered in Hyderabad under the Andhra Pradesh (Telangana areas) Public Registration Act 1350 Fasli (Act I of 1350 F November 22, 1997). Currently the Association has a membership of 325.

The Objectives of the Association are :

- To serve as a pool of resource persons for scientific and extension bodies.
- To bring about awareness of developments in science and technology among the farming community and general public.
- To recognize and felicitate outstanding scientists for their lifetime achievements.
- To safeguard the general welfare and to provide a forum for sustaining professional interest of the members.

Publications

Keeping in tune with the changing times a website (www.ricarea.org) was launched to disseminate information about all activities of RICAREA to members as well as other interested organizations.

A Newsletter containing information about current topics on Indian Agriculture, health and nutrition, Administrative matters and members' views is published and circulated to RICAREA members, ICAR Institutes, input agencies and NGO's.

A Directory of RICAREA members with addresses and phone numbers along wth other useful information about medical facilities,ICAR and its institutes etc. has also been published.

As part of the activities the Retired ICAR Employees' Association (RICAREA) has instituted a prestigious National award in the name of the Doyen of Indian Agriculture Prof. MS Swaminathan in 2004-2005. So far five awards in the years 2005, 2007, 2009, 2011, 2012 and 2013 were presented to leading Scientists in animal and Agricultural Sciences.

National Seminar

Realizing the urgent need to revamp the rural agricultural scenario to turn the farming into a productive activity, RICAREA have organized a two days' National Seminar on Integrated Farming Systems for Sustainable Agriculture and Enhancement of Rural Livelihoods on the 13th and 14th December 2015 in collaboration with the ICAR and National Academy for Agricultural Research Management (NAARM) at Rajendranagar in Hyderabad. Several organizations including ICAR, ITC, Nuziveedu Seeds Pvt. Ltd, ANGRAU, PJTSAU, NABARD, Satya Seeds, Bayer (India) Ltd., NAL and the ICAR Institutes located in Hyderabad came forward and extended their support for the Seminar. An Exhibition relevant to the theme of the Seminar was organized on the occasion in which the local ICAR Institutes and some voluntary organizations participated. Mrs.V Usha Rani, IAS, Director-General MANAGE inaugurated the Exhibition and chaired the proceedings of the Seminar. Dr. S Ayyappan, Director-General ICAR and Secretary to the Govt. of India (DARE) delivered the Keynote Address. Around 25 Expert Invitees who have worked in the area of Integrated Farming Systems, five successful progressive farmers, several scientists and research workers engaged in the area of Integrated Farming Systems and members of RICAREA participated in the Seminar. The Book of Abstracts of all the contributions was distributed to the participants and other interested agencies. Proceedings of the National Seminar has recently been published.

Annual Day

RICAREA Annual Day is beeing organized since 1998 in which members with their families also participate. A custom was started from 2001 onwards to invariably invite an eminent personality as Chief Guest for the function. The list of luminaries who graced the annual day function was Dr D. Bala Subramaniam (2001), Justice. G Raghuram (2002), Gen. KV Krishna Rao (2003), Dr. Kakarla Subba Rao (2004), Dr. YL Nene (2005), Dr. A Appa Rao (2006), Dr. A Panduranga Rao (2007), Dr. AV Gurava Reddy (2008), Dr Palle Rama Rao (2009), Dr. PK Joshi (2010), Dr P Krishnaiah (2011), Dr S L Goswami (2012), Dr. A Padma Raju (2013), Prof. V Rajani Kantha Rao (2014) Dr. D Rama Rao (2015) and Dr. WR Reddy, IAS (2016).

Members who have completed 75 years are being felicitated on the annual day. So far around 132 members have been felicitated with a Citation, a Shawl and a Memento.

Many members have contributed to the growth of this association. We place on record our fond memories of those departed and left an indelible mark on the growth and development of our Association. Among them are : Drs. B Venkateswarlu, PV.Ramana Murthy, KVP Rao, MJ Balakrishna Rao, TP Sriharan, NS Rao, K Vidyasagara Rao, APK Reddy, R Mallikarjuna Rao, Dr. MVS Sastry, Hon. Life time President, Dr. MV Rao, Dr. P.S. Reddy, NGP Rao and SS Narayanan.

The members who are actively associated and still contributing to the overall growth of the Association are : Prof. K Madhusudhana Rao, Dr. V Jaya Mohan Rao, Dr. S Indira, Dr. EA Siddiq, Dr. MV Gupta, Dr. MVR Prasad, Dr. GGSN Rao, Dr. K Krishnaiah, Dr. NP Sarma, Dr. U Prasada Rao, Dr. PSVV Vidysagar, Dr.VVS Murthy, Sri. VV Ramana Rao, Sri G Narayanappa, Dr. J Rama Krishna Rao, Dr. G Nagaraj, Dr. AGK Murthy, Dr. Y Muralidharudu, Dr. K Muralidharan, Dr. PR Vanamayya and Sri. T Damodaram. The Executive Body of the Association is able to function effectively due to the whole hearted support and help received from all the RICAREA members especially the past and present office bearers and executive members.

Executive Committee of RICAREA

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President

Dr. G.G.S.N. Rao
Vice-President

Dr. G. Nagaraj
General Secretary

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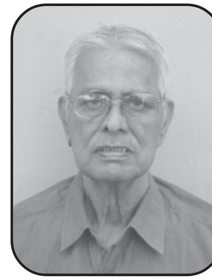

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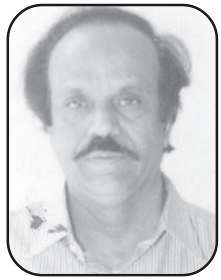

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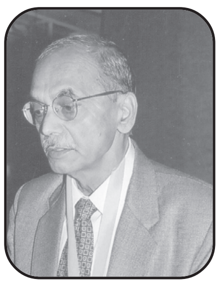

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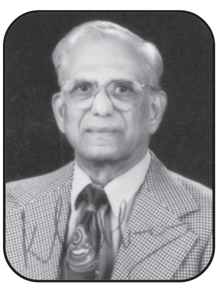
Dr. B.S. Prakash

Dr. V.L. Chopra

Justice G. Raghuram



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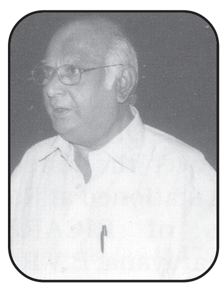

Sri A.Pandu Ranga Rao

Dr. A.V. Gurava Reddy

Dr. Palle Rama Rao

Dr. R.B. Singh

Dr. B.S. Dhillon

Dr. Surender Lal Goswami

Nuziveedu Seeds Limited - Highlights

During the year 2016-17, Nuziveedu Seeds Limited (NSL) has further made significant strides on all fronts in line with its vision to be the first choice of farmers. As the most preferred seed brand in India, NSL has further accentuated its crop breeding programs in rice, maize, cotton, millets and vegetables. With a robust product pipeline in all crops, NSL has made foray into two more new crops this year with test marketing of its products in redgram and Jute taking the total crops to 29 for which crop breeding programs have been initiated. NSL also plans to launch new cotton and vegetable products in test marketing before commercialization.

NSL's leading cotton hybrids Bhakti, Raja, Mallika, Puja, Malini, Super Raksha and Balwan recorded high sales growth in times when overall cotton acreage went down in 2016-17. Similarly NSL recorded higher sales growth in maize, paddy, bajra ,wheat, etc. NSL's maize hybrids Sunny, Bond, Sandhya and Shresta have further grown in their respective markets improving NSL's market share.

We have commenced a major project to develop insect resistant GM cotton technology as an alternative to the technologies that are available in the market.This alternative technology is also expected to correct some of the deficiencies in the technologies available in the market. Several new products in variouscrops like NBH 5812 and NBH 5817in bajra: NPH 2006 in Hybrid paddy; NP 3056 in OP paddy; NOKH 1003 in Okra; NCH 121 and NCH 6007 in chilli ; NTH 1009 and NTH 1813in tomato etc., were introduced in the market during the year. These new products will deliver value additions in terms of higher yield and tolerance to various biotic and abiotic stresses to our current product portfolio. The technological and scientific proficiency at NSL helped to develop breakthrough products at affordable prices. NSL's summer bajra product, MaxHot launched in Gujarat region in 2015, has performed well and is slated to grow further in the coming years. NSL's new products in vegetables such as Rajesh in tomato, Raja in cotton, Dragon in maize , Sunlight in sunflower and Simran in okra have all hit the growth path in their initial years of product life cycle and have gained wide acceptance across agro-climatic conditions in the country.

The financial year 2016-17 observed a second consecutive drought with a 14% rainfall deficit, among the worst in three decades. This had wide ramifications in agriculture and farm livelihoods. We continued with our efforts to make a difference to the lives of farmers through our products and services during the difficult crop season. During the year 2015-16, the Company reported an encouraging profitability with total revenue of Rs. 1,051.36 crore and net profit of Rs. 131.68 crore. 2015-16 was a year of consolidation for us with focus on cost optimization.

To strengthen the distribution network to optimize costs, the Company initiated distribution of products directly to distributors instead of C&F location or trans-shipment locations.This measure, in turn will help in the placement of right quantity of products directly to dealers, thereby reducing freight cost. This will also minimize goods returns, translating into freight savings. Our sales primarily come from cotton seeds. However, the Company took a conscious decision to enhance sales of other crops, thereby reducing dependence on cotton. Accordingly, the Company's cotton to non-cotton sales mix shifted from 80:20 in 2010-11 to 67:33 in 2015-16, which further is aimed at achievement of 60:40 by 2018-19.

NSL's national presence is backed up by a strong and decentralized supply chain. Nearly 6000 seed growers produce improved seed supplied to them from NSL R&D. The seeds sourced from seed growers across several locations feed the 11 processing plants of NSL which have been established in different regions of the country to meet the local demand. With nearly 88000 sq ft of ambient storage and 36000MT of cold storage, NSL has world class seed storage infrastructure to effectively meet the market demand. NSL has commissioned the Aurangabad conditioned storage facility and the Lucknow processing facility during the year and started full-fledged operations at these facilities. The strong and efficient supply chain enables NSL to smoothly operate with its 10 marketing offices through a network of 2200 distributors and 50000+ retailers, who help us reach nearly 5.5 million farmers in 19 States of the country. NSL has also further strengthened its presence in international markets with significant sales growth in Bangladesh, Pakistan and Indonesia.

NSL has also been consistently ranked as the leading Bio-Agri company since 2009 by the Annual Biospectrum Biotechnology industry survey and has been considered in 2015-16 also. In addition to the recognitions, NSL has also been awarded for the best company display stall at the national level agriexposition, the Rastriya Krishi Unnati Mela held at Indian Agricultural Research Institute, New Delhi. Further NSL also got best stall display awards at Pantnagar Krishi Mela, another national level event. In addition to accolades in sales and marketing events, NSL has also been consecutively adjudged as the best private sector R&D in maize in 2013-14 and 2014-15 in the All India coordinated Maize Improvement Project Workshops. Our Seed Testing Laboratory at Kompally has continued its ISTA (International Seed Testing Association) accreditation in good stead in 2016-17 and has been among the six ISTA accredited labs in India.

NSL has also further embarked on enhancing its Customer relationship management (CRM) through use of Information Technology and has commissioned for a Field Force Monitoring software application for sales and marketing staff. Further NSL has also strengthened it barcode system of product traceability and extended it to all field crops in addition to Cotton. In addition to operations software, NSL launched a new integrated HR management software called as “HRWHIZZ” as a single point information source for all employee needs.

NSL has actively participated in Corporate Social Responsibility (CSR) initiatives in the fields of rural development, promotion of sports and culture, healthcare, education, preserving cultural heritage, etc. The “Subeejkrishivignan” (SKV) program under CSR is a unique program by NSL which provides for extension services and awareness programs to farmers with a goal to improve farmer profitability.

The Indian Seed Industry: Achievements and Way Forward

R.R. Hanchinal

Indian agriculture has made spectacular progress in the last six decades. The food grain production has increased from 50 million tons in 1950 to 264 million tons in 2013-14. The country has advanced from a situation of food scarcity and imports to that of food security and exportable surpluses. The "green revolution" has been universally acclaimed as a successful enterprise of the farmers, the scientists and the government. However, the growth of agriculture sector has not kept pace with the growth of the population and has stagnated. The slow growth of agriculture, apart from serious implications for food security of the nation, has been adversely impacting the growth rate of country's economy. The imperative of National food security, nutritional security and economic development demand a very focused and determined approach to raise productivity and production in agriculture. In view of the fact that the area under cultivation is unlikely to increase significantly, thrust will have to be on raising productivity per unit of cultivated land. Around 17 percent of world population is in India with only 2.4 percent global land area and 4 percent water bodies.

Seed is the critical and most important input in agriculture that acts as a catalyst for all other inputs to realize higher productivity in any crop species. Without good quality seeds, the investment on all other inputs will not furnish desired dividend. The direct contribution of quality seeds to the total production is around 20 percent.With efficient management of other inputs *viz.*, water, fertilizer, plant protection, growth regulating chemicals etc., the added dividend in production can be raised to 45 percent.Even the importance of quality seed in agriculture has been recognized as early as vedic period (*Yajurveda*). In one of the ancient books on Indian Agriculture, Parashara (400 BC) states "Origin of Plentiful Yield is Seed". Later Manu (200 BC) in his scripture "*Manu Smriti*" also mentions the importance of quality seeds as "*Subijam Sukshetre Jayate Sampada Yete*" which means good seed in good soil yields abundantly. Hence the importance of seed has gone up with the passage of time for greater realization of crop productivity. Inspite of release of several improved varieties/hybrids in each crop, their spread among the farming community is not satisfactory resulting in the wastage of huge resources spent on the development and release of such varieties / hybrids over a long period. It could be because of the lack of seed availability in sufficient quantity or non-performance of released variety/hybrid in farmers' fields-due to late sowing etc. In view of these facts timely availability of quality seeds of improved varieties/hybrids at right place in adequate quantities in required pocket size at affordable price is crucial in realizing the better performance and decides the health of an Indian agricultural economy.In order to address these challenges, seed sector has to play an important role in improving agricultural productivity on sustainable basis, through

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application of innovative and frontier technologies.

Evolution of the Indian Seed Industry

India has a long history of informal seed systems. When cultivation of farmers/ traditional varieties was a common practice, the farmers used to apply selection pressure in their fields, select healthy and productive heads/ plants, keeping adaptability, resistance to biotic and abiotic stresses, quality and taste in their mind, store the seeds separately and use in subsequent season for sowing. For multiplication and use India had a unique *sui generis* system of save, use, sow, re-sow, exchange, share and sell farm produce including seed locally in the village or in weekly markets.

To have a robust seed system to attend to challenges posed by increase in population growth and low productivity of crops, in the 1950s, Government of India requested the Rockefeller foundation and United States Department of Agriculture to provide technical support for systematic plant breeding research to boost the productivity in field crops. As a result, during 1957, first All India Co-ordinated crop improvement project in maize was started and in 1961, first four maize hybrids were released which laid the foundation for organized seed industry in India.In 1963, the National Seeds Corporation Ltd. (NSC) was established. This became the first public sector seed company to be started in the country, primarily to produce the foundation/certified seeds of Maize hybrids and subsequently pearl millet (bajra), sorghum (*jowar*) and other crops.

Duringn the early 1960s, to attend to the food security issues, Indian government imported semi dwarf wheat varieties developed at the International Maize andWheat Improvement Centre (CIMMYT) Mexico, and promoted for cultivation in the farmers' fields. Subsequently the introduction of high yielding rice varieties altered the Indian Agriculture to move forward for attaining food security which led to the most eventful scenario of "green revolution". This positive development made the policy makers to think of regulatory issues to control the supply of quality seeds to farmers. For this purpose, the seed review team was constituted to prepare a draft for seed laws, which in turn led to the enactment of seeds Act 1966 and formulation of Seed Rules in 1968. The formation of the National Commission on Agriculture promoted the Seed activities. Further the Seeds (control) order 1983 helped in regulating the quality of seeds available in the market. The responsibility of seed law enforcement is vested with the state governments. The seed Act/Rules are applicable to extant notified variety/seed hybrid (section 5 of the Act) seeds. The first set of varieties was notified on September 29, 1969 (S.O. 4045). To day in 164 crop species, 8187 varieties have been notified. The details of varieties notified in different groups of crop species is presented in Table-1.

Table: 1. Details of extant notified varieties as per Seed Act 1966.

S. No.	Category (Crops)	No. of varieties
1.	Cereals (03)	2165
2.	Pulses and Millets (16)	3194
3.	Oilseeds (16)	1605
4.	Fibers (06)	624
5.	Vegetables (10)	414
6.	Sugar crop (01)	99
7.	Cash crop (01)	2
8.	Flower (01) &Fruit (01)	5
9.	Forage crops (21)	79
	Total	8187

The Seed Act-1966 provided the required impetus for the establishment of state seed certification agencies. Under the control of the Department of Agriculture the Maharashtra state was the first to establish seed certification agency during 1970, whereas Karnataka state was the first to establish the state certification agency as an autonomous body during 1974. According to the survey, conducted by IARI, New Delhi during 1988, no private seed company had been active in plant breeding before 1947. While between 1948 and 1970, only three seed companies began plant breeding research, and six seed companies began plant breeding research and seed related activities between 1971 and 1985 (Agrawal, 2012). The Seed Act brought a system in place to conform to a minimum stipulated level of physical and genetic purity and assured percentage of germination either by compulsory labelling or voluntary certification. Further the Act provided a system for seed quality control through Independent state seed certification agencies which were placed under the control of state departments of agriculture.Thus from a pre-dominantly public sector company (NSC) in the 1960's, the Indian seed sector evolved gradually in to a multifaceted industry with involvement of large number of commercial seed companies and investing more on research and development activities to develop their own products both in varietal and hybrid segments rather than simply depending on public institution Research and Development efforts (Hanchinal 2012).

New Policy Initiatives

The seventies and eighties witnessed significant reforms in the seed policies. The World Bank aided National Seed Program (1975-1985) was launched in three phases; in 1975; 1981 and 1985 leading to the creation of state seeds corporations, seed certification agencies, state seed testing laboratories, Breeder Seed programs etc. The state seeds corporations were formed on the model of the Tarai Seed Development Corporation. The state seeds corporations largely took over the role of NSC in their respective states. The National Agricultural Research System (NARS) has the responsibility of producing the breeder seed, which forms the backbone of the quality seed program to facilitate seed sector. Meanwhile the government of India realized that inspite of good infrastructure developed in the public sector (national/state seeds corporations and federations), there is need to involve private domestic seed companies in marketing so as to reach the farmers at the grass root level. The breeder seed of public bred varieties/ hybrids was allotted to the private sector for the production of foundation and commercial seed. This process is still continued particularly in the varietal segment.The new seed policy (1988) eased the regulations on import and exports of seeds. Although export restriction on seeds have been mostly removed, restrictions still apply on export of seeds of jute, onion, cotton, castor, fodder etc., as well as wild plant genetic resources/farmers' varieties for plant biodiversity reason. Export of seeds of the restricted category is allowed on a case to case basis under licence issued by the Directorate general of foreign trade on recommendations from the Department of Agriculture, Co-operation and Farmers Welfare, Government of India.From July 1991, foreign investors were allowed to establish equity participation up to 51% in private sectors including the seed sector. The new seed policy very much liberalized import of vegetables and flower seeds and also seeds of other commodities in a restricted manner and also encouraged the multinational companies/corporations centre into Indian seed business.

The export of seeds and planting materials is further liberalized under the Export and Import Policy (2009-14). Under the new EXIM policy, seed of all crops are allowed for free export except (i) Breeder or foundation seeds or seeds of wild plants; (ii) Seeds or planting material of onion, berseem, cashew, nux vomica, rubber, pepper cuttings, sandalwood, saffron, neem, forestry species, red sanders, russa grass, tufts and seeds of tufts. The export of these seeds (i & ii) is restricted and is only allowed on case-to-case basis.

Recently, Central Seed Committee, Ministry of Agriculture, Government of India also recognized the testing, evaluation and release mechanism of rice varieties of Bangladesh and Nepal and accordingly notified Binadhan 8, Binadhan10, Binadhan 11 and Binadhan 12 from Bangladesh for cultivation in West Bengal, Tripura and Assam through S.O. 921 (E) dated April 1, 2015 (Anonymous 2015b). Similarly, two varieties (Sukhadhan 5 and Sukhadhan 6) of Nepal were also notified for cultivation in Uttar Pradesh and Bihar. However, these six varieties were notified for the whole of India for the purpose of the Seed Act, 1966.

OECD Varietal Certification

The Organization for Economic Cooperation and Development (OECD), established in 1958 with its headquarters in Paris also provides an international framework for the certification of agriculture seed moving in international trade. The main objective of the OECD Seed Schemes is for the varietal certification of seed to encourage the use of "quality-guaranteed" seed in participating countries. Since October 2008, India is a member of the OECD Council. A total of 58 countries participate in the OECD Seed Schemes (Trivedi, 2012; Anonymous 2015f; www.oecd.org) which has 109 varieties of 20 crops from India.

ISTA Accreditation

International Seed Testing Association (ISTA) was founded in 1924, with the aim to develop and publish standard procedures to upgrade accuracy and reproducibility in the seed testing results throughout the world and is linked with the history of seed testing with member laboratories in over 70 countries world wide (Masilamani and Murugesan, 2012). ISTA is engaged in the development of standardized seed testing procedures in the form of International Rules for Seed Testing. ISTA rules are being used in our country for seed testing purposes. In India, the first Central Seed Testing Laboratory (CSTL) was established at IARI, New Delhi in 1960. Section 4(2) of the Seed Act, 1966 empowers the state government to establish one or more State Seed Testing Laboratories in the State. Presently, there are 124 state and 2 central laboratories in the country (Anonymous, 2014b; agricoop.nic.in). The central laboratories include National Seed Research and Training Centre at Varanasi and the laboratory at Central Institute for Cotton Research, Nagpur (for GM cotton only). Of these, one public (Seed Testing Laboratory, Department of Seed and Organic Certification Agency, Tamil Nadu) and five private seed testing laboratories (Bejo Sheetal Seeds Pvt. Ltd., Jalna; Indo-American Hybrid Seeds, India, Pvt. Ltd., Bangalore; Maharashtra Hybrid Seeds Company Ltd, Jalna; Nuziveedu Seeds, Hyderabad and Namdhari Seeds Pvt. Ltd., Bengaluru) have been accredited by ISTA. Further, 18 are ISTA member laboratories form India. The ISTA certification would facilitate seed trade from India in international market.

Protection of Plant Varieties and Farmers' Rights Act

India, being signatory of Trade Related Aspects of Intellectual Property Rights (TRIPS). Enacted PPV&FR Act, 2001 in compliance to Article 27.3(b) of TRIPS. Article 27.3(b) provided that the member countries must protect the plant varieties either by way of patents or *sui generis* or a combination of both. India chose the *sui generis* system of plant variety protection keeping in mind the national requirements and enacted "Protection of Plant Varieties and Farmers' Rights (PPV&FR) Act, 2001. The PPV&FR rules were notified in September 2003 and the Act came into force from November 2005. This legislation provides a more comprehensive framework for the Plant Variety Protection (PVP) containing several deviations from the International Union for Protection of New Varieties of Plants (UPOV) model. This is the only Intellectual Property (IP) law in India that gives dual proprietorship of IP on variety and its denomination. Another special feature of this legislation is that the protection accrues to a person from the date of filing of application for it gives priority and provisional protection. The objective of the Act is to establish effective system of plant varieties, rights of farmers and plant breeders and to encourage increased breeding activity, encouragement of new types of breeders such a private breeders, researchers and farmer breeders and to accelerate agricultural development in the country, protect plant breeders rights, stimulate investment for research and development both in public and private sector for the development of new plant varieties to facilitate the growth of seed industry which will ensure the availability of high quality seeds and planting material to farmers. The Act also recognizes and protects the rights of farmers in respect of contribution made at any time in conserving, improving and making available plant genetic resources for development of new plant varieties. The Act, provides an exclusive right on the breeder or his successor or his agent or licensee, to produce, sell, market, distribute, import or export the variety registered under the Act. A breeder may authorize any person to produce, sell, market or otherwise deal with the variety registered under this Act. The Act also provides researcher to use any of the variety registered under this Act for conducting experiments or research. However, authorization of the breeder of a registered variety is required where repeated use of such variety as parental line is done for commercial production of other newly developed variety.The Act treats the farmer also as plant breeder so far as the farmers' variety is concerned and they can register them under the Act. Other provisions of the Act are compulsory licensing and benefit sharing.

As per the Act, a breeder can register the new varieties, extant varieties notified under Section 5 of the Seed Act 1966, variety of common knowledge (VCK), farmer's varieties and essentially derived varieties. The progress in the receipt of applications from 2007 to 2015 is presented in table 2a &2b, which clearly shows that the commercial seed industry is very much aware of the Act and ahead for registration of varieties to get Intellectual Property Rights (IPR), in comparison to public institutions.

Table: 2a Institution-wise details of applications received in different categories of plant varieties for registration (IPR entitlement)

Category	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Public	287	322	193	31	125	129	141	136	89	1453
Private	143	220	368	505	295	266	534	420	420	3171
Farmer	2	5	127	4	941	304	1002	1964	1957	6306
Individual Breeder	0	0	0	0	0	0	0	0	2	2
Total	432	547	688	540	1361	699	1677	2520	2468	10932
Extant	358	390	384	106	274	254	255	196	181	2398
New	72	133	162	397	133	143	350	340	329	2059
EDV	0	19	16	33	15	0	71	22	2	178
Farmer	2	5	126	4	939	302	1001	1962	1956	6297
Total	432	547	688	540	1361	699	1677	2520	2468	10932

National IPR-Policy

India has a TRIPS compliant, robust equitable and dynamic regime to stimulate dynamic, vibrant and balanced IPR system and to create awareness about the importance of IPR as a marketable financial asset and economic tool, India released IPR-Policy on 12th May 2016. The National IPR-Policy assigned the following responsibilities to PPV&FR Authority to promote IPR in protecting plant varieties.

1. Support increased registration of new, extant and essentially derived varieties of plants and streamline procedures;
2. Facilitate development of seeds and their commercialization by farmers;
3. Establish links between the Authority and Agricultural Universities, Research Institutions, Technology Development & Management Centers and Krishi Vigyan Kendras;
4. Coordinate with other IPOs for training, sharing expertise and adopting best practices;
5. Augment awareness building, training and teaching programs;
6. Modernize office infrastructure and use of ICT

Players in Indian Seed Industry

The present Indian seed industry is quite vibrant, consisting of players from both public and private sectors. Public sector seed industry concentrates mainly on "high volume low value" crops. Infact over six decades the Indian public institutions have played a significant role in increasing the production and productivity in not only food crops but also in vegetables and fruits (Table-3).

Table: 3. Growth in agricultural production in six decades

Commodity	Production in 1950 (Million tonnes)	Production in 2013-14 (Million tonnes)
Food grains	50.00	264.38 mt
Vegetables	58.50*	170 mt
Fruits	28.60*	84.41 mt

*Base year is 1991-92

The best example that can be quoted is wheat, where in only with the efforts of breeders from public institutions,the production in wheat was increased from 10 mill tonnes in 1964-65 to 95.00 mill tonnes in 2013-14 (Fig. 1). In cross pollinated crops, with the introduction of new seed policy, investment in Research & Development was made by both public and private institutions. As a result the productivity was enhanced. In case of maize, marginal productivity increase was witnessed form 1950-51 (547 kg/ha) to 1990-91 (1518 kg/ha). This was mainly because the investment in research was mainly form public institutions. With the new seed policy in place commercial seed industry also invested in research and development. With the increased investment in a decades time, the productivity increased to 255.57 kg/ha (Table-4).

Fig.1 Incremental benefit in Production and Productivity of wheat due to conventional plant breeding activities over five decades

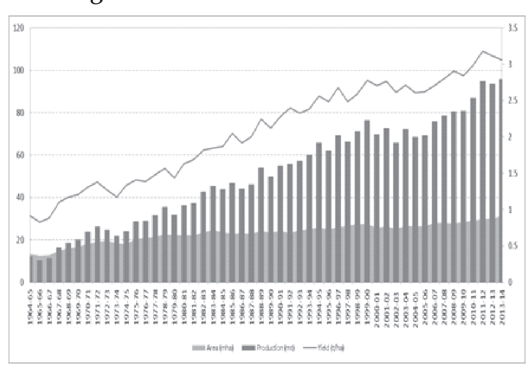


Table:4. Incremental benefit in production and productivity of maize due to public-private investment in plant breeding activities

Year	Area (m ha)	Production (m t)	Yield (kg/ha)
1950-51	3.16	1.73	547
1960-61	4.40	4.08	926
1970-71	5.85	7.49	1279
1980-81	6.01	6.96	1159
1990-91	5.90	8.96	1518
2000-01	6.61	12.04	1822
2010-11	8.55	21.73	2540
2012-13	8.67	22.26	2566
2013-14	9.43	24.35	2583
2014-15	9.07	24.26	2557

India also witnessed a unique experience of commercial seed sector alone increasing the yield levels in cotton. The introduction of Bt-in cotton, quickly spread the whole cotton growing regions of India with Bt-cotton hybrids. As a result, the area under Bt-cotton which was only 2 precent in 2002 with productivity of 302 kg/ha cotton lint increased to almost 92 percent with more than 490 kg/ha cotton lint yield in 2011(Table-5) which speaks the robustness of the technology (Kranti 2012). Today 98 percentage of the area in India is covered by Bt-cotton.

Table:5. Cotton yield increase with improved plant breeding activities by commercial seed industry

Year	Totalarea lakh ha	Bt area lakh ha	Bt area %	Lakh bales	Kg/ hectare
2002	78	0.294	0.38	139	302
2003	77.85	0.931	1.2	182	399
2004	89.2	4.985	5.59	246	470
2005	88.17	10.148	11.51	244	472
2006	91.73	38	41.42	281	521
2007	94.39	63.34	67.1	307	554
2008	94.06	76	80.8	289	524
2009	103.12	58	82.43	305	503
2010	111.61	101.2	90.67	339	517
2011	121.91	111.9	91.79	352	492
2012	-	121.78	91.8	353	489

The Achievements in Seed Production

Realizing the importance of quality seeds in enhancing the productivity in different "high volume-low value" crops, the government of India promoted a mega seed project during 2005-06 to promote quality seed production and supply throughout India. As a result, India could achieve a great success in making available the quality seeds including planting material and has ushered in significant positive impact in enhancing the quality seed to help seed and food security. It also facilitated in emergence of new seed hubs in many State Agriculture Universities/ICAR Research Institutes. The increase in availability of quality seeds also reflected in improved Seed Replacement Rate (SRR) in different crops mainly cereals, pulses and oil seeds where SRR was quite low before **(Table-6)**. Taking to 2004-05 as the base year, where average SRR was 22.4 percent, increased to 39.9 percent, which also reflected in productivity increase (Table-1). In crops like groundnut the SRR was increase from 7.1 percent in 2004-05 to 24.00 percent in 2014-15 which reflected on the availability of quality seeds with the implementation of mega seed project.

Table:6. Seed Replacement Rate (SRR) in important field crops, pulses and oilseeds over years after promotion of mega seed project.

Crop	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15
Wheat	16.5	17.6	21.8	25.2	26.8	31.9	32.6	32.6	33.8	34.9	35.5
Paddy	16.3	21.3	22.4	25.9	30.1	33.6	37.5	40.2	39.1	57.6	32.8
Maize	31.5	35.4	43.8	44.2	48.5	46.9	54.1	56.6	54.2	63.5	71.8
Jowar	19.3	19.0	194	19.9	26.2	26.3	25.9	23.9	26.0	28.0	40.1
Bajra	44.9	55.4	55.1	48.5	62.9	48.9	61.4	60.4	56.7	54.9	53.6
Ragi	28.1	24.7	23.6	30.3	36.1	7.9	40.2	40.1	44.7	25.5	52.4
Barley	8.9	10.6	14.3	16.8	26.9	28.2	26.6	56.5	29.1	19.8	28.6
Urd	17.2	15.7	13.7	23.9	26.3	30.9	29.2	34.4	34.0	49.6	30.3
Moong	12.3	12.5	20.0	21.8	21.9	23.0	26.7	30.3	32.4	49.6	23.6
Arhar	9.8	10.5	11.6	16.1	16.0	27.8	17.5	22.2	21.5	46.3	41.0
Peas	9.0	12.1	13.8	16.2	20.6	33.1	23.5	21.8	28.5	4.5	34.1
Gram	9.9	9.4	9.0	11.9	14.4	22.0	11.4	19.4	21.2	31.4	25.4
Lentil	14.7	12.8	15.3	15.9	18.1	16.9	22.6	20.2	21.5	34.1	31.5
Groundnut	7.1	6.9	9.8	14.3	17.0	23.0	24.5	22.5	24.9	25.4	23.7
Rape /must	58.5	55.4	60.7	58.6	52.7	74.8	63.6	78.9	57.3	51.3	54.6
Til	13.6	15.9	18.2	25.0	19.5	18.5	20.1	22.8	19.8	23.6	19.5
Sun flower	60.2	67.7	66.9	62.9	43.6	51.5	61.2	32.5	35.8	86.3	96.3
Soya bean	23.9	25.6	25.1	29.5	29.3	39.0	35.9	52.8	51.6	37.5	30.5
Castor	30.6	37.3	26.9	31.3	42.0	31.6	28.3	60.6	61.5	41.1	42.9
Saf flower	15.7	15.7	13.7	15.7	26.0	23.2	28.6	32.9	14.6	32.9	29.1
Average SRR	22.4	24.1	25.3	27.7	30.2	31.9	33.9	38.1	35.4	39.9	39.9

Before launching mega seed project, against the requirement of 110.83 lakh qtls in 2004-05 the availability of seed was 132.27 lakh quintals a surplus availability of 21.44 percent. With continued awareness among the farming community by NARS and developmental departments, increase in the demand for quality seed went up to 344.55 lakh qtls with production of 352.00 lakh qtls during 2014-15. Inspite of drought throughout the country, there was a demand for quality seeds **(Table-7).**

Table:7. Incremental trend in seed production in different crops (In lakh quintals)

Year	Requirement	Availability	Status
2004-05	110.83	132.27	+21.44
2005-06	107.08	140.51	+33.43
2006-07	128.76	148.18	+19.42
2007-08	180.74	194.31	+13.57
2008-09	207.28	250.35	+43.07
2009-10	249.12	279.72	+30.60
2010-11	290.76	321.36	+30.60
2011-12	330.41	353.62	+23.21
2012-13	315.00	329.00	+14.00
2013-14	335.00	347.00	+12.00
2014-15	344.17	352.00	+7.83

The above figures cover seeds of cereals, pulses, oilseeds, fibre, fodder and potato

This mega seed project to promote production of quality seeds by public seed sector also reflected in sharp jump in share of public seed sector in seed production from 77.25 lakh qtls in 2004-05 to 151.00 lakh qtls in 2014-15. However over the years, commercial seed industry developed better infrastructure facilities to overtake public institutions **(Table-8)**. This project also helped in developing strong linkages between public institutes with commercial seed companies.

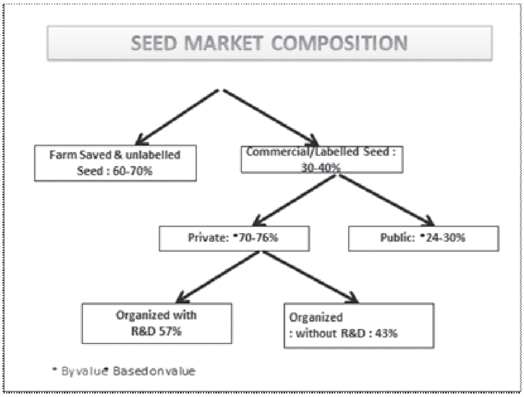
Indian Seed market composition

Inspite of huge investments in infrastructure by both public and private seed sector and supportive government seed development polices, still today around 60-70 percent of seed available is either farm saved seeds or unlabelled seeds. Commercial/labelled seed availability is around 30-40 percent, which speaks a great scope for bridging the gaps further. By value the contribution commercial seed industry is to the tune of 70-76 percent,whereas the contribution of public seed sector is to the tune of 24-30 percent. This difference is mainly because the commercial seed industry is mainly concentrating the activities in 'high value-low volume' crops namely: cotton, maize, sorghum, bajra, rice hybrids, sunflower, vegetables etc. (Fig. 2). Although commercial seed industry is investing in Research & Development activities, it is only to the tune of 57 percent. This may be because Indian commercial seed industry consists of more than 500 seed companies and many of them do not have strong Research & Development facilities and these companies still depend on public institutions for both in varietal and hybrid segment for their seed business.

Table:7. Incremental trend in seed production in different crops (In lakh quintals)

Year	Total seed production	Seed produced by public sector	Seed produced by private sector
2003-04	132.27	69.47	62.80 (47.5%)
2004-05	140.51	77.25	63.26 (45.0%)
2005-06	148.18	78.83	69.35 (46.8%)
2006-07	194.31	114.64	79.67 (41.0%)
2007-08	194.23	111.51	82.72 (42.6%)
2008-09	250.40	150.79	99.61 (39.8%)
2009-10	280.00	171.00	109.00 (38.9%)
2010-11	322.00	166	156.00 (48.4%)
2011-12	354.00	181.00	173.00 (48.9%)
2012-13	329.00	161.00	167.00 (50.9%)
2013-14	347.00	168.00	179.00 (51.6%)
2014-15	352.00	151.00	206.00 (58.8%)

Fig 2. Details of Indian seed market composition.



Global Status of Indian Seed Industry

Presently global seed market is estimated to be around US $ 45 billion and estimated growth by 2020 would be around US $ 92 billion. Interestingly 66 percent of global seed market is concentrated in five countries *viz*., USA, France, China, Brazil and India. About 75 percent of global seed market is in maize, soybean and vegetables. Present international seed export amounts to around US $ 10 billion with north America and Europe being the major exporters. During last one decade India achieved an impressive growth rate of 14-16 percent in seed market which is almost double of the global growth rate. Today Indian seed market is almost Rs. 16000 crore and with this growth rate Indian seed business may become third largest seed market in the worldwith almost US $ 3.50 billion by the year 2020. But in global seed business India stands 26th position with export of around US $ 67 million.Whereas small countries like Chile and Hungary are in 5th and 6th position. India imports seeds of field and vegetable crops to the tune of US $ 23 million and US $ 52 million respectively. Of the total export from India 50 percent is form maize and rice.

Strength of Indian Seed Sector

India is bestowed with tropical, sub-tropical and temperate climates, wherein all kinds of crops can be grown for seed production. This is an advantage. Through All India Co-ordinated Research Projects (AICRPs), India has so far released 8187 varieties and hybrids in different crops **(Table-1)**. India has a strong research base and network of public and private stake holders. India is also rich in Plant Genetic Resources (PGR) in all crop species which could be used for trait development. India also has bio-technology laboratories in public and private seed sectors to address the molecular breeding and trait development programs. India has a well established seed regulatory and legislative frame work. There are nearly 500 organized seed companies in the commercial seed sector with fairly good Research and Development facilities. In addition, there are 14 vibrant state seed corporations and a National Seed Corporation (NSC). For seed quality assurance, fairly a good network of 20+ Seed Certification Agencies and 126 notified seed testing laboratories and Quality Control System. In both public and private sector ISTA Certification Centres exist which help in seed quality control for export of seeds. India is a member of DECD, ISTA and ITPGRFA. Over 160 varieties in 37 crop species of five OECD schemes India has enlisted. This strength in seed sector can be taken as an opportunity.

The way forward

A systematic, strong and vibrant seed production system is needed to attend to sustainable food security. Increase in SRR to 35 percent in case of open pollinated varieties in self-pollinated crops; 50 percent and above in cross pollinated crop varieties and 100 percent in case of hybrids will certainly help in doubling the food grain production. Increase in variety replacement following a logical system of notified high yielding varieties/ hybrids will also add to the productivity gain.Upgradation of existing seed system is need of the hour to attend to the great challenge of reducing the usage of farm saved seeds which is almost 60-70 percent. An effective farmer friendly model should be developed to make available the quality seeds of improved varieties/hybrids timely at affordable price. Modified seed village model adopted first time at UAS Dharwad (Hanchinal *et al*., 2006) and participatory seed production models involving farmers may be the options. In tribal hilly regions, farmers' varieties /local varieties are still popular may be because of excellent quality associated with therapeutic/medicinal value, resistance to biotic and abiotic stresses, climate resilience and special attributes associated with these varieties. But as these varieties are not in the seed chain, efforts should be made to bring such varieties in informal seed chain with some amount of genetic purity through special maintenance breeding methods. These farmers' varieties are quite important in future breeding programs as they possess useful gene/gene blocks for certain traits. These varieties are the products of dynamic evolution in a target ecosystem and quite adapted to the region. Community seed banks for promotion of local varieties and community nursery banks for the promotion of planting material in case of tree species is one of the option to promote farmers' varieties. Enabling the resource poor farmers with quality seed and suitable production technology for sustainable livelihood is a big challenge which needs a concentrated focus. Since 82 percent farmers in India are small and marginal, providing quality seeds at affordable price is also a challenges as seeds produced by using varieties/hybrids with bio-tech traits are costly. To focus research on biotech traits in plant breeding which can be made available to resource poor farmers at affordable price, good infrastructure facilities are to be created and capacity building to undertake such advance research be given the priority. Forage crops are the most neglected once and effects should be made to bring them in effective seed chain. Restructuring quality assurance and quality enhancement system is need of the hour to maintain high standards of seed quality.

As Prof. MS Swaminathan in 2009 said "The "Second Green Revolution will depend on quality seed". There is an-urgent need to bestow attention by policy makers to promote healthy seed industry and achieve the second *green revolution* through seeds.

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Impact of Global Warming on Indian Agriculture

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Climate change is currently the biggest long term threat to food security and life on earth. Rise in environmental temperatures may drive thousands of species to extinction, trigger more frequent floods and droughts and sink low lying islands and coastal areas by the rising sea levels. It is the result of rising atmospheric Co_2 content mainly due to increased burning of fossil fuels. Destruction of forests and their degradation too contribute both directly and indirectly, to rise in carbon dioxide levels. The IPCC (2006) projected the rate of warming for the 21[st] century to be between 0.8 and 4.4 ^oC at various stabilized CO_2 levels in the atmosphere and it is most likely to be 2-3°C by end of this century. It could cost global economy almost $7 trillion by 2050, which is equivalent to a 20 percent fall in growth. If current actions are intensified/sustained, it can limit the costs, with reduced losses in future. Interestingly, latest reports of IPCC indicated that the rate of increase has slowed down in recent years when compared to long term average temperature, even though the current climatic conditions indicate a continuous increase in warming conditions year after year.

Increase in all-India mean temperatures is due to increase in maximum temperature (0.6^oC/100years) with minimum temperature remaining practically trendless. Consequently, there is a general increase in diurnal range of temperature. The rate of increase was more during the post monsoon season (0.87^0C), followed by winter (0.72^0C). Across different zones of the Country, the rate of increase was more in West Coast of India, followed by the Western Himalayas of India. In respect of rainfall, there was a slight decrease since last 50 years, the decrease being conspicuous in certain regions like the Northeast. It appears that rainfall cycle is advanced by two weeks, since increase in rainfall was noticed during May and June while it declined in July and August in North-West, West and Eastern parts of the Country. Further, it is noticed that though the annual rainfall remains about the same, an increase in high rainfall events and increase in inter spell duration has been visible in many regions across India. Futuristic analysis indicate a marked increase in rainfall and temperature in India during the current century. The maximum expected increase in rainfall is likely to be 10-30% over central India. Temperatures are likely to increase significantly towards the end of the century. It is expected to be more pronounced over Northern parts of India. The mean sea level rise is likely to be slightly less than 1mm/ year along the Indian coast. Greater number of high surges and increased occurrences of cyclones in post-monsoon period along with increased maximum wind speed are also expected as per reports from Ministry of Environment and Forests (MoEF), Govt. of India and Department of Environment, Food and Rural Affairs (DEFRA), U.K.

Climate trends since 1980 were large enough in many countries to offset a significant proportion of the potential increases in average crop yields due to technological advances, CO_2

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fertilization, and other factors. The AR5 report showed an estimated warming of global average temperature by 0.85°C since 1880 with the fastest rate of warming in the Arctic. By the end of the twenty-first century, the global surface temperature increase is likely to exceed 1.5 °C relative to the 1850 to 1900 period, for most scenarios and is likely to exceed 2.0°C for some of the scenarios. In addition, precipitation will become more variable, and episodes of extreme weather will become more frequent, intense and last longer. Projected climate change scenarios will affect crop productivity and also food security over the coming decades, more so in developing and under developed countries.

Earlier, the year 1998 was the warmest and declared as the weather related disaster year, which caused hurricane havoc in Central America and floods in China, India and Bangladesh. Canada and New England in the U.S suffered heavily due to ice storms in January while Turkey, Argentina and Paraguay with floods in June 1998. The 1997/1998 El Nino event, the strongest of the last century affected 110 million people and cost the global economy nearly US$ 100 billion. A string of 16 consecutive months saw record high global mean temperature in 1997-98. Statistics compiled from insurance companies for 1950-1999 showed that major natural catastrophes, which were weather related, caused estimated economic losses of US$960 billion. However, the global warming impacts persisted further and most of the losses were recorded in recent years since 1995 onwards, as the top ten warmest years occurred during the decade. Australia experienced a severe drought in 2002 and heavy crop damage, while Europe experienced the worst heat wave conditions during the year 2003.

The year 2005 was one of the historic worst warmest years on record for hurricanes in North America. In India, heavy downpour over Mumbai on 26th July, 2005 (Single-day the highest record rainfall of 944 mm) and 3rd September, 2005 over Bangalore; severe tropical storms in Andhra Pradesh in September; floods in Kerala, Karnataka, Maharashtra, Gujarat, Orissa and Himachal Pradesh during the Southwest monsoon (June-September), 2005 caused misery to people and devastated cropped area to a large extent in addition to losses of human lives. In contrast, 2005 was declared as a famine year in 24 sub-Sahara African countries due to drought and attack of locusts. The winter 2007 was the warmest in the Northern Hemisphere. The world had been recording the warmest years consecutively for the past few years. Out of 16 years during the current century, 13 years recorded as warm years, revealing that the global temperatures shot up year after year. The warmest year on record now is 2016, with 2017 indicating to overtake it. This year 2017 has already recorded the warmest January in the past 120 years and the signs of early summer are already visible across India with increased day temperatures and warm night temperatures, indicating that this would be a early and very hot summer.

The Indian agriculture is currently facing a host of challenges from the climate change and associated impacts on food security. Climate change projections for the mid-term (2012-2039) period for India indicate a 4.5 to 9.0 % yield reductions, which may roughly amount to 1.5% GDP per year. About 60% of India's total cropped area is still rain-fed and is thus strongly dependent on the vagaries of the monsoon and is highly vulnerable to impacts of climate change. Changes in climatic variables such as quantum of rainfall and increasing inter spell durations, above normal temperatures are thus having an adverse impact on agricultural productivity and farmers income. Even in the irrigated regions, especially in case of the major food crops like wheat, rice and potato, the increased day and night temperatures are adversely affecting their yields. Studies of Dr. M.S. Swaminathan and Dr.S.K.Sinha and also by Dr. P.K. Aggarwal showed that for every increase of 1^{0}C in mean night temperatures during the reproductive stage over the major wheat growing region of northern India, reduces growing season by 5 to 6 days and in turn reduces the wheat yields by 400 kg per hectare. This could mean a loss of productivity across the country by more than 4.0 million tons.

The Indian economy is mostly agrarian based and depends on onset of monsoon and its further behaviour. The year 2002 was an example to show how Indian foodgrain production depends strongly on the rainfall of July. This year was declared as the all-India drought year, as the rainfall deficiency was 19% against the long period average of the country and 29% of cropped area was affected due to drought. The *kharif* foodgrain production was adversely affected in 2002, by a whopping fall of 19.1%. Considerable drop in agriculture productivity was also observed during the monsoon seasons of 2009 and 2012. The Country experienced consecutive droughts during monsoon season in 2014 and 2015. The impact of El-Nino during 2015 was quiet evident with large agricultural regions like Marathwada, experiencing drought conditions and crop failure. Currently the southern regions are in the grip of deficit rainfall and drought conditions. It is mainly the occurrence of droughts and floods during South West monsoon across the high production regions of the country that affects foodgrain production to a greater extent. It is one of the reasons that the foodgrain production is not in tune with plan estimates to declare India as one of the developed countries. However, the Indian food grains production is likely to cross a record production of 270 million ton mark during the current year 2016-17 after stagnation around 250 million tons since last five years due to weather aberrations across the country. During this year greater focus was laid on increasing pulse production and the farmers responded by planting pulses along with traditional crops. Pulses were sown in 29 million hectares with record pulse production during 2016-17. However, the increasing temperatures during the cropping seasons are of great concern as they exert strong adverse affect on plant growth and productivity. Looking the warmest conditions being recorded in the 2016-17 cropping season, Dr. M.S. Swaminathan suggested that India should take significant measures to insulate major crops from the adverse impact of high mean temperatures as a step towards future food security for the country. He also cautioned that " our Country's Potato revolution by healthy seeds, during Aphid free season may be diluted if mean temperatures go up and aphids multiply. We should perfect the technology for growing potato crops from true biological seeds, to cope with increase in temperatures. " He also felt that actual mean temperature increase can be higher than the 1.5^{0}C as suggested by IPCC and said that anticipatory research and action cannot wait any further as there are clear cut evidences that indicate that future temperature regimes are likely to be higher as per the evidence we have been seeing for the last few years and the indications in 2017, recording the warmest January crossing over more than a century record.

To meet all these challenges being posed by the climate change and climate variability issues, India has to gear up its efforts to reach the farmers with technological innovations and provide timely help to the farming communities, especially the rainfed farmers, to empower them to meet the targets of the country to meet the food security issues, with sustained productivity inspite of the odds.

However, the farmers dependent on rainfed agriculture are in majority small and marginal and are less endowed in terms of financial, physical and social capital, limiting their abilities to adopt to these impacts of climate change. They need support in terms of knowledge empowerment, including adaptation measures and technological support that can increase their capacity to meet the challenges of climate change. Evolving climate resilient agricultural technologies, improved strategies for efficient management of natural and manmade resources, improved crop varieties will constitute an integral part of sustaining agriculture and meeting the challenges posed by climate change. Various combinations of food crop choices are currently being adopted by small and marginal farmers as a response to climate risk. These include some of the prevalent systems like inter cropping and mixed cropping, to reduce the risk. Recent studies on farmers food crop fortfolio in semi arid regions indicate that small farmers tend to choose less risky crops, while better endowed and wealthy farmers, with access to new technological innovations, come forward to meet the challenges of climate change and choose relatively riskier food crops.

To meet the challenges of climate change and especially to create resilience in agricultural production systems, ICAR had launched the National Innovations in Climate Resilient Agriculture (NICRA) project in 2011. The project aims to enhance resilience of Indian Agriculture to Climate Change and Climate Variability through Strategic Research, Technology Demonstration, Capacity Building and Sponsored projects. The aim of this project was to enhance the capacity building of Scientists and other stake holders in climate resilient agricultural research and its application and to demonstrate site specific technology packages on farmer's fields for their knowledge empowerment towards adopting to current and future climate risks in agriculture. The project had made successful inroads into various farming systems where the technological interventions were implemented in the farmers fields in a participatory mode.

The KVKs in these demonstration regions played a pivoted role under the guidance of ICAR, especially by CRIDA and the concerned ATARIs in implementing four key modules that focussed on Natural Resource Management, Crop Production, Livestock and Fisheries, and on Institutional interventions. Water harvesting and recycling through water saving irrigation methods, in-situ moisture conservation, improved drainage in flood prone areas and artificial ground water recharge. For meeting the challenges of thermal and moisture stress conditions on crop performance, introduction of drought/temperature tolerant varieties, advancing the planting dates and rescheduling the cropping patterns and adopting contingency crop plans to meet the aberrant weather situations, promoting inter-cropping systems with high sustainability index have been few of the technological interventions that have been successfully demonstrated. Similarly focus on livestock management included improved use of community lands for fodder production, improved fodder/feed storage and feed enrichment methods, introduction of genetically superior breed of small ruminants, improved shelters for reducing heat stress in livestock and preventive vaccination, introduction of backyard poultry for nutritional needs and income generation, all gave positive results enhancing the productivity from the demonstrated regions and improving the income of the farmers. Similar interventions in fish production, especially captive rearing of fish seed, optimization of stocking density of grass carp in IMC (Indian Major Carp) culture, use of lime and fertilizers for plankton development, water quality management in fish ponds, all proved to be successful interventiond that led to enhanced income generation to farmers. These interventions also helped farmers to gain knowledge on mechanization, custom hiring approaches, developing of seed and fodder banks. This enhancement of climate literacy among the small and marginal farmers enabled them to realize the importance of the interventions that can help them to adapt to meet the challenges of climate change. The efforts of NICRA helped in the capacity building of the farmers and village youth on climate resilience in agriculture and encouraged them to form village climate risk management centers, to meet the future challenges of climate change on agriculture, on their own. There is now a need to upscale these interventions and also provide value added agro advisories to farmers at block/ village level, so that more specific information, on their needs is provided to them on good weather management, besides linking them with the markets by creating efficient IT platforms for them, to engage with key players in the agriculture ecosystem, such as farmers in other communities, businesses buying the agricultural produce and good quality seed and other input suppliers.

Meeting the Future Challenges of Climate Change

Models on global warming indicate that rise in temperature is likely to be around 2^{o}C or more, by end of this century. It is also very likely that the extreme weather events like droughts and floods, cold and heat waves will keep on increasing in coming decades, in spite of the efforts by various countries to reduce the GHG emissions. The global economy will be adversely affected, as per the latest report of IPCC. If the sea level increase as projected happens, the coastal areas which are thickly populated will be in peril and for the existing population, the safe drinking water will be a great problem. Future climatic projections for India, show that monsoon onset dates are either likely to become earlier or not to change much. But, monsoon withdrawal dates are likely to delay, resulting in an extended monsoon season in many regions. El Nino is one of the factors often influencing the onset as well as performance of SWM. In most of the tropics including India, severe meteorological droughts develop preferentially during El Nino events. The recent model based studies on climate change and the occurrence of El Nino, showed the chances of doubling of its frequency in future. The whole climate change that is associated with increasing greenhouse gases and human- induced aerosols and the imbalance between them, may lead to uncertainty even in year-to-year monsoon behaviour over India. Therefore, there should be a determined effort from developed and developing countries to make industrialization environment-friendly by reducing greenhouse gases pumping into atmosphere, to a major extent. In the same fashion, awareness programs on climate change and its effects in various sectors *viz*., agriculture, livestock, poultry, fisheries, health, water, forestry, biodiversity and sea level and the causative role played by human beings in climate change, need to be taken up on priority so as to educate the public in taking measures that will act towards reducing the negative impacts of climate change. In the process, life style of people should change, so as not to harm Earth-Atmosphere continuum by minimizing the release of CFCs, and other GHGs into atmosphere. From the food security point of view, effects of extreme weather events on important food crops including animal, dairy and fish species are to be documented so that it will be handy to planners and weather insurance agencies in such re-occurrence events for mitigating the ill effects so as to sustain food security and rural livelihoods. Finally, we have to foresee these extreme weather events and prepare ahead to combat them so that the losses can be minimized under the projected climate change scenario.

Climate Change and Dryland Agriculture

B.Venkateswarlu

Climate change impacts on agriculture are being witnessed all over the world, but countries like India are more vulnerable in view of the high population depending on agriculture and excessive pressure on natural resources. The warming trend in India over the past 100 years (1901 to 2007) was observed to be 0.51^{0}C with accelerated warming of 0.21^{o}C per every10 years since 1970 (Krishna Kumar 2009). The projected impacts are likely to further aggravate the yield fluctuations of many crops with impact on food security and prices. Cereal productivity is projected to decrease by 10-40% by 2100 and greater loss is expected in *rabi*. There are already evidences of negative impacts on yield of wheat and paddy in parts of India due to increased temperature, increasing water stress and reduction in number of rainy days. Modeling studies project a significant decrease in cereal production by the end of this century (Majumdar 2008). Climate change impacts are likely to vary in different parts of the country. Parts of western Rajasthan, Southern Gujarat, Madhya Pradesh, Maharashtra, Northern Karnataka, Northern Andhra Pradesh, and Southern Bihar are likely to be more vulnerable in terms of extreme events (Mall *et al.* 2006). For every one degree increase in temperature, yields of wheat, soybean, mustard, groundnut and potato are expected to decline by 3-7% (Agarwal 2009). Water requirement of crops is also likely to go up with projected warming and extreme events are likely to increase.

Greater Vulnerability of Rainfed Agriculture

While climate change impacts agriculture sector in general, rainfed agriculture is likely to be more vulnerable in view of its high dependency on monsoon. Nearly 85 m ha of India's 141 m ha net sown area is rainfed. Rainfed farming area falls mainly in arid, semi-arid and dry sub-humid zones. About 74% of annual rainfall occurs during South-West monsoon (June to September). This rainfall exhibits high coefficient of variation particularly in arid and dry semi-arid regions. Skewed distribution has now become more common with reduction on number of rainy days. Aberrations in South-West monsoon which include delay in onset, long dry spells and early withdrawal, all of which affect the crops, strongly influence the productivity levels (Lal 2001). These aberrations are likely to further increase in future. The risk of crop failure and poor yields always influence farmers' decision on investing on new technologies and level of input use. Numerous technological (e.g. cropping patterns, crop diversification, and shifts to drought-/salt-resistant varieties) and socio-economic (e.g. ownership of assets, access to services, and infrastructural support) factors will come into play in enhancing or constraining the current capacity of rainfed farmers to cope with climate change.

Trends in Key Weather Parameters and Crop Impacts

Rainfall is the key variable influencing crop productivity in rainfed farming. Intermittent and prolonged droughts are a major cause of yield reduction in most crops. Long term data

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for India indicates that rainfed areas witness 3-4 drought years in every 10-year period. Of these, 2-3 are in moderate and one may be of severe intensity. For any R&D and policy initiatives, it is important to know the spatial distribution of drought events in the country. A long term analysis of rainfall trends in India (1901 to 2004) using Mann Kendall test of significance by AICRPAM, CRIDA indicate significant increase in rainfall trends in West Bengal, Central India, coastal regions, south western Andhra Pradesh and central Tamil Nadu. Significant decreasing trend was observed in central part of Jammu & Kashmir, Northern MP, Central and western part of UP, northern and central part of Chattisgarh. Analysis of number of rainy days based on the IMD grid data from 1957 to 2007 showed declining trends in Chattisgarh, Madhya Pradesh, and Jammu & Kashmir. In Chattisgarh and eastern Madhya Pradesh, both rainfall and number of rainy days are declining which is a cause of concern as this is a rainfed rice production system supporting large tribal population who have poor capabilities.

Temperature is another important variable influencing crop production particularly during *rabi* season. A general warming trend has been predicted for India but knowing temporal and spatial distribution of the trend is of equal importance. An analysis carried out by AICPRAM, CRIDA using maximum and minimum temperature data for 47 stations across India (DARE, 2009) showed that 9 out of 12 locations in south zone showed an increasing trend for maximum temperature, where as the north, only 20% locations showed increasing trend (Fig. 1). For minimum temperature, most of the stations in India are showing increasing trend. This is a cause of concern for agriculture as increased night temperatures accelerate respiration, hasten crop maturity and reduce yields. The increasing trend is more evident in central and eastern zones where rainfall is also showing a declining trend which is an area of concern and requires high attention for adaptation research.

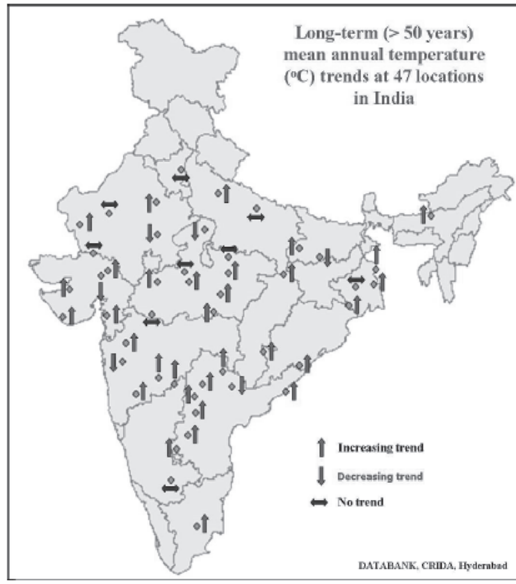

Fig. 1. Trends in mean temperature over different parts of India

Besides hastening crop maturity and reducing crop yields, increased temperatures will also increase the crop water requirement. A study carried out by CRIDA on the major crop growing districts in the country for four crops, viz., groundnut, mustard, wheat and maize indicated a 3% increase in crop water requirement by 2020 and 7% by 2050 across all the crops/locations for 2020 and 2050 based on HadCM3 model outputs.

Adaptation and Mitigation Strategies

Successful adaptation to climate change requires long term investments in strategic research and new policy initiatives that mainstream climate change adaptation into development planning. As a first step, we need to document all the indigenous practices farmers have been following over time for coping with climate change. Secondly, we need to quantify the adaptation and mitigation potential of the existing best bet practices for different crop and livestock production systems in different agro-ecological regions of the country. Thirdly, a long term strategic research planning is required to evolve new tools and techniques including crop varieties and management practices that help in adaptation.

The Indian Council of Agricultural Research (ICAR) has initiated a Network Project on Climate Change (NPCC) in X Five year Plan with 15 centers which has been expanded in the XI Plan covering 23 centers. The initial results of the project through crop modeling have helped in understanding the impacts of changes in rainfall and temperature regimes on important crops and livestock. Currently, the focus is on evolving cost effective adaptation strategies. More recently during 2010, ICAR has launched the National Initiative on Climate Resilient Agriculture (NICRA) as a comprehensive project covering strategic research, technology demonstration and capacity building. Targeted research on adaptation and mitigation is at nascent stage in India but based on knowledge already generated, some options for adaptation to climate variability induced effects like droughts, high temperatures, floods and sea water inundation can be suggested. These strategies fall into two broad categories *viz*., (i) crop based and (ii) resource management based approaches.

Crop Based Strategies

Crop based approaches include growing crops and varieties that fit into changed rainfall and seasons, development of varieties with changed duration that can over winter the transient effects of change, development of varieties for heat stress, drought and submergence tolerance; evolving varieties which respond positively in terms of growth and yield under high CO_2. In addition, varieties with high fertilizer and radiation use efficiency and also novel crops and varieties that can tolerate coastal salinity and sea water inundation are needed. Intercropping is a time tested practice to cope with climate variability and climate change if one crop fails due to floods or droughts second crop gives some minimum assured returns for livelihood security. Germplasm of wild relatives and local land races could prove valuable source of climate ready traits. We need to revisit the germplasm collected so far which has tolerance to heat and cold stresses but not made use in the past due to low yield potential.

Strategies Based on Resource Conservation and Management

There are large number of options in soil, water and nutrient management technologies which contribute to both adaptation and mitigation. Much of the research done in rainfed agriculture in India relates to conservation of soil and rain water and drought proofing which is an ideal strategy for adaptation to climate change. Important technologies include *in situ* moisture conservation, rainwater harvesting and recycling, efficient use of irrigation water, conservation agriculture, energy efficiency in agriculture and use of poor quality water. Watershed management is now considered an accepted strategy for development of rainfed agriculture. Watershed approach has many elements which help both in adaptation and mitigation. For example, soil and water conservation works, farm ponds, check dams etc. moderate the runoff and minimize floods during high intensity rainfall. The plantation of multi-purpose trees in degraded lands helps in carbon sequestration. The crop and soil management practices can be tailored for both adaptation and mitigation at the landscape level. Some of the most important adaptation and mitigation approaches with high potential are described below.

Rainwater Conservation and Haravesting

These are based on *in situ* and *ex-situ* conservation of rainwater for recycling to rainfed crops. The arresting of soil loss contributes to reduced carbon losses. Lal (2004) estimates that if water and wind erosion are arrested, it can contribute to 3 to 4.6 Tg year^{-1} of carbon in India. Increased ground water utilization and pumping water from deep tube wells is the largest contributor to GHG emissions in agriculture. If surface storage of rainwater in dug out ponds is encouraged and low lift pumps are used to lift that water for supplemental irrigation, it can reduce dependence on ground water Sharma *et al* estimated that about 28 m ha of rainfed area in eastern and central states has the maximum potential to generate runoff of 114 billion cubic meters which can be used to provide one supplemental irrigation in about 25 m ha of rainfed area. For storing such quantum of rainwater about 50 million farm ponds are required. This is one of the most important strategy not only to control runoff and soil loss but also contribute to climate change mitigation. Conjunctive use of surface and ground water is an important strategy to mitigate climate change. Innovative approaches in ground water sharing can also contribute to equitable distribution of water and reduced energy use in pumping.

Soil Carbon Sequestration

Soil carbon sequestration is yet another strategy towards mitigation of climate change. Although, tropical regions have limitation of sequestering carbon in soil due to high temperatures, adoption of appropriate management practices helps in sequestering reasonable quantities of carbon in some cropping systems particularly in high rainfall regions. The potential of cropping systems can be divided in to that of soil carbon sequestration and sequestration in to vegetation. Tree based systems can sequester substantial quantities of carbon in to biomass in a short period. Total potential of soil C sequestration in India is 39 to 49 Tg year^{-1} (Lal 2004).This is inclusive of the potential of the restoration of degraded soils and ecosystems which is estimated at 7 to 10 TgC year^{-1}. The potential of adoption of recommended package of practices on agricultural soils 6 to 7 Tg year^{-1}. In addition, there is also a potential of soil inorganic carbon sequestration estimated at 21.8 to 25.6 TgC year^{-1}. Long term manurial trials conducted in arid regions of Andhra Pradesh (at Anantapur) under rainfed conditions indicate that the rate of carbon sequestration in groundnut production system varied from 0.08 to 0.45 t ha^{-1} year^{-1} with different nutrient management systems (Srinivasa Rao *et al*., 2009). Under semi arid conditions in alfisol region of Karnataka, the rate of carbon sequestration was 0.04 to 0.38 t ha^{-1} year^{-1} in finger millet system under diverse management practices. Under *rabi* sorghum production system in vertisol region of Maharashtra (semi arid) the sequestration rate ranged from 0.1 to 0.29 t ha^{-1} year^{-1} with different integrated management options. In soybean production system in black soils of Madhya Pradesh (semi arid) the potential rate of carbon sequestration is up to 0.33 t ha^{-1} year^{-1} in top 20 cm soil depth.

Site Specific Nutrient Management

Integrated Nutrient Management and Site-Specific Nutrient Management (SSNM) is another approach with potential to mitigate effects of climate change. Demonstrated benefits of these technologies are; increased rice yields and thereby increased CO_2 net assimilation and 30-40% increase in nitrogen use efficiency. This offers important prospect for decreasing GHG emissions linked with N fertilizer use in rice systems. It is critical to note here that higher CO_2 concentrations in the future will result in temperature stress for many rice production systems, but will also offer a chance to obtain higher yield levels in environments where temperatures are not reaching critical levels. This effect can only be tapped under integrated and site directed nutrient supply, particularly N. Phosphorus (P) deficiency, for example, not only decreases yields, but also triggers high root exudation and increases CH_4 emissions. Judicious fertilizer application, a principal component of SSNM approach, thus has two fold benefit, i.e. reducing greenhouse gas emissions; at the same time improving yields under high CO_2 levels. The application of a urease inhibitor, hydroquinone (HQ), and a nitrification inhibitor, dicyandiamide (DCD) together with urea also is an effective technology for reducing N_2O and CH_4 from paddy fields. Very little information is available on the potential of SSNM in reducing GHG emissions in rainfed crops.

Conservation Agriculture (CA)

In irrigated areas, zero tillage (ZT) in particular has effectively reduced the demand for water in rice-wheat cropping system of Indo-Gangetic plains and is now considered as a viable option to combat climate change. ZT has some mitigation effect in terms of enhancing soil carbon, reducing energy requirement and improving water and nutrient use efficiency but actual potential has to be quantified from long term experiments. The scope of CA in rainfed agriculture has been reviewed by Singh and Venkateswarlu (2009). While reduced tillage is possible in few production systems in high rainfall regions in eastern and northern India, non-availability of crop residue for surface application is a major constraint, particularly in peninsular and western India where it is mainly used as fodder.

Bio-mass Energy and Waste Recycling

A large amount of energy is used in cultivation and processing of crops like sugarcane, food grains, vegetables and fruits, which can be recovered by utilizing residues for energy production. This can be a major strategy of climate change mitigation by avoiding burning of fossil fuels and recycling crop residues. The integration of biomass-fuelled gasifiers and coal-fired energy generation would be advantageous in terms of improved flexibility in response to fluctuations in biomass availability with lower investment costs. Waste-to-energy plants offer twin benefits of environmentally sound waste management and disposal, as well as the generation of clean energy.

Livestock production has been an integral part of agriculture in India. Livestock provides an excellent recycling arrangement for most of crop residue. Most by products of cereals, pulses and oilseeds are useful as feed and fodder for livestock while that of other crops like cotton, maize, pigeonpea, castor and sunflower and sugarcane are used as low calorie fuel or burnt to ashes or left in open to decompose over time. Ideally such residue is incorporated into soil to enhance physical properties of the soil and its water holding capacity. Lack of availability of proper chipping and soil incorporation equipment is one of the major reasons for the colossal wastage of agricultural biomass in India. Increased cost of labour and transport is another reason for lack of interest in utilizing the biomass. This is one area where little or no effort has gone in despite availability of opportunities for reasons such as aggregation, transport and investment in residue processing facilities. Many technologies like briquetting, anaerobic digestion vermin-composting and bio-char etc. exist, but they have not been commercially exploited. This area is gradually receiving attention now as a means to producing clean energy by substituting forest biomass for domestic needs. Modest investments in decentralized facilities for anaerobic digestion of agricultural residue through vermin-composting and biogas generation can meet the needs of energy-deficit rural areas and simultaneously contribute to climate change mitigation.

Biochar

When biomass is exposed to moderate temperatures, between about 400 and 500°C (a kind of low-temperature pyrolysis), under complete or partial exclusion of oxygen, biomass undergoes exothermic processes and releases a multitude of gases in addition to heat along with biochar. Pyrolysis produces biochar, a carbon-rich, fine-grained, porous substance and solid byproduct, similar in its appearance to charcoal, which when returned to soil, produces a range of environmental benefits, such as enhanced soil carbon sequestration and soil fertility improvement. Both heat and gases can be captured to produce energy carriers such as electricity, hydrogen or bio-oil which can be used as a fuel for various purposes in the process of manufacturing biochar. In addition to energy, certain valuable co-products, including wood preservative, food flavoring, adhesives etc. can be obtained.

This is a novel approach to sequester carbon in terrestrial ecosystems which has several associated products in the process of its manufacture and also the end product. In India, it has been projected that about 309 m t of biochar could be produced annually, the application of which might offset about 50 % of carbon emission (292 TgC year^{-1}) from fossil fuel (Lal 2005). Rice-wheat cropping system in the Indo-Gangetic plains of India produces substantial quantities of crop residues, and if these residues can be pyrolysed, 50 % of the carbon in biomass is returned to the soil as biochar, increasing soil fertility and crop yields, while sequestering carbon. Addition of biochar to soil has also been associated with enhanced nutrient use efficiency, water holding capacity and microbial activity. At CRIDA, research on biochar use in rainfed crops has been in progress for last 5 years. Biochar from castor, cotton and maize stalks was produced by using a portable kiln and used as an amendment for pigeonpea during *kharif* 2010. The crop growth was significantly superior in biochar applied plots from all three sources.

Agroforestry

Agroforestry systems like agri-silvi-culture, silvipasture and agri-horticulture offer both adaptation and mitigation opportunities. Agroforestry systems buffer farmers against climate variability, and reduce atmospheric loads of greenhouse gases. Agroforestry can both sequester carbon and produce a range of economic, environmental, and socioeconomic benefits; the extent of sequestration can be up to 10 t ha^{-1} year^{-1} in short rotation Eucalyptus, leucaena plantations. Agrisilviculture systems with moderate tree density with intercrops have however lower potential.

Policy Issues

Apart from the use of technological advances to combat climate change, there has to be sound and supportive policy framework. The frame work should address the issues of redesigning social sector with focus on vulnerable areas/ populations, introduction of new credit instruments with deferred repayment liabilities during extreme weather events, weather insurance as a major vehicle to risk transfer. Governmental initiatives should be undertaken to identify and prioritize adaptation options in key sectors (storm warning systems, water storage and diversion, health planning and infrastructure needs). Focus on integrating national development policies into a sustainable development framework that complements adaptation should accompany technological adaptation methods.

In addition, the role of local institutions in strengthening capacities e.g., SHGs, banks and agricultural credit societies should be promoted. Role of community institutions and private sector in relation to agriculture should be a matter of policy concern. There should be political will to implement economic diversification in terms of risk spreading, diverse livelihood strategies, migrations and financial mechanisms. Policy initiatives in relation to access to banking, micro-credit/ insurance services before, during and after a disaster event, access to communication and information services is imperative in the envisaged climate change scenario. Some of the key policy initiatives that are to be considered are: Mainstreaming adaptations by considering impacts in all major development initiatives

Facilitate greater adoption of scientific and economic pricing policies, especially for water, land, energy and other natural resources. Consider financial incentives and package for improved land management and explore CDM benefits for mitigation strategies.

Establish a "Green Research Fund" for strengthening research on adaption, mitigation and impact assessment (Venkateswarlu and Shanker 2009).

Conclusions

Even though climate change in India is now a reality, a more certain assessment of the impacts and vulnerabilities of rainfed agriculture sector and a comprehensive understanding of adaptation options across the full range of warming scenarios and regions would go a long way in preparing the nation for climate change. A multi pronged strategy of using indigenous coping mechanisms, wider adoption of the existing technologies and or concerted R&D efforts for evolving new technologies are needed for adaptation and mitigation. Policy incentives will play crucial role in adoption of climate ready technologies in rainfed agriculture too as in other sectors. The state agricultural universities and regional research centers will have to play major role in adaptation research which is more region and location specific while national level efforts are required to come up with cost effective mitigation options, new policy initiatives and global cooperation.

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Save our Soils for Sustainable Agriculture

J. Venkateswarlu

Introduction

We are losing about 4.9 ha crop land per minute through various degradation processes (Bai *et al,* 2008). It is the smallholder that is the most affected. Thus smallholder farming in less-favoured areas (LFAs) need to be considered on priority if sustainable development is the aim.

Further, droughts induce desertification. This is besides human indulgence in over exploitation of natural resources. It is pertinent to consider the climatic factors in land degradation. Sivakumar (2009) points out that the climate stresses result in rainfall extremes that would be variable leading to increased soil erosion and land degradation. Floods result in suspended sediments. High temperatures and winds with low relative humidity culminate in dust storms. Wild fires become more frequent.

While dealing with land and water management issues, Kerylenstierna (2009) pointed out that scarcity of water, food and energy besides economic security are all linked to land and water issues and thus to climate change adaptation. Many land and water issues are "local" while most of the discussions are on "global scale".

For instance, water is a state subject and groundwater is managed on individual basis. The CWS (Centre for World Solidarity) has shown that under limited groundwater (due to over exploitation), the community can come together to share water from the functional wells and this participatory groundwater management has been accepted by GoAP and being put on ground in the state on a pilot scale. In any case, water harvesting for upgrading rainfed agriculture is a large window of opportunity (Falkenmark *et al.,* 2001). Similarly we preach proper land use systems without considering that the poor largely own only class IV and above lands. The DDS (Deccan Development Society) and the NATP study of CRIDA have clearly shown that in such marginal lands farmers practice mixed cropping. They attempt to improve their soils overtime with the leaf litter and the sloughed off burrows of deep rooted crops like niger, castor, etc. besides adding fine soil like silt.

While discussing the options to face the dangers of Climate Change (CC), Holdren (2007) pointed out three options – mitigation, adaptation and suffering the adverse impacts. Neither of them singly can be a solution 'Mitigation only' strategy will not work because it is too late to avoid substantial CC. 'Adaptation only' strategy won't work because these measures are too expensive and less effective as the magnitude of CC is becoming larger. So win-win approach is the need. Measures to improve water conservation and water management have great value even in the absence of climate-driven increases in stress on water systems. Similar is the case with enhancing SOC, which makes the soil drought-tolerant and also productive besides reducing erosion levels. More recently Janzen (2015) pointed out besides carbon sequestration, soil has to be considered as a conduit of solar energy by maintaining 'flows' of carbon stocks uses using the energy it carries.

While discussing the Indian climate policy,

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Mahanta (2009) reminded us that the failing monsoon of 2009, followed by the unprecedented rains in early October in the southern states, establish the need for addressing such anomalies more frequently than ever. Even during this year (2015) we are having similar anomaly.

Only 15-20% of rainfall is generally used by crops. With degradation of the soils due to CC, this would be only 5%. With loss of top soil, the loss in productivity will be further accentuated. Thus the soils are endangered, but the degradation can be rolled back (FAO, 2015).

Organic agriculture (OA) that saves about 27% energy is one of the routes. OA sequesters more carbon. Zero-tillage as with rice-wheat of Indo-Gangetic plains covering 1.7 Mha involving 620,000 farmers is another example. However as rainfall intensity and frequency of storms increase the above may not provide adequate protection to the soil. The researchers, producers and soil conservationists have to aggressively pursue soil management practices to protect the soil under these changing rainfall conditions, as pointed by Hatfield and Prueger (2004). Land husbandry preached by Hudson (1992) could be one other possible solution. All such systems are in some form or other under practice by the smallholders. In fact SERP of GoAP adopted a paradigm shift from 'external input driven agriculture' to 'knowledge, skill-based and local natural resources' model in their community managed sustainable agriculture (CMSA-Eco-agriculture). SERP strongly believe that this CMSA will lead smallholders from agricultural distress to viable farming. All such systems do cool the climate and protects top soil which is the most strategic resource. Business as usual is NOT an option when it comes to soil, food and people. It is time for a greener revolution (Montgomery 2010). And those who practice non-chemical farming need be paid for the cological protection service rendered by them.

We like to quote of Eleventh Commandment of Lowdermilk (1994). "Thou shalt inherit the Holy Earth as a faithful steward, conserving its resources and productivity from generation to generation. Thou shall safeguard thy fields from soil erosion, thy living waters from drying up, thy forests from desolation, and protect thy hills from overgrazing by thy herds, that thy descendants may have abundance forever. If any shall fail in the stewardship of the land, thy fruitful fields shall become sterile stony ground and washing gullies, and they descendants shall decrease and live in poverty or perish from off the face of the earth".

So we have to move from the present chemical agriculture to green agriculture (UNEP, 2011). Some details are provided hereunder for these two systems of farming.

A comparison of chemical and green agriculture

Chemical Agriculture	Green Agriculture
- Depletion of inexpensive gas and oil; continued surface mining of soil nutrients	- Location specific organic resource input and natural biological processes to restore and improve soil fertility
- Increasing scarcity of fresh water	- Achieve water use efficiency
- Aggravated water pollution by poor nutrient management	- Provide clean water
- More annual additions of GHGs	- Reduced GHGs
- Heavy use of toxic pesticides and herbicides	- Integrated pest and weed management
- Deforestation on increase	- Promote employment, more on-farm employment with small and family farmers

Source: UNEP (2011)

By adopting green agriculture, ecosystem services and natural capital assets would be improved with reduced soil erosion and chemical pollution, high crop and water productivity and reduced deforestation. It leads to reduced GHG emissions by sequestering more atmospheric CO_2. Over time it leads to resilience to climate change. Green agriculture will reduce poverty, reduce waste and inefficiency. It creates more jobs with significant environmental benefits (UNESCAP, 2009).

Sustainable Agriculture

In short sustainable agriculture is meant to

- Satisfy environmental quality and the natural resource base
- Make most efficient use of renewable resources and on-farm resources, integrating with biological cycles
- Sustain the economic viability
- Enhance the quality of life of farmers and society as a whole.

Key principles for sustainable food and agriculture include (FAO, 2014)

- Improving efficiency in the use of the resources is crucial for sustainable agriculture
- Sustainability requires direct action to conserve, protect and enhance natural resources
- Agriculture that fails to protect and improve rural livelihoods, equity and social well-being is unsustainable
- Enhanced resilience of people, communities and ecosystems is key to sustainable agriculture
- Sustainable food and agriculture requires responsible and effective governance mechanisms

In our opinion sustainable agriculture can be achieved through ecologic farming. By definition, ecological farming ensures healthy farming and healthy food for today and tomorrow, by protecting soil, water and climate, promotes biodiversity and does not contaminate environment with chemical inputs or genetic engineering (Tirado, 2009).

Thus ecological farming is polyculture, integrated tee cropping, animal husbandry and cop production - in practice since the beginning of the civilisation. It is eco-friendly, independent, self sustaining and cost effective. Such a system is dialectical in approach taking into consideration not only the human needs, but also aiming at sustaining the nature and the life supporting systems. It is an internalized system (Venkateswarlu, 2009).

In our present discussions we limit to soils, the main natural resources for sustainable agriculture.

Land Degradation

Soil degradation poses risk to earth's future. It is a more serious threat to human health than climate change (Mercer, 2012). But it is rarely discussed in the media and by governments. There is a need to realize that soil carbon itself is a lynchpin in securing soil for the world. So basically by increasing the carbon content in the soils we can contribute to lots of global problems like food security, energy security, climate change mitigation and biodiversity protection, said Mercer. Causative factors include intense farming and now the climate change, besides others. Once the soil loses its carbon, producing more abundant yields become much more difficult because of the lack of nutrients in the production base (UNESCAP, 2009). In fact 1/4th of the world population is affected with the global degradation. Area estimated works out to be 20% of the cultivated area, 30% of forest area and 10% of grasslands (FAO, 2008). Globally 78% of the degraded lands are in humid area.

The next stages in agricultural development will need to be much more about conserving the natural resources, recycling carbon and ensure soils retain vital nutrients. Also there is a need to protect the biodiversity, the lifeline of the smallholders and regenerate the natural resources of soil and water (UNESCAP, 2009).

The kinds of degradation of land include, among others, wind erosion, water erosion, nutrient depletion, salt infestation and physical components including compaction and water relations. According to NRAA, about 120.72 Mha are affected with some or the other of the degradation processes.

The extent of degradation under each type of degradation is estimated to be

Type of degradation	Extent Mha
- Wind erosion	- 12.0[a]
- Water erosion	- 91.0[a]
• Ravines	- 4.0[b]
• Shifting cultivation	- 4.9[b]
- Water logging	- 7.6[b]
- Salt infestation	- 8.6[c]
- Severe fertility limitations	- 7.9[d]

Source: a: NRAA, b: MoRD, c: CSSRI, d: FAO

Paradigm Shift in Soil Conservation

Retrieving degraded lands, which are largely result of soil erosion, calls for a paradigm shift from the traditional soil conservation through mechanical structures to land husbandry. Here we like to quote the doyen in soil conservation, Hudson (1992). He said "Current changes include even the term soil conservation will probably fade away to be replaced by land husbandry because that better describes the fundamentals of the new approach. The idea of the care of crops and their management and improvement has for years been called crop husbandry. Animal husbandry has described the care and management of livestock. Soil conservation was appropriate when we were mainly concerned with increasing knowledge and awareness of soil degradation and learning how to decrease the process. But that was mainly a defensive strategy and what we now seek is a positive approach where care and improvement of the land resource comes first and control of erosion as a result of good land husbandry".

Guidelines for land husbandry techniques and technologies have been detailed by Lundgren and Taylor (1993). They are as follows.

- Develop and improved agricultural technologies that are adapted within the local context – ecologically, economically, socially and culturally – including locally developed biological and technical measures. Build on improved indigenous practices and species, whenever possible.
- Emphasize the maintenance of the land's productivity, rather than limiting soil loss.
- Emphasize the prevention of land degradation rather than the treatment of symptoms.
- Use biological (agronomic) technologies, e.g. agroforestry, and plant species that provide cover, organic matter, wood, fodder, food, soil nitrogen, etc.
- Emphasize productive diversity so as to minimize short-term risks both for the farmer and the land.
- Employ physical measures only when necessary, and only as supplements to biological measures.
- Physical measures, when used, should be simple and easy to adopt, requiring as little expense and labour as possible. Farmers should be able to deign, construct and maintain the structures without outside assistance.
- Promote techniques whose benefits can be captured by women and others secondary tenure rights holders (such as labour- and time- saving techniques, and planting of grasses or bushes along contours).

Source: UNEP (2011)

- Promote techniques that accomplish more with less – i.e. economize on water and nutrients.
- In arid areas, for the sake of sustainability, ensure that plans to increase biological production are based on thorough understanding of the local water balance.
- Concentrate on areas which are most cost-effective from both the society's and the land users' points of view.
- Avoid the 'comprehensive' landuse planning approach in which land capability is determined by elaborate physical surveys carried out by outsiders and imposed upon local land users.
- Encourage simple landuse planning by the land users themselves, with only complementary support from outsiders as locally requested through dialogue. Be aware that the planning process is more important than the plan itself.
- When promoting land husbandry on a catchment basis, respect administrative boundaries as being more important than hydrological ones, as this reinforces the management capacity of existing institutions.

In so far as control of soil erosion is concerned, we have to realize that only severe to very severe wind erosion (which works at 40%) and > 12 t/ha annual soil loss in the case of water erosion (that works to 33%) need treatment. The other areas should be treated at the farm level with good land and crop husbandry. In any care vegetation through agroforestry in arable areas along with grassing the field bunds and waterways have to be essential components.

Coming to water logging subsurface drainage systems evolved by CSSRI and ANGRAU (Sreedevi *et al.*,2008) may be considered. These treatments are expensive (>Rs 30,000/ha) and need Governmental support.

In areas, where we have to live with the water logging, the treatment may shift to growing multipurpose trees. CSSRI (Singh *et al.*, 1993) suggested trees like *Prosopisjuliflora, Tamarix articulata, Casuarina glauca* and *Acacia nilotica*.

While tackling salt infestation, NARS has ample suggestions to control salinity as well as sodicity. But in areas where arable farming is not feasible tree components, as suggested by CSSRI (Dagar and Tomar, 2002) need consideration.

Trees for sodicity	Trees (examples)
- **Sodicity (pH)**	
> 9.8	- Prosopisjuliflora, Acacia nilotica, Tamarixarticulata
9.1 to 9.8	- Pithecellobiumdulce, Casuarinaequisetifolia, Salvadoraoleides
8.2 - 9.0	- Buteamonosperma, Gravelliarobusta, Azaridactaindica
- **Salt level**	
High	- Prosopisjuliflora, Salvadorapersica, Tamarixarticulata
Tolerant	- Casuarinaequisetifolia, Acacia nilotica, Acacia tortilis
Moderately tolerant	- Eucalyptus teretormis, Acacia catechu, Terminaliaarjuna

In the southern Deccan region, sub soil salinity is common (upto 30% area) in the Vertisols. The choice of rainfed crops in such areas, as identified by the farmers include local sorghums (shallow rooted), coriander and safflower.

A specific mention has to be on the irrigated sodic vertisols in this region. While we take 15 ESP as the criteria for sodicity, in these soils it has to be 8 ESP where the dispension occurs. Exchangeable Mg accentuates the problem of dispersion.

While considering the nutritional disorders the emerging scenarios need our attention. the nutritional disorders started showing up (Singh, 2004).

Emerging nutrient deficiencies

Year	Deficient nutrient
1950	N
1960	N, Fe
1965	N, Fe, P, Zn
1970	N, Fe, P, Zn, K
1975	N, Fe, P, Zn, K, S
1980	N, Fe, P, Zn, K, S, Mn
1985	N, Fe, P, Zn, K, S, Mn, B
1990	N, Fe, P, Zn, K, S, Mn, B, Mo
2000	N, Fe, P, Zn, K, S, Mn, B, Mo, Cu
2020	N, Fe, P, Zn, K, S, Mn, S, Mo, Cu, Ni

Source: Singh (2004)

It is evident that with reduced or no turnover of organics in crop production and with continuous monocropping (e.g. groundnut, soybean) the nutrient disorders would continue to limit crop production. Also with excessive application of chemical fertilizers like Urea and DAP, problems like phosphate induced Zn deficiency in groundnut and sulphur deficiency in soybean have emerged.

As in 2010, the extent of deficiencies of nutrients in India was as follows (FAO 2005)

Nutrient	Extent of deficiency (%)
N	63
P	42
K	13
S	40
Zn	49
B	33
Mo	13
Fe	12
Mn	5
Cu	3

Existing practices and possible interventions in the case of unique problem soils are provided below (Venkateswarlu, 2012).

Sl. No.	Problem soils	Present practices	Possible interventions
1.	Shallow soils (18.7 Mha). Mostly owned by the poor in the Deccan plateau in both red and black soil regions.	Growing food crops. Now shifting to commercial crops	• Tree based farming systems. • Provide / encourage traditional RWHSs for creating protective irrigation systems. • Livestock enterprises also need consideration. • Traditional soil and water conservation should be encouraged.
2.	Coarse textured soils (30.0 Mha). These soils are in MP,	They are textural profiles generally owned by the	• Deep ploughing once in 3 years to capitalize on

Sl. No.	Problem soils	Present practices	Possible interventions
	Orissa, West Bengal, south India.	poor. All types of crops are grown during monsoon. Commercial crops are grown continuously. Nutritional disorders are common, besides physical constraints like crusting.	textural profiles need be taken up. • Tree based cropping so as to plough back some crop / plant residues to improve the soil productivity. • Secondary occupation (livestock, horticulture) with protective water sources need attention. • Soil and moisture conservation with traditional systems as a backstop need attention. • Monocropping be replaced with crop rotations and legume as a component.
3.	Soils with severe fertility constraints (7.9 Mha)	The acid soils are largely deficient inherently in calcium and phosphorus. The poor farmers in such per humid and humid regions farm crops that demand less of such nutrients (cassava, sweet potato, niger and rice)	• About 200 kg / ha of lime application with 100 kg/ ha of single super phosphate improves productivity of such soils and need support from the government agencies. • On-farm rainwater harvesting would be an useful adjunct in the overall development of such regions
4.	Flood prone areas (7.56 Mha). They occur in east Uttar Pradesh and south Bihar.	*Diara* and Tal land with receding water, crop cultivation is in practice (rice in Tal or legumes and maize in *Diara* lands)	• While taking up short duration crops like Satta Maize with receding moisture, there is a distinct possibility of taking a second crop also if only a come-up irrigation is provided through shallow tube wells

Mine Spoil Rehabilitation

Mine spoils if not rehabilitated, not only create human health problems but also encroach on the adjacent arable areas with wind or water erosion. With the heaps of the spoils even the ecology would be affected. The hydrology may be in jeopardy. There could be an affect the lives of livestock and birds. For instance with mining the great Indian bustard moved out of the plain desert areas.

Technology to rehabilitate the mines is available. For example, Sharma *et al* (2001) provided the protocols for rehabilitating the gypsum mined areas.Now what is needed is to see the treatment is taken up by the minor himself or with the charges paid by him, any civil society may be encouraged to take up the rehabilitation work.

Industrial Effluents: Problem

A large part of the industrial effluents originate from textile dyeing and printing industries located near Jodhpur, Pali and Balotra. The effluents do not meet the requirements of the ISI standards. The effluents are discharged into non-perennial rivers of Barndi, Luni and Jojri. The effluents are carried into these ephemeral rivers are 15, 7 and 10 million per day respectively. These effluents are highly saline and coloured and affect the nearby wells. The water in wells deteriorates. The areas under these wells as well as the off-season fruit and vegetable growing in the basins of the rivers are adversely affected.

Industrial Effluents: Possible Solution

Efforts need be made to rigorously follow the ISI standards in the discharge of the effluents into the streams/ rivers. Till then the effluents may be decolourised using flyash and tree (*Acacia tortilis*)farming and fruit (*ber*) cultivation may be encouraged as livelihood support systems for those affected by this malady in these light textured sands and sandy soils.Government should come forward to assist such disadvantaged communities.

Toxicity of Heavy Metals

With increasing urbanization and industralization heavy metals are increasingly entering agricultural ecosystems. For instance the municipal solid waste (about 70 Mts / year in the country) is one of the sources of heavy metals dumped on arable lands.

The Indian standards for heavy metals in soils are:

Heavy metal	Soil limits (ppm)	Water (mg/l)
Cd	3-6	0.01
Cu	135-270	0.05
Ni	75-150	-
Pb	250-500	0.1
Zn	300-600	5.0

Source: Awasti (2000)

Saha and Panwar (2014), in a pot culture study found the heavy metal levels are lower than critical toxic levels for Cd, Cr, Cu, Ni and Zn.

Heavy metal	Present level in spinach (Normal)	Toxic limits in spinach leaves	
		Significant (ppm)	Limits at 20% reduction
Cd	0.003	0.08	0.100
Cr	0.052	0.582	0.465
Cu	0.637	1.581	1.357
Ni	0.022	1.63	1.350
Zn	3.800	15.258	13.987

Evidently present levels of accumalation in soils are at safe limits in acidic light textured alluvial soils used in the study.

In any case we need to constantly watch heavy metal levels in soils and plants in different soil types, as once the soil is contaminated with heavy metals, it would be rather difficult to reclaim them.

Soil Health

Healthy soil maintains diverse communities of soil organisms that help control plant diseases, insects and weed pests, from beneficial symbiotic association with plant roots, recycle essential plant nutrients, improve soil structures with positive repercussions for soil and nutrient holding capacity and ultimately improve production (Collette *et al*, 2011). Population growth, industrialization and climate change threaten soil health (FAO, 2015).

From an ecosystem perspective a healthy soil does not pollute the environment, rather it contributes to mitigate climate change by maintaining or increasing its carbon content. Functional interactions of soil biota with organic and inorganic components, air and water determine a soil's potential to store and release nutrients to plants to sustain their growth.

"Soil health is the capacity of a soil to function". Soil health is reflected through how well is the soil functioning to infiltrate water and recycle nutrient to water and feed growing plants. Soil is controlled by macroscopic and microscopic flora and fauna. They need food (being heterotrophic) to survive and help in making the soil functional (USDA, 2010). Soil life adds life. A living soil enriches soil. In order to make the soil live effectively, the needs are water, food (organic matter), air and favourable pH and temperature. The below ground biodiversity provides ecosystem goods and services to crop plants (Johri, 2006).

The SOM generally, contains some fresh residues (<10%), decomposing organic matter (33-50%) and stabilized organic matter (33-50%) and living organisms (~5%). It is the stabilized organic matter that forms the humus component in the soil. It holds water 4-6 times its weight and its cation exchange capacity (nutrient holding capacity) is 250-400 me per 100 g soil. It decomposes slowly @ 2.5% per annum. A 15 cm soil with 1.0% SOM contains 1000 kg N, 100 kg P and 5 kg S ha-1 (Krishnamoorthy and Venktaeswarlu, 1976).

A teaspoon of living soil contains more of these organisms than the population on the earth. Some details of the fauna and flora are provided in the following table.

Soil Biota	Examples	Functions
1.	Earthworms	• Major decomposer of dead and decomposing organic matter and derive nutrition from bacteria and fungi leading to recycling of nutrients • Generate tonnes of casts each year, drastically improving structures • Stimulate microbial activity • Mix and aggregate soil • Increase infiltration • Improve water holding capacity • Provide channels for root growth • Improve water quality
	Nematodes	• Many help in controlling diseases and recycle nutrients • Help in dispersal of microbes • Omnivores feeding on roots of plants (plant parasites)

Soil Biota	Examples	Functions
	Arthropods (e.g. insects, springtails, beetles)	• Shred organic matter • Stimulate microbial activity • Enhance soil aggregation • Mineralize plant nutrients in bacteria and fungi • Burrow improving water infiltration • Control pests
Flora	Fungi	• Nutrient cycling through their hyphae (VAM) • Water dynamics • Disease suppression • Decompose organic matter
	Bacteria	• Decomposer - Decompose and breakdown pesticides and pollutants - Retain nutrients in their bodies • Mutualists - N-fixing, nitrifying, denitrifying • Autotrophs - Obtain energy from components of N, S, Fe or H instead of carbon compounds
	Actinonycetes	• Degrade recalcitrant compounds
	Protozoa	• Mineralize nutrients making them available for use by plants and other soil organisms and thus help in nutrient recycling

Source: USDA (2010)

Thus soil flora and fauna have been grouped into three classes(Kittredge, 2015). They are chemical engineers, biological regulators and ecosystem engineers.

The chemical engineers include bacteria and fungi which help in the decomposition of organic matter and in N-cycle. The biological regulators regulate the abundance of chemical engineers. They include nemoatodes, mites and microarthopeds. The ecosystem engineers include earthworms, termites, ants and the plant roots. Bioturbulation by earthworms and roots in particular and the casts, mounds and heaps improve soil productivity.

The earthworms open the soil by making burrows (8-30% by volume), thereby facilitating the infiltration of air and water. These burrows would be colonized by the roots of the plants. They neutralize the soil pH. The other function of earthworms is to eat and digest the soil alongwith debris, mix it with organic matter and throw it out in the form of castings. These small heaps of castings are suppliers of nutrients to the soil. They weigh 3-10 tonnes / ha depending on the soil type and rainfall.

- Two times the available Mg
- Five times the available N
- Seven times the available P
- Eleven times the available K
- Thousand times more microorganisms

than the surrounding soil. Similar results were earlier reported.

Stimulation of microbial activity that occurs in the casts. This enhances the transformation of *soluble* nitrogen into microbial protein, thereby preventing (a) losses by leaching to the lower horizon in the soil column and (b) avoiding excess N and thus preventing NO_3-N causing health problems to humans and luxury consumption by the plants.

The important requirement for earthworms to be effective is the easy availability of organic matter and the soils remaining moist, but not waterlogged (Russell, 1960). Ca-supply should be adequate. Heavy soils are not a good abode for them.

The other important effect of soil fauna (in particular earthworms) is enhancing soil porosity through the burrowing. The porosity enable roots to easily penetrate into the subsoil and encompass more volume of soil. Without or even reduced porosity leads to reduced conditions, whenever a big rain event occurs, more so in heavy textured soils or soils with compact layers in sub-surface zone leading to liberation of toxic products.

So earthworms as well as deep rooted crops grown in rotation help in burrow formation and enhance porosity and avoid such eventualities. Even organic recycling leads to better soil aggregation, thus encouraging soil porosity. As pointed out earlier, with enhanced SOM, even runoff and nutrient losses would be reduced.

Vesicular – arbuscularmycorrhizal fungi (VAM): Of the various soil microorganisms, perhaps the less is known about mycorrhizal fungi. Of these the vesicular-arbuscularmycorrhizal fungi (VAM) are the most common type (Malajczuk *et al.,* 1992). The fungal hyphae enter the root cells causing no noticeable structural changes on the outside of the roots. The name, vesicular arbuscular, comes from structures which are found within the root cortical cells :vesicals, which are thaught to be the storage or reproductive structures ; and arbuscles, branched multiple tipped hyphal structures within the plant cells. VAM fungi associate with both legumes and cereals. The extent to which the roots are colonized by the VAM is one of the key determinants of a roots ability to acquire nutrients from the surrounding soil. Mycorrhizae improve seedling growth and survival by enhancing the uptake of nutrients and water and increasing the root life span. VAM also helps in protecting the root against other microorganisms and other environmental stresses such as heavy metal toxicity or soil salinity. They are thought to be crucial for acceptable growth and survival of plants in many cases such as nutrient deficient soils or degraded habitats, arid ecosystem and drought (Barea, 1991).

VAM activities can be affected by the level of soil fertility, which in turn is "modified" by the VAM by changing the ability of a plant to use the nutritional potential of a given soil (Barea, 1991). He further stated that the "VAM effect" is mainly accounted for by the changes they induce in the phosphate uptake properties of the root system. The VAM mycelia grow beyond the zone depleted of slowly diffusing nutrients. Thus, VAM leads to a better exploitation of soil phosphates and to more efficient use of fertilizer phosphorus. Powell (1984) had shown that un-inoculated plants need more phosphates than inoculated ones.

It is clear that VAM can be harnessed to improve the productivity in agriculture, horticulture and forestry by (i) reducing the input of fertiliser and (ii) by enhancing the plant survival, thus saving environmental and ecological costs. In fact, Roy - Bollue and Hijri claim VAM would be the corner stone for a second green revolution.

Termites: It is very unfortunate that termites or white ants are branded as enemies in agriculture. Actually the termites and earthworms are the builders of the soil, aptly known as 'soil engineers'. Narayana Reddy (2008) would say that termites are the chief engineers and earthworms are assistant engineers. They create a huge amount of space in the soil, that helps in improving the availability of air (oxygen for the roots) and infiltration of water into the soil. Many people think that termites would kill a plant or tree, which is a myth. Actually they eat way a plant while it is struggling to dry away due to lack of moisture. It is like mercy killing. They graze only on dead bark of the tree which otherwise could have encouraged fungus growth during rainy season. In reality, the termite hill built up with their saliva moistened mud is not only fertile but also a very good antibiotic. We use this termite hill mud for bathing and shaving. In many African countries it is applied in the pit before planting saplings.

Thus soil biodiversity underpins a multitude of ecosystem functions and processes that are essential both for sustainable food production and to manage the agroecosystems beyond farming. It arrests the current alarming state and trend in degradation of agricultural soils.

Soil biodiversity is a key determinant of land productivity and farming, which is presently facing significant sustainability challenges. Improved management of soil biodiversity in agro-ecosystems offers solutions for sustainable farming and food security, whilst simultaneously increasing carbon storage (C-sequestration), improving water cycling and reducing off-farm pollution (Dias and Coates, 2012).

The soil biodiversity regulates three major bio-geochemical cycles on earth, namely nutrient, carbon and water cycling which are essential for food, energy and water security. Additional important functions of soil include

- Regulating pests and diseases
- Supporting pollinators
- Reducing chemical pollution

Thus soil biodiversity can be used as a direct intervention in the production systems. For example

Inoculation with soil beneficial organisms, such as nitrogen fixing bacteria, mycorrhiza, and earthworms

In summary, the biota in the living soil help in nutrient cycling, soil carbon sequestration, improving soil physical conditions, assisting in plant nutrient and water acquisition, fixation and mobilization of nutrients, enhance plant health and enable biotic and abiotic stress tolerance. But we are losing soils and soil biodiversity at a rapid pace, with substantial ramification on human health worldwide. It is time to recognize and manage soil biodiversity as an under utilized resource for achieving long-term sustainability goals related to global health, not only for improving soils, food security, disease control water and air quality, but because biodiversity in soils is connected to all life and provides a broader, fundamental ecological foundation working with other disciplines to improve human health (Wall *et al*, 2015).

Since most of the beneficial biota are heterotrophic, they need to be provided with energy through organic matter. Presently the SOM stock in the arable area is quite poor. This is all the more so where farmers moved to chemical agriculture leaving the traditional systems. We need to have a revisit to the these earlier practices for revival with suitable/ possible adaptations. Let us also realize that available potential of organic nutrients 110.75 Mts. But we are tapping only 3.75 Mts (Singh, 2012). These are estimates based on bulky organics. But if we take traditional systems also into account there is a plenty of scope to go non-chemical in crop production.

Further, organic matter also drives several other chemical processes and physical properties (Fan *et al*, 2005). Thus SOM contributes considerably to increasing soil stability and resilience that are so important in food supply stability (Niggli *et al*., 2007). Pimentel *et al*, (2005) argue that enhanced SOM leads to better aggregate stability and biologically more active soils, increasing water retention. In fact, they reported 28 to 34% high maize yields in the Rodale experiments in the organically managed plots in years of drought. This is what the author used to see in Anantapur District during 1955-56 in the farm fields where mixed cropping had been the practice contributing more and more leaf litter on to the soil which provide the "Sponge" water to enable crop plants mitigate intermittent moisture stresses due to breaks in the rainfall events in the monsoon season. Even runoff and nutrient losses would be reduced (Niggli *et al*, 2007; Thorup-Kristensen, 2007). However the level of SOM that can be maintained in soil depends on its texture, the way it is managed and the climate. thus SOM is always in equilibrium with the environment (Broadbent, 1957).

Emerging Issues

Soils Back on the Agenda

FAO (Anonymous, 2011) called for Global Soil Partnership for food security and climate change mitigation and adaptation. They point at the need to build capacities and enlarge knowledge and technologies for sustainable management of soil resources at all levels to enhance food security in the era of climate change. Further they call for evolving means from national and international agencies for soil quality-soil health best practices, standards, guidelines and monitoring systems. Their vision is for healthy productive soils for food secure world.

More recently, Global Soil Week as a support to the global soil partnership was held (Anonymous, 2012). with the objectives of :

- Foster the exchange of knowledge and experiences on sustainable soil management between scientists, decision makers and practitioners on an equal footing.
- Setting up agenda for action to improve the sustainable management of soil and its restoration for sustainable development
- Outlining ways in which global soil week can contribute to implement the agenda

We also have been insisting over the last decade that fuller expression of the potential of improved crop genotypes (hybrids, GMOs) would not be possible unless the base (soil) is made productive by improving the soil organic matter.

The Government (ICAR/DARE and MoA) is now emphasizing on soil health cards for farmers wherein the focus is on soil testing that was put in place in fifties of last century That is, the thrust is on chemical analysis. Globally soil health is preceived holistically that includes physical, biological and chemical components. Even soil health kits are available in the west. Only a few Agricultural Universities (e.g. TNAU) are suggesting to move beyond chemical analysis of soils while considering soil health.

Planetary Boundaries

There was an interesting study of the Stockholm Resilience Centre (Rockstrom*et al*., 2009) on identifying and quantifying planetary boundaries that must not be transgressed, which could help preventing human activities from causing unacceptable environmental changes. The planetary boundaries set by the group are provided below alongwith the parameters, proposed boundaries and current status.

As seen below the loss in biodiversity, climate change and human interference in N-cycle have already crossed the planetary boundaries and causing unacceptable environmental changes.

Modern agriculture is a major cause of environmental pollution, including large-scale nitrogen and phosphorus induced environmental damage. When we consider biological global cycle, ~ 80 Mt of atmospheric N is industrially fixed (fertilizer) and ~40 Mt is through agricultural fixation (Rhizobia and other N fixing organisms). Much less of it is actually utilized, leaving 50-70% to pollute the groundwater and ocean as NO_3-N and as nitrous oxide in the atmosphere. In fact the estimates of crop physiologist Abrol (2005) indicate 67% of the annual loss of N fertilizer worth uptoRs 72,000 crores is from urea. Insofar as P is concerned, mineral P-fossil (phosphate rock) is mixed for human use. About 63 Mt of P_2O_5(26 Mt of P) is present annual fertilizer production, of which ~10.5 Mt are lost from crop lands through erosion and ~20 Mt is through human excreta. About 1.0 Mt of it is added naturally to the earth ecosystem through geological and weathering processes. These enter the water bodies leading to eutrophication, environmental damage and loss in public health. Thus P additions to the earth ecosystems is on the verge of becoming a threat, if boundary for P is taken as 11.0 Mt per year.

Organic agriculture possibly is one route that may partly mitigate the problem. Presently (Willer, 2011) 37.2 Mha are under organic agriculture in 160 countries, of which only 1.18 Mha is in our country, the maximum being in Australia (12.0 Mha).

A frequently asked question is "how many years it takes for non-chemical agricultural production equals or superceeds chemical systems?" The data from the Indian Institute of Farming Systems Research, Modipuram (Uttar Pradesh) provides answer as seen in the ensuing table.

Mean yield of crops tested in cropping systems under organic input management and yield trend over the years

Crop	N	Mean yield (kg/ha) under organic input management	Yield trend under organic system over the years (% increase (+) or decrease (-) over inorganic input management)						
			1st year	2nd year	3rd year	4th year	5th year	6th year	7th year
Basmati rice	67	3099	-13	-14	-3	2	2	8	7
Rice	56	3639	-12	-13	5	2	1	2	1
Wheat	56	2952	-15	-9	-7	-3	-7	-13	-4
Maize	55	4541	-5	9	4	0	3	10	16
Green gram	12	905	-	-4	-	-9	3	13	13
Chickpea	25	1269	-10	5	9	3	0	1	5
Soybean	58	1697	1	1	5	0	3	0	12
Cotton	29	1243	8	9	11	12	11	14	12
Garlic	9	7878	-10	-19	8	15	-	-	-
Cauliflower	12	10683	-8	-8	4	2	-	-	-
Tomato	11	20577	-13	-13	-30	-28	35	26	20
MEAN			-6.7	-4.8	0	1	8.4	5.6	9.0

It takes 3-4 years for equal yields under both the systems. And availability of adequate organics for non-chemical agriculture is absolutely feasible.

Way Forward

Increased production must be achieved with a decreased impact on the natural resources, more so at a time when the cost of energy continues to rise. This can be achieved by building up the impoverished soil organic matter (SOM). Enhanced SOM improves nutrient and water holding capacity of the soil.

That organic manures mean composts or FYM and animal manure is a MUST is not wholly true. Biomass, in any form (trees, dung and crop residues) should be in focus. All the needed nutrients for the present and future production can be met from such sources. For instance Partap (2006) and Chillat (2007), extensively using the data from Michigan State University (USA), found that greater use of N-fixing crops and trees globally could result in the production of 140 Mt of N, which would be more by 82 Mt than the presently produce chemical nitrogen (i.e. 58 Mt). Multipurpose Trees (MPTs) are a boon of not only providing fodder and fuel, but also supply much needed plant nutrients and biomass for pest management. In one estimate, the working group on animal husbandry for the XI Five Year Plan (FYP) indicated that as much as 800 Mt animal dung would be available annually, of which even if 1/3rd is used as manure, it would provide 7.5 Mt of nutrients (2.90 Mt N, 2.75 Mt P_2O_5, and 1.89 Mt of K_2O). Such simple technological innovations were upscaled through community managed development with SHGs as the platform by Vijayakumar (2007). Such sustainable, regenerative and eco-friendly systems (Johl, 2006) as an alternative to chemical agriculture needs all the support of the government through incentivization using Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) for works and by providing subsidies as done for chemicals (fertilizers and pesticides).

For biomass generation Revitalisation Rainfed Agriculture (RRA) network identified the following possibilities.

(i) Improving quantity and quality of FYM/ Compost at homesteads

(ii) Improving quantity and quality of biomass based manure at farm level

(iii) Green manures and cropping systems

(iv) Concentrated manures (e.g. cakes, meal based manures)

(v) Sheep penning

(vi) Mulching, cover crops and reduction in the intensity of tillage

The network emphasizes that the needed biomass as a substitute to chemical nutrients is possible with continuing and concentrated efforts of all the stakeholders – the farmer, the CBOs, civil societies, researchers of Govt. institutions and the government.

The potential biomass (t/ha) that can be generated per year through various means would be,

Biomass sources	Biomass produced (t/ha)
Compost at homestead	- 10 to 12.5
Biomass based manure	
- Gliricidia (500 plants / ha planted on bunds and around compost pits)	- 7.5 to 10.0
- Sunheamp on bunds	- 0.8 to 1.0
- Biomass yielding MPTs	- 1.0 to 1.5
- Weeds	- 0.5 to 0.75
- Crop residue	- 1.25 to 3.0
- Legume as intercrop	- 1.25

On a modest estimate, about 10 to 12.5 t ha-1 of farm-based fresh biomass can be generated with little or no effect on the main crops grown in the fields. Even that small loss, if any, will be amply compensated in the subsequent years through recycling processes. This is besides carbon sequestration.

Epilogue

Sustainable development in agriculture can be achieved by encouraging the smallholders and women to take up internalized production systems. There need be a paradigm shift from overexploitation of groundwater to efficient participatory management. Similarly the shift has to be from routine soil conservation to improved land husbandry. Ecological niches for crops and cropping systems help in proper crop planning. In this context, the traditional systems need to be considered as the first step.

Soil health has to be retrieved to exploit the roles of soil biota in the production systems. We are happy that the Global Biodiversity initiative was launched in September 2011 with its secretariat housed in the School of Global Environmental Sustainability, Colorado State University, USA. Such initiatives are also seen in Canada and with European Union. Synergy between crop-livestock-tree systems must be on the agenda. With these thrusts, the production costs would come down. The farmers, particularly the smallholders could free themselves from dependence on ever increasing costly external inputs to internalized independence in production systems. The present IWMP as well the MGNREGS could be the sources to achieve these goals. The Self Help Groups and other CBOs could be the platforms for upscaling these objectives.

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Research Priorities for Increasing Pulses Production in India

Sanjeev Gupta

Chickpea, pigeonpea, lentil, mungbean, urdbean and fieldpea are major pulses grown and consumed in India. The split grains of these pulses called *dal* are excellent source of high quality protein, essential amino and fatty acids, fibers, minerals and vitamins. India is the largest producer, consumer, importer and processor of pulses in the world contributing to around 25-28% of the total global production (Ali and Gupta, 2012). About 90% of the global pigeonpea, 75% of chickpea and 37% of lentil area falls in India (FAOSTAT 2015). Recognizing the importance of pulses in Indian agriculture, several R&D programmes were initiated by Govt. of India. An All India Coordinated Pulse Improvement Project was created in 1966 and a national institute "Indian Institute of Pulses Research" was established in 1993. As a result of this, new varieties and production technologies were developed, and productivity increased from 476 kg/ha in 1970-75 to 738 kg/ha (55.5%) during 2010-15, with an increase in area from 22.2 million ha to 24.6 million ha. In recent times the pulses production showed a spectacular increase from 14.76 million tonnes in (2006-07) to a record level of 19.27 million tonnes (2013-14).

Despite the fact pulses are vital food crops; they are grown predominantly in stressed rainfed environment (only 16.1% area was irrigated during 2011-12). Therefore, major breakthrough in pulses is not evidenced as has been witnessed in cereals (rice, maize and wheat). Diseases like wilt in chickpea and pigeonpea and yellow mosaic disease in mungbean and urdbean have been so serious in the past that without bringing resistance against these diseases, their cultivation could have been impossible. With advanced screening facilities and techniques, donors for major diseases were identified and used in breeding programme to develop disease resistant/tolerant varieties with high yield. Short duration varieties were developed to fit in different environments and cropping systems. With identification of such short duration varieties, some of the pulses were introduced in new niches (rice fallows-urdbean, mungbean) and non-traditional seasons (summer mungbean, *rabi* rajmash and *rabi* pigeonpea) and thus helped in bringing additional area into cultivation. Quality improvements were brought in for seed size, colour and luster in chickpea, lentil and mungbean as desired by consumers/ traders.Development of low lathyrus and development of biofortfied varieties of lentil for high iron and zinc are making these crops important in pulse basket. Efforts have been made to exploit heterosis through hybrid development in pigeonpea and as a result three hybrids IPH 2671, ICPH 3762 and ICPH 2740 were developed and are being popularized among farmers. Efforts are on the way to mine genes for various stresses, gene pyramiding for pathogenic variability and transgenic for Gram pod borer. New cropping systems (crop rotation and intercrops) have been developed for different regions which are more productive and efficient and facilitated area

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expansion under pulses. Agro-techniques such as raised bed planting, integrated nutrient management including bio-fertilizers, secondary (sulphur) and micronutrients (Zn,B, Mo) , foliar nutrition, integrated weed management (cultural+herbicides), irrigation schedule based on IW/CPE ratio and crop growth stages, micro-irrigation, bio-intensive integrated pest management modules and resource conservation have been developed, refined and standardized for various agro-ecological zones. Technology for pulse production in rice fallows and agronomy of non-traditional pulses in new niches have been developed.

Due to the ever increasing population, rising income of people and pulses being the major source of protein in Indian diet, the demand for pulses continues to increase at 2.8% per annum (Chauhan *et al.*, 2016). Due to this ever increasing demand, the net availability of pulses has come down from 60 g/day/person in 1951 to 30 g/day in 2014. To meet the demand of pulses, India is at present importing about 5.79 million tones. In order to ensure self-sufficiency, the pulse requirement in the country is projected at 32 million tonnes by the year 2030 which necessitates an annual growth rate of 4.2%. This requires a paradigm shift in research, technology generation and dissemination, and commercialization along with capacity building in frontier areas of research.

Genetic Enhancement for Yield and Quality: Intensive breeding efforts led to development of new plant types, varieties with short duration , disease resistance, large seeded, photo-insensitivity and amenable for late planting besides higher yield in many crops which facilitated crop diversification, intensification and introduction in new niches and cropping systems.

(i) New Plant Types: In 1988, a dwarf-leafless (leaflets converting into tendrils) variety of fieldpea (Aparna) was developed. This dwarf variety responded well to high plant population, irrigation and nitrogen, and thus significant increase in productivity (Ali, 1988). Later on, many dwarf and semi-dwarf varieties (Sapna, Uttra, Malviya Matar 15, KPMR 400, KPMR 522, Vikash, Prakash, Pant P 74) were developed.. In chickpea, a tall-erect variety (BG 261) with basal branching and bold seeds was developed in 1984. This variety was found ideal for intercropping with mustard cv 'Varuna' in 6:2 row ratio (Ali, 1992). Now, more emphasis is laid on tall- erect plant types in chickpea, lentil and mungbean to facilitate mechanical harvesting. In short duration pigeonpea, a few varieties with determinate growth habit (ICPL 87, ICPL 151, ICPL 85010) were developed to facilitate synchronous maturity and timely harvesting but it could not click due heavy infestation of pests.

(ii) Short Duration: The traditional long duration varieties often experienced terminal drought resulting in partial or complete failure of crop, encountered more pest infestation and favoured mono-cropping. Therefore, efforts were made to develop short duration varieties in all pulse crops with matching phenology for different agro-ecological regions. The advent of short duration varieties of pigeonpea during 1975-76 such as 'PusaAgeti', 'UPAS 120', etc. led to introduction of pigeonpea in the irrigated area of north-west plains under pigeonpea - wheat double cropping system (Ramanujam, 1971). Later on, many short duration (130-160 days) varieties such as ICPL 151, Pusa 33, Pusa 855, Manak, Al 15, Al 201 and Pusa 992 were developed (Ali and Kumar, 2009). Mid May to mid June was found to be the optimum time of planting for success of pigeonpea-wheat rotation.

In chickpea, first short duration (110 days) variety (ICCV 2) was developed in 1991. Subsequently, many short duration (90-110 days) varieties such as ICCV 10, JG 11, JG 74, BGD 72, ICCV 37, SAKI 9516, JAKI 9218, Vijay etc. were developed which revolutionized chickpea cultivation in central and south India. In mungbean, development of short duration and photo-thermo insensitive variety possessing synchronous maturity (PusaBaisakhi) in 1974, led to its cultivation as a catch crop during mid-March to mid-June after harvest of *rabi* crops such as potato, mustard, sugarcane and wheat. Later on, many short duration (60-65 days) varieties such as PDM 54, PDM 11, Pusa 9531, Pusa Vishal, SML 668, HUM 12, Pant Mung 5 etc. were developed which played a catalytic role in spread of spring/summer mungbean and crop intensification in north India. In 2016, an extra short duration mungbean variety, IPM 205-7 (Virat) has been released which matures in 52-55 days finds suitability after wheat harvest in irrigated tract of Indo-gangetic plains, cana command areas of Madhya Pradesh and Gujarat and after rice-rice cropping system new delta area of Tamilnadu. Similarly, development of short duration (70-75 days) varieties of urdbean such as BasantBahar, PU 19, PDU 1, UG 218, KU 300, WBU 109 etc. led to its cultivation in spring season. Agronomy of spring/summer mungbean and urdbean was comprehensively worked under AICPIP. Intercropping of mungbean and urdbean with spring sugarcane has been found quite promising.

(iii) Disease Resistance: Pulse crops suffer heavily due to several fungal, viral and bacterial diseases which brings instability in their productivity. The most common diseases are *Fusarium* wilt (chickpea, lentil and pigeonpea), rust (lentil, peas), MYMV (mungbean, urdbean, cowpea), BGM and Ascochyta blight (chickpea), Phytopthora stem blight and Sterility mosaic (pigeonpea) and powdery mildew (peas, urdbean, mungbean). Therefore, breeding for disease resistant varieties remained a core programme under varietal improvement. Since more than one major disease occurs in many crops, emphasis is now placed on multiple disease resistance as well as introgression of genes for different races/ pathotypes of diseases. Some of the important varieties possessing resistance to major diseases in different crops are given in the Table.

Disease resistant/tolerant varieties of pulse crops

Crop	Disease	Resistant/tolerant varieties
Chickpea	*Fusarium* wilt	Avrodhi, Bharti, DCP 92-3, GG 1, HC 1, ICCC 32, JG 11, JG 16, JG 315, JG 74, Kranti, KWR 108, Phule G 12, Vaibhav, Vardan, JG 322, GNG 1581, GNG 663
	*Ascochyta*blght (AB)	PBG 1, Gaurav, PBG 5, GNG1581, Samrat, HC 5
	Wilt+AB	GNG 1581, BGM 417
Pigeonpea	*Fusarium* wilt	Maruthi, Asha, BSMR 736, BSMR 853, ST 1, BirsaArhar, JKM 7, BDN 708, Vipula, Rajeev Lochan, BDN 711
	Sterility mosaic (SMD)	Bahar, Hy 3C, Sharad, Pusa 9, VarendraArhar 1, BSMR 853, GT 100, Amar, MA 6, BDN 708, BDN 711, IPA 203
	*Alternaria*blight	Sharad, Pusa 9, NDA 3
	Wilt+SMD	GT 100, BDN 708, BDN 711, BSMR 853, Rajeev Lochan, MA 6, Vipula, GJP 1
Mungbean	MYMV	ML 267, PDM 11, PDM 54, MUM 2, NarendraMung 1, ML 613, Pant Mung 4, Pusa Vishal, HUM 1, Meha, COGG 912, HUM 16, IPM 02-14
	Powdery mildew (PM)	TARM 2, Pusa 9072, TARM 1, TARM 18, Pairymung TJM 3
	MYMV+PM	Pusa 105, ADT 3, LGG 407, LGG 450
Urdbean	MYMV	Pant U 35, NarendraUrd 1, BirsaUrd 1, TU 94-2, KU 301, Azad Urd 1, Uttra, KU 96-3, Pant U 31, WBU 109, NUL 7, IPU 07-3

Crop	Disease	Resistant/tolerant varieties
Lentil	Powdery mildew (PM)	LBG 17, LBG 402, AKU 4, WBG 26, TU 40
	MYMV+PM	LBG 20, NUL 7, IPU 02-43
	Rust	Sapna, Lens 4076, Priya, Sheri, Pant L 6, IPL 406
	Fusarium Wilt	Sekhar2, Sekhar 3. HM 1, LL 931, JL 3, Vl 507
	Rust+Wilt	NarendraMasur 1, Pant L 4, Priya
Fieldpea	Powdery mildew (PM)	Aparna, Pant P 5, JP 885, Sikha, DDR 27, Uttara, Ambika, KPMR 522, HFP 715,
	Rust	MalviyaMatar 15, Prakash, Aman, Pant P 74
	PM+ Rust	MalvyaMatar 15, Prakash, Pant P 74, HFP 529

Large Seeds: The myth about negative linkage between large seeded varieties and higher yield was dispelled with release of bold seeded (20-25 g/100 seeds) desivarieties of chickpea such as Pusa 256, Phule G 5, Pusa 391, K850, BGD 72, Pusa 362, Samrat, GG 2 etc. which became very popular. Similarly, in kabuli chickpea, extra-large seeded (> 55g/100 seeds) varieties such as PG 0517, PKV Kabulli 4and MNK 1 released in 2010 have become very popular in central and south India as they earn premium price in international market. Similarly, the first bold seeded variety of lentil (Malika) was released in 1986 and thereafter, several large seeded (>2.5 g/100 seeds) varieties such as Priya, Sheri, Noori, JL 3, VL 507, IPL 406 etc have been developed which fetch premium price inmarket and also meet export requirements.

Vast genetic resources would further be required to be used for development of new plant types for different agro-climatic zones. Wider adaptation is rare in pulses; therefore, largely, most of the pulses are locally adapted. Conventional breeding needs to be much focused on development of high yielding varieties with wider adaptation, minimizing anti-nutritional factor and enhancing nutritive values of the pulses. Breeding for low neurotoxic compounds in lathyrus may be prioritized for lifting the ban and ensure consumption of lathyrus which is most hardy, drought resistant and widely adapted species among pulses.

Hybrid Pigeonpea to Trigger Pulse Revolution: Among pulses, pigeonpea and lathyrus are often cross pollinated crops. The floral biology and mode of pollination in pigeonpea offered an unique opportunity for the researchers to exploit the advantage of hybrid vigor as in other field crops. The concept of developing hybrids in pigeonpea was developed at ICRISAT in 1974. Initially, genetic male sterility was identified in this crop and based on this technology, the world's first pigeonpea hybrid ICPH 8 with mean standard heterosis of 25-35 % in various trials was released for cultivation in the year 1991 by ICRISAT (Saxena *et al*.1992). This was followed by the release of five other GMS based hybrids, PPH 4, CoPH 1, CoPH 2, AKPH 4101 and AKPH 2022 bred at different centres of ICAR . These hybrids showed yield advan*tage of 25-40% in different trials (Saxena* et al. 2006). However, these could not become popular due to inherent difficulties in seed production. The major drawback was rouging of fertile counterparts from the female plot, which was time consuming and labour intensive. Owing to such difficulties and high cost of seed production of GMS based hybrids, efforts were made to identify cytoplasmic and genetic male sterility systems (CGMS) to transmute the crop to complete cross pollinated nature. This system works on three plant genetic systems and therefore it is popularly known as a " three line hybrid system" that includes male- sterile (A-line); its maintainer (B-line), and restorer (R-line). Extensive efforts were made to use three line hybrid system in pigeonpea and resultantly the first CMS based hybrid GTH 1 was developed using A_2 cytoplasm from *Cajanusscarabaoides* (Tikka *et al*., 1997) which released for cultivation in Gujarat state in 2004. However due to variation in flowering in parental lines and mixtures and incomplete fertility restoration, this hybrid could not be successful. Experiences with the development of this first CMS based hybrid suggested that availability of stable male-sterility system, efficient mass pollen transfer mechanism, hybrid vigour and large scale seed production of hybrids are major requisites for commercial acceptance of hybrids in pigeonpea. Availability of stable male sterile sources from the wild relatives and complete fertility restoration from the cultivated gene pool ushered the crop further in to the field of hybrid breeding. By exploring the wild relatives of the crop, eight male sterile sources were identified and designated as A_1 to A_8 cytoplasmic sources. Out of these sources, one source (A_4 cytoplasm from the wild relative *Cajanuscajanifolius*) is promising due to stability of the male sterility and complete fertility restoration. Using A_4 cytoplasm, one commercial pigeonpea hybrid ICPH 2671, produced by crossing ICPA 2043 with ICPR 2671, was released in 2010 for cultivation in Madhya Pradesh (Saxena *et al*. 2013). In 21 multi-location trials this hybrid recorded 41.6 % superiority over the check. ICPH2671 is highly resistant to wilt and sterility mosaic diseases and to drought and water logging. On farm trials with ICPH 2671 were also conducted in Maharashtra, Andhra Pradesh, Karnataka, Madhya Pradesh and Jharkhand which recorded 47% yield superiority over checks. This hybrid has dark brown seed and thus fetches low price in the market. After ICPH 2671, two more medium duration hybrids with high yield potential were released in India. In 2014, ICPH 3762 was released in Odisha state. Like ICPH 2671, this hybrid has registered 20 to 67 % superiority over check in multi-location testing. In on farm demonstrations over 144 locations it has out yielded local check by 124 % superiority. ICPH 3762 possesses resistance against *Fusarium* wilt and Sterility mosaic. In 2015, Telangana state released another hybrid of medium duration, ICPH 2740. The performance data of these hybrids have shown that in pigeonpea significantly high productivity levels can be achieved by farmers by realizing the available heterosis in various combinations. However, the success of hybrid breeding in pigeonpea will be measured by its large scale adoption by farmers. Therefore, it is essential to expand research and development base involving various national programmes and public and private seed companies, develop high yielding hybrids for specific agro-ecological regions, fine tune the hybrid seed production technology for increased efficiency and capacity building in hybrid pigeonpea technology.

Development of Transgenic Chickpea Resistant to Pod Borer (*Helicoverva armigera*): Pulses suffers heavy losses due to several abiotic and biotic stresses. Although the conventional breeding methods have contributed to the improvement of pulses crops. However, the required momentum for development of transgenic pulses has been slow because of constraints like recalcitrance of pulse crops for regeneration, low competency of regenerating cells for transformation and lack of reproducible system. However, efforts were made to develop requisite transformation protocols in chickpea and pigeonpea. Using these protocols, efforts have also been made to develop Bt transgenics against *Helicoverpa armigera*. Several transgenic events using insecticidal genes (*cry1Aabc, cry1Ac*and *cry 1 Ab*) with high mortality rate of larvae under insect bio-assay are under testing at IIPR, ICRISAT and other institutes. Out of these five events of each of chickpea and pigeonpea were approved for event selection trials (IIPR, 2016). Besides *Helicoverpa* resistance, drought tolerance in chickpea and blackgram using *DREB1A* and nematode tolerance in pea using RNAi techniques are underway at ICRISAT and JNU, respectively. At present 10 Indian institutes/University/SAU are actively working for development of transgenic pulses for different traits.

Realizing the Potential of Genomics for Crop Improvement: The impressive progress has been made in transferring major genes for improvement of pulse crops through conventional breeding. With the discovery of reliable molecular markers linked to the traits (STS, SSRs, RFPLs, RAPDs, CAPS, dCAPS), it is now possible to capture allelic variation in the form of QTLs which can be transferred into superior agronomic base. A rapid progress has been witnessed over the last 10 years generating a pleothera of information worldwide for extensive use of molecular markers in pulse improvement programme. However, in India a slow but definite progress is being made in developing genomic resources which will lead to use of such resources in precision breeding. With the development of whole genome sequencing information in chickpea and pigeon pea, the marker assisted breeding is now being routinely used in chickpea as all India network project funded by Department of Biotechnology, Government of India. Similarly, under this network project, genomic resources are being utilized in chickpea in diversity analysis studies in order to identify the level of genetic diversity among the different gene pools (Taunk *et al*., 2012). Efforts have also initiated to use MAS in urdbean for disease resistance (Gupta *et al*., 2013; Suframanien and Gopalkrishnan, 2006) and lentil for drought tolerance and improving nutritional quality. Once favourable QTL alleles are identified, in further generations MAS can help deploy them in existing agronomic base. In pursuance of this efforts have been made to identify markers linked to desirable genes/ QTLs for marker assisted selection or marker assisted recurrent selection in different pulse crops.

Bio-intensive Integrated Pest Management Modules: Diseases and pests are wide spread in pulses which include fungal, viral, nematodes and insects. Chemical control for management is hazardous for human health. Therefore, an integrated approach is required to control the problems. Integrated pest management involves the use of alternative techniques and options that are available and help keep the pest population below economic threshold level (ETL); this approach recommends use of chemicals as a last option for pest control. Biopesticides are biochemical pesticides that are naturally occurring substances that control pests by nontoxic mechanisms. *Trichoderma harzianum* is fungi that are present in substantial numbers in nearly all agricultural soils and is the potential antagonistic fungus which prevents the crops from diseases *viz*. Root rots, Wilts and other soil borne diseases in crops. *Trichoderm*a is able to suppress more than 60 species of pathogens (*Pythium, Botritis, Phoma, Sclerotinia, Fusarium, Ascochyta, Alternaria* and others) on different plants.

Conservation Agriculture / RCTs and Mechanization: Conservation agriculture should be a vital component of the strategy for food security and poverty alleviation, health for all, rural development, enhancing productivity, improve environmental quality and preserve natural resources. RCTs / CA is also a strategy to mitigate and adapt to climate change. Generic elements of Conservation Agriculture are: significant reductions in tillage, retention of crop residues on soil surface, reduce compaction, and economically feasible, diversified crop rotations, zero tillage and raised bed planting, timely crop establishment and improved water productivity. Of 44 million ha area under rice, about 11 million ha remains fallow during *rabi* season due to several bio-physical, biotic and abiotic stresses and socio-economic constraints. Soil moisture is the most critical constraint for cultivation of *rabi* crops in rice fallows. Short duration pulses are considered to be the most ideal crops. Efforts have been made to identify suitable crops and varieties for rice fallows.

Lentil, lathyrus and chickpea in eastern and central regions and urdbean/mungbean in peninsular region have shown great promise. Seed priming (soaking in water for 8-10 hrs.), enhanced seed rate (25-30%), pelleting of seeds with Rhizobium culture, single superphosphate and plant protection chemicals, folia spray of 2% urea at flowering stage and spray of post-emergence herbicide (quizalofop-ethyl) have been found quite effective for establishment of desired plant population, crop growth and yield (Ali *et al*., 2014).

Integrated Nutrient Management: Nutrient imbalance is one of the major abiotic constraints limiting productivity of pulses. The inbuilt mechanism of biological N_2 fixation enables pulse crops to meet 80–90 per cent of their nitrogen requirements; hence a small dose of 15–25 kg N/ha is sufficient to meet out the requirement of most of the pulse crops. However, in emerging cropping systems like Rice - Chickpea, a higher dose of N (30–40 kg/ ha) had shown beneficial effect. Phosphorus deficiency in soils is widespread and most of the pulse crops have shown good response to 20–60 kg P_2O_5/ha depending upon nutrient status of soil, cropping system and moisture availability. Response to potassium application is location specific. A comprehensive study on soil fertility status in pulse growing regions showed that out of 135 districts, 87 districts were deficient (20-60%0 in sulphur. Deficiency of sulphur has gradually developed in these areas due to absence of organic manures, use of sulphur free fertilizers (DAP), leaching losses and increased cropping intensity. The need of sulphur application in pulse crop was realized during early 1990s when multi-locations studies under AICPIP showed good response to 20 kg S/ha . In the recent years, some of the micronutrients such as Zn, B, Mo and Fe have improved productivity of pulse crops considerably in many pockets. During 1990s, response of pulses to micro-nutrients like Zn (Dhingra *et al*., 1979; Saxena and Singh, 1977), Mo (Mudhalkar and Ahlawat, 1979) and Fe (Saxena and Sheldrake, 1980) have been reported. Basal application of 15-20 kg Zn SO_4 /ha has been recommended in zinc deficient soils. Nutrient requirements for cereal-pulse rotation as well as for cereal+pulse intercrops have been worked out for different regions. Boron and placement of phosphatic fertilizers and use of bio-fertilizers enhance the efficiency of applied as well as native P. Foliar nutrition of some micronutrients proved quite effective. The amount and mode of application is determined by indigenous nutrient supply, moisture availability and genotypes. Balanced nutrition is indispensable for achieving higher productivity.Foliar application of urea in field crops was advocated in 1960's. However, this could not become popular due to marginal gain in yield. Several studies showed 10-15% yield enhancement with foliar application of 2% urea/DAP at reproductive stage under soil moisture stress . Further, studies showed that the main reason for increase in productivity was increased N concentration in the middle leaves which made them photosynthetically more active and thus higher seed yield (Ali, 1984).Enhancement of BNF capacity of pulses received due attention right from beginning of AICPIP. Efficient strains of *Rhizobium* have been identified and genotype-strain interaction as well as efficient mode of their application has been recommended. Dual application with *Rhizobium* culture and Phosphate solublizing bacteria has been found quite effective. A large no. of field experiments and FLDs have shown 10-15% increase in yield due to seed inoculation with *Rhizobium* culture. In view of increasing nutrients demand, there is immense need to exploit the alternate source of nutrients *viz*., organic materials and bio-fertilizers to sustain the productivity with more environment friendly nutrient management systems. The environmental issues and other hazards emerging out of the imbalanced use of nutrients should also be addressed properly.

Minimizing Post-harvest Losses: Enhancing milling efficiency is one of the major issues to reduce the post-harvest yield loss. Besides this, efforts would be made towards exploitation of genetic variability for milling characteristics and resistant to stored grain pests, development of efficient harvest and threshing machine, design and development of efficient dhal mills and development of improved technologies for storage.

Innovative Technology Transfer System: Effective delivery mechanism would greatly help in bridging the wide gap between the potential and the realized productivity. A number of innovative extension modules are available for improving adoption, technology dissemination of pulse-based technologies at village level. A Pulse seed village concept and popularization of summer mungbean had been successful for promotion of seed production, adoption of varieties and efficient utilization of fallow land for additional income. Farmers largely adopted the improved varieties, IPM modules involving bio-control of pod borer through neem seed kernel extract. The programme on "Rural entrepreneurship through value addition" was the venture in this direction. Mobile Apps for package of practices, Voice SMS advisory to growers clubs, e-ToT applications, farmers portal and web based services are some of the innovative methods need to be applied for effective transfer of pulses production and protection technologies. Extensive training programme for the extension workers, *Kisanmela*, frontline demonstrations would be the efficient mechanisms of enhanced knowledge sharing of pulse-based technologies.

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Oilseeds Status, Targets and Strategies for India

K. S. Varaprasad

Plant based oils are indispensable in the human food as also for industrial purposes. The oilseeds sector constitutes an important determinant of agricultural economy in the country. The demand for edible oils being highly income and price-elastic, the increase in population coupled with rise in income levels have led to demand growth at a faster rate than it is possible to enhance the productivity. There is also a high degree of variation in annual production of oilseeds owing to their cultivation predominantly under low and uncertain rainfall situations and input starved conditions coupled with poor crop management. Trade policy reforms in the mid 1990s have increased market access, and domestic price support policies have generally favoured production of crops that compete with oilseeds, resulting in waning oilseeds production and stagnant yields. Efficiency gains in the oilseed processing sector have also been hampered by poor infrastructure and policies restricting the scale of processing plants. Due to comfortable build up of foreign exchange reserves, the Government has been managing the deficit through imports, which is causing severe injury to the domestic oilseed sector.

Status and Targets

Current domestic oilseeds production is about 30 million tons contributing to about 10 million tons of vegetable oil which is less than 50% of current needs at percapita consumption of edible oil by about 14kg/ annum. About Rs 60, 000 crores worth foreign exchange is depleted annualy to fill the demand for doemstic needs currently. However, India exports vrious oil and related commodities to the tune of 25,000 crores. Projected Indian population by 2025 is 1.4 billion with estimated percapita consumption of 17kg/annum, we need to almost triple the oilseeds production to be self sufficient. In the current world trade situation, it is not practicable to target self sufficiency. Hence, the strategy shall be balancing the export/ import value at the national level and profitability at farmer level shall be focussed rather than focussing on enahncingproductivity alone. Such a target needs multi-pronged approach involving diverse stakeholders.

Major contributors to annual oilseeds production are soybean, groundnut and rapeseed mustard. Global average productivity of soybean, groundnut and mustard are 2.5, 2, and 1.8 tons/ha respectively. Highest productivity of soybean (2.9 tons/ha), groundnut (4.5 tons/ha) and mustard (3.9 tons/ ha) are reported from Brazil, USA and Germany. In the recent past groundnut contribution to edible oil reduced considerably and table purpose consumptions both domestic and export enhanced.Highest productivity for sesame (1.3 tons/ha) is reported from China. Average productivity of sesame in India is 450 kg/ha.Current levels of productivity of soybean (1000 kg/ha), groundnut (1240 kg/ha), rapeseed mustard (1250 kg/ha), sesame (450 kg/ha) and safflower (580 Kg/ha) can be enhanced to 1600, 2000, 1820, 750 and 950 kg/ha respectively with appropriate technology transfer, policy and price support. Among the industrial oils, castor productivity can be enhanced from 1454 to 1850 kg/ha. Within India, at state level, the

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highest productivity for soybean (1.6 tons/ha) groundnut (2.8 tons/ha), mustard (1.6 tons/ha) and sesame (0.9 ton/ha) is reported from erstwhile AP, Tamil Nadu, Haryana and West Bengal. Rainfall pattern in MP and Maharashtra, the major soybean states rainfall has become erratic in several districts and disease inoculum built up, hence the lower yields. National average productivity of groundnut is pulled down by the productivity of Ananthapur district of Andhra Pradesh with scanty rainfall and poor soils. Major area of groundnut in Tamil Nadu is irrigated. Soil moisture availability and soil fertility are major reasons for higher productivity of sesame in West Bengal.

Current area covered by annual oilseeds is about 27 million ha. With commitment of government with policy and price support and from the implementing/ developmental agencies working hand in hand with research organisations, private seed industry and NGO's, an enhancement of about 7 million ha over the current area is practicable. Major crops to be focused to enhance the area of cultivation and productivity are soybean, mustard, sesame, safflower and castor to introduce in to the new niches. Current sunflower area is mainly in Karnataka, wherein productivity has come down drastically. Productivity of sunflower as new crop in West Bengal is almost double the Karnataka state average. *Kharif* sunflower performance is very poor due to terminal drought and SND.

Focus on soybean and mustard for research and development is likely to pay more dividends for edible oil than groundnut. Undisputedly, sesame is the next crop on which we need to invest time and energy for rich dividends. Sesame with proper input and technology supply, yield can be doubled in about a million hectares under cultivation. Sesame and safflower are potential profitable crops with technology readily available and has potential to replace several unprofitable *Rabi* crops facing moisture stress. Among the secondary sources for oil, cotton and rice bran oil contribute significantly to edible oil with almost negligible R&Dinput for oil from agricultural research. Though maize also can contribute to oil, currently the crop is more focused for food security as against oil source. Linseed, though cultivated as oilseed crop in a limited area (less than one lakh hectares), it should be more viewed as a health crop and comparable to recently introduced chia. Chia is cultivated in about few hundreds of hectares only in Karnataka and Rayalseema region of Andhra Pradesh.

Chia Seeds (*Salvia hispanica*)		**Flax Seeds (*Linum usitatissimum*)**	
Nutritional value per 100 g (3.5 oz)		**Nutritional value per 100 g (3.5 oz)**	
Energy	2034 kl (486 kcal)	Energy	2234 kl (534kcal)
Carbohydrates	42.12g	Carbohydrates	28.88 g
Dietary fibre	34.4 g	Dietary fibre	27.3 g
Fat	30.74 g	Fat	42.16 g
Saturated	3.330 g	Saturated	3.663 g
Monounsaturated	2.309 g	Monounsaturated	7.527 g
Polyunsaturated	23.665 g	Polyunsaturated	28.730 g
Omega 3	17.8 g	Omega 3	22.8 g
Omega 6	5.8 g	Omega 6	5.9 g
Protein	16.54 g	Protein	18.29 g

Chia Seeds (*Salvia hispanica*)		Flax Seeds (*Linum usitatissimum*)	
Trace Minerals		Trace Minerals	
Calcium	63 % (631 mg)	Calcium	26 % (255 mg)
Iron	59 % (7.72 mg)	Iron	44 % (5.73 mg)
Magnesium	94 % (335 mg)	Magnesium	110 % (392 mg)
Phosphorus	123 % (860 mg)	Phosphorus	92 % (642 mg)
Potassium	9 % (407 mg)	Potassium	17 % (813 mg)
Zinc	48 % (4.58 mg)	Zinc	46 % (4.34 mg)

Flax seed is the best vegetarian source of omega 3 FA after fish based cod liver oil. Linseed oil is mostly used in paint industry. Linseed is also grown for its fiber, the linen. However, the quality of Indian linseed fiber is not suitable for textile industry. Hence linen is entirely imported by the textile industry. Recently four varieties have been identified with fiber quality equivalent to imported fiber. Niger is a tribal crop mostly grown on high altitude regions. It has export potential as bird feed.

Among the non-edible oilseed crops, castor both in *Kharif* and *Rabi* need to be selectively promoted as cash crop bringing profitability to farmers.

Tree Borne Oilseeds (TBOs) are cultivated/ grown in the country under different agro-climatic conditions in a scattered form in forest and non-forest areas as well as in waste land/ deserts/hilly areas. Over 125 species of tree borne oilseed crops are known in India.India has enormous potential of oilseeds of tree origin like Mahua (*Madhuca indica*), Neem (*Azadirachta indica*), Simarouba (*Simarouba glauca*), Karanja (*Pongamia pinnata*), Ratanjyot (*Jatropha curcas*), Jojoba (*Simmondsia chinesis*), Cheura (*Diploknema butyracea*), Kokum (*Garcinia indica*), wild Apricot (*Prunus armeniaca*), wild Walnut (*Juglans nigra*), Kusum (*Schleichera oleosa*), Tung (*Vernicia fordii*) *etc.* which can be grown and established in the wasteland and varied agro-climatic conditions. These have domestic and industrial utility like agriculture, cosmetic, pharmaceutical, diesel and substitute, cocoa-butter substitute *etc.*, but it is not being utilised fully due to lack of awareness of their uses, collection, proper processing facilities and organized marketing sector.

Strategies

New Crops for industrial needs

Oilseeds have the built in capacity to synthesize highly complex molecular structures that can be used by the industry to displace significant amount of petroleum oil- derived compounds. Substituting petroleum with plant-derived oils as feedstock for different industries can make a substantial impact. Traditionally, the oleochemical industry in North America, Western Europe, and Japan was based on local or imported oils and fats, but this has changed since countries in South East Asia, in particular Malaysia, have become major producers of native raw materials such as palm oil (*Elaeis guineensis* L.).For example, oils containing unusual FAs, such as, hydroxylated or conjugated-double bonds in the alkyl-chain, could be of particular interest as a suitable raw material for production of chemicals needed in the industry. Such oils could include these derivatives from calendula, lesquerella, vernonia, euphorbia, castor bean, and flax.The uniqueness of their oil composition can make these crops irreplaceable, thus justifying their cultivation even with lower seed yields compared with conventional species.

Recently twenty-four plant species were assessed as potential new oilseed crops for Europe (F Zanetti *et al.*, 2013). Results are interesting and worth examining from the

Indian context. Vernonia (*Vernonia galamensis* L.) and stokes aster (Stokesia spp.) appear unsuitable to European environments due to obligated photoperiod requirements. These two species need to be tested under Indian conditions. Species such as Cuphea spp., echium (*Echium plantagineum* L.), borage (*Borago officinalis* L.), and euphorbia (*Euphorbia lagascae* L.) have still considerable physiological constraints, e.g., lack of seed retention, seed dormancy, and indeterminate growth. The scenario for honesty (*Lunariaannua* L.), lesquerella (*Physariafendleri* L.), field pennycress (*Thlaspiarvense* L.), and calendula (Calendula officinalis L.) is less clear, as the proper agronomic management is still greatly unknown. Finally, Ethiopian mustard (*Brassica carinata* L.), crambe (*Crambe abyssinica* Cranz), meadowfoam (*Limnanthes alba* L.), and camelina (*Camelina sativa* L.) emerged as mature oilseed crops for large-scale cultivation and commercialization. Coriander (*Coriandrumsativum* L.), cardoon (*Cynaracardunculus* L.) and hemp (*Cannabis sativa* L.) are cultivated crops worldwide, and their re-introduction into Europe, could probably increase the number of oilseed crops cultivated in a short term. With diverse climatic range from temperate to tropical some of these new crops could potentially contribute to oilseeds production. Potential value of crops from industrial angle based on fatty acid composition is provided below.

Long Chain Fatty Acids (FAs)

Ethiopian mustard, meadowfoam, honesty and pennycress are likely to contain similar or higher amount of long-chain FAs than rapeseed. Significant yield variability over time and across Europe and the low value of the meal for animal feed after oil extraction restricted the marketing of crambe.

Short-to-medium-chain FAs

Cuphea FAs profile is unique, characterized by high content of capric (C10) and lauric acids (C12). A similar FAs profile can be found only in tropical species, such as coconut and oil palm. PSR23 (*Cuphea viscossisima* × lanceolata) is the only domesticated genotype of Cuphea genus that performed quite successfully in the USA. Nonetheless, the insufficient yield and significant agronomic/biological constraints such as seed shattering and indeterminate growth remain a limitation for large-scale production.

Hydroxylated FAs

Worldwide, the major source of hydroxylated FAs is castor seed. One alternative source, lesquerella, was the object of an intensive research program for many decades in Europe and USA. However, lesquerella has a low yield potential, which can be partially explained by its limited environmental adaptability. Current domination of India and China for castor cultivation may change if an alternative to ricinolic acid is found.

Epoxidized and conjugated FAs

Epoxidized FAs are another interesting feedstock for the green industry. Oilseeds naturally rich in these FAs include euphorbia, vernonia, and stokes aster. Calendula does not contain epoxidized FAs but does have a conjugated-double bond FAs that can be used in many similar applications to those of epoxidized FAs. Unfortunately, all these species are still rather unknown from the agronomic point of view, especially concerning the mechanization strategies to cope with indeterminate growth and seed shattering.

Poly Unsaturated FAs

Flax and camelina seed oils are rich in alpha linolenic acid (an omega 3 FA). However, unlike flax, the agricultural management of camelina is still greatly unknown, as significant interest in camelina has occurred only recently. Camelina is also rich in eicosenoic acid (C20:1),an uncommon FA with unique industrial applications (e.g., polyamide-11, a polyamide bio-plastic). Other minor oilseeds rich in PUFAs are echium, evening prim- rose (*Oenotherabiennis* L.) and borage. These species are still undomesticated, with indeterminate growth habit and limited seed retention, making them difficult to harvest. Nonetheless, the relative high content of unusual FAs such as stearidonic acid (C18:4, Omega-3) in echium and hemp seed oils opens up attractive perspectives for pharmaceutical, nutraceutical, and cosmetic industries.

Mono Unsaturated FAs

Among MUFAs (oleic acid (C18:1), an omega-9 FA, with high oxidative stability, is the dominant FA for industrial applications such as cosmetics, metal working fluids, paint manufacturing, welding and soldering agents, and pulp and paper manufacturing. Sunflower (HOS) is by far the most important source of oleic acid globally for industrial applications. Among the alternative MUFA crops high oleic types exist in rapeseed, safflower, and cardoon.There is interest in coriander cultivation as a feedstock for the chemical industry. Coriander seed oil content is approximately 25% and can be used for the production of surfactant, soap, and detergent due to a high content of petroselinic acid (65–74%) in the seed oil. This particular MUFA is a positional isomer of oleic acid with the double bond in the delta-6 position, a rare position among octadeconoic acids making it suitable for the production of unique derivatives such as lauric acid (C12:0) Coriander seed oil methyl esters have excellent fuel properties as a result of its unique fatty acid composition. Coriander now used largely as herb and seed spice, needs a relook from industrial application angle.

Tree-borne oilseeds from livlihood to commercialisation

Some of the important treeborne oilseeds that require research and commercialisation through expansion and new product development through value addition are given below.

Wild apricot (*Prunus armeniaca*, vernacular names: Chuari, Zardalu, Khubani, Chola, Chulu) is an important oilseed of tree origin. It is a hardy plant species and can be grown in most of the deep well drained soils. The wild apricot tree grows to a height of 10-15m and found in the dry temperate regions of North-western Himalaya particularly in the valleys of Jammu & Kashmir, Chenab, Kullu and Shimla regions of Himachal Pradesh, Garhwal hills of Uttarakhand and in Nainital, Almora and Pithoragarh of Kumaon region. The oil is used for medicinal, cosmetic, confectionary purpose and also as biodiesel source. The cake extraction of oil can be used as manure and as cattle feed after detoxification of hydro-cyanic acid. Improved varieties/accessions in wild apricot are Shipley Early, Kaisha, New Castle, St. Ambroise and Royal and improved CPTS collection from KumaunUniversity.

Cheura (*Diploknema butyracea*, vernacular names:Cheura, Phulware) is distributed in the sub-Himalayan tracts and outer Himalayan ranges, also sporadically found in tropical moist deciduous, semi-deciduous and ever green forests of Andaman Islands. It is a medium sized, hardy plant species with economic age of 80-100 years**.** The large and fleshy fruits are traded for edible purpose. The oil content of seed, known as phulwa or phulwara ghee is used as substitute for ghee and butter in cooking. It is also used in preparing medicines and cosmetic creams. The defatted cake can be used as manure as it has pesticid properties

Pongamia (*Pongamia pinnata,* vernacular names: Karanj, Beech, Pongam, Honge, Karanj)is a drought tolerant, semi-deciduous medium sized treewith short bole and spreading crown. It is widely grown from tropical dry to subtropical dry forest zones. It is a good shade bearer, suitable for planting in pastures, for afforestation in watershed areas and drier part of the country. It grows under a wide range of climate and soil conditions and can grow even in dry areas with poor, marginal, sandy and rocky soils. In addition to drought, it can tolerate saline conditions. Pongamiais a preferred species for controlling soil erosion and binding sand dunes because of its dense network of lateral roots. Root, bark, leaves, flower and seeds of this plant also have medicinal properties and traditionally used as medicinal plants.

Simarouba (*Simarouba glauca,* vernacular names: Simarouba, Paradise tree, Aceituno), is an ever green multi utility tree of medium size. It isboth a source of edible oil and also biofuels. The oil can be used as cocoa butter substitute/ extenders in confectionary and bakery industry. The oil cake is valued organic manure.The plants are polygamodioecious with varying percentage of staminate, pistillate, male and few bisexual flowers in the population. It can grow well in tropical climate and can withstand scanty to high rainfall. All types of well drained soil are suitable for simarouba cultivation.

Mahua (*Madhuca indica,* vernacular names : Mahua, Mahwa, Mowra, Illpai, Hippe, Yappa)is one of the important tree species in central India, as it produces abundant delicious and nutritive flowers. This is used for edible purpose either fresh or dried and stored for indefinite period. It is fast growing with 20 m height, ever green tree cultivated in warm regions for its oleaginous seeds. Its oil is used by tribal as vegetable butter in addition it is used in skin care products, soaps, detergents, *etc.* It serves as an important fuel oil, hence a good source of biodiesel. The seed cake is used as manure. The flowers are used to produce an alcoholic drink in several parts of India. Improved accessions available for cultivation are NDMC 9, 7,10 and 3 for central plateau and hills region.

Neem (*Azadirachta indica,*vernacular names : Neem, Bevu,Tamaka, Tamabin, Margosa Tree,Veppu, Nimba, Vepa)is one of the most valuable tree species found in India. It can grow on wide range of soils upto pH 10, which makes it suitable for every agro-climatic zones except in high and cold regions. It has deeper root system, thus does not compete with annual crops for soil moisture. It is a multipurpose tree which provides all the requirements of rural areas *viz.*, timber, fuelwood, fodder, oil, fertilizers, pest repellant, *etc.* Neem is known for its Azadirichtin content and it has been commercially exploited in many products like medicine, manure, pesticide, insecticide, *etc.* Neem is regarded for its environmental value.

Kokum (*Garcinia indica,*vernacular names : Kokum, Mangosteen, Kokum butter tree, Aamsol) is an important minor fruit, besides seed oil source for edible and non-edible applications. It is reported to be imported from Zanzibar to India. It is found to be grown widely in tropical rain forests of Western ghats in Konkan, Goa, Southern Karnataka and Kerala. It is a slender ever green tree with dropping branches. Kokum fruit is a promising industrial raw material for commercial exploitation in view of its interesting chemical constituents. The seed yield a valuable edible fat known as kokum butter, used in chocolate and confectionary preparations and also in manufacture of soap, candle and ointments. It is an important source for biodiesel. Improved accessions available for cultivation in west coast palins and hills are Konkan Amrita, Loanwala kokum, Khola kokum and Khane kokum.

The tung trees (*Aleurites fordii,*vernacular names : Tung, Candlenut, Candleberry, China wood tree, Balucanut) are cultivated for their seeds, the endosperm of which provides a superior quick drying oil, utilized in the manufacture of lacquers, varnishes, paints, linoleum, oilcloth, resins, artificial leather, *etc.* It is also used to coat containers for food, beverages, medicines, insulating wires and other surfaces as in radios, radar, telephone and telegraph instruments, in addition to biodiesel production. Tung is a fast growing deciduous tree that reaches a height of about 12 m at maturity with a life span of 30 years. It needs long hot summers with abundant moisture, hence most suitable for sub-tropical areas like North Eastren states, Himachal Pradesh and Uttarakhand. Improved accessions available for cultivation in Eastern Himalayan Region are La crosser, Lampton, Isabel, Cahl, Folsum.

Jojoba (*Simmondsia chinensis*, vernacular names : Goat nut, Coffeeberry, Quinine nut, Wild hazel, Pig nut)is a potential tree borne oilseed, which can be commercially cultivated in arid and semi-arid areas having low rainfall, extreme cold and hot temperature. It was introduced in India around 1965, but it was given importance only during 80s. It is an ever green slow growing dioecious desert shrub, which can live up to 150 years. It can tolerate extremely high and low temperature. The seed oil is used as lubrication as a substitute for sperm whale oil, in heavy machinery, as it can be used with little or no refining at high temperatures and pressures. It is a good source for biodiesel, also in pharmaceuticals, cosmetics, food related and other chemical industry.

Olive (*Olea europaea*) is a commercial plant of the Mediterranean since ages and in India it was imported for use in salads and other culinary preparations. In 2007, with an Indo-Israel collaboration, its cultivation was tried in Rajasthan and first fruits were harvested in 2011-12. The oil content of the seeds from Indian cultivation ranged from 9-14 % in comparison to 12-16 % of the other olive growing countries. At present, olives are grown in an area of 182 ha inseveral parts of Rajasthan with 14000 MT. It has global demand for culinary preparation, and edible oil. Improved accessions available for cultivation in arid zone are Barnea Olive; Coratina Olive; Frantoio Olive;Koroneiki Olive; Picholine Olive and Picual Olive. However, two of seven varieties tested in Rajasthan are high yielders under our conditions. Further germplasm and varities need to be tested.

Jatropha (*Jatropha curcas*, vernacular names : Ratanjyot, Danti, Physic nut, Purging nut) is a fast growing multi-purpose deciduous large shrub capable to grow and establish in tropical and subtropical region of the country and even on wasteland. It has the capacity to rehabilitate degraded or dry lands by improving water retention capacity. It has various advantageous characteristic features *viz.*, not browsed by cattle, best hedge plant, less gestation period (two years), capable to grow and establish in various biotic and abiotic stress conditions, high oil content (30-42% in seed), which has multiple uses as biodiesel, direct fuel, lubricant, medicine, besides other industrial uses. The by-product of biodiesel are also quite useful for industrial application such as glycerine and biofertilizers. The residue is a good substrate for biogas production. Recently two varities are also released for Chattisgarh region. Instead of hype, suitable niche promotion would have been successful. It is still a potential biodiesel plant that deservesattention.

Cultivated Area Expansion

Three approaches will largely help in increasing the area under oilseeds cultivation. Innovative intercropping is the first approach. To quote an example, recently in Telangana, sesame was cultivated as intercrop in sugarcane withprofitability. Potentially soybean can be intercropped with sugarcane (irrigated), blackgram, greengram, pigeonpea& cotton; groundnut with pigeonpea, castor, soybean, maize, sorghum, pearl millet, cotton, sugarcane, coconut and cassava; mustard with sugarcane, potato, chickpea, lentil and wheat; castor with groundnut and pigeonpea based on local needs and market state-wise. Rice fallows with an area of over 12 million ha is the second option for enhancing the area under cultivation particularly in east and north east region. Groundnut and sesame are readily accepted in view of their acceptability for local consumption. Mustard is also widely accepted in east and north east due to inherent preference for the oil in the region. Sunflower cultivation in West Bengal is a success story in a limited area. With policy and price support soybean has potential in Punjab as rice fallow crop to prevent ground water depletion. The third approach is non-traditional area expansion. Soybean, *Rabi* / summer castor and mustard in south India are potential crops for spread in non-traditional areas. ICAR- IIOR conducted preliminary trials for these crops in Telangana, Andhra Pradesh and Tamil Nadu proving the potentiality.

Genetic Enhancement

- Development of photo-thermal insensitive varieties of soybean with high yield & wider adaptability across planting time and latitudes
- Development of specialty soybeans for higher quantities & quality of oil, low/null anti-nutritional factors and vegetable types.
- Development of high yielding groundnut varieties with better confectionary / food qualities and tolerant to moisture heat and photoperiod stresses
- Genetic enhancement of rapeseed-mustard for yield, quality and tolerance to abiotic & biotic stresses and identification of genes to breed climate resilient genotypes; and development of hybrid technology
- Development of hybrids/ varieties for high seed yield in castor, safflower, sesame, sunflower and linseed with tolerance to biotic and abiotic stresses
- Breeding refinement of CGMS based hybrid seed production in safflower and development of CMS hybrids in sesame
- Development of specialty type varieties- high oleic sunflower & safflower, white & large seeded sesame, dual purpose safflower with high petal yield and linseed with good quality fibre & high linolenic acid (70%)
- Soybean: To bring down the crop duration to 80-85 days
- Sesame:Short duration varieties (80-90 days) for contingency cropping/ new niches & season
- Groundnut: Development of early maturing (85-95 days) varieties with least reduction in biomass; Use of endophytic microbes to tide over extreme environmental conditions & reduce duration; Development of photo- and thermo-insensitive pre-breeding genotypes which can be used in breeding programmes as donors to eventually reduce the crop duration
- Rapeseed-mustard: Population improvement in toria for 75-80 days and recombination breeding for high seed yield with early maturity and development of high yielding early maturing hybrids for yellow sarson and Indian mustard for 90-95 days and 110-115 days, respectively
- Castor: Development of short duration hybrids (90-100 days) with ideal plat type for mechanical harvest
- Safflower :Development of short duration varieties/hybrids (90-100 days) for late sowing and paddy fallows

Crop Management

- Developing climate resilient conservation agriculture practices for oilseed based cropping systems
- Refinement of agro-techniques for high productivity of oilseeds
- Biotic and abiotic stress management techniques in oilseeds
- Development of bio-pesticides & bio-inoculants and SSNM based balanced nutrition and efficient weed control
- Development of new agricultural machinery
- Development/refinement of broad bed-furrow planting methods and fertigation through drips using liquid fertilizer for red soil areas of AP, TN, and medium black soils of Karnataka & Maharashtra.

Policy Support

- Delineating oilseed crops' eco-logical zones for higher production in the major oilseed growing states such as Gujarat, Rajasthan, Karnataka, Telangana, MP, MS, AP, TN.

- Credit, insurance, subsidies, MSP & procurement
- Infrastructure for processing - innovative institutional models of processing & marketing like Amul, Parag, Dhara, Saffola etc.
- Marketing support in non-traditional areas, cooperative, contract farming.
- Referral Labs to estimate aflatoxins in groundnut & pesticide residue in sesame
- Cold-storage for export-quality groundnut production in Gujarat, AP & TN

Technology Outreach and Development

- Advance planning for each state rolling seed plan; public-private partnership & participatory seed production; production of sufficient quantity of breeder seed & their conversion into foundation & certified seed; maintenance of seed buffer
- Large scale demonstration of technologies
- Capacity building of stakeholders
- Micro-irrigation through sprinklers/drip, rain-gun technologies to save crops and rainwater harvesting
- Timely availability of critical inputs like bio-fertilizers, sulphur, zinc, gypsum, boron, bio- pesticides etc. at field level
- Farm machinery for essential agricultural operations through cooperatives or custom hiring

Conclusion

Implementation of above strategies is expected to enhance the oilseeds production from the current 30 million tons to 48 million tons in the next 3-5 years. Oilseeds can play a vital role as cash crops enhancing farmer's income. Diversity of oilseed crops including treeborne and diversified uses known traditionally is strength of India which is largely unexploited economically. Value addition is key for enhancing the profitability. Sesame, safflower, linseed and niger have enormous traditional value and are potentially nutraceutical crops. Tagging these crops on science based evidence and linking to industry for value addition is need of the hour. Industry sponsored cultivation only of linseed and niger be promoted so as to enhance the farmer profitability. Strong inter institutional linkages across the country and beyond the country boarders including government, non government and private industry organsiations. There is a need for close collaboration with developmental agencies at state and national level. It is very important to infuse corporate culture, obtaining projections through outsourcing competent organisations and bringing crop diversification and cropping pattern dynamically as per the market needs. As of today oilseeds are not included in the Food Security Mission, business approach aiming profitability at farm level shall be the main focus.

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Development in Indian Marine Fisheries

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Introduction

Fish has six times more protein than milk (varying in different fishes from 18% in cod fish to 29%.in tuna fish), making it one of the best sources of protein and it contains all the amino acids, micronutrients, Omega-3 fatty acids and Vitamins A and D needed for healthy growth and development of human body and termed as poor man's luxury food. The demand for fish is increasing year by year and the undernourished sector of our society is dependent on fish for eliminating hunger, promoting health and reducing their poverty.

Constraints and methods to overcome.

Recent estimates indicate that per capita fish to be at low level of consumption in India around 8 to 10 kg per year. In this context the marine fish production of the country plays an important role, which is entirely from capture fisheries. But in recent years the capture fisheries scenario in India is characterized by increased and excessive fishing effort, over exploitation of certain resources from the inshore grounds and increased conflicts among different stakeholders in the sector. Due to continuous exploitation of inshore waters, the production from near shore waters has reached a saturation point. Mariculture is a potential sector which can augment the seafood production for meeting the additional demand for fish in future.

Mariculture practices

Though mariculture practices have developed globally it remains untapped in India. The mariculture activities are confined to coastal brackish water aquaculture, mainly shrimp farming. The other coastal aquaculture activities pertain to green mussel in Malabar Coast in Kerala with an annual production around 15,000 tonnes and marine algal (Seaweeds) culture along coastal Tamil Nadu producing about 17,000 tonnes wet weight annually.

In India, brackishwater aquaculture is a significant contributor to seafood production, constituting mainly the shrimps like *Penaeus monodon and Litopenaeus vannamei*. However, it was realized that the vast coastal and saline water bodies are suitable for mariculture with resources such as oysters, mussel, crabs, lobsters, seabass, groupers, cobia, pompano and seaweeds that has potential to capture new markets with a wide range of seafood products, could be farmed had led to the consideration of them as candidate groups. Presently, commercial level seed production techniques of three species of marine finfish *viz*., sea bass (Lates calcrifer), cobia (Rachycentron canadium) and silver pompano (*Trachinotus blochii*) which have very high potential for mariculture have been developed. Though experimental success in the seed production of sand lobster (*Thenus unimaculatus*) and the blue swimmer crab (*Portunus pelagicus*) was obtained the technique still remains to be standardized.

In India a lot of attention has been given in recently to develop sea cage culture. Cobia, sea bass and spiny lobsters were the major groups

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employed for farming .These demonstrations created an awareness regarding prospects of sea cage farming in the country. Many entrepreneurs, fishermen and farmers are coming forward to take up this venture. The prerequisites for starting this are identification of suitable sites with proper depth, water quality and water current .Survey and identification of sites suitablefor cage farming deserves urgent attention. In addition, policy for leasing, bank finance and governmental subsidy are the needs of the hour.

Bivalve farming techniques have been accepted by small scale farmers and presently being adopted by them. The candidate species being *Perna indicia*,*P.virdisand* Crassostrea *madrasensis*. Spat collection is done mainly from the wild for both oyster and mussel. In the long run it may not be possible to meet the seed demand from wild collection alone. Hence the seed production techniques already developed has to be scaled up as per the requirement of the sector.

Marine algal (seaweed) culture has the potential to develop in protected bays and lagoons and techniques had already been developed and demonstrated. Recently the culture of the carrageenan yielding seaweed *Kappaphycus alvarezii* has become very popular due to its fast growth and less susceptibility to grazing by fish. The development of protocol for ornamental fish breeding and management has provided important livelihood options for marginal and land-less farmers in certain localities.

Through eco friendly polyculture practices by integrating commercially important species of different trophic levels (e.g. Seaweed, bivalve and finfish/shrimp) sustainability, environmental degradation and consequent disease problems can be mitigated ,which otherwise are prevalent through monoculture.

It is necessary to bring awareness among policymakers, managers of resources, fishers and farmers and other stakeholders of the impact and vulnerability from climate change and the need for adaptation and mitigation of negative impacts.It is also necessary to build Institutional and legal frame works that consider and respond to climate change threats along with other pressures such as over fishing, pollution and changing hydrological conditions.

With the capture fisheries hovering at potential level, not much production is anticipated from fishing. The thrust is to utilize the coastal water bodies for mariculture related activities to enhance production. Another major milestone is the development of pelagic fish biomass estimation model for the effective management of pelagic fishery with the support of satellite remote sensing technology. While allowing light fishing outside territorial waters, the brieflays down certain conditions. It restricts the number of fishing vessels; regulates the power of lights used on board/ and limits the number of days of purse-seine light fishing operations in a month. The traditional fishers argue that using light fishing will affect the marine ecology of the region due to excessive capture of large spawning adults. The protests have forced the Goa government to ban the use of LED and other light attractants in fishing practices within its territorial waters. There is also growing resentment in Karnataka against the practice, especially since it tends to catch high-value fishes.This method has come into vogue at a time when the overall marine catches along the south-west coast has declined by 17 per cent and that in Goa by a steep 55 per cent, mainly due to the decline in oil sardine catches, the mainstay of traditional fishers. Rather than an outright ban, it is egalitarian and reasonable if a regulated fisheries management regime is introduced. Beyond production enhancement, employment generation has become a challenge in State fisheries. The problem could be met through preservation of the harvested fish and promotion of value-added products. Andhra Pradesh promoting aquaculture in artificial water bodies. Finally it may be concluded that efforts must be made by all concerned organizations to plan for additional requirement of fish from mariculture and by judicious exploitation of fishery resources through declaration of fishing holiday to save the juveniles and allowing fish stocks to replenish themselves in the coming years.

Innovations in Poultry Research and Production for Rural Poverty alleviation

R. N. Chatterjee and U. Rajkumar

Introduction

India ranks 3rd in egg production and 7th in chicken meat production in the world (Watt Executive Guide, 2015). About 3.4 million tons (74 billion) of eggs are produced from 260 million layers and 3.8 million tons of poultry meat is produced from 3000 million broilers per annum in India. The Poultry Industry is contributing about Rs. 70,000/- crores to the national GDP and providing employment to more than 3 million people either directly or indirectly. About 2-2.5 million tons of poultry litter, a valuable fertilizer, is produced as a by-product every year. The per capita consumption of eggs and meat is about 62 eggs and 2500 g chicken meat per annum in India. It is about 100 eggs and 3000 g meat in urban areas whereas 25 eggs and 900 g chicken meat per annum in rural areas against the recommended level of 180 eggs and 10.25 kg meat. Further, these poultry products are expensive (10-40% higher) in rural / tribal areas due to their non-availability and cost of transportation. The poultry industry is concentrated in certain pockets of the country. The States of Andhra Pradesh and Telangana lead the country followed by West Bengal, Maharashtra, Tamil Nadu and Punjab. However, the industry is mostly confined to urban and peri urban areas due to operational limitations and economics.

Village poultry/backyard poultry/family poultry offers a bright scope for increasing the poultry produce in the country. Production by masses instead of mass production involving 65% rural population and bringing them in to poultry production and consumption cycle will definitely boost the production and also improve the nutritional and livelihood security of the rural/tribal people. Rural backyard poultry with native chicken and duck contribute nearly 22% to the national egg production. It is essential to provide nutritious food with supplementation of animal proteins to rural people to protect them from protein malnutrition. As chicken meat and egg are highly nutritious animal protein sources in rural areas, these can effectively supplement the animal protein needs. Apart from this it can be a source of subsidiary income with minimum inputs to the family and improves the economic status of the family. The backyard poultry farming can be converted into a highly profitable venture by imparting rural people with skills for scientific rearing of backyard poultry and at the same time keeping the input cost low by using locally available environment friendly natural food base available in rural areas. The major inputs required for poultry farming i.e., feed ingredients are available in abundance in rural/tribal areas. Besides fallen food grains, the rural backyards are rich source of "natural food base" like insects, earthworms, kitchen waste, green grass, etc. These waste food materials can be ploughed back into the human food chain, by converting them in to highly balanced and delicious egg and chicken meat with backyard poultry farming with improved chicken varieties. This leads to empowerment of women in rural areas and improve the overall socio-economic status.

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Eggs of native chicken are brown in colour and meat has specific texture and juiciness. Thus there is a need to take up rural poultry production with improved chicken varieties to meet the specific requirements of large majority of Indian population.

Rural Poultry

Rural (village) poultry is characterized by rearing of chicken in small units (10-20 birds per household) primarily reared for the family consumption and social events. The birds are multi coloured, tolerant to climatic stress and are better producers in terms of eggs and meat compared to the native chicken. The birds scavenge for feed, consume household waste, insects and also utilize the resource that are not directly useful to human beings or livestock. This makes rural poultry important due to low input costs and low cost of poultry products in the system.

The birds or varieties developed should resemble the native birds and also have the farmer'sacceptance.

Improved Rural Germplasm

The backyard poultry is to develop a bird which has higher growth and productivity than native chickens, resemble them and has consumer acceptability on par with native birds. The backyard poultry though existed since ages in villages, the scientific modern backyard poultry started from nineties with initiation from Karnataka Agricultural University with Giriraja bird from Bangalore. The bird was well accepted among the rural farmers. Subsequently, Directorate of Poultry Research (formerly Project Directorate of Poultry), Hyderabad initiated research on backyard poultry during 1995 and developed improved chicken varieties by the beginning of the millennium. Central Avian Research Institute (CARI) and other agricultural/ veterinary universities also initiated work and came out with new varieties.

Directorate of Poultry Research, eveloped chicken varieties like *Vanaraja, Gramapriya* and *Srinidhi* suitable for backyard free range farming which are well accepted by the rural and tribal people cutting across the different sectors, religions, etc., throughout the country. These chicken varieties with multicoloured plumage resemble the native chicken in their feather pattern; produce more meat and eggs than the natives. The women are earning a substantial amount of Rs. 200 to 250 per bird, a small unit of 10 birds can fetch about Rs. 2000 to 2500/ with minimum input cost by rearing birds in free range system. Presently, the people are very much fascinated towards these chicken varieties in almost all the states/union territories of India.

Vanaraja : A dual-purpose variety for free range farming in rural and tribal areas was developed and continuously being improved further based on the feedback from end users. *Vanaraja* males weigh about 1.5 to 1.8 kg at 12 weeks and females lay up to 160 eggs under farm conditions and up to 110 eggs in free range condition in a laying year. The bird is hardy with longer shanks and having better immune competence. Because of its multi colored plumage and brown eggs, it is well accepted by the rural people. The birds have good majestic appearance with well built body shape. The male birds are sold at 12 weeks of age with premium price on par with the native birds. Hens produce eggs from 24 weeks onwards which resemble the native eggs in size and colour.

Gramapriya : A layer type coloured chicken variety was developed for free range farming in rural and tribal areas. It can lay upto 180 eggs per year in backyard/free-range conditions with required supplementary feedand produce upto 220 eggs under farm conditions. It has coloured plumage and lays bigger size eggs (52-58g) with brown shell colour. These tinted eggs are preferred by rural and tribal people. It is hardy and livability is high. The male weighs around 1.2 to 1.5 kg at 15 weeks of age and suitable for *tandoori* preparations.

Srinidhi : A promising dual purpose variety for free range farming was developed by this Institute which has fast growth and higher egg production potential under farm as well as backyard conditions. Unique feature of this bird is feather pattern, which is highly diversified resembling to the native chicken breeds. The birds can weigh about 1.8-2.0 kg at 15 weeks of age and can lay about 150 eggs under field conditions.

Other Varieties

During the past one and half decade many new varieties have been developed at both ICAR and state agricultural / veterinary universities. Some of the varieties developed and propagated are as follows.

Table : 1 Improved chicken varieties available for rural poultry farming

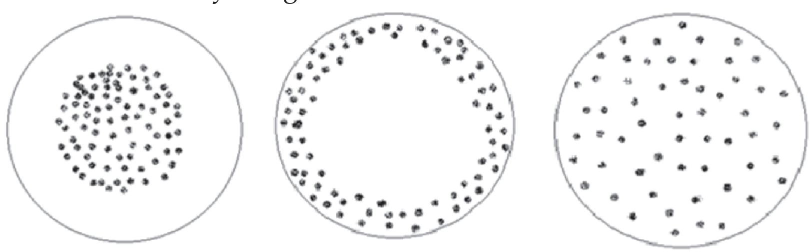
Variety	Type/purpose	Institution
Vanaraja	Dual	DPR, Hyderabad
Giriraja	Dual	KVAFSU, Bangalore
CARI Devendra	Dual	CARI, Izatanagar
Nicorock	Dual	CARI, Portblair
Krishna Priya	Dual	KAU, Manuthy
Gramapriya	Egg	DPR, Hyderabad
CARI Shyama	Egg	CARI, Izatanagar
UPCARI	Egg	CARI, Izatanagar
Krishna J	Egg	JNKV, Jabalpur
Gramalaxmi	Egg	KAU, Manuthy
Kalinga Brown	Egg	CPDO, Bhubaneswar
Kamrupa	Dual	AAU, Guwahati (AICRP)
Jharsim	Dual	BAU, Ranchi (AICRP)

Package of Practices

Nursery Rearing

Basically, day old chicks are produced with artificial incubation and they need initial mother care in the form of nursery rearing, where they will be provided with balanced feed, artificial heat, protection from predators and health care up to 4 / 6 weeks of age. On attaining 6 weeks, these birds can be introduced in backyards for free range farming, where the management and care is just similar to the native birds.Nursery rearing of chicks up to 6 weeks of age plays a major role in success of backyard poultry farming as chicks require balanced ration during the early stage of life. Balanced nutrition, required warmness, good quality drinking water and vaccination are important steps in nursery rearing.

Brooding: Brooding is essential to provide the required temperature. Before housing the chicks prepare the pen by spreading the clean litter material (rice husk/ground nut husk/saw dust/sand) of 2-3 inches thickness uniformly. Spread the news paper on the litter and arrange the feeders and drinkers alternatively. Hang the brooder hovers with electrical bulbs of different capacity (60/100 watt) based on the temperature requirements. The movement of the chicks can be restricted with the help of the chick guards. The temperature may be adjusted based on the behavior of the birds as shown in the Fig . 1 If the temperature is higher the birds move away from the heat source, if temperature is inadequate, the chicks huddle under the brooder near to the heat source. At ideal temperature, chicks are uniformly distributed across the brooding area.



Low temperature ***High temperature*** ***Ideal temperatures***

Fig. 1 Distribution pattern of chicks at different temperatures

Feeding: Complete balanced feed containing all nutrients, minerals, vitamins and amino acids should be provided to the chicks during the nursery phase up to 6 weeks of age. In general, rural chicken varieties require about 2400-2500 kcal ME, 16% protein, 0.77 % lysine, 0.36% methionin, 0.35 % available phosphorus and 0.7% calcium up to 6 weeks of age. Farmers can buy commercially available feed (layer chick feed) or can be prepared their own with the locally available ingredients as shown in the Table 2 (Brochure, DPR, Hyderabad)

Table : 2 Making of feed with locally available feed ingredients

Ingredients	Proportion
Maize/Bajra/Ragi/Broken Rice etc.	50 parts
Rice bran/Wheat bran/ de oiled rice bran etc.	20 parts
Soybean meal/Ground nut meal/ Sun flower meal/Till cake/ Linseed cake etc.	28 parts
Vitamin and mineral mixture (Commercial)	2 parts

Free range Rearing

The chicks are introduced into the farmers' backyards from 4-6 weeks of age depending on the environmental temperature. The number of chicks per house hold depends on the area and the natural food base available. However, 10-20 birds per house hold is ideal for successful and effective management of birds. The birds are let out for foraging during the day time while are kept in night shelter during the night. Based on the natural food availability, the birds have to be provided with supplementary feed (cereal grains and oil seed cakes) to meet the growth and production requirements. Generally, birds meet their protein requirements through scavenging under backyards. Therefore, feeding the birds with available cereals is always beneficial to sustain the production. During the laying stage calcium supplementation (shell grit, stone grit and lime powder) is essential to avoid the shell less eggs and broken eggs.

Health care: Prevention and control of the diseases is utmost important in poultry than the cure. Proper biosecurity measures and good management practices minimizes the incidence of diseases in poultry farms. Proper vaccination schedule during chick and adult stage is very important to control the diseases. The important diseases prevalent in rural areas causing considerable losses to farmers are New Castle disease, Fowl pox and fowl cholera under free range conditions. Endo and ecto-parasite infestation is common under free range conditions. Infestation of internal parasite can largely minimized by providing fresh drinking water with proper protection during early hours before the birds left for scavenging. Periodic deworming (preferably a week days before vaccination) will also help to reduce the incidence of internal parasites. Ecto-parasite infestation can be prevented by providing clean, dry and proper ventilated night shelters. The vaccination schedule (Table 3)followed for rural poultry is as follows (Brochures, DPR, Hyderabad)

Table : 3 Vaccination programme for rural poultry

Age	Vaccine	Strain	Dose	Route
Hatchery				
1st day	Marek's disease	HYT	0.20 ml	SC injection
Nursery				
7th day	Newcastle disease	Lasota	One drop	Eye
14th day	Infectious Bursal disease	Georgia	One drop	Oral
21st day	Fowl Pox	Fowl pox	0.20 ml	IM/SC injection
28th day	Newcastle disease	Lasota	One drop	Eye
Field (free range conditions)				
9th week	Newcastle disease *	R2B	0.50 ml	SC injection
12th week	Fowl Pox*	Fowl pox	0.20 ml	SC injection

*Repeat these two vaccines at every six months interval

Innovations in backyard poultry

Rural Poultry Farming for Meat Production

Backyard poultry farming aims at producing egg and chicken meat with minimum input cost. Conventionally, both male and female chicks are grown together under this system. Males are used for meat purpose after attaining about 1.5-1.8 kg at about 12-15 weeks of age depending on the variety of the improved chicken germplasm. Where ever there is a great demand for meat of coloured chicken varieties, dual type improved rural chicken varieties are reared under intensive system by providing balanced feed (preferably broiler feed) for faster body weight gain. In this system, the birds are fed on high density broiler feed from day 1 of age to till they attain the desired (targeted) body weight (8-10 weeks of age for 1 to 1.2 kg). This practice is preferred when the coloured bird has premium price over the commercial broilers. This farming also can be practicedin anticipationof higher demand for coloured birds especially for cultural/social events.

Availability of Improved Germplasm

To meet the ever growing demand for the improved chicken varieties all over the country, ICAR has established twelve poultry seed project centres to cater to the needs of the farmers in their local regions. Availability of improved germplasm at farmer's door steps or at least nearby areas is one of the identified constraints for the expansion of backyard poultry activity. It also reduces the transportation cost of the germplasm. Therefore, to improve the availability of improved germplasm at different locations across the country.The seed project centres are in operation in different states i.e., Bihar Agricultural University, Patna, Bihar; West Bengal University of Animal and Fishery Sciences, Kolkata, West Bengal; ChatthisgarhKamadhenuViswaVidyalay, Durg, Chattisgarh; Tamil Nadu Veterinary and Animal Sciences University, Hosur, Tamil Nadu; Central Coastal Agricultural Research Institute, Panaji, Goa; Central Island Agricultural Research Institute, Portblair, Andaman & Nicobar Islands; Indian Veterinary Research Instutute, Mukteswar, Uttharakhand; Sher-e Khasmir University Agricultural Sciences and Technology, Srinagar, Jammu &Khasmir; ICAR Research complex for NEH Region, Sikkim Centre, Gangtok, ICAR Research complex for NEH Region, Nagaland Centre, Jharnapani, ICAR Research complex for NEH Region, Manipur Centre, Imphal, ICAR Research complex for NEH Region, Barapani. The project came in to operation during 2009-10 and further strengthened during 12th plan. The main mandate of these centres is to rear and maintain the parents of improved rural chicken germplasm (*Vanaraja,Gramapriya, Srinidhi, Pratapdhan etc.)* at the centres and produce the commercial chicks and supply the chicks to the farmers of the region. This will definitely help in reducing the pressure on the nodal institution (DPR) and also reduces the cost of transportation of chicks. In addition, the location specific chicken varieties are also available at different AICRP centres (12) across the country. However, the improved chicken varieties are also developed at different state agricultural/veterinary universities which are being propagated in their respective regions.

Effective Propagation of Backyard Poultry

Directorate of Poultry Research is acting as the nodal agency for maintenance and supply of parents of Vanaraja, Grampriya and Srinidhi varieties of chicken apart from supplying commercial day old chicks and fertile eggs. Parents are supplied to several Government agencies (AH depts., SAUs, CPDOs, ICAR institutions, DRDO, etc.) where in they produce chicks and supply to the farmers in their respective regions. The commercial chicks are supplied to farmers through government and non government organizations (NGO) which rear the birdsupto 5-6 weeks of age under standard brooding and management practices (Nursery rearing) before distributing chicks to the farmers. Fertile eggs are also supplied to the governmental and private agencies which have an established hatchery for incubation and hatching. The fertile eggs are supplied to some individual farmers in limited numbers who intend to brood with the help of *desi*(native) hen.

Apart from providing the germplasm, the institute undertakes the consumer education programs to popularize the technologies among the farmers. The institute participates in all poultry / livestock / agricultural developmental activities across the country to popularize the rural poultry farming concept with improved chicken varieties among the farmers. The transfer of technology section of the Directorate took up the extension activities through training programs, exhibitions, broachers, information booklets, apart from utilizing mass media (television, radio programs and press) to popularize the technology. The Directorate has established linkage with all state and central developmental departmental institutions across the country.

Community Based Vaccination Program

Incidence of diseases is common in rural areas, especially NewCastle disease in India. Control of viral and bacterial disease is at most important for success of backyard poultry. Standard vaccination schedule protocol has been developed and being practiced all over the country. Availability of vaccine in smaller doses is a constraint for traditional poultry farmers as the number of birds is very less. Therefore, community level vaccination keeping a village as unit has been proved to be successful. The medication and vaccination on a community level will reduce the incidence of diseases in poultry under free range conditions.

Establishment of Mother Units

Mother unit is place where chicks are grown during nursery period for a period of 4-6 weeks before distributing to the farmers. This activity offers a small scale enterprise development in rural poultry where in progressive farmer/ unemployed youth can establish a rearing facility for 1000 chicks with all necessary equipments by availing loan or self financing. After rearing for 4-6 weeks chicks can be made available to the farmers in and around the village with a reasonable price adding his inputs and profit. Since lot of demand is there for improved chicken varieties, mother units plays an important role in providing the chicks at farmers door steps reducing add on cost of transportation and possible mortality.

Establishment of Small Hatcheries

Small hatchery is another activity which offers an enterprise development in rural poultry farming. An unemployed youth or progressive farmer can establish a small facility with an incubator of 500-1000 eggs capacity in a village. Fertile eggs from Govt. organizations or local sources will be collected and incubated. The chicks produced will be distributed to the farmers on cost basis. With little technical guidance and training, a farmer can establish a sustainable small scale poultry enterprise with reasonable profits.

Marketing

The feedback and our experience from the field clearly reveal that there are no organized marketing channels for effective disposal of bird after attaining the desired market weight. Marketing component is vital for success of the rural poultry. Marketing is one of the major problems faced by the rural poultry farmers. Creation of marketing channels through self help groups or co operative model of marketing will help the farmers to market their produce.

Native Chicken Farming

Most of the farmers/consumer prefers local country chickens which have got good market in both rural and urban areas. The new development in rural poultry is rearing of country chicken for meat purpose. Chicken breeds like Aseel, Kadaknath, Gaghus, Punjab Brown etc. are known for their meat qualities. These local chicken breeds are reared under intensive conditions till they reach market age 4-6 months depending on the breed. All these local chicken breeds have lot of demand and are sold for meat purpose at premium price.

Selection for Desired Traits

Some of the other innovations include, selection program based on farmer's feedback, livability under free range conditions, low plane of nutrition, higher immune response, higher shank length etc., are being considered for improving through selection in parents.

Conclusion

Backyard poultry has proven to be one of the viable technologies for alleviating poverty among the rural / tribal people and source of women empowerment across the country. The rural and tribal women are earning a subsidiary income to their family. The backyard poultry rearing with improved chicken varieties is playing a vital role in the livelihoods and nutritional status of the rural and tribal people in our country.

Extension Programmes in Fisheries Development with Special Reference to their Impact on Environment in Coastal Aquaculture

K. MadhusudhanaRao

There exists a large gap with regard to transfer of the existing fisheries technologies to the production level. While the agricultural sector has achieved tremendous progress through technology transfer, fisheries extension has remained one of the weakest links in our agricultural scenario.

The recommendations of the working group on the Fifth Plan regarding research, training and extension drew the attention of the Government to the fact of glaring inadequacies and fragilities in the fisheries extension network and recommended the following measures.

(a) Establishment of extension training centres for inland fisheries,

(b) Provision of equipment and literature to support the extension units at the provincial level

(c) Starting of Fish Farmers' Developmental Agencies (FFDAs) and

(d) Starting Fisheries Data and Information & Forecasting Services for both inland and marine fisheries.

Establishment of Fisheries Extension Network

Organized fisheries extension service in India started at the Central Inland Fisheries Research Institute (CIFRI) with the basic objective of promoting fish seed trade. The impressive success achieved at the Fish Extension Unit in Kolkata led to the creation of nine extension units in the Second Five Year Plan. These units organized work pertaining to survey of cultivable water area, correction and improvement of ponds, prospecting and location of fish seed collection centres from riverine sources, demonstration of induced breeding by hypophysation, nursery management, weed control, transport of fish seed and breeders, organizing short-term refresher courses for the benefit of staff at state fishery units and private entrepreneurs and conducting exhibitions and popularization of fish culture through diverse extension mechanisms.

The Extension Unit at Mandapam accomplished good work in marine fisheries by extending technologies on improved methods in fish handling, fish curing, use of sea weeds, brackish water fish farming with mullets, *Chanos*, pearl-spot, Tilapia, live fish transport etc. The other units located could not achieve rapid progress as the field of inland fisheries was vested with the State Governments with which no meaningful coordination could be established. There was lack of coordination among the different units in the field of inland fisheries and this resulted in winding up of the unproductive units in 1967. In their place Regional Fisheries Cooperatives and Training Centres were instituted particularly in Agra and Hyderabad.

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The review of the on-going fisheries extension activities conducted during the Fifth Plan led to the setting up of Extension Service Units with the assistance of Government of India. Under this scheme extension service kits, audio-visual equipment etc., were provided by the Central Government to support the fisheries extension activities at the state level.

Fish Farmers' Development Agencies (FFDAs)

The FFDAs were started during the Fifth Five Year Plan to support the rural fis farmers with financial and technical support to develop inland tanks and ponds for intensive fish farming. The Extension Officer were entrusted with the responsibility of spreading the relevant technologies into the remote rural areas. Fifty such FFDAs started functioning by the end of the fifth plan and the network of such agencies spread throughout the country particularly in West-Bengal, Bihar, Orissa, Madhya Pradesh and Uttar Pradesh with the support of World Bank.

Fish Handling & Processing

These activities are usually carried out by illiterate fishermen and their family members; but their processing activities are handicapped for want of proper technological input. Hence, efforts are underway to train them in procedures of cleanliness and proper maintenance of their boats, icing of fish, use of proper quantity of ice and ice prepared from potable water, washing fish in clean seawater and avoiding bruises. Also they receive training in maintenance of their sheds used for cutting in clean ambience, maintenance of the water quality, personal hygiene, use of proper equipment and maintenance of the prescribed low temperature. The Export Inspection Agency (EIA) and MPEDA have been entrusted with the enforcement of the above procedures. While in-plant inspection and pre-shipment inspection are the needed regulatory measures, what is more important is the upgrading the skills of fishermen and their families through educational approach and training by Extension staff.

Extension Needs in Fishing Techonology

There is an urgent need to introduce the improvements in the design of traditional Catamaran, canoe and plank built boats. In order to modernise the fishing craft there is a need to introduce fibre glass boats and out-board engines. Designing new gears has been slow so far which needs to be looked into.

Brackish Water Farming

Shrimp culture is becoming popular in many coastal zones due to the availability of water areas like bheels, paddy fields etc. Organizations such as CMFRI, CIFE, CIBA, MPEDA must take up on these activities. Likewise, there is scope for extension work in mariculture of mussels, edible oysters, pearl oysters, sea weed

Fishery Information and Forecasting

The fishery information should be available to the fishermen and other clientele engaged in fish production in advance i.e., before the pattern changes. By a system of collection and collation of information, the likely trends regarding the movement and abundance of fish may be indicated by the past experience, available oceanographic data etc. It should be possible to come up with a mathematical model in this regard based on the available data.

Technology Transfer

The technology transfer in fisheries is being carried out through the Operational Research Projects, Demonstrations, Pilot Projects, Sponsored Projects, KrishiVigyanKnedras (KVKs), the Extension Literature published by the ICAR and State Instituttions and some Consultancy Projects carried out by various organizations in liaison with the ICAR Institutes and Universities.

The existing lacunae in the demonstrations conducted by public organizations pertain to lack of credible economic analysis of the recommended technologies.

Lack of strong linkages between the Research and Extension Systems is another area that needs immediate attention.

Environmental Impacts in Coastal Aquaculture

The intensification and expansion of aquaculture have resulted in a variety of conflicts in coastal ecosystems as indicated below.

i. **Aquaculture *vs.* Agriculture:** The land use patterns are subjected to alarming change as a result of conversion of paddy (rice) fields into qua farms. This has resulted in deterioration of water quality for agricultural purposes. This has caused decline in rice yields and also abandonment of rice cultivation,

ii. **Aquaculture *vs.* Forestry:** A large part of Bhitarkanika wild life sanctuary in Orissa got converted for aquaculture. The consequent reduction of the area and mangrove forest is posing a serious threat to the environment and the fragile regional eco-system.

iii. **Aquaculture *vs.* Society:** There are reports of reduction of drinking water sources as a result of intensification and expansion of aquaculture. The higher water demand for shrimp production has also resulted in decline in the water tables of different zones. The fisher folks of many coastal villages have to transport drinking water from far-off areas. Several incidents of water borne diseases have been reported due to the pollution of water bodies due to aquaculture.

iv. **Aquaculture *vs.* Capture fisheries:** Coastal zone fishery resources are getting depleted as a result of indiscriminating capture of brood stocks and shrimp fry from the sea, causing conflict with capture fisheries.

Secondly there is a minor dislocation caused to the operation of fishing boats due to water-intake structures constructed for the purpose of pumping in sea water for aqua farms.

Need for a Rational Policy Framework

It may be noted that aquaculture is generating more incomes and employment as compared to traditional agriculture, thereby creating new opportunities particularly in marshy saline regions of coastal ecosystems. However looking at the above environmental issues, there is a need to regulate the aquaculture industry based on the sound scientific guidelines leading to its sustainability in complementation with agriculture. This endeavour needs to be supported by infrastructure in terms of usable canals, hatcheries and high quality feed processing units.

Sustainability of Some Sources of Renewable Energy

M.V.R. PRASAD

Renewable clean energy has become important and imperative not only from the point of view of receding sources of fossil fuels, but in the light of deteriorating ecosystems all over due to the emissions from the use of fossil fuels. Renewable energy sources have the potential to provide energy services with almost zero emissions of both air pollutants and greenhouse gasses.

The technologies that are being developed in this context tend to offer promise to produce marketable energy through the conversion of natural materials into useful forms of energy. Currently these renewable sources supply 14% of the total world energy demand.

Renewable energy sources are from the natural, mechanical, thermal and growth processes that repeat themselves within our lifetime and may be relied upon to produce predictable quantities of energy when required.

Despite the fact that renewable technologies like hydro and wind power probably would not have provided the same kind of fast increase in industrial productivity as did fossil fuels (Edinger and Kaul 2000), the share of renewable energy sources is expected to increase in future.

Table : 1 Global renewable energy scenario by 2014

	2001	2010	2020	2030	2040
Total Consumption (Million ton Oil equivalent)	**10,038**	**10,549**	**11,425**	**12,325**	**13,310**
BIOMASS	1,080	1,313	1,791	2,483	3,271
Large Hydro	22.7	2.66	309	341	358
Geothermal	43.2	86	186	333	493
Small Hydro	9.5	19	49	106	189
Wind	4.7	44	266	542	688
Solar thermal	4.1	15	66	244	480
Photovoltaic	0.2	2	24	221	784
Solar thermal Electricity	0.1	0.4	3	16	68
Tidal wave /Ocean	0.05	0.1	0.4	3	20
TOTAL RENEWABLE	1,365.5	1,745.5	2,694.4	4,289	6,351
Renewable Energy Contribution (%)	13.6	16.6	23.6	34.7	47

(Source: Demirbas, A. 2008)

According to Khan (2013) a mere total of 13% is renewable energy and the balance 87% is still fossil fuel (coal, gas and petroleum). Nuclear and Hydro together stand at 11.3%, while solar and wind and other renewables add to merely 1.6% of global energy production. The limiting factor that comes in the way of use of alternate energies is measured as scalability. Scalability limits are different for each kind of alternative. For example solar panels need ground area, reliable sunlight, and availability of silicon etc., wind mills need suitable locations with winds above a critical minimum speed for sufficient number of days. Alternatives such as solar, wind, hydro, nuclear, geothermal, waves, tides, fusion and fuel cells may generate only electricity and they need oil and fossil-fuel based infrastructure that needs to be assembled, run and maintained.

The thesis of Khan (2013) may be summed up as follows:

- Alternate Energies cannot run the Modern Industrial World in the manner, cost and scale that we have designed and become used to.
- Sensibly used alternative can fill important niches but intrinsically requires scaling down our gross energy usage.
- This means Economic Shrinkage cannot be averted. Only managed in non-disastrous way.
- However, liquid fuel alternatives like Biofuels (Ethanol and Vegetable Oils) or fuel extracted from tar-sands and oil-shale seem to have some future. Despite these being poor performers, they are counted as most vital because they can directly replace oil and therefore stand a chance to contribute to running the modern industrial world the way it is built. These fuels however, don't exist in nature; but they have to be produced.
- Biofuels can provide up to 27% of the world transportation by 2050 (IEA 2011)

Biomass Based Renewable Energy

Biomass is the name given to all earth's living matter, which represents solar energy stored in chemical form in plant and animal materials. This is one of the most precious and versatile sources on earth. The components of biomass consist of cellulose, hemicelluloses, lignin, extractives, lipids, proteins, simple sugars, starches, water, hydrocarbons, ash and others. Among the renewable energy sources biomass is considered important. In the year 2055, the distribution of renewable energy consumption as percentage of total renewable energy in world was as follows: biomass 46%, hydro electric 45%, geothermal 6%, wind 2% and solar 1% (EIA, 2006). These renewable energy scenarios depend on environmental protection, which is an essential characteristic of sustainable development. World biomass production is estimated at 146 billion metric tons a year consisting of mostly wild plant growth (Cuff and Young 1980). Worldwide biomass ranks fourth as an energy source, providing around 14-15% of world energy needs (Hall *et al*., 1992).Biomass currently represents 3% of primary energy consumption in industrialized countries. Nevertheless, much of the rural population in developing countries, which represents around 50% of world population, relies on biomass, mainly in the form of wood, for fuel (Ramage and Scurlock 1996). New research is urgently needed on the potential impact of second generation lignocellulosic biomass based biofuels on deforestation. Initial studies suggest that these biofuels may have substantial impacts if short rotation plantations are established on former agricultural land. Also, the potential deforestation and forest degradation-induced effects of second generation biofuels due to the competition for fibre and fuel may be very significant if not properly addressed, particularly if organized production displaces fuelwood and charcoal production in developing countries' informal energy sectors.

Collection and transportation of the scattered biomass and subjecting them to suitable digestion systems depending upon the extensive network of massive equipment demand heavy costs. The major criticism in this case is about the huge costs involved and collection, transportation and processing of biomass which causes heavy dependence on fossil fuels.

Decentralization of the processing of biomass at the rural levels too seems to be beset with unmanageable expenses as it involves setting up of suitable equipment and employing trained workers at different and diverse places. Processing of lignocelluloses of biomass is known to generate gases prejudicial to environment and hence United States is deferring the processing of these materials for production of biofuels.

Extensive use of diverse sources of biomass as feed-stocks for biofuel is reported to lead to deforestation without any matching efforts to conserve the forest cover which would lead to disastrous consequences. . One of the concerns around the use of biomass for bio-energy and bio-based products centers on the direct or indirect changes in land use and loss of biodiversity.

Table : 2 Importance of biomass in different world regions

Region	Share of biomass in final energy consumption
Africa	60.0
Souh Asia	56.3
East Asia	25.1
China	23.5
Latin America	18.2
Europe	3.5
North America	2.7
Middle East	0.3

(Source: Demirbas, A. 2008)

Many of the other touted options such as algae which may also be considered a component of Biomass sector have been in tested for 50 years in labs, but the problem still remains of making it on a large scale to be viable and contributing.

According to Khan (2013) none of the alternatives yield any of the by products that fossil oil gives us such as bitumen, plastics, fertilizers, fossil lubricants or pharmaceuticals on which the complete fabric of our modern industrial world is designed and built.

Vegetable Oils as Feedstocks for Biofuels

There could be an exception in the case of non-edible vegetable oils that could be recovered from wide range of biological sources, provided suitable niches for their production and management could be chalked out.Considering the oil yielding or carbohydrate yielding plant species as feed stocks for biofuels, one could see a preponderance of choice towards crops yielding edible food commodities viz., maize, sugarcane etc., for production of bio-alcohol as energy fluid. On the other hand we also observe extensive use of edible oil bearing plant species *viz*., soybean, mustard, oil palm etc., as feed stocks to produce oil for bio-diesel.

In both of the above cases, one can't escape noticing the vivid exploitation of fertile crop lands under conditions of intensive crop management using enormous quantities of chemical nutrients, irrigation water and plant protection chemicals to produce feed stocks for biofuels. This scenario is generating intense debate viz., food-*vs*-fuel. The pertinent question is being asked repeatedly if this kind of production of biofuels is really sustainable. In this scenario firstly the edible crops are being diverted for production of biofuels causing shortage of food and feed and secondly the entire production system of this kind is heavily dependent upon the use of fossil fuels in terms of the use of chemical fertilizers, plant protection chemicals and irrigation (demanding heavy use of diesel) for production of biofuels, which can't be sustainable in the very next few years to come (Khan 2013). An analysis, using the ratio of biofuel production to total oil production in 2009, shows that bio diesel from oil palm may have been responsible for up to 2.8% and 6.5% of direct deforestation in Indonesia and Malaysia (Yan Gao *et al*., 2011). Bio diesel from soybean in the Brazilian state of MatoGrosso may have been responsible for up to 5.9% of the direct annual deforestation over the last few years (Yan Gao *et al*., 2011). Jatropha has been promoted as a crop that uses 'wastelands', marginal lands or abandoned agricultural lands. However, in practice, dry secondary forests have often been affected.

Preliminary findings from sub-Saharan Africa show that a portion of the lands acquired for establishing plantations are located within or surrounding closed forests, and were purchased without proper land use planning and sustainability criteria. (Yan Gao *et al*., 2011). Promoting a very rapid large scale expansion of biofuels based on intensive production systems will likely induce further direct and indirect deforestation. This is a result of the enormous economic pressure exerted by private firms to access land, combined with lack of adequate in-country institutions, regulations and capacity to enforce sustainability concerns. The current economic crisis, which has slowed down the biofuel 'boom', provides a good opportunity for national governments to reassess current targets and to build appropriate institutions at the local and international level to help cope with these concerns. Efforts such as the Roundtable on Sustainable Biofuels (RSB) are encouraging and should be promoted and reinforced.

Table : 3 Sources of world's biofuel production

Region	Biofules produced (Litres)	Major feed stocks
Europe	10 billion	Corn / Soybean
North America	40 billion	Corn / Soybean
South America	25 billion	Sugarcane / Corn/Soybean
Arica + Middle East	2 billion	Animal dung + jatropha
Australia +Asia	4 billion	Palm oil / Corn
TOTAL	Around 81 billions	Edible Crops produced under intensive Agriculture demanding chemical/ petroleum based products.

Then what is the way to achieve sustainability for production of biofuels? Let us consider the kind of strategy to be adopted for the production of plant based biofuels:

- It is necessary that the feed stocks used for bio fuels should not be produced/ grown under conditions of intensive agriculture and hence the pertinent need not to encroach upon the fertile lands used for food and feed crops. This would stop the debate *viz*., food vs fuel.
- The plant species employed as feed stocks for biofuel production must yield non-edible products *viz*., non-edible oil for energy purposes. In other words it is necessary to avoid using edible product yielding plant species for bio fuel production.
- These plant species should be grown on marginal lands not used for agriculture totally under rain-fed conditions.
- In other words, these plant species should possess good degree of drought resistance.
- The plants should offer good seed and oil yield ensuring yield stability.
- The plantations should not suffer due to biotic a stress, which means that they should possess good resistance to pests and diseases not warranting any use of chemical pesticides.
- The plant species should be eco-friendly and
- Avoid competition with arable crops.
- Have costs competitive with fossil fuels (Produce Biodiesel with costs under US$ 0.36/litre or INR 22.00 /litre or $ 40.00 /barrel).

When the above criteria are fulfilled, it may be assumed it would be possible to ensure a base for raising sustainable plantations of the feed-stock materials.Following intensive efforts to screen eighty one oil bearing tree species (Prasad1994) for sustainability of seed and oil yield under rain-fed conditions of Hyderabad over eight to nine years, it was found that *Pongamia pinnata* was the most sustainable as compared to several other species of trees including *Calophyllum inophyllum, Madhuca indica, Azadirachta indica, Melia azadirach, Moringa, Thevitia nerifolia* and *Jatrpoha curcus.* The seed yield and oil content in the case of *Pongamia* were more stable and remunerative as compared to rest of the above tree species.The oil content of *Pongamia* was of the order of 33 to 37% of the seed weight with a seed yield of 9 to 14 kg of kernels per tree at 7 years of age of tree. Azametal (2005) too reported that the non-edible yielding oil bearing crops like *Pongamia pinnata* offer bright prospects for production of liquid biofuels.

Pongamia Offers Promise

As compared to the other oil yielding trees such as oil palm and Jatropha, Pongamia is found to be more sustainable (Table 4)

Table : 4 Comparison of pongamia with other biofuel plants

	Temp. Range	Rainfall (mm)	Soil	Type	Time to maturity (yrs)	Life cycle (yrs)	Fuel yld (Liter/ha)	Oil content (%)
Crude palm Oil	24 ⁰C -30 ⁰C	1780-2280	Well drained deep	Edible	3	30	4900	15-25
Rapeseed	0 ⁰C-10⁰C	<500	Medium textured drained	Edible	3-5 months	1	1188	40-45
Soybean	20⁰C-30⁰C	600-1500	Alluvial	Edible	3-5 months	1	512	17
Jatropha	20⁰C-28⁰C	500-2400	Multiple	Non-edible	5	40	1200	20-30
Normal Pongamia	0⁰C-50⁰C	250-2500	Multiple	Non-edible	7	60	2300	28-33
VayuGrid Pongamia	0⁰C-50⁰C	250-2500	Multiple	Non-edible	3	60	9375	30-35

The Key issue in developing sustainable plantation of the second generation feedstocks such as Pongamia depends on the right kind of planting material, which should enjoy genetic superiority in terms of seed and oil yield as compared to normal unselected populations of *Pongamia pinnata.*

Superior and genetically elite trees have been selected and multiplied by vegetative propagation adopting a special method of grafting tailored to Pongamia (Prasad2013). The range of seed yield of the elite Pongamia trees is in the range of 35 kg to 60 kg/ tree with oil content of 36.2% to 38.6% as against the average seed yield of 10kg/ tree with oil content of 28.7% in respect of average unselected trees of Pongamia (Prasad 2013)).The shelling percentage (seed to pod proportion) in Pongamia is around 40%. The pod and oil yield of genetically elite Pongamia trees is presented in Table 5.

Table : 5 Pod yield (kg/tree) & oil yield(t/acre) of vayusap (elite Pongamia)

Tree yage(yrs)	3	4	5	6	7	8	9	10	11	12	13	14	15
Pod yield/tree (kg)	7	15	30	45	51	67	77	89	100	110	120	135	150
Oil yield/acre (tons)	0.2	0.4	0.8	1.1	1.5	1.7	1.9	2.2	2.5	2.8	3.0	3.4	3.7

(Source: VAYUGRID 2015. Annual Report 2015. Board of Directors.VAYUGRID Bangalore, India.)

The clonal progenies of the elite trees, which are currently less than four years old, have maintained the significant superiority with regard to seed yield and other key characters of the elite mother trees (Table 6).

Table : 6 Pod yield (kg/tree) & oil yield(t/acre) of VayuSap (elite Pongamia)

S.No.	Attribute	Elite Clonal progenies (range)	Normal Unselected seed progenies / plant (range)
1	Canopy diameter (m)	2.85 -3.12	0.8 – 1.5
2	Canopy Circumference (m)	9.00-13.00	2.0 -4.3
3	Canopy Area (Sq.m.)	3.63 -7.65	0.50 -1.76
4	No. of pods /tree	991 -1932	0 - 12
5	Kernel (seed) Yield / tree (kg)	1.65 -3.22	negligible
6	Resistance to Pod malformation (Asphodyiliaponagamiae)	Totally resistant	Susceptibility to tolerance
7	Kernel (seed) yield / acre	1,400 kg	negligible

(Source: Prasad and Kumar 2016)

Green Coal

The yield of pod shells, after shelling the entire produce were converted into briquettes. Density of the briquettes is estimated to be 0.6819 g/ml with calorific value of 4052 cal/g and very low ash content. The briquettes made out of the pod shells of *Pongamia* are considered "Green Coal" and could be an ideal source of energy for rural kitchens (Prasad and Kumar 2016).

Oil Yield

The oil could be used directly to operate the motors of the irrigation pump-sets, tractors and trucks for transportation of goods in the rural areas. It is also well known that *Pongamia* oil could form an excellent candidate for conversion into bio-diesel through trans-esterifation (Vayugrid 2015).

Based on the growth, development and yield performance of *Pongamia* trees, it is estimated that the elite clones of *Pongamia* would yield more than 2 tons of oil /acre in the 10th year and over 3.5 tons of oil/ acre in the 15th year (Table 5). The seed cake left out after oil extraction forms a good and valuable organic fertilizer (Osman *et al*., 2005).

Symbiotic Nitrogen Fixation and Soil Amelioration by *pongamia*

Pongamia produces its own nitrogen through Symbiotic Nitrogen Fixation, thereby displacing approx $200 / ha/year of nitrates applied as compound fertiliser. Soils under *Pongamia* stands of +15 years' age accumulate almost 1100 to 1300 kg of Nitrogen per hectare per annum, apart from enhancing the soil organic matter and consequent positive soil biological activity (Elevitch and Wilkinson 1999). As reported by Prasad (2013) the soil under six year old trees of *Pongamia* exhibited marked improvements not only soil organic matter and Nitrogen, but also in other plant nutrients v*iz*., Phosphorous and Potash.

Carbon Sequestration

The Carbon sequestration potential of *Pongamia pinnata* during the 10 to 15 years of its growth was found to be many folds higher than that of several other tree species. Pongamia was found to sequester around 45 to 50 kg of C per tree per annum as against 28 to 35 kg of Neem (*Azadirachta indica*), 23 to 26kg of Mahua (*Madhuca latifolia)* and 11 to 15 kg in respect of Tendu (*Diospyros melanoxylon*). (Chaturvedi *et al.*, 2011; Jesse More, 2009; Gupta, 2008; Kamarkar et al., 2012 and Reddy *et al.*, 2009).

The current trends of global warming are of great concern. It is estimated that an increase of 2.5% of global temperature would reduce agricultural productivity in USA by 6%; but by 38% in India (Sengupta 2013). It is therefore necessary to come up with appropriate technologies involving tree species that are efficient in cutting down global warming and bring about perceptible levels of C sequestration in addition to oil yield. *Pongamia* is one such species that need attention in this regard. It is absolutely necessary that the tree types grown for bio-fuels, must not occupy fertile irrigated lands to avoid competition with regular food and commercial crops. *Pongamia pinnata* meets the above condition and as such forms an excellent feed stock for bio-fuel production. (Prasad 2013).

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