Vision 2030

भाकृअनुप
ICAR

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(Indian Council of Agricultural Research)
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FOREWORD

The diverse challenges and constraints as growing population, increasing food, feed and fodder needs, natural resource degradation, climate change, new parasites, slow growth in farm income and new global trade regulations demand a paradigm shift in formulating and implementing the agricultural research programmes. The emerging scenario necessitates the institutions of ICAR to have perspective vision which could be translated through proactive, novel and innovative research approach based on cutting edge science. In this endeavour, all of the institutions of ICAR, have revised and prepared respective Vision-2030 documents highlighting the issues and strategies relevant for the next twenty years.

Vegetable oils are an important ingredient of an average Indian diet. The per capita consumption of edible oils is likely to be about 20 kg per annum by 2030. In India groundnut is an important oilseed crop that is cultivated largely under rain-fed situations and therefore, its productivity is, by and large, determined by the pattern of rainfall. This challenge has been viewed as an opportunity for conducting scientific research to improve the agricultural productivity in the dryland areas, especially in the sandy soils of Gujarat and Rajasthan. The new high yielding varieties and cultivation practices developed by the Directorate of Groundnut Research (DGR), Junagadh, have contributed significantly in improving the productivity and production of groundnut in India besides enhancing quality of the produce.

It is expected that the analytical approach and forward looking concepts presented in the *'Vision 2030'* document will prove useful for the researchers, policymakers, and stakeholders to address the future challenges for growth and development of the agricultural sector and ensure food and income security with a human touch.

Dated the 12 th July, 2011
New Delhi

(S. Ayyappan)

Preface

Groundnut is one of the few crops that can be cultivated even on marginal lands with low inputs. It is one such plant, whose all parts contribute to economy of the farmers. The seeds can be used directly as food stuff or crushed for expulsion of oil. The expeller cake, which contains about 7% residual oil, can be solvent-extracted for recovery of residual oil. Both the expeller and solvent extracted cakes are used as cattle feed-supplement. The groundnut shell is used as a fuel for industrial boilers either directly or in form of compressed extruded briquettes. In its root nodules, groundnut harbours Rhizobium bacteria, which in every crop season fix about 180-200 kg atmospheric nitrogen per hectare. The foliage obtained after stripping the pods provides a nutritious fodder for cattle.

It is now being increasingly realized that groundnut is much more than a mere oilseed crop, and in the Indian context, it should rightly be described as an oilseed, food, and forage crop.

Due to persistent efforts of the scientists of DGR and AICRPG, several improved groundnut varieties have been developed along with crop production and protection technologies. The productivity of groundnut has also improved over the years but the quantum of improvement has not been as much as has been for cereal grains. In the recent years, the average productivity of groundnut in India has been around 1100 kg/ha which is even lower than the world average of about 1500 kg/ha. This relatively small improvement in productivity of groundnut over the years has been a matter of concern for both planners and researchers.

This **Vision 2030** document has been prepared to provide a road-map for the course of research to be followed in years to come leading towards not only substantial improvment in the productivity of groundnut but also enhancing its quality.

I should like to express our gratitude to Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR for his inspiring words. I should also like to thank Dr. S. K. Datta, Deputy Director General (CS) for providing guidance. I acknowledge the valuable suggestions of Dr. B.B. Singh, Assistant Director General (O&P), ICAR, and Dr. J.H. Kulkarni, Chairman, Research Advisory Committee. My special thanks to Dr. R. Dey, Dr. K.K. Pal and Dr. Radhakrishnan T., for critically going through the manuscript and giving valuable suggestions. The contributions of all the scientists of DGR and AICRPG in bringing out this document is acknowledged.

(J. B. Misra)
Director, DGR & Project Coordinator

Preamble

Agriculture is and will continue to be the vocation of crores of Indians in decades to come, providing food-security to fellow Indians it would be a compulsion to engage at least a half of the population in the production of food.

The vegetable oils are essential ingredient of Indian cookery. No wonder, in India the oilseeds are the second largest commodity after cereals in acreage, production and value.

A wide range of oilseeds crops are grown in India. Groundnut, rapeseed-mustard, sesame, safflower, linseed, niger and castor are the major traditionally cultivated oilseeds. Soyabean and sunflower have gained considerable ground in the past few decades. Among the non-conventional sources of edible oils, rice-bran and cottonseed have found their place and among the plantation crops coconut is most important. Efforts are also being made to promote oil palm plantations in India.

With a view to giving a fillip to scientific research for enhancing productivity of this crop, Govt. of India decided to take out the component of groundnut from the Directorate of Oilseeds Research, Hyderabad and establish an independent research unit exclusively for groundnut– a crop, which then accounted for 43% of total area under oilseed crops and 60% of total production. Accordingly, the National Research Centre for Groundnut (NRCG) came into being on the 1st October, 1979. The selection of Junagadh (2131' N; longitude 7036' E; altitude 200 m above mean sea level) for establishing the NRCG was most appropriate as the crop was already very popular among the farmers of Saurashtra. Thirteen years later in 1992, the All India Coordinated Research Project on Groundnut (AICRPG) was brought under complete administrative control of NRCG. While communicating the EFC memo for the XIth five year plan; the Govt. of India re-designated the NRCG as the Directorate of Groundnut Research or DGR in short.

Since its inception, the DGR has strived hard to conduct and coordinate scientific research for developing new technologies to enhance the productivity of groundnut in India. Although over the years, the productivity of groundnut has improved significantly yet the extent of improvement has not been of the order that was required and expected.

In times to come, the DGR would require a much enhanced financial and policy support from the ICAR so as to enable it to further refine the production and production technologies that can bring about a remarkable improvement in the productivity of groundnut in India. The Vision 2030 document puts the planning and resolve of DGR for conducting and managing such scientific research on groundnut crop into a perspective.

Contents

The Scenario

Groundnut (*Arachis hypogaea* L.) is an important oilseed and ancillary food crop of the world. A native of South America, groundnut is cultivated in tropical, sub-tropical, and warm temperate regions of the world. The commercial cultivation of groundnut, however, is confined to areas between 40°N and 40°S latitudes. Groundnut requires long and warm growing season in a climate having well distributed rainfall in the range of 500-1000 mm. It grows best in temperature range of 25-30°C in sandy loam soils which permit easy entry and growth of pegs in the soil and harvest of mature pods. The optimum soil pH for groundnut is 6.0-6.5.

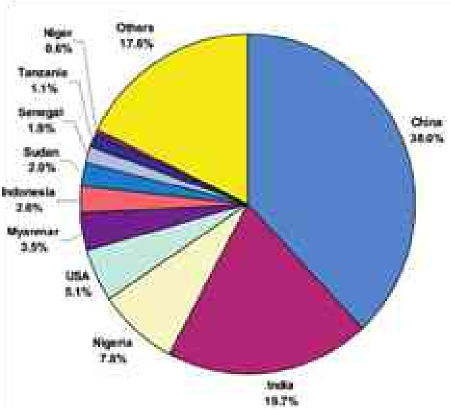
Among the seven commercial edible oilseed crops of India, viz. groundnut, rapeseed-mustard, soybean, sunflower, sesame, safflower and niger, currently groundnut is the third most important oilseed crop after rapeseed-mustard and soybean. It is annually cultivated in about 60 lakh hectares comprising nearly one-fourth of the total area under oilseeds.

THE GLOBAL PRODUCTION SCENARIO

The triennial (2007-09) averages of area, production and yield, indicated that annually 371 lakh tonnes of groundnuts are produced in the world from a cropped area of 235 lakh hectares with an average productivity of 1579 kg/ha. China, India, Nigeria, USA and Myanmar are the top five producers.

Though India ranks first in area, it ranks second (after China) in production. India accounts for 25.4% of global area and contributes 19.7% to the world production with an average productivity of 1220 kg/ha which is nearly one-third of those of USA (3731 kg/ha) and China (3339 kg/ha) and even lower than that of the world (1579 kg/ha).

Country	Area (lakh ha)	Production (lakh tonne)	Yield (kg/ha)
China	42.1	140.6	3339
India	59.7	72.9	1220
Nigeria	23.9	29.0	1211
USA	5.1	19.0	3731
Myanmar	8.0	13.0	1613
Indonesia	6.4	9.8	1530
Sudan	8.3	7.4	890
Senegal	8.3	7.0	837
Tanzania	5.5	4.0	724
Niger	5.5	2.4	431
Others	61.7	65.4	-
World	234.6	370.3	1579



Share of countries in global production

Global scenario of groundnut production

Wide variations are frequently observed in production and productivity across and within the regions around the world. The crop is grown in more or less two distinct systems low-input and high-input. Low-input system, predominant in Asia and Africa, is characterized by rain-fed cultivation with none or a little inputs and hence the yields remain quite low (700 to 1100 kg/ha) while the high input system, prevalent in USA, Australia, Argentina, Brazil, China and South Africa, is practiced under irrigated conditions coupled with mechanization and hence the yields are quite high (2000-4000 kg/ha).

Nutritive value of groundnut

The groundnut kernels contain 45-48% oil and 25-30% protein and as such it is the fourth most important source of edible oil and third most important source of protein in the world. Though groundnuts are considered high in fat, they primarily contain "good" fat (unsaturated and free from trans types).

Groundnut oil is good from both nutritive and culinary points of view. It contains good quantities of MUFA (oleic acid, 40-50%) and PUFA (linoleic acid, 25-35%). Due to high oleic/linoleic ratio, groundnut oil has a longer shelf-life than those of most vegetable oils. Moreover, groundnut oil contains tocopherol (approx. 0.9 mg/g oil) which being an antioxidant prevents development of rancidity.

As groundnuts help to maintain blood cholesterol levels they have been recognized as heart friendly. Groundnuts provide over 30 essential nutrients and are considered a rich source of fiber, vitamins (niacin, folate, and vitamin E) and minerals (magnesium, manganese, and phosphorus) and free from sodium.

GROUNDNUT CULTIVATION IN INDIA

Since 1951, the largest area under this crop was 87.1 lakh hectares in 1989-90; the highest production was 96.6 lakh tonnes in 1988-90; while the highest productivity was of 1460 kg/ha in the 2007-08. In the year 2007-08, groundnut crop occupied 62.1 lakh hectares (*kharif* + *rabi*-summer) with a production of 93.6 lakh tonnes and productivity of 1460 kg/ha and thereby accounted for 33% of the cropped area under the oilseeds, contributed 32% of total oilseed production and 30% of the domestic edible-oil supply.

Currently, six states viz. Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra, and Rajasthan account for more than 90% of the groundnut area. Madhya Pradesh, Uttar Pradesh, Orissa, and West Bengal are the other states having substantial areas under this crop. In addition, Chattisgarh, Jharkhand, Punjab, Goa, and Kerala also contribute to national groundnut production to some extent. In the last decade, the crop has been successfully introduced in the north eastern states of India. The area, production and yield of groundnut since 2000-01, are shown below.

Area, production, and yield of groundnut in India

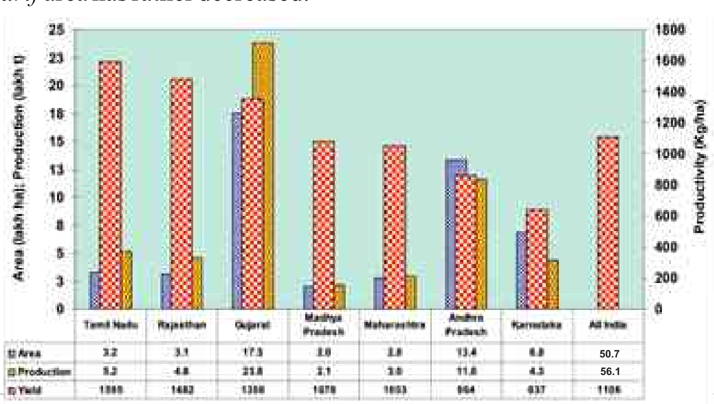
Year	*Kharif*			*Rabi*/summer			Total		
	A	P	Y	A	P	Y	A	P	Y
2000-01	57.0	47.1	817	10.0	15.1	1563	67.3	62.2	924
2001-02	54.6	56.2	1030	7.8	14.1	1808	62.4	70.3	1127
2002-03	52.7	30.9	587	6.6	10.3	1548	59.4	41.2	694
2003-04	57.9	52.6	909	8.5	15.1	1771	66.4	67.7	1020
2004-05	52.0	68.6	1320	7.9	12.7	1602	59.9	81.3	1357
2005-06	57.4	63.9	1097	10.0	17.0	1702	67.4	79.9	1187
2006-07	47.8	32.9	689	8.4	15.7	1880	56.2	48.6	866
2007-08	53.0	74.8	1412	11.1	18.8	1691	64.1	93.6	1460
2008-09	52.3	56.4	1077	9.9	17.0	1726	62.2	73.4	1180
2009-10	46.2	38.5	835	8.6	15.8	1830	54.8	55.3	991

A = area (lakh hectares); P = production (lakh tonnes); and Y = yield (kg/ha); Source: Department of Statistics and Economics, Government of India.

The records for as high as 9500 kg/ha yield of summer crop in Kolhapur in Maharashtra state are available. In the year 2009-10, in Thiruvallur and Kancheepuram districts of Tamil Nadu, the average yields were 4281 and 4181 kg/ha, respectively.

Groundnut crop: *kharif* vs. *rabi*-summer

In India, groundnut is cultivated largely in *kharif* season under rain-fed conditions with low-inputs and if available, with a few protective irrigations. The pressures of diseases, insect-pests and weeds are high in this season. The productivity depends more on the quantity and pattern of distribution of rain fall rather than on biotic and abiotic factors. An evenly distributed rainfall of 700-800 mm would assure a good productivity whereas a higher and erratic distribution would have adverse effects. The dry spells that often prevail at the time of flowering or pod-filling would reduce the yields and excessive rains coinciding with the first flowering would spoil the flowers and promote more vegetative growth. Hence *kharif* productivity has shown wide variations over the years. In the past decade, the total *kharif* area has rather decreased.



Kharif **groundnut: area, production and yield in important states of India (values are triennial averages for 2007-08 to 2009-10)**

In *rabi*, the crop is grown under residual moisture of rice fallows or river beds under minimal irrigation situations and also in summer as an irrigated crop. The cultivation of groundnut in summer is practiced generally under high-input conditions and the pressures of diseases, insect-pests and weeds are relatively quite low and hence the productivity is high. The spring groundnut, cultivated after the harvest of potato/toria, also gives high productivity. The area under *rabi*-summer groundnut system has expanded over the years. Various seasons of cultivation along with the respective months of sowing and harvest and the states concerned are shown below.

Groundnut growing seasons in various states of India

Season	Sowing	Harvest	States
Rain-fed (about 80% area)			
Kharif	Jun-Jul	Sep-Oct	Uttar Pradesh, Rajasthan, Gujarat, Madhya Pradesh, Chattisgarh, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu and Jharkhand
Post rainy (about 20% area)			
Rabi (residual moisture)	Oct-Nov	Feb-Mar	West Bengal, Orissa, Karnataka, Andhra Pradesh and Tamil Nadu
Summer (irrigated)	Jan-Feb	Apr-May	Gujarat, Maharashtra, Karnataka and Andhra Pradesh
Spring (irrigated)	Mar-Apr	Jun-Jul	Punjab and central Uttar Pradesh

Groundnut was earlier grown mainly in the rainy season (*kharif*). From 1970-71 onwards groundnut established itself as a winter (*rabi*) and summer crop also in Andhra Pradesh, Tamil Nadu, Karnataka and Orissa giving a much high yields (1500-4000 kg/ha) compared to that of *kharif* (about 1000 kg/ha). Subsequently, *rabi*-summer groundnut gained ground in Gujarat and Maharashtra. The current area of *rabi*-summer in India is about 1 million hectares.

The sizes of land-holdings of groundnut farmers

In 2005-06, small and marginal land-holdings in India accounted for about 83% of the total number of holdings but these holdings represented only 41% of the total land area and comprised only 36% of the total groundnut area. The distribution of groundnut area across various land-holding categories is given below.

Distribution of groundnut area across various types of land-holdings

Land holding (farm size)	Share in total holdings (%)	Share in total area (%)	Share in groundnut area (%)	Irrigated groundnut area (%)
Marginal (<1.0 ha)	64.8	20.2	12.3	13.2
Small (1.0-2.0 ha)	18.5	20.9	24.2	10.8
Medium (2.0-4.0 ha)	10.9	23.9	30.1	11.2
Large (> 4.0 ha)	5.8	35.0	33.4	12.6
Total	100	100	100	11.8

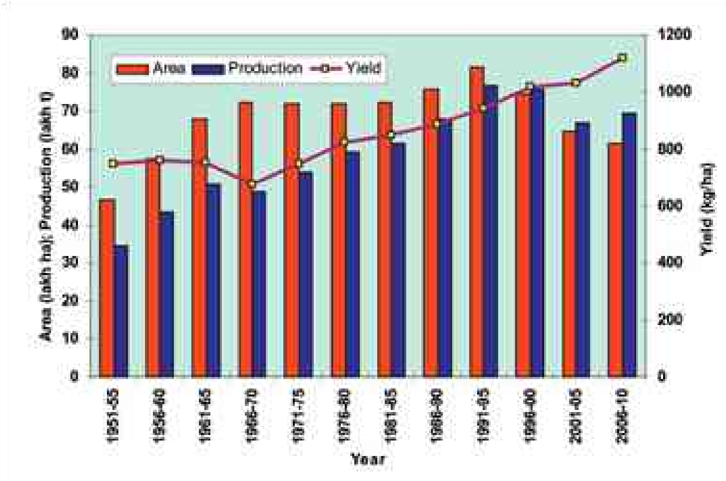
Source; Agricultural Census. Available at http://nic.in/cendata/databasehome.aspx

Trends in area, production and productivity

During 1900-01 to 1909-10, the area under groundnut in India was only 2.3 lakh hectares, which increased to 76.8 lakh hectares by the turn of twentieth century. The decennial annual compound growth rates of area and production during different periods explicitly depict that the growth in area (17.2%) was the major contributor to the increase in groundnut production in India during 1951-1960.

The quinquennial averages of area, production and productivity in India indicate that the average area increased from 46.6 lakh ha (1951-55) to an all time high of 81.6 lakh hectares during 1991-95. The productivity levels, which fluctuated between 676 and 759 kg/ha before 1970s, registered a steady increase subsequently. This could be attributed to release of several high-yielding and biotic and abiotic stress-tolerant varieties and improved packages of practices, and also to a certain extent to cultivation of groundnut in summer under high-input assured irrigation.

Considering the quinquennial average productivity of 1966-70 as the base, the decadal progressive improvement in productivity was 21.7% during 1971-80; which further increased up to 31.4% during 1981-90; to 50.6% during 1991-2000 and to 65.5% during 2001-2010. Thus post 1970, the increase in yield contributed more significantly towards increasing groundnut production than the area alone. This aspect clearly establishes the slow but steady impact of improved production technologies on enhancing productivity of groundnut in India.



Quinquennial averages of area, production and yield of groundnut in India since 1951-55

Constraints in production

The major factors which hamper the improvement in productivity of groundnut in India are:

i) cultivation of old and inferior varieties on by and large marginal lands under low-input and rain dependent situations (~5.0 to 6.0 million hectares)

ii) flawed application of fertilizers, and

iii) inefficient use of water resources.

The biotic and abiotic stresses also limit the production during the rainy season. Among the biotic stresses, the foliar fugal diseases (early leaf spot, late leaf spot and rust), viral diseases (peanut bud necrosis diseases and peanut stem necrosis disease) soil borne diseases (stem rot, collar rot and pod rot complexes), and the insect pests like defoliators (red hairy caterpillar, tobacco caterpillar, gram pod borer and leaf miner) and sucking pests (jassids, aphids, and thrips) are the major ones. Problems of nematodes and white grubs are also encountered in certain areas. The major abiotic stresses are: soil-moisture deficit stress at one or the other stage of crop during rainy season; and low-temperatures prevailing during germination as well as vegetative stages followed by high-temperatures during the pod-filling and maturation stages during summer season. In addition, build-up of salinity and acidity and deficiencies of micronutrients in certain areas, lower the productivity.

The pre- and post-harvest invasions of groundnut by the fungi of *Aspergillus* group, which produce aflatoxin, lower the quality. The aflatoxin contamination is now regarded as the major hurdle in export of groundnuts and its products from India.

In case of summer crop, sometimes due to early rains, the soil-moisture becomes high at the time of harvest and the problem of *in situ* germination is often encountered. Another peculiar problem associated with both *rabi* and summer produce is that of rapid loss of seed viability during post-harvest storage which renders the seed unfit for raising the new crop in the next *rabi*-summer season. There is need for cold-tolerant varieties for post-rainy season, for varieties with ability to germinate at low-temperatures to allow early sowing for assured-irrigation for summer season, and short-duration varieties possessing fresh-seed dormancy for spring season.

The cost benefit ratio (CBR) of groundnut cultivation

Seed alone accounts for about 35-40% cost of cultivation in groundnut. The cost of cultivation varies widely and depending upon season and inputs applied and the yield realized, the CBR may vary between 0.70 and 5.0.

Season	Level of inputs	Rain-fed situation		
		Scanty rains (drought affected)	Moderate rains	Good and well distributed rains
Kharif	Low-input	1:0.70	1:1.5	1:2.5
	High-input	1:1.50	1:2.0	1:3.0
		Assured irrigation situation		
Rabi-summer	Low-input	1:2 to 1:3		
	High-input	1:3 to 1:5		

State-wise scenario of area, production and productivity

The triennial (2007-08 to 2009-10) averages of area and production of groundnut in main groundnut growing states of India indicate that 90.8% of the groundnut area (54.59 lakh hectares), distributed across six states (Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra and Rajasthan), contributes 90.1% (65.8 lakh tonnes) of the total national production.

Average of area, production and yield of groundnut in various states of India for the triennium 2006-07 to 08-09

State	Area (lakh ha)	Production (lakh t)	Yield (kg/ha)
Gujarat	18.46	24.68	1336
Andhra Pradesh	16.29	16.32	1002
Karnataka	8.30	5.47	659
Tamil Nadu	5.30	10.41	1962
Maharashtra	3.97	4.19	1054
Rajasthan	2.99	4.70	1568
Madhya Pradesh	2.00	2.03	1009
Uttar Pradesh	1.65	2.30	1392
Orissa	0.81	0.94	1156
West Bengal	0.66	1.22	1841
Chhatishgarh	0.28	0.35	1250
All India	60.78	72.86	1198

Source of data: Department of Economics and Statistics, Government of India

Among the major groundnut growing states, Gujarat and Andhra Pradesh are the most important ones and account for 31% and 27%, respectively of the total groundnut area in India while Karnataka, Tamil Nadu, Maharashtra and Rajasthan account for 13.9%, 7.9%, 5.9% and 5.1%, respectively. Among the states, the average productivity is quite high in Tamil Nadu and West Bengal while it is much below the national average in Karnataka and Andhra Pradesh.

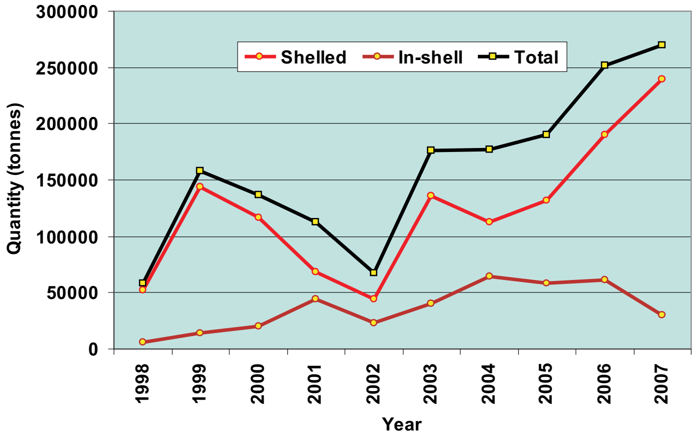
In addition to the states mentioned above, groundnut is cultivated in Bihar, Haryana, Himachal Pradesh, Kerala, Goa, Jammu and Kashmir, and north-eastern states, but the area in each of these states is small. The productivity of groundnut in NEH region and Goa, however, is more than the national average. In the year 2009-10, in Thiruvallur and Kancheepuram districts of Tamil Nadu, the average yields were 4218 and 4181 kg/ha, respectively.

Annual growth rates in input-use, output, and total factor productivity (TFP)

TFP reflects the quantum of increase in total output that is not due to increase in total inputs and thus among others accounts for growth due to long-term technological change or technological dynamism. A study conducted by the National Centre for Agricultural Economic and Policy Research (New Delhi), on the basis of data for thirty years (1975-2005), indicated that in Gujarat, the output growth (2.5%) was higher than the input growth (1.1%) and the TFP growth accounted for 54% of output growth while the real cost of production declined at the rate of 1.8%. In Andhra Pradesh, the growth rates of input-use, output, and TFP were 3.5%, 4.9% and 1.4%, respectively indicating that share of TFP in output growth was 29%. Orissa has shown an outstanding performance in output growth besides high growth in input-use, which led to 2.1% annual growth in TFP and this TFP growth was the cause of 28% growth in output. A moderate TFP has been observed in Andhra Pradesh. The groundnut production in Karnataka and Tamil Nadu is heading towards un-sustainability, but other states have shown moderate to high growth.

Export of groundnut

China, India, USA and Argentina are the major groundnut exporting countries of the world while the Netherlands and Nicaragua are the other important countries. During 1999 to 2002, the export of groundnut from India declined but it registered a considerable increase subsequently.



Trend in export of groundnut from India (source FAOSTAT)

Groundnut is exported both in-shell and shelled (kernels) forms. For export purpose, two broad categories are defined- java and bold. The java types have smaller pods with constriction and the shell is thicker than the bold types. The kernels are oval with a testa of pink colour. For bold types, the pods and kernels are bigger than the java types and the kernels are oblong with a red skin which becomes darker with ageing.

The European Union (EU) has set a very stringent maximum permissible limit (2 ppb) for aflatoxins in groundnut. Many Indian consignments are rejected at the destination ports due to aflatoxin contamination. The aflatoxin contamination is now recognized as the chief non-tariff trade barrier for export of Indian groundnuts. Currently, the import by EU, accounts for only 15% of the total groundnut exported from India and bulk of the export is destined to Indonesia, Malaysia, the Philippines, Singapore, Belgium, Taiwan, Saudi Arab, Kuwait and Maldives.

The problem of aflatoxin can be overcome by adopting good cultivation practices and proper post-harvest handling by the farmers and the processors. The do's and don'ts in this regard have been worked out by the researchers in India.

Utilization of groundnut in India

The bulk of groundnut produced In India is used for oil-expulsion, for direct consumption as table nuts, and for seed to raise the next crop. In nineteen eighties, about 80% of the produce was crushed for oil expulsion, about 6% was used for direct consumption (including 1% for export) and the remaining 14% was used for seed. In the past two decades, there has been a shift towards direct consumption, which in the recent years has gone up to about 35% and only about 50% of the produce is crushed for oil expulsion. This has been due largely to availability of other cheaper edible oils, especially palm oil and soybean oil, and urbanization induced changes in food preferences. A wide range of products can be obtained through value-addition in groundnuts. The important ones are roasted and salted groundnuts, roasted in-shell groundnut, and boiled in-shell groundnut. A sweet-snack made by using jaggary (or sugar) and roasted kernels (whole, split or pieces) and popularly called 'chikki', is one of the most widely consumed and relished items. The demand for peanut butter and peanut sauce is also growing slowly. There is a considerable scope for marketing low-calorie partially-defatted groundnuts to figure-conscious persons. Prior to crushing, some groundnut shell is mixed with kernels as a crushing aid because of which the groundnut cake which is very rich in protein (35-40%), can not be used directly for human consumption, as these cakes also contain some extraneous substances in addition to the shell. Hence, the prospects of promoting direct consumption of groundnut kernels offers an opportunity to channelize the precious protein for human consumption.

The current availability of groundnut in India works out to be 5.5 kg pods/per capita per annum after saving the seed required for sowing the next crop. With technology led enhanced productivity, this availability is likely to be doubled by 2020.

Considerable scope also exists to improve the available production technologies by developing high-input responsive varieties and complementary cultural practices for efficient management of available irrigation-water and other inputs. Groundnut offers excellent opportunities for value-addition and utilization of byproducts viz., groundnut shell and the cakes left behind after oil extraction.

SWOT Analysis

Strengths

- The crop can be grown by small farm holders even on marginal soils; the produce is semi-perishable and can be stored under ambient conditions; unlike most oilseeds, groundnuts can be consumed directly as munchies; being a legume crop, its cultivation improves soil texture and fertility; the foliage can be used as fodder. In most cases at least two crops can be taken in a year and scope exists for introducing the crop in non-traditional areas. The crop is responsive to organic cultivation and the potential for export is very high
- Genetic diversity is available in form of a very large collection of germplasm
- Protocols for genetic transformation are available
- A large number (>180) of varieties are available for diverse agro-climatic regions
- Trained human resource and well developed infrastructure for scientific research is available
- AICRP-Groundnut provides a platform for simultaneous evaluation of genotypes as well as production and protection technologies in diverse production zones

Weaknesses

- Grown largely under rain-fed conditions (*kharif*) on marginal soils with low inputs and hence production highly dependent on quantities and pattern of rainfall
- Non-availability of short-duration (95 days) varieties
- Highly self-pollinated crop with cleistogamy, a constraint in developing hybrid varieties
- A very low SRR (slow penetration of new varieties) due to a low seed multiplication ratio (1:8) and high seed rate (160 kg pods/ha)
- High cost of inputs due to high seed rate (120 kg/ha)
- Rapid loss of seed viability in *rabi*-summer produce
- Produce highly susceptible to contamination by aflatoxin
- Lack of high profile infrastructure for research in the low-productivity areas of Andhra Pradesh, Karnataka and Maharashtra

Opportunities

- Exploitation of untapped potential for conventional breeding
- Seed encapsulation for preserving seed viability and prevention of damage by insects
- Production of biological control agents and compound fertilizers
- Micro-irrigation systems for efficient management of irrigation water
- Fertigation for enhanced synergy between application of water and nutrients
- Development of transgenic varieties tolerant of biotic and abiotic stresses
- Value-addition for direct consumption as snack, high-nutrition supplementary food, and functional food
- Prospects of growth of area in *rabi*-summer (Orissa and West Bengal) and Rajasthan (*kharif*) and in Uttar Pradesh (spring)
- Responsiveness to application of beneficial micro-oraganisms
- Intercropping in wide-spaced plantation crops

Threats

- Replacement of area by more profitable crops in traditional belts
- Spread and increase in the occurrence of soil-borne diseases, especially stem rot and collar rot and of viral diseases especially PBND and PSND
- Global climate change (damage of crop due to excessive precipitation during end of the season)
- Competition from countries like China, Argentina and the USA in the export

STRATEGIES TO INCREASE PRODUCTION

A. EXPANSION OF AREA

Though in the past decade, there have been trends of decrease in groundnut area in many states, scope does exist for bringing another five lakh hectares under groundnut crop in the next ten years. The potential areas are:

- Rice-fallows in the peninsular India (about 0.5 lakh hectares)
- Potato fallows in western Uttar Pradesh and Punjab and in Deesa district of Gujarat (about 1 lakh hectares) for spring groundnut
- As an intercrop with sugarcane in Uttar Pradesh, Maharashtra and Tamil Nadu; with cotton in Punjab, Rajasthan, Gujarat and Maharashtra; and with plantation crops in Karnataka, Tamil Nadu and Kerala (about 1 lakh hectares)
- Further spread in some parts of NEH region (about 0.5 lakh hectares)
- Further spread of *kharif*-groundnut in Rajasthan (0.8 lakh hectares) and that of *rabi* in West Bengal, Orissa and NEH region (1.2 lakh hectares)

B. CRUCIAL ISSUES TO BE ADDRESSED JOINTLY BY THE CENTRAL AND STATE DEPARTMENTS

- Strategy for rapid penetration of new groundnut varieties
- Revamping of seed production system to ensure adequate supply of quality seed
- Transfer of available technologies like intercropping and crop rotation, integrated nutrient management, integrated pest and disease management, efficient irrigation water management through micro-irrigation and *in situ* soil moisture conservation

C. POLICY INTERVENTIONS

- Measures to ensure multiplication of breeder seed through five-stage seed multiplication chain to be taken up in high productivity areas
- Manufacture and supply of fertilizer grade gypsum
- Manufacture and supply of compound fertilizers (containing major, secondary and micronutrients) suitable for major groundnut growing areas
- Manufacture and supply of genuine biofertilizers and biocontrol agents in viable forms (containing at least 10^8 - 10^{10} cfu or spores/g preparation)
- Incentive to farmers for using new groundnut varieties
- Incentive to farmers for adopting micro-irrigation techniques
- Enhancing minimum support price on annual basis

D. UP-GRADATION OF INFRASTRUCTURE FOR RESEARCH

In order to fully avail the opportunities for developing new technologies for enhancing productivity of groundnut in various groundnut growing areas of India, the existing infrastructure of DGR and AICRP-Groundnut would need up-gradation in its human, physical and financial resources. Facilities for work on genomics, proteomics and transcriptomics; phenotyping; containment for evaluation of transgenics, glasshouses with controlled RH and temperature for basic and applied research; rhizotron for studies on root; state-of-the-art facilities for medium-term conservation of germplasm and regional research stations at Pune (Maharashtra), Chitradurga (Karnataka) and Mainpuri (UP) would have to be created. So far as AICRP-Groundnut is concerned, facilities for hybridization under controlled RH and temperature, screening for resistance to diseases, a central quality evaluation laboratory at one of the main centres and additional centres one each at Modipuram (Meerut) in UP; at Bagwai (near Shivpuri) in Madhya Pradesh, at Tindivanum in Tamil Nadu; and at Tirupati in Andhra Pradesh will be required.

Profile of DGR

The scientific research for improving the productivity of groundnut in India began as early as in 1947 with formation of Indian Central Oilseeds Committee. This, however, gained momentum only in 1967 with the launch of All India Coordinated Research Project on Oilseeds (AICORPO). Later in 1972, a position of full time Associate Project Coordinator was created for groundnut and subsequently in 1977 the position was elevated to level of full time Project Coordinator. In 1979 an independent research unit exclusively for groundnut crop was created at Junagadh in Gujarat by the name National Research Centre for Groundnut (now known as DGR) with a full time Director. This was followed by bringing of headquarters of All India Coordinated Research Project on Groundnut under auspices of NRCG at Junagadh in 1992.

The NRCG made a humble beginning in a small building with 18 hectare farm land on Junagadh-Veraval state highway. As the land was not enough for accommodating the growing needs, NRCG acquired another 100 ha land in 1986 about 4 km away from its original location to establish its new infrastructure. The construction of a new laboratory-cum-office building was completed in the third quarter of 1991 and entire establishment of NRCG was shifted to the new location. Since then the infrastructure of the centre has been continuously growing and now this centre occupies an enviable position among various crop commodity research institutions. The current mandate of DGR is:

Mandate of DGR

- To conduct basic and strategic research to enhance production, productivity and quality of groundnut
- To act as the national repository of working collection of groundnut germplasm and information on groundnut research
- To establish relevant institutional linkages
- To offer consultancy and training, and
- To provide logistic support and coordination mechanism for generation of location-specific technology through the All India Coordinated Research Project on Groundnut.

Land and farm resources

Though the total area of farm is about 105 ha, so far only 75% of this is being used profitably. The remaining area of 26 ha is yet to be developed and made arable. The soil type is Vertisol belonging to Vertic Ustochrept taxonomic class. The average annual rainfall is 650 mm.

Buildings

The main four-storey laboratory-cum-office building provides adequate laboratory spaces for disciplines like genetic resources, biotechnology, biochemistry, plant physiology, plant breeding, genetics, microbiology, agronomy, soil science, plant pathology and entomology. Over the years, the DGR has acquired an array of scientific equipments right from simple conventional ones to the modern state-of-the-art equipments. Integrated with this building are a conference hall, an auditorium and an Information and Documentation Cell.

In addition to main lab buildings, there are two annexe labs, three field sheds, one FS office cum tractor shed, one canteen and a recreation club, two scooter-motorcycle sheds, one car parking shed, one seed store and one cold-store, a generator room, etc.

There is a guest house for the visitors and a hostel for trainees besides 43 residential quarters.

Human Resource

The sanctioned cadre strength inclusive of all the categories of employees is 141. Out of these, there is one position of RMP, 39 of Scientific, 40 of Technical, 15 of Administrative, and 26 of Supporting personnel.

The research activities are pursued through multidisciplinary in-house research projects which are developed after thorough discussion in the Institute Research Committee (IRC) meetings chaired by the Director and attended by all the scientists of the centre. Currently there are 18 research projects each with a PI and one or more Co-PIs. The duration of each project generally coincides with the five-year plans.

All India Coordinated Research Project on Groundnut

Besides in-house research projects, an umbrella research project **'All India Coordinated Research Project on Groundnut'** or AICRPG in short, is also administered by DGR, Junagadh. The financial grants for this project are allotted separately by the ICAR under the head 'Plan'.

Mandate of AICRP-Groundnut

- Conducting multidisciplinary research on the aspects of Crop Improvement, Crop Production and Crop Protection in groundnut at regular and voluntary centres and also at selected KVKs
- Development of high-yielding groundnut varieties possessing resistance/field tolerance to drought; diseases and pests; and high temperature, salinity and acid soils
- Development of groundnut based cropping system and economically viable production and protection technologies for exploiting the yield potential of the crop varieties

- Demonstration of proven production and processing technologies on quality aspects through on-farm demonstrations in target areas
- Identification of stable sources of resistance to biotic and abiotic stresses at hot spots and their utilization in varietal improvement programme through national and international collaboration
- Production of nucleus and breeder seed of important groundnut varieties

Main and supporting centres of AICRP-Groundnut

Human Resource of AICRPG

Among the scientific category, there are 27 Plant Breeders, 13 Agronomists, 10 Plant Pathologist, eight Agricultural Entomologists, two Plant Physiologists, and one Cytogeneticist. There are 85 technical positions and five ministerial positions .

Under AICRPG, the country is divided into five zones keeping mainly the agroclimate of the region in view. This coordinated inter-disciplinary location specific research is being conducted in collaboration with the SAU's, several ICAR Institutes and KVK's. The Director with the help of principal investigators/scientists of the DGR coordinates the research programmes developed during the technical meetings of the AICRPG at the national level. At present there are five main and seventeen supporting centres under AICRPG.

Financial Resources of DGR and AICRPG

DGR: The outlay for the Xth five year plan (2002-07) was Rs. 878 lakhs besides the grants given under the head 'non-plan'. The actual expenditure under the head 'plan' was Rs 623.19 lakhs and Rs 1150.85 under the head 'non-plan'. Thus the total expenditure during 2002-07 was about Rs. 18 crores. The outlay for the XIth five-year (2007-12) plan is Rs. 1545 lakhs. This amount includes Rs 550 lakhs for equipments and Rs 240 lakhs for works. A grant of Rs. 2461 lakhs has been given under non-plan for the period of 2007-12. Thus a total of Rs. 4006 lakhs has been allocated for 2007-12.

In addition to grants received from the ICAR, during 2007-12 a sum of Rs 361 lakhs have been provided by various public and private agencies for operating externally funded research projects.

AICRPG: This is purely a plan activity. The outlay for the Xth five-year plan (2002-07) was Rs. 1272 lakhs. For XIth five year plan (2007-12) a sum of Rs 2237 lakhs has been provided.

Achievements of DGR and AICRPG

High yielding groundnut varieties

- Developed by DGR: Three (Girnar 1, Girnar 2 and Girnar 3)
- Developed by AICRP-G centres from the segregating materials generated at DGR (NRCG): Four (HNG 10, AK159, GG 5, and GG 7)
- Developed through AICRP-G: 98 varieties resistant/tolerant of one or more biotic and abiotic stresses and suitable for cultivation in one or more groundnut production zones

Management of groundnut germplasm

- Accessions assembled: 8983
- Accessions characterized: 5000
- Accessions developed and registered: 21
- Accessions of wild relatives of *Arachis* 105

Tissue culture and development of transgenics

- Protocols developed for transformation of groundnut
- Transgenic plants developed using coat protein genes for incorporation of resistance to viral diseases, PBND and PSND (currently being evaluated in glasshouse)
- Transgenics developed using *mtlD* gene (for enhancing tolerance of drought and salinity, currently being evaluated in glasshouse)
- Putative transgenics developed using genes like *defensin* (for resistance to fungal diseases); *annexin* (for enhancing tolerance of abiotic stresses); and *PR 10* (for enhancing tolerance of salinity)

Cultural practices for realizing high yields

- 'Low-input' technologies for resource-poor farmers
- 'Inter-row water harvesting' for rain fed systems
- 'Raised-bed-and-furrow' for water-harvesting in rain fed systems
- 'Paired-rows' sowing for rain fed systems
- 'Criss - cross' sowing for post rainy season
- 'Groundnut + pigeon pea intercropping' for assured returns under irrigated conditions
- Use of polythene sheet as mulch in *rabi* to facilitate early sowing when the temperatures are sub-optimal
- Imposition of 'transient water-deficit-stress' in vegetative phase of *rabi* - summer crop to induce early and synchronized flowering

Nutrient management

- Integrated nutrient management module comprising judicious doses of chemical fertilizers, organic manures and biofertilizers
- Amelioration of soil micronutrient deficiencies to realize productivity potential of cultivars
- Application of plant growth promoting rhizobacteria (PGPR 1, PGPR 2, PGPR 4) and rhizobia (IGR 6, IGR 40, NRCG 4, NRCG 9, Tt 9 and TNAU 14) for enhancing nutrient use efficiency

Introduction of groundnut in non-traditional areas

- Introduction of groundnut in NEH Region, Goa and Andaman and Nicobar Islands
- Varieties identified for NEH region: ICGS 76, ICGS 44, ICGV 86590, BAU 13 and JL 24

Protection from diseases and insect-pests

- Integrated pest and disease management modules comprising cultural operations, intercropping, crop rotation, use of pheromone traps, spray of biological pesticides, use of biocontrol agents and need based application of chemical fungicides and pesticides
- Package of cultural and other practices for safeguarding groundnut from contamination by aflatoxins

Utilization of groundnut byproducts

Enzymes used in cloth and food industry can be produced by subjecting groundnut by products to fermentation by microbes

- Shell → *Phanerochaete chrysosporium* or *Trichoderma viride* → production of cellulase
- Deoiled cake → *Aspergillus nidulans* or *Penicillium roquefortii* → production of protease
- Deoiled cake → *Bacillus cereus* → production of amylase

Technology for retaining seed-viability

- A low-cost method of storing groundnut pods (produced in *rabi*-summer) has been developed to prevent rapid loss of seed-viability.

Co-ordination of breeder seed production

The DGR has been coordinating production of breeder seed of groundnut varieties against the consolidated indent placed by the Department of Agriculture and Cooperation, GOI on behalf of various state governments and other public agencies. The quantity of breeder seed being produced every year (> 12,000 q) is enough to attain the desired seed replacement rate provided all the breeder seed is converted into certified seed through the recommended seed chain.

IMPACT OF RESEARCH

The quinquennial averages of productivity in India which fluctuated between 676 and 759 kg/ha before 1970s, registered a steady increase subsequently. This can be correlated by and large with release of several high-yielding and biotic and abiotic stresses tolerant varieties with matching packages of practices for different cropping systems and also to a certain extent to cultivation of groundnut in summer under high-input assured irrigation. On the basis of the quinquennial averages of productivity and taking 1965-70 as the base, the decadal progressive improvement in productivity was 21.7% during 1 971-80; which further increased up to 31.4% during 1981-90; 50.6% during 1991-2000 and 65.5% during 2001-2010. Thus subsequent to 1970, the increase in yield contributed more significantly towards increasing groundnut production. This aspect clearly establishes a slow but steady impact of new technologies on enhancing productivity of groundnut in India.

The impact of various components of technology on the economics of farmers was assessed through the data of FLDs.

In the year 2009-10, compared to national average of 1007 kg/ha, the average yield of groundnut in FLDs, conducted at various locations in India, was 2218 kg/ha thereby indicating a gap of 120% between the realized and realizable yields. Data from FLDs also indicate that the adoption of improved varieties in combination with improved packages of practices have the potential of enhancing yield in farmers' field by 30-50% in *rabi*-summer and 15-40% in *kharif*.

Impact of new varieties and production and protection technologies

Component of technology	Increase over Farmer's Practice (%)		
	GMR	COC	NR
Improved Variety	26.7	12.2	43.2
Integrated Nutrient Management	16.2	16.9	17.8
Plant Growth Promoting Rhizobacteria	15.5	3.4	2.4
Integrated Pest Management	7.2	2.2	18.4
Integrated Weed Management	9.3	2.7	18.2
Irrigation Management	14.2	0.3	20.0

GMR = gross monetary returns; COC =cost of cultivation; and NR =net returns

DGR 2030

Since its inception in 1979, the DGR has been working relentlessly to address various issues concerning productivity of groundnut. Being largely a rain-fed crop, challenges are much too many. Overcoming the adverse effects of various biotic and abiotic stresses in an economic and eco-friendly manner by coordinating a multi-disciplinary approach has been the underlying ethos for formulating research projects. The efforts in future would be to make DGR an international repository of scientific knowledge and its application for improving productivity, quality, and utilization of groundnut.

Vision

The vision statement for DGR is "Development of technologies for enhancing efficiency of groundnut based production system on a sustainable basis through appropriate cropping system, value-addition and diversification of products so that the groundnut system as a whole becomes sustainable, remunerative and globally competitive".

Mission

"Conduct research for improving the crop production technologies to eventually enhance groundnut productivity from the current 1050 kg/ha to 1500 kg/ha for *kharif* (rainfed) and from 1500 kg/ha to 2000 kg/ha for *rabi*-summer (irrigated) by the year 2017 by developing remunerative, globally competitive and sustainable crop production and protection technologies for groundnut based cropping systems in different agro-ecological regions of India through a blend of basic and strategic multidisciplinary research."

Focus

- Collection, evaluation and characterization of germplasm and to act as a national repository of groundnut genetic resources
- Genetic up-gradation of groundnut for higher kernel and oil yields coupled with resistance to biotic and abiotic stresses by employing both conventional breeding and biotechnological approaches
- Development of production technologies for both low-input rainfed and high-input assured irrigated conditions while integrating technologies to enhance resource-use efficiency
- Development of technologies for management of major pests and diseases of groundnut

- Development of technology for value-addition in groundnut at cottage and small scale industry levels
- Refinement and integration of available and new technologies for Integrated Nutrient Management (INM), Integrated Pest Management (IPM) and water management
- Refinement of technology for prevention of aflatoxin contamination in groundnut
- Identification of the socio-economic constraints in adopting new technologies and in flow of technology to farmers and other stakeholders
- Strengthening groundnut seed production system
- Development of modelling and forecasting as a tool for crop management through assessment of risks and relevant decision making for amelioration
- Development of institutional linkages for conducting research in a collaborative mode or for strengthening the ongoing research programmes through sponsored projects

Harnessing Science

The important scientific options that would be available to scientists for research for improving productivity of groundnut are:

Genetic resource enhancement for conventional breeding

DGR has been functioning and in times to come, will continue to function as the national repository of groundnut germplasm. A collection of over 8983 accessions and 105 wild relatives of *Arachis* species, represents a huge reservoir of genes. Another huge collection (about 15,000 acessions) of groundnut germplasm is available with International Crop Research Institute for Semi-Arid Tropics, Patancheru. So far, only a fraction of this reservoir has been utilized for altering genetic constitution of groundnut plants to develop varieties possessing desirable attributes. The available variation can further be enhanced by pre-breeding, mutation, interspecific hybridization etc. To address the future needs, this germplasm collection will be thoroughly characterized for additional attributes to facilitate its use in trait specific varietal improvement programmes.

Biotechnological interventions

The biotechnology has now established itself as a powerful tool for developing genotypes that can perform even in harsh environments. The advances in genomics coupled with bioinformatics and understanding of stress biology can provide useful genes or alleles for imparting tolerance of specific stresses.

Through molecular breeding useful genes available in any groundnut genotype can be transferred into high-yielding varieties. While the genetic engineering offers the opportunity to move such genes across the different species from any species in plant or animal kingdom.

Work on transformation of groundnut using available useful genes has been going on at DGR and elsewhere in the country. Transgenic plants, using coat protein genes for incorporation of resistance to viral diseases PBND and PSND, have been developed and are being evaluated. Groundnut plants expressing *mtlD* gene for enhancing tolerance of drought and salinity are also being evaluated. Putative transgenics expressing genes like *defensin* for affording resistance to fungal diseases; *annexin* for enhancing tolerance of abiotic stresses; and *PR10* for enhancing tolerance of salinity have also been reported. In near future, development of transgenic varieties tolerant of one or more biotic or abiotic stresses is foreseen. Both molecular breeding and genetic engineering either alone or in combination has the potential of developing transgenic groundnut varieties with kernels free from allergen and other undesirable attributes. Enhanced oleic/linoleic ratio will be another area to venture upon. A good progress has already been reported in identification of markers for tolerance of rust disease.

In future, besides molecular breeding and genetic engineering, relatively new approaches of transcriptomics and proteomics may be employed to identify the novel genes and promoters and their use for developing multiple stress tolerant varieties.

Synergies of frontier sciences

Nanotechnology applications have considerable potential for weed management through nanopesticides and nutrient management through nanofertilizers. Nano particles can be used as carriers of various agrochemicals, biocontrol agents and beneficial micro-organisms with a reduced requirement of chemicals or inoculums. These aspects will be integrated with the on going and future research projects for improving the effectiveness and economics of various inputs.

Management of natural resource

Land (soil) and water are considered the most important natural resources for cultivation of any crop. It is now well established that cultivation of groundnut helps in conservation of both soil and water resources. Being a leguminous crop groundnut crop improves soil fertility by enhancing both soil organic and nitrogen contents. Groundnut has ability to thrive even in residual fertilizers applied to preceding crop. The fertilizer requirement of this crop is quite low compared to most field crops and as such there are little chances of deterioration in soil quality due to cultivation of groundnut. Growing deficiencies of micronutrients in soil, however, is being reported from most of traditional groundnut growing regions emphasizing the need for their external application for sustainable production of groundnut. Moreover, for judicious application of fertilizers, information of soil test crop response would come handy. As this crop is grown in rows, spaced apart by at least 30 cm, a good scope exists for promoting fertigation, which combines irrigation and fertilization and thus maximizes the synergy between these two agricultural inputs increasing their efficiencies.

Among the natural microbial resources, enhanced use of competitive strains of *Rhizobium*, phosphate solubilizing microbes, and consortia of beneficial microorganisms including non-toxigenic strains of aflatoxin producing fungi on the one hand and enhanced use of biocontrol agents like *Tirchoderma* on the other hand, would make cultivation of this crop even much less polluting. Hence continuation of research is needed for identifying efficient micro-organisms and formulation of microbial consortia as bio-fertilizers along with their delivery system and development of IPM modules with enhanced use of biocontrol agents and botanicals.

Crop diversification

Since groundnut is grown largely under rain-fed conditions on marginal soils, the economic returns to farmers depend on the pattern and extent of rainfall which shows a considerable year-to-year variations. Moreover, on such poor lands possibility of groundnut being replaced by other crops is also quite low. Hence, it is necessary that groundnut farmers opt for crop diversification through groundnut based cropping systems. Intercropping, to some extent helps farmers to avoid the risk of huge losses due to near total loss of a crop due to drought, excess rains, or sudden outbreak of a disease or insect as the chances of failure of both the crops remain quite low. Intercropping pigeon pea with groundnut has already gained popularity among the groundnut farmers. Depending on agro-ecological situation and demand for other commodities, suitable crops can be identified and promoted for intercropping with groundnut. The groundnut farmers would also do well by skipping groundnut cultivation, in rotation, in one or the other plot of their farms every second or third year. This would not only reduce the build up of pathogens of soil borne diseases but would also provide a little economic safeguard against chances of groundnut crop failure.

Post-harvest handling and value-addition

Although groundnut is considered a semi-perishable crop yet a lot of care is required to be exercised in post-harvest handling of the produce. Several storage pests are known to damage the produce during storage and in the past decade the bruchid beetle (*Caryedon serratus*) has emerged as an important storage pest. Somehow, the groundnut seed is required to be stored in-shell only because otherwise the seeds lose the viability. This, storing of seed in form of pods i.e. in-shell occupies large storage space. Development of technology to enable storing of groundnut in form of kernels for seed purpose will reduce the space requirement for both storing and transporting groundnut seed.

Markets for value-added products of groundnut have been growing with increasing emphasis on quality and packaging of the value-added products. Groundnut is unique among oilseeds in that a large number of items can be produced from it for direct consumption by value-addition. As groundnuts blend well with other commodities, it is very often used for enhancing the visual appeal and organoleptic properties of value-added products of other food commodities.

Management of energy and by-products

As the crop canopy is short, scope exists for reducing the demand on fuel energy required for mechanization of cultivation. Small tractors of 12-14 HP with appropriately designed implements have considerable potential for reducing the energy requirement of groundnut cultivation.

Shells and groundnut cakes (oil- and de-oiled) are the two main byproducts of groundnut besides the foliage. Currently shell is by and large used as an industrial fuel after its conversion into briquettes, oil-cake is solvent extracted to remove the residual edible oil while the de-oiled cake is used mainly as cattle feed supplement. Foliage is used as fodder for farm animals. Considerable scope exists for research for better and more economic utilization of shell and cakes. Development of 'stay green' type of cultivars would enhance yield of fodder.

Bio-risk management

A host of insects and diseases are known to affect groundnut crop. The integrated management of diseases and insect pests will have to be the focus of research on management of biotic stresses. Phasing out of chemical control to the extent possible is being envisaged by introducing resistant varieties and use of biocontrol agents and botanicals in the available IPM modules.

The climate change that is in offing will also bring along a new pattern of threats from insect pests and diseases on groundnut. The groundnut crop may suffer from excessive rains instead of drought. The diseases and pests, hitherto considered not important may become serious and even acquire epiphytotic dimensions. Research for development of early-warning systems for drought, excessive rains, and bio-risk agents etc. would be needed to cope with the climate change induced risks. A huge data is available on the incidence of insect-pests and the weather parameters in respect of various AICRP-Groundnut centres. Compilation and statistical analysis of this data may help in modelling the occurrence of diseases and pests in the changed climate.

Institutions and policies

Policies will have to be developed to derive benefits of research being conducted elsewhere within the country and abroad. The issue of intellectual property rights will have to be resolved without jeopardizing the interests of groundnut farmers and other stake holders. The strengths of institutions like ICRISAT and SAUs will have to be recognized to promote synergy. A policy support for rapid phasing out of old and inferior groundnut varieties and production and sale of compound fertilizers would bring about substantial improvement in groundnut productivity in a short time.

Human-resource development

Up-gradation of skills of scientific and technical personnel is essential for implementing not only the ongoing research projects but also for conceptualizing new ones. To implement the research programs in frontier areas especially nanotechnology and bioinformatics, capacity development of scientific and technical human resource would be accorded priority. For this various national and international agencies competent to provide relevant training would be identified. The DGR would also organize national and international symposia to bring the groundnut research workers on a common platform for interaction and exchange of views. Apart from enhancing competence of its own scientists and technicians, DGR would also enhance the skills of functionaries of line departments by way of affording them training on the latest technologies of groundnut production to enable them in turn pass on the technologies to the farmers of their respective states.

Technology transfer systems

An effective transfer of technology system is very crucial for fetching maximum dividend on the investment made in research. This system will have to be efficient not only in transfer of developed technologies to end users but also in assessing the acceptability and survival of new technologies. Arrangements would be made for obtaining feedback from the farmers and extension agencies to refine the technologies for their greater acceptability and ease of adoption. The future transfer of technology system will have to make maximum use of Information and Communication Technology, GPS, and GIS to disseminate the technology. The functioning of KVKs and the line departments of the state governments will be crucial in this endeavour.

Strategy for Research and Framework

The strategy for enhancing productivity is conceived for the next five years by taking into consideration the current status and emerging trends in scientific knowledge as well as the likely availability of human, financial and infra structural resources in the near future. With strengthening its on site research activities in the areas with high groundnut cropping intensity and augmenting its research infrastructure in these areas, the DGR envisages adoption of a six-pronged strategy to realize the vision of doubling the productivity of groundnut crop in the years to come. The strategic framework for identified goals along with the approaches to be followed and indicators of performance is given in Annexure-1. The essential features of this strategy are:

1. **Development of new groundnut varieties possessing one or more of the desirable traits like**
   - Enhanced moisture deficit stress tolerance for rain-fed system in general
   - Enhanced salinity tolerance for coastal belts
   - Enhanced acidity tolerance for rice fallows, river beds and NEH region
   - Enhanced cold tolerance for rice fallows, river beds and NEH region
   - Low temperature tolerance (to overcome delay in germination) and high temperature tolerance (to overcome heat stress during pod filling stages) for cultivation in spring season in northern India
   - Fresh-seed dormancy in Spanish cultivars to prevent in situ germination on exposure of crop to rains coinciding with harvest time
   - Enhanced tolerance of foliar fungal diseases (rust, leaf spots, *Alternaria*), viral diseases (PBND and PSND) and defoliating insect pests (leafminer, tobacco caterpillar and gram pod borer)
   - Resistance to invasion by *Aspergillus* flavus in bold-seeded varieties to minimize aflatoxin contamination (for enhancing export)
2. **Enhancing understanding of**
   - Morpho-physiological traits imparting tolerance of water-deficit and high-temperatures to facilitate trait based breeding for drought tolerance
   - The effect of climate change (especially rise in temperature and atmospheric CO_2-levels) on productivity of groundnut in various growing zones and ways to manage the same
3. **Development of package of practices for**
   - Enhancing irrigation water use efficiency by adopting micro-irrigation techniques and use of hydrogels

- Enhancing fertilizer use efficiency by applying principles of soil test crop response technology
- Combined enhanced use efficiency of both water and fertilizers through fertigation
- Formulation of components of compound fertilizers (containing NPK, secondary and micronutrients) suitable for major groundnut growing regions to overcome flawed application of fertilizers
- New groundnut based intercropping systems in keeping with the changing preferences of the farmers and consumers
- Use of polythene mulch to overcome delay in seed germination under low-temperature conditions for spring groundnut
- Development of more efficient and competitive strains of rhizobia, PGPR and phosphate solubilizing microbes to reduce the requirements of application of chemical fertilizers

4. Development of encapsulation techniques

- For preventing the loss of seed viability in rabi-summer produce
- For application of micronutrients, biofertilizers and biocontrol agents
- For application of fungicides to manage seed borne diseases

5. Development of eco-friendly crop protection technologies

- Identification of new and more efficient bio-control agents and their use for managing biotic stresses
- Use of pheromones for management of insect pests
- Development of practices for controlling bruchid and other storage pests

6. Development of management practices for preventing aflatoxin contamination in groundnut

- Packages of practices for pre- and post-harvest handling of produce by the farmers
- Package of do's and don'ts by the traders
- Packages of do's and don'ts by the processing industry

In addition, the research work for development of new value-added products to promote secondary agriculture, identification of multi-cut rhizomatous species for forage-production on under utilized lands will also be undertaken. While the production of breeder seed would continue to be an essential activity, the farmer participatory seed production programme will be undertaken at DGR headquarters and all AICRPG centres. The component of nanotechnology will be integrated with the ongoing research projects at appropriate time for delivery of weedicides, pesticides, micronutrients, biofertilizers and biocontrol agents.

Epilogue

The DGR is fully committed to bringing about a technology-led improvement in sustainability and profitability of groundnut production system as well as in the quality of groundnuts for value addition.

Moreover, emphasis would also be given to more economic utilization of the byproducts of groundnut industry i.e. groundnut shell and oil- or deoiled-cakes. It is envisioned that by introducing early-maturing varieties for *rabi* rice-fallows, riverbeds and in traditional summer areas, and expansion of area in spring groundnut in potato fallows will result into a quantum jump in productivity of groundnut. Introduction of drought tolerant varieties with resilience to respond to normal rains would help in arresting further decrease in area under this crop. Introduction of Virginia large-seeded varieties in sandy-soils with assured irrigation will give a fillip to production of export quality groundnut. Quality seed production in farmer participatory mode would help achieve desirable seed replacement rate and also rapid penetration and spread of new improved varieties.

Although currently only about 15% of the area under groundnut is cultivated under assured irrigation it offers a great opportunity for soil-test-crop-response based application of nutrients with a potential of nearly doubling the yield in such areas. The areas where groundnut foliage is not valued much as fodder polythene sheet can be used as mulch to facilitate early sowing, economize on irrigation water and thus enhancing the yield.

Plant protection technologies with a greater use of biocontrol agents will make groundnut cultivation more eco-friendly than ever before. Use of nanotechnology would reduce the quantities of agrochemicals required for controlling weeds, insect pests, and diseases and profitability.

Value-addition at cottage industry level would ensure creation of opportunities for secondary agriculture making cultivation of groundnut even more attractive.

The total area under groundnut is not likely to change much in the next decade. The area lost in certain states may be compensated for by the areas gained in other states. The available technologies have all the potential of enhancing average national yield of groundnut to the level of 1600-1700 kg/ha by the end of the year 2015 and enhance it further to the level of 2100-2200 kg/ha by the year 2020. The growth in scientific knowledge and resulting development of new and more efficient tools for crop improvement, crop production and crop protection will help in further elevation of productivity to the level of 2500-3000 by the year 2030.

The current availability of groundnut in India works out to be 5.5 kg pods/per capita per annum after saving the seed required for sowing the next crop. With the technology led enhanced productivity, the availability is likely to be doubled by 2025.

The growth in Information and Communication Technology (ICT), Geographic Information System (GIS) and Global Position System (GPS) would speed up the communication amongst the farmers, extension workers, state and central agencies and research organization. There would then hardly be any loss of time in exchanging information on outbreak of insect-pests and diseases and the remedial measures to be taken by agencies concerned. Each farmer will be able to receive advisory while being in his field or village.

The synergies amongst the research organizations (ICAR and SAUs), seed production agencies (public and private) and the line departments of central and state governments would, however, be crucial for attaining the projected yields.

In future, utilization of pattern of groundnuts is likely to be much different from what it is today. While it would continue to be one of the important source of edible oil in India, unlike other oilseeds it would emerge as a major supplementary food crop owing to the nutritive value it has and the range of products that can be made from it without expulsion of oil from its kernels.

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Annexure-1 : Strategic Framework for Five Years

Goal	Approach	Measure of performance
Genetic enhancement of groundnut for improvement of productivity and quality	Conservation of germplasm collection. Characterization and evaluation of working collection for the traits of economic importance	Accessions conserved *ex situ* (in cold store). Accessions characterized, evaluated and identified
	Maintenance and multiplication of wild *Arachis* species	Accessions conserved *in situ* (in field)
	Supply of germplasm accessions to other institutions	Indents satisfied
	Evaluation of advanced breeding lines	Genotypes evaluated and high-yielding and/or early-maturing genotypes identified
	Screening of advanced breeding lines for tolerance of water-deficit stress	Genotypes screened and drought tolerant genotypes identified
	Effecting fresh crosses for enhancing tolerance of biotic and abiotic stresses	New crosses developed
	Field screening of germplasm and advanced breeding lines for tolerance of biotic stresses	Genotypes screened and identified
	Confirmation of phosphorus-use efficiency in germplasm accessions	Genotypes evaluated and identified
	Screening of genotypes for quality traits	Genotypes screened and identified
	Yield evaluation of large-seeded advanced lines	Genotypes evaluated and identified
	Effecting fresh crosses for quality and yield components	New crosses developed
	Evaluation of genotypes for quality (oil, protein, and sugars and O/L ratio)	Number of samples analyzed
	Development of high-yielding genotypes with improved fodder quality	Number of crosses effected
	Interspecific hybridization	Number of interspecific crosses developed
	Screening of interspecific derivatives for resistance to stem rot and/or PBND	Numbers of genotypes screened identified
	Phenotyping of RILs for reaction to stem rot	Number of genotypes
	BSA of interspecific populations for reaction to major diseases	Bulks identified

Goal	Approach	Measure of performance
Genetic enhancement of groundnut for improvement of productivity and quality (contd.)	Identification of NaCl-induced transcripts from *A. glabrata*	Functional transcripts identified
	Survey of DNA polymorphism in parental genotypes	SSR makers used
	Hybridisation for developing mapping populations	Probable hybrid pods harvested
	Co-cultivation of explants with Agrobacterium containing gene constructs, identification of the putative transgenics and confirmation of transgenics	Explants regenerated, putative transgenics identified and transgenics confirmed
	Molecular characterization of *A. glabarata* accessions for reaction to abiotic stresses	Polymorphic markers identified
	Nucleus and breeder seed production of DGR varieties	Quantity produced
Management of abiotic and biotic stresses, and mycotoxins in groundnut	Evaluation of intercrops for managing insects	Effective reduction in pests
	Evaluation of new insecticides for managing sucking pests	Effective reduction in pests
	Management of S. *rolfsii* and *A. flavus* through bio-agents	Effective control
	Management of alternaria-leaf diseases using fungicides	Effective control
	Management of soil borne diseases through supply of nutrients	Effective reduction in susceptibility
	Evaluation of cropping systems for management of aflatoxin	Reduction in aflatoxin load
	Evaluation of cultivars for tolerance of irrigation water salinity	Cultivars evaluated and identified
	Assessment of ameliorating effect of K on salinity stress	Extent of amelioration
	Characterization of impact of water deficit stress on physiological attributes and genotypic variation	Genotypes evaluated and traits identified
	Studies on root traits associated with drought tolerance	Traits identified
	Survey of Saurashtra region for occurrence of pests and diseases	District *(Talukas)* surveyed
	Allele mining for tolerance of abiotic stresses	Genes identified

Goal	Approach	Measure of performance
	Development of suppressive soils for management of soil-borne fungal pathogens using microorganism	Suitable organisms identified
Development of agronomic practices for sustainable groundnut production	NPK fertigation (through drip)	Monetary gains
	Use of polythene mulch and hydrogel for optimizing nutrient and water requirement	Monetary gains
	S-nutrition in g'nut-maize cropping system	Yield gain
	Harmonization of various sources of nutrients for combined application	Yield gain
	Application of citric acid for enhancing P availability	Yield gain
	Evaluation of AM fungi	Yield gain
	Evaluation of delivery systems for biofertilizers	Yield gain
	Evaluation of efficient strains of rhizobia	Yield gain
	Evaluation of fluorescent pseudomonads	Yield gain
	Characterisation and identification of endophytic microorganisms	Endophytes identified and characterized
	Molecular characterization and identification of microorganisms of groundnut cropping systems	Authentic identity (DNA profiling)
	Identification of abiotic stress tolerant microorgsnisms	Tolerant microorganisms identified
	Zn-fortification through foliar spray	Increase in Zn content of seed
	Studies on Ni and Co nutrition	Enhancement in nodulation and/or yield
	B and Zn fertilization in cultivars	B- and Zn- responsive genotypes identified
	Screening of mini-core collection for high Fe- and Zn-density in seed	High micronutrient density genotypes
	Revisiting statistical models for analysis of data of field trails	Improved model(s)
Post-harvest technology and value-addition	Screening of proteolytic microbes for thermo-, salt-, and heavy metal-tolerance	Isolates screened
		Isolates identified

Goal	Approach	Measure of performance
	Potential of microbes for protease production from groundnut cake	Enzyme yield (units/g cake)
	Production of partially defatted groundnut	Extent of reduction in kernel oil content
Evaluation of socio-economic impact of technologies	Impact analysis of new varieties in Karnataka, Gujarat and AP	Taluka covered
	Survey to assess economics of cultivation and post-harvest losses (in Anantapur and Chitradurga districts)	Completion of data collection (interview)
	Evaluation of economics of mitigating risk factors in cultivation	Risk factors evaluated
	Changing scenarios in area and productivity	States covered
To provide logistic support and coordination mechanism for generation of location-specific technology through the All India Coordinated Research Project on Groundnut (AICRPG)	Hybridisation	Cross combinations
	Conducting multi-location yield trials	Genotypes evaluated
		Promising genotypes
	Conducting multi-location agronomical trials	Trials conducted
		Components identified for recommendation
	Conducting multi-location plant protection trials	Trials conducted
		Components identified for validation
	Breeder seed production	Target achieved
	On-farm demonstration of improved technologies	FLDs conducted
To develop institutional linkages and to offer consultancy and training	To establish and foster linkages and to impart trainings	Linkages established and trainings imparted