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किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

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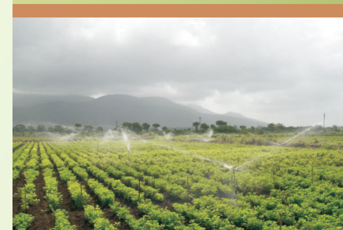
Vision 2050

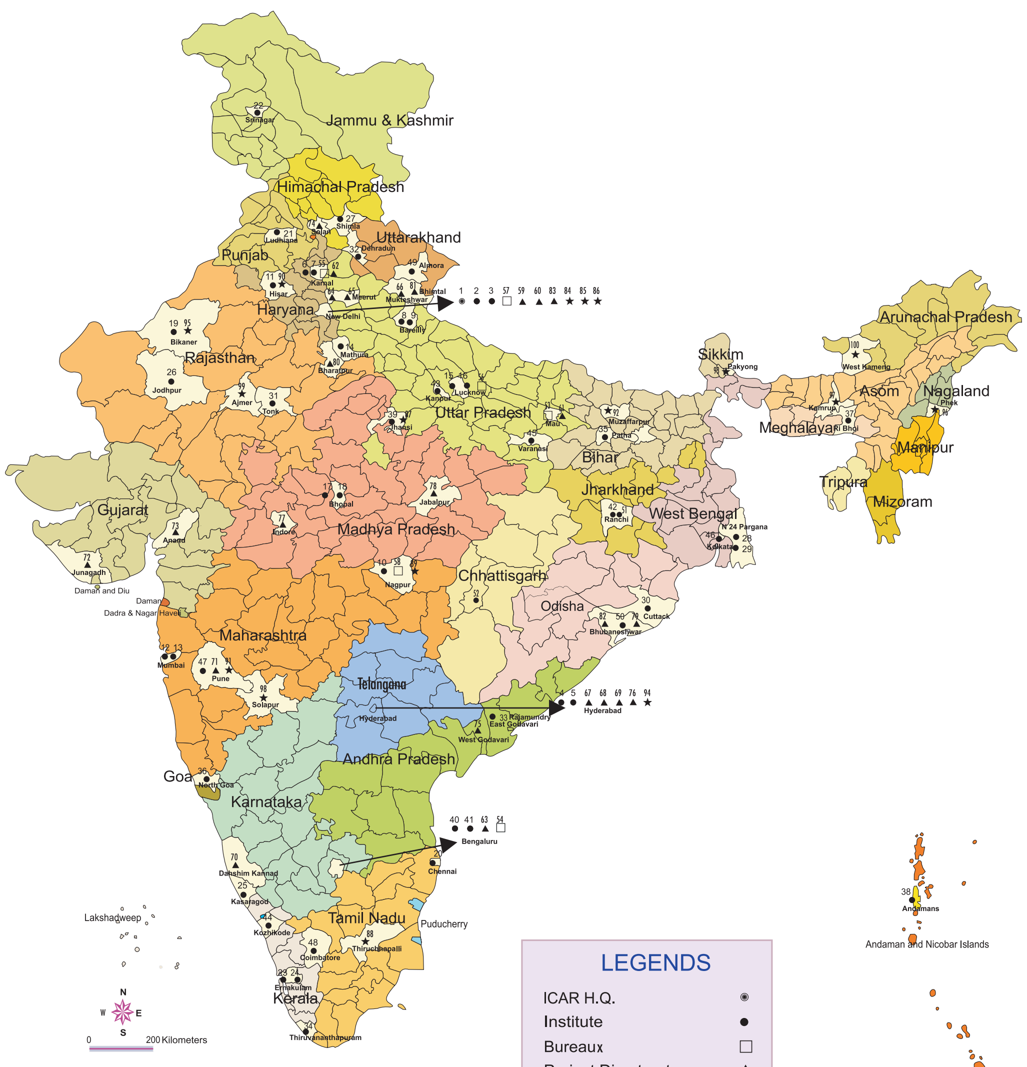


Directorate of Groundnut Research

Indian Council of Agricultural Research

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Institutes, Bureaux, Directorates and National Research Centres



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Vision 2050

Directorate of Groundnut Research
(Indian Council of Agricultural Research)
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Gujarat 362 001

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संदेश

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

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

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

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

(राधा मोहन सिंह)

केन्द्रीय कृषि मंत्री, भारत सरकार

Foreword

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

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

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

Vision-2050 document of ICAR-Directorate of Groundnut Research (DGR), Gujarat has been prepared, based on a comprehensive assessment of past and present trends in factors that impact agriculture, to visualise scenario 35 years hence, towards science-led sustainable development of agriculture.

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

(S. AYYAPPAN)
Secretary, Department of Agricultural Research & Education (DARE)
and Director-General, Indian Council of Agricultural Research (ICAR)
Krishi Bhavan, Dr Rajendra Prasad Road,
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Preface

The groundnut is the fourth most important source of edible oil and the third most important source of protein in the world. Groundnut is a leguminous plant and can easily be cultivated even on marginal lands with low inputs. It is one such plant, all parts of which contribute to the 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-and-extruded briquettes. In its root nodules, groundnut harbours Rhizobium bacteria, which in every crop season fix about 150-200 kg atmospheric nitrogen in a hectare. The foliage obtained after stripping the pods provides a nutritious fodder for cattle.

In the last decade direct consumption of groundnut has increased so much that instead of being considered merely an oilseed crop, it is now being recognized as a supplementary food, an oilseed, and a forage crop.

As an outcome of release of several improved groundnut varieties along with improved crop production and protection technologies, the productivity of groundnut crop has improved over the years. The quantum of improvement, however, does not meet the expectations.

Envisioning a long-term road map for attaining a cherished goal of enhancing crop productivity by developing improved technology entails visualizing developments in several areas of science and the possible industrial production of several gadgets which may not be in the reach of Indian farmers today but would be available at affordable prices twenty years hence. This 'Vision 2050' document is an outcome of such an exercise.

I should like to express our gratitude to Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR for emboldening us to write this 'Vision 2050' for ICAR-DGR. I should also like to thank Dr. S. K. Datta, Former Deputy Director General (Crop Science) and Dr. J.S. Sandhu, the present Deputy Director General (Crop Science) and Dr. B.B. Singh, Assistant Director General (O&P), ICAR, for providing

constant encouragement and guidance. The contributions of all the scientists of ICAR-DGR in bringing out this document are gratefully acknowledged.

Radhakrishnan T.
Director

Contents

Context

Groundnut (*Arachis hypogaea* L.) is an important oilseed and food legume crop of tropical and subtropical world. It is annually grown on about 20-24 million ha of land in about 120 countries under different agro-climatic zones between latitudes 40^{o}S and 40^{o}N. It belongs to family Fabaceae and is the most widely cultivated annual legume crop worldwide.

Light and sandy-loam soils are most suitable for cultivation of this crop though it can be profitably grown on a variety of soils including light and heavy textured soils. Compared to several other crops, groundnut can survive in much less favourable agro-climate conditions and needs 105-130 days to mature. It requires warm growing season with well distributed rainfall in the range of 500-1000 mm. Though a native of South America, groundnut is presently cultivated mainly in the semi-arid regions of Asia, Africa and American continents. China, India, Nigeria, USA, and Myanmar, are the top five producers of groundnut and together contribute nearly three-fourths of the global production.

Among the important food crops of the world, groundnut occupies the 13th position. Groundnut is the sixth most important source of

Potential of groundnut as a crop

- Can be grown on marginal soils and its cultivation improves soil fertility
- High plasticity for adaptation to adverse climatic conditions
- C3 crop with high energy conversion efficiency
- Genetic diversity exists in germplasm for desirable traits
- More than 190 varieties are available for diverse agro-climatic regions
- Fits well in cropping systems and at certain places two crops can be taken in a year
- High biological nitrogen fixation potential
- Being a cover crop, prevents soil erosion
- Dual purpose varieties available for food and forage purpose
- Very high potential for export and value-added products
- Trained human resource and well developed infrastructure for scientific research is available
- AICRP-Groundnut provides a platform for multi-location evaluation of technologies in diverse agro-climatic zones
- Kernels being rich in energy and protein have potential of providing food and nutritional security
- Foliage can be used as fodder and other by-products for industrial applications
- Opportunities for institutionalizing contract farming

edible oil and the third most important source of vegetable protein in the world. Groundnut kernels contain 48-50% high quality edible oil, 25-34% easily digestible protein and 10-20% carbohydrates and are rich source of vitamins E, K and B complex. Groundnut oil is good from both nutritive and culinary points of view as it contains good quantities of MUFA (oleic acid, 40-50%) and PUFA (linoleic acid, 25-35%). With its high oleic/linoleic ratio, groundnut oil has a relatively longer shelf-life. The tocopherol, (approx. 0.9 mg/g oil), an antioxidant present in groundnut oil prevents development of rancidity. Because of its higher iodine value (smoking point), it is most suited for deep frying.

Nutritional and other characteristics of groundnut oil and kernel are given in figure.Though high in fat, groundnuts primarily contain "good" fat (unsaturated and free from trans types) and help to maintain blood cholesterol levels and therefore friendly to heart.

The Global Production Scenario

Groundnut is generally grown under low input and rain-fed conditions across wide range of environments where frequent drought adversely affects the productivity. The groundnut productivity is below 1000 kg/ha in about 50% of the groundnut growing countries, 1000-2000 kg/

Country	Area* (lakh ha)	Production* (lakh tonne)	Yield* (kg ha^{-1})
China	46.7	166.3	3562
India	51.1	70.4	1367
Nigeria	23.7	30.1	1268
USA	5.0	22.0	4330
Myanmar	8.9	13.8	1560
Senegal	7.8	6.4	827
Indonesia	5.4	12.0	2234
Niger	7.2	3.2	452
World	249.3	420.9	1688

*Triennial (2011-2013) averages

ha in 35-40% of the countries, and more than 2000 kg/ha inonly 10-15% of the countries.

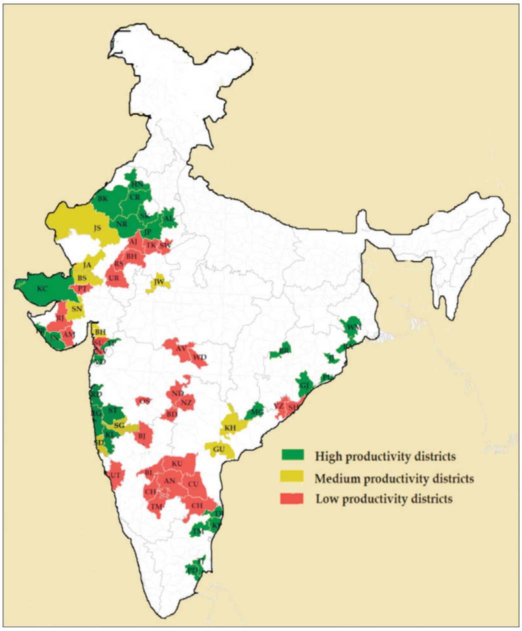
The world average yield of groundnut is about 1688 kg/ha and about 70% of production comes from areas in semi-arid and arid tropics comprising mainly Asia and Africa.

The triennial (2011-13) averages of area, production and yield indicatethat annually 421 lakh tonnes of groundnuts are produced in the world from a cropped area of 249 lakh ha with an average productivity of 1688 kg/ha.

Distribution of groundnut area (*Source:* www.indexmundi.com)

The Indian Scenario

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 1988-89; while the highest productivity was of 1460 kg/ha in the 2007-08. Currently, six states viz. Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra, and Rajasthan account for nearly 90% of the groundnut area. Madhya Pradesh, Uttar Pradesh, Orissa, West Bengal, Chhattisgarh, Jharkhand, Punjab, Goa, NEH states and Kerala also contribute to national groundnut production to various extents. In India, groundnut is cultivated mainly in kharif season (rain-fed conditions) with low inputs and if available with a few protective irrigations. In kharif, the pressures of diseases, insect-pests and weeds are high. The productivity depends largely on the quantity and distribution of rainfall over the season. An evenly distributed rainfall of 600-800 mm would generally assure a good productivity. The dry spells which often occur during pod development phase would reduce the yields and hence kharif productivity shows wide variations over the years.

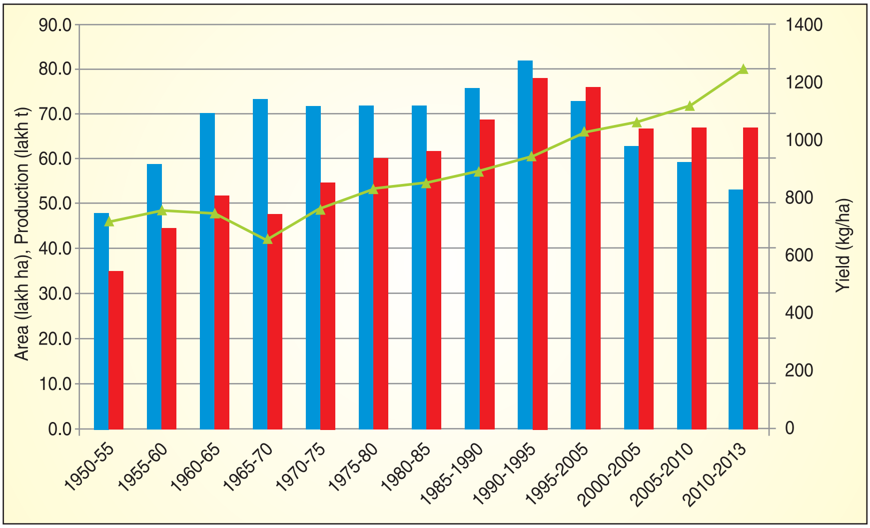


The area under rabi-summer groundnut system has expanded over the years. In rabi, the crop is grown under residual moisture of rice fallows or river beds under minimal or no irrigation and also in summer as an irrigated crop. The summer cultivation is practiced generally under high input conditions and the pressures of diseases, insect-pests and weeds are much low and hence the productivity is high. Spring groundnut, cultivated after the harvest of potato/toria, also gives high productivity.

Groundnut growing seasons in various states of India			
Season	**Sowing**	**Harvest**	**States**
By and large rain-fed, supplementary irrigation, if available (about 85% area)			
Kharif	June-July	Sept-Oct	Uttar Pradesh, Rajasthan, Gujarat, Madhya Pradesh, Chhattisgarh, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, and Jharkhand
Post rainy (about 15% area)			
Rabi (residual moisture)	Oct-Nov	Feb-Mar	West Bengal, Odisha, 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 Uttar Pradesh

Trends in Area, Production and Productivity

The area under groundnut in India during 1900-1910, was only 2.3 lakh ha which increased to 76.8 lakh ha by the end of century. During 1951-1960, the growth in area (17.2%) had the major contribution in increasing groundnut production in India. The area increased from



Quinquennial averages of area, production and yield of groundnut in India

4.66 million ha during 1951-55 to an all-time high of 8.16 million ha during 1991-95. After hovering above 8 million ha from 1988-89 to 1993-94 period, it started declining and hit a low of 4.32 million ha in 2013-14 due to various reasons, which include competition from other crops such as Bt cotton, soybean, sunflower, maize etc., availability of cheaper edible oil such as palm oil and frequent and persistent drought in major groundnut growing areas.

The productivity was below 800 kg/ha till 1975 but increased steadily to reach beyond 1000 kg/ha during 1996-2000. The increase in productivity was due mainly to release of high-yielding varieties and improved packages of practices, and also to a certain extent to cultivation in summer under high-input assured irrigation. Seed alone accounts for about 35-40% cost of cultivation in groundnut. Depending upon season and other inputs applied and also the yield realized, the CBR may vary between 0.7 and 5.0.

State-wise Scenario of Area, Production and Productivity and Constraints

The triennial (2010, 2011, and 2012) averages of area and production of groundnut indicate that 91.5% of the cropped area is distributed across six states which together contribute 91.4% of total production. These states are Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, and Rajasthan. Among other groundnut growing states are Madhya Pradesh, Odisha, Uttar Pradesh and West Bengal which together comprise nearly 7% of area and contribute about

Triennial (2010-11 to 2012-13) averages of area, production and yield of groundnut in various states of India			
State	Area (lakh ha)	Production (lakh tonnes)	Yield (kg ha^{-1})
Gujarat	16.5	22.8	1354
Andhra Pradesh	14.26	11.3	790
Tamil Nadu	3.7	9.1	2495
Karnataka	7	5.4	742
Maharashtra	2.8	3.6	1182
Rajasthan	3.8	7.1	1813
Madhya Pradesh	2	3.1	1543
Odisha	0.6	0.82	1199
West Bengal	0.6	1.26	2042
Uttar Pradesh	0.9	0.9	966
Chhatishgarh	0.2	0.4	1391
All India	52.8	66.4	1243

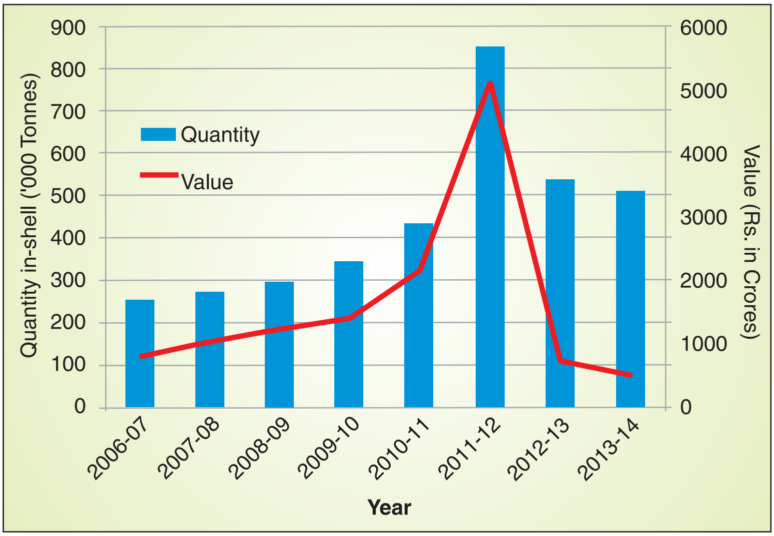
Source: Ministry of Agriculture, Govt. of India, India Vanaspati producers association

7% of the total production. The average productivity of groundnut during the period 2001 to 2010, though ranged from 700-1460 kg/ha, the average productivity in three major groundnut growing states of the country, was in the range 510-2270 kg ha-1 in Gujarat, 300-1360 kg/ha in Andhra Pradesh, and 1150-1880 kg/ha in Tamil Nadu for kharif season and the corresponding values for the rabi-summer season were 1473-2390 kg/ha in Gujarat, 1400-2130 kg/ha in Andhra Pradesh and 2100-3730 kg/ha in Tamil Nadu. The productivity of groundnut in NEH region and Goa, however, is more than that of national average.

Export of Groundnut

China, India, USA and Argentina are the major groundnut exporting countries of the world. During 1999 to 2002, the export of groundnut from India declined, but it registered a considerable increase subsequently. A record high export of 853 thousand tonnes was registered in 2011-12. Groundnut is exported both in-shell and kernels forms.

For export purpose, two broad categories are defined- java and bold. The java types have smaller pods with constriction, kernels are oval with pink skin and the shell is thicker than the bold types. In bold types, the pods and kernels are bigger than the java type and the kernels are oblong with a red skin which becomes darker with ageing. A very stringent maximum permissible limit (2 ppb) of aflatoxin contamination in groundnut has been set by the European Union. Aflatoxin contamination



Export of groundnut from India (source: DGCIS)

is now recognized as the chief non-tariff trade barrier for export of groundnuts from India as many a Indian consignments are rejected at the destination ports due to aflatoxin levels beyond the permissible limits.

Current Utilization Pattern of Groundnut

The direct consumption of groundnut has been growing and its food value is being increasingly realized due to availability of other edible oils at economical prices. In 1960s, about 80% of the produce was crushed for oil expulsion and only about 6% was used for direct consumption while the

remaining 14% was used for seed. During the 1980s, about 81% of the total produced was used for oil expulsion and only 6% was used for direct consumption. However, in recent years, nearly 50% of the produce is used for direct consumption especially as value-added products like roasted, boiled and salted groundnut, chikki and peanut-butter. In the past two decades, the direct consumption (roasted and salted groundnuts, chikki, peanut butter and sauce) has gone up to 40% and currently about only 50% of the produce is crushed for oil expulsion.

Challenges

Possible impacts of climate change on groundnut crop

Groundnut, being a C_3 plant, the projected rise in atmospheric CO_2 is likely to enhance rate of photosynthesis as the current levels of atmospheric CO_2 do not saturate Rubisco. The pod yield would also increase even if harvest index is not affected. The relative benefits would be more under water limiting conditions, as higher CO_2 will enhance water use efficiency.

Any rise in temperature leading into a regime of 25-30°C, will promote germination and establishment of seedlings. Any increase beyond 35°C would adversely affect germination and seedling establishment. Stomatal conductance and transpiration rate would increase with increase in temperature. The rise in temperature may lead to early flowering but cause a little reduction in harvest index and induce early leaf senescence in certain cultivars.

So far as *kharif* crop is concerned, rise in temperature would not have any significant impacton time of sowing. For summer crop, a rise by 2-4°C would help advance time of sowing by 10-15 days in northern India, thus help farmers harvest, dry and cure their produce before pre-monsoon showers. The increase in temperature, however, is likely to hasten crop maturity, especially in the peninsular India, by about 5 days in all the seasons of cultivation.

In India, nearly 85% area under groundnut crop is sown in *kharif* season which is by and large dependent on rainfall. The erratic and excessive rainfall would impact the crop adversely. Excessive rainfall early in the season would delay the opportunities for field preparations.

By 2050, overall in India, the possible physical impact of climate change will be:

- An increase in the average surface temperature by 0.8–1.8 °C
- Projected increase in total radiative forcing is 2–4 W m^{-2}
- Changes in rainfall (both distribution and frequency) during both monsoon and non-monsoon months
- Changes in precipitation by –4% to +6%
- Increase in evaporation rate by 0–5%
- Increase in the frequency and intensity of cyclonic storms
- Increase in CO_2 levels (as high as 530–550 ppm)

Excessive rainfall right after sowing would hamper the germination and may even necessitate gap filling or re-sowing. Torrential rains coinciding with flowering would smother the flowers and reduce the number of pegs. Prolonged spells of cloudy weather and extra rainfall would induce profuse vegetative growth and lower the harvest index. Frequent stagnation of water in the groundnut fields during reproductive phase beyond 5-6 hours would adversely affect the yield.

Existing and potential threats to groundnut cultivation

- Infestation by new insect-pests
- Spread of soil-borne diseases (stem rot, root rot, and collar rot)
- Widespread occurrence of *Aspergillusflavus* causing contamination of kernels with aflatoxin
- Possible replacement of area by more profitable crops in traditional belts
- Competition from other countries in international markets
- Changes in temperature and rainfall pattern due to climate change
- Erratic and excessive rainfall due to climate change may force farmers to shift to another crop

In a nut shell, in most groundnut growing areas, the beneficial effects of rise in CO_2 levels are likely to outweigh the predicted adverse effects of rise in temperature. The erratic rainfall, however, may spell out its adverse impacts irrespective of increase in CO_2 levels and temperature.

The interrelations between the predicted climatechange and consequent changes in soil are based on hypothetical scenarios and hence impact can be described at best only in qualitative terms. The rise in temperature and increase in rainfall would enhance the rate of soil erosion unless amelioration measures are in place. Experiments show that global warming will accelerate the rate of soil organic carbon decomposition due to increase in the activities of soil microflora and thus reduce fertility (C and N content) even as increasing CO_2 would increase soil organic carbon through net primary production. A small increase in temperature in low carbon soil would result in higher CO_2 emissions as compared with medium and high carbon soil thus making low carbon soil more vulnerable to warming. However, there may not be any significant effect on soil physical properties but the biological nitrogen fixation is likely to go up due to increased availability of photosynthate for sustaining the nitrogen fixation by rhizobia in the root nodules.

Impact on soil and biological nitrogen fixation

- Possible shift in the population dynamics of microflora due to likely increase in soil temperature and thus there is chance of adverse effect on soil fertility, positive effect on reduction of pathogen population

- Possible enhancement in BNF in groundnut because of higher rate of translocation of photosynthate
- Possible enhancement in the rhizodepoistion vis-à-vis enhanced load of microflora due to likely enhancement of average temperature and higher rate of translocation of photosynthate

Impact on occurrence of pests and diseases

Impact of climate change on occurrence of pests and diseases

The changing climatic conditions are more likely to have negative impacts such as a rise in the spread of diseases and pests, which will reduce yields. Some pests and disease hitherto considered uneconomical may acquire economic dimensions. The changing climate would need to revampexisting forewarning/ prediction models for diseases and pests.

Rise in CO_2 levels

Increased CO_2 assimilation into plants results in higher C:N ratio. Therefore, herbivorous insects have to feed more on plants to fulfill their nutrient demand. Defoliators such as *Spodoptera litura*, *Helicoverpa armigera*, *Amsacta* sp. and *Aproaerema modicella* will devour more foliage, thus reducing the available photosynthetic area.

Sucking pests such as aphids, thrips, leafhoppers and mealy bugs suck more plant sap and excrete resulting in sooty mold growth on infested plant parts. Ants associated with such pests also pose problems during field

Reasons for poor production and productivity in groundnut

- Grown largely under rain-fed conditions (*kharif*) with low inputs and hence production highly dependent on quantum and pattern of rainfall
- Non-availability of short-duration (90 days) high-yielding varieties for specific low rainfall areas
- Low seed multiplication ratio (1:8) results non-availability of quality seeds of new varieties and slows down their spread
- Difficult to develop hybrid due to cleistogamy
- Low seed replacement rate due to a low seed multiplication ratio (1:8) and high seed rate (120 – 150 kg seed pods/ha) and high volume seed crop (seed alone costs about 35% of the cost of cultivations)
- Rapid loss of seed viability in *rabi*-summer produce rendering the seeds unfit for sowing in the next *rabi*-summer
- Highly susceptible to aflatoxin contamination
- Narrow genetic base in released cultivars and cultivated germplasm
- Lack of infrastructure for post-harvest processing and village or community level storage
- Lack of incentive for producing high quality groundnuts (free from aflatoxin)
- Lack of enthusiasm for adopting high-cost technologies due to inadequate financial support

operations. However, the increased CO_2 levels have limited influence on the pest of stored groundnut. Increased CO_2 may not have an impact on the seed quality as such.

Rise in temperature levels

Rise in temperature results in shortening of plant as well as insect life cycles. As the life cycle is depending on the degree days, the insect-pests as well as natural enemies shift their seasonal occurrence pattern to suit to advanced cropping patterns. The insects that are severe in south and central India such as, *S. litura*, *H. armigera*, *Amsacta* sp. and *A. modicella* may expand their distribution to Gujarat, Uttar Pradesh, etc. Sucking pests such as thrips and mealy bugs will broaden their distribution to Central and North India. The number of generations may be increased in case of sucking pests. This situation may favouran increase of vector borne viral diseases like PBND and PSND.

New insect-pests or minor insect-pests such as mealy bugs may gain major pest status. Pests of stored groundnut may have shorter generation time and may cause more damage to the produce. The rise in temperature would also influence production and survival structures of pathogens. Population of stem rot pathogen *Sclerotium rolfsii* may increase in soil. Severity of leaf spot caused by *Cercospora arachidicola*, *Phaeoisariopsis personata* and leaf blight caused by *Alternaria* sp. may also increase due to increase in temperature. The availability of thermo-tolerant strains of bio-control agents would be helpful in managing the diseases like stem rot.

Changes in rainfall (amount, frequency and distribution)

Intense and off-season rains result in washing out of the sucking pest populations. In some areas, the increase in frequency of rainy days results in increased humidity favouring defoliators and sucking pests. Prolonged dry spells, result in increased infestation by thrips and aphids. The severity and occurrence of soil-insects such as, termites and white grubs is highly dependent on rainfall. Increasing rainfall will attract/ increase the stem rot pathogen *S. rolfsii* incidence. In the situation of low rainfall combined with high temperature regimes will increase collar rot and dry root rot incidence.

Genomics

The availability of whole genome sequence of major pests and pathogen will facilitate better identification as well as understanding in pests/pathogen population.

Aflatoxin management

Availability of on-farm aflatoxin estimation kit would help farmers to estimate the aflatoxin level at their field and bargain premium for produce.

Intervention of Information Technology

IT based instrument or smart interface would be available for the forecasting/or forewarning of a disease and pests situation, which would help groundnut grower for the better management of pests and diseases.

Projected demand of groundnuts in 2050

The population of India is likely to touch a figure of 1,690 million by 2050. Providing food security to such a large population would be daunting task and also a challenge to agricultural scientists for developing production technologies to bridge the gap in the demand and supply on a sustainable basis. In times to come, groundnut would play a greater role as a supplementary food crop besides continuing to be an oilseed crop.

The projected domestic demand of groundnut would be about 25 million tonnes. The area under groundnut may not shrink any further and would stay around 6-7 million hectares. Considering the current national average productivity of 1200 kg/ha, a growth rate of about 4-5% in productivity is called for.

Projected total oilseeds demand and groundnut as oilseeds and oils demand in India (in million tonnes)

Year	Total oil seed required	Groundnut production	Groundnut oil requirement
2020	50.4	14.8	3.5
2030	63.7	17.8	3.9
2040	79.6	21.6	4.3
2050	93.0	24.6	4.9

Attainable Yield Potential of Groundnut Crop

It has been shown through experiments and crop-modelling that under best management practices the attainable yield potential of groundnut crop is in the range of 8000 to 11000 kg ha^{-1}. State-wise three years (2010-11 to 2012-13) data on potential yields achieved through Front Line Demonstrations and actual yields obtained by farmers indicated that the yield gap ranges from 19% to 148% in different states. Overall, yield gap in groundnut in India is 77%. Yields of 6000-6500 kg ha^{-1} have often been realized in AICRP-G yield evaluation trials. In the year 2009-10, the average yields of 4218 and 4181 kg ha^{-1} were realized in Thiruvallur and Kancheepuram districts respectively, in Tamil Nadu. There are authentic reports of realization of >8000 kg ha^{-1} yield by a few Indian groundnut farmers. In Rajasthan, several farmers are realizing the yield of more than 5000 kg ha^{-1}. Thus envisioning a technology-driven rise in an average yields to the level of 5000 kg ha^{-1} in India may not be regarded unrealistic.

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Operating Environment

During last decade, research in groundnut has witnessed a sea change in its approach by the use of newer and upcoming research tools like –omics (genomics, proteomics, transcriptomicsand metabolomics), nano-technology and extension tools like information and communication technologies. There is no doubt that there would surely be a complete transformation by the year 2050 in the operating environment for groundnut crop production in terms of resource use translation into productivity. The details are discussed below:

Emerging technologies for integration in agricultural research by the year 2050

- Dependable weather forecasting system
- Dependable disease and insect-pest forewarning system
- Excellent cropping system based farm advisory service having all farmers in its ambit
- Smart sensor based input delivery system (irrigation and nutrients)
- Biodegradable films for use as mulch
- All-India database on individual farmer's soil resources
- Commercial supply of crop and region specific soluble fertilizer formulations inclusive of micronutrients
- Availability of cost effective water conservation products (e.g. hydrogels) for *in situ* moisture conservation
- Application of endosymbionts for management of biotic and abiotic stresses
- Installed capacity of irradiation for destruction of aflatoxin and harmful biological entities
- Nanotechnology for application of weedicides, pesticides, and fertilizers etc.
- New energy efficient agricultural machinery

Potential of genetic resources

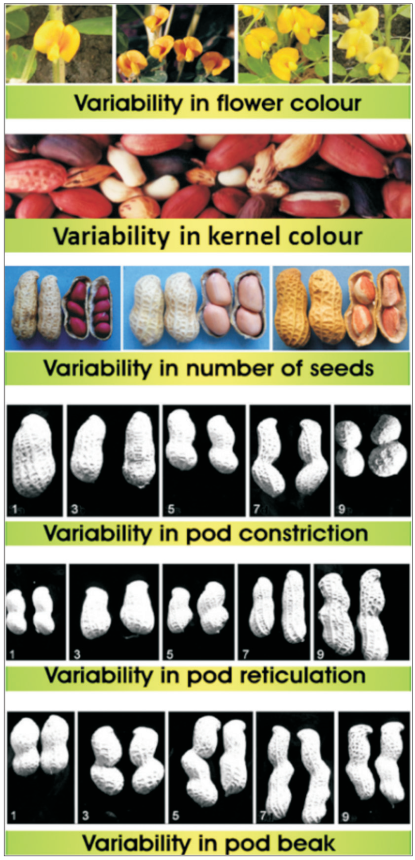
A collection of over 9000 groundnut germplasm accessions and 105 wild relatives of *Arachis* species at ICAR-DGR and 15,000 accessions at International Crop Research Institute for Semi-Arid Tropics is available for exploitation as a huge reservoir of genes. The available variations can be tested and utilized for developing stress tolerant cultivars by pre-breeding, mutation breeding and interspecific hybridization etc.

New plant types

- Development of new plant types with enhanced harvest index
- Development of new plant types for low thermo and photo-insensitivity

Biotechnological interventions

- The advances in genomics coupled with bioinformatics will help identify useful genes or alleles for various traits
- These useful genes thus identified can be transferred into high-yielding varieties through conventional, molecular as well as genetic engineering approaches
- Development in metabolomics will unravel the biochemical mechanism of stress resistance and also identification of genes



Management of natural resource

- Application of specialty fertilizers correcting acute deficiencies and imbalances
- For enhancing synergy between fertilization and irrigation, optimization of use of soluble fertilizer and micro-irrigation for developing protocols for fertigation technology will improve water and fertilizer productivity
- Improved IPM modules with enhanced use of biocontrol agents and botanicals will make the groundnut cultivation more eco-friendly
- Technology for exploiting natural nitrification system to enhance N availability in groundnut on the onset on monsoon
- Improving soil and plant health by enhancing beneficial plant microbe (rhizobia, endophytes, PGPR) association through plant breeding
- Exploiting complex phenomenon of beneficial plant-microbes association for optimum utilization of photosynthate, nutrient mobilization and uptake, rhizodeposition and yield

Crop diversification

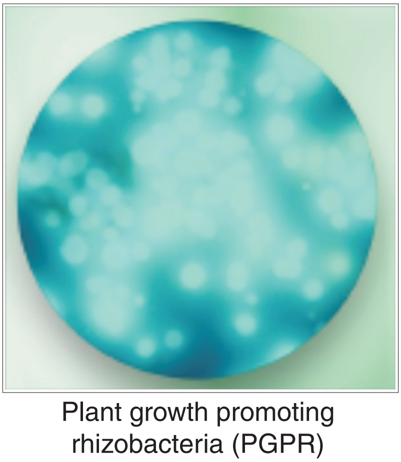
- Depending on agro-ecological situation several new groundnut based cropping systems are to be identified and validated with respect to climate resilience and crop diversification
- Raising groundnut in early stages of widely spaced horticultural crops will enhance land productivity. Intercropping with tall C4 crops like maize, sugarcane, and sorghum will protect groundnut crop from heat stress in areas of high temperatures
- Crop diversification through intercropping of groundnut with pigeon pea, maize, sorghum, sesame, cotton, plantation crops or by introduction in rice and potato fallows situation or by replacing *rabi* rice with groundnut will help in improving the livelihood
- Precision farming will minimize the gap between yields realized and the attainable yield potential

Post-harvest handling and storage

- Groundnut seeds are required to be necessarily stored in-shell as otherwise the seed viability is rapidly lost. Moreover during storage attack by storage pests especially bruchid beetle (*Caryedon serratus* O.) spoils the seed as well as the food value of kernels. Hence, development of storage technology for adoption at farm level is very much required.

Marketing and value-addition

- The prevailing *mandi* based marketing system does not allow the farmer to realize the remuneration they deserve. A productivity zone based minimum support price and nationwide procurement system encouraging producer company model among the groundnut growers may be required to sustain groundnut cultivation especially in the low productivity areas.
- Groundnuts being tasty and nutritious hold a lot of potential for value-addition. An array of processed products of groundnuts alone or in combination of other foodstuffs can be popularized for enhancing direct consumption.



Plant growth promoting rhizobacteria (PGPR)

- Bio-fortified groundnuts can be used as a functional food.
- Considerable scope exists for research for better and more economic utilization of shell and cakes
- Institutionalization of contract farming would fetch premium price to farmers for adopting Good Agricultural Practices (GAPs)
- The export oriented processing units need to become more and more responsive to consumer preference and meet all the criteria of health and hygiene on the one hand and become a partner in the contract farming of groundnut

Risk management in relation to climate change

- Use of region specific stress tolerant varieties would be the first approach towards risk management
- Technology for management of drought by most efficient and effective use of available rain water and in situ conservation of soil moisture to manage drought
- Proper adoption of the plant protection measures will insulate the crop from serious damage by diseases and insect pest
- Technology of drainage and conservation of water in the field itself during the periods of excessive rains and reusing the stored water during the spells of scanty rains will protect the crop from ill-effects of excessive as well as poor rains
- 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

Institutions and policies

- Policies for enhancing synergies with SAUs and ICRISAT would reduce the time for research output and avoid spending on duplication of research.
- Policies for intellectual property rights will have to be such that they do not jeopardize the interests of groundnut farmers and other stake holders nor cause any procedural delay in release of technology.
- A policy support for rapid phasing out of inferior varieties and production and sale of location specific fertilizer mixtures will improve groundnut productivity in a short time.

Human-resource development

- Capacity development of scientific and technical personnel would be necessary to implement the research programs in frontier areas especially nanotechnology and bioinformatics and also in soil-water management

- Organize national and international symposia (at least once in two years) to bring the groundnut research workers on a common platform for interaction and exchange of views
- Regular training of extension functionaries on the latest production technologies will be crucial for showcasing new technologies and their dissemination
- Organizing conferences and symposia on groundnut based cropping systems will facilitate exchange of views on emerging concepts for research and new technologies

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New Opportunities

The groundnut researchers are going to face unprecedented challenges for improving the production and productivity of groundnut by the year 2050. Therefore the strategy would be to develop technologies for maximum realization of attainable yields in various crop growing regions. This would increase the overall production by enhancing productivity rather than bringing additional area under this crop. Being a C_3 photosynthesis type grown largely in *kharif* season, groundnut is not likely to be much affected by the predicted change in climate by 2050. Adoption of best package of practices (new technology) would raise groundnut production dramatically as large variations and considerable scope for improvement exist in productivity of individual farms within and across the states of India.

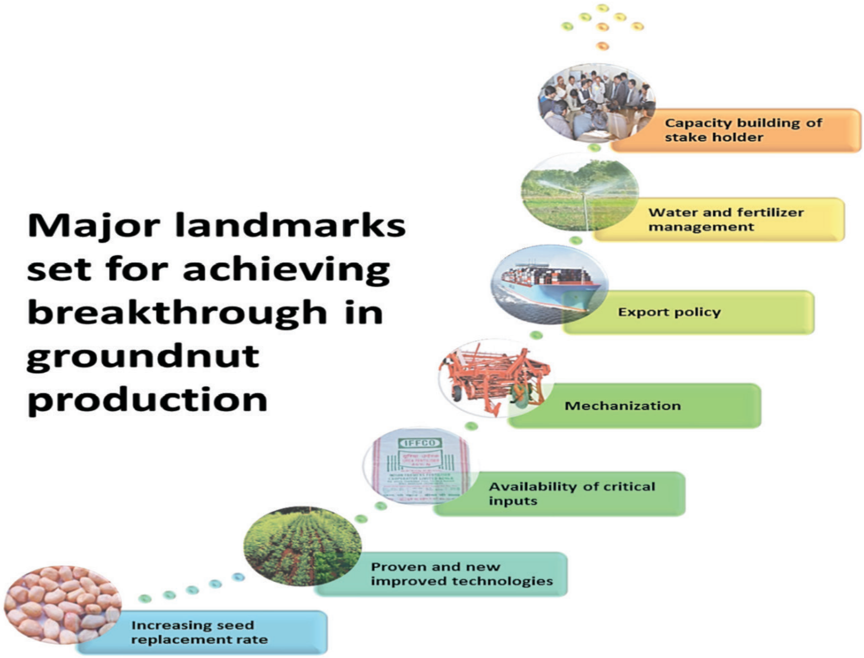
Addressing the Threat of Climate Change

- Identification and development of varieties with high photosynthesis and nitrogen fixation for producing more biomass under elevated atmospheric-CO_2 in future
- Identification of areas where groundnut cultivation would face severe challenge, the potential areas where production may go up, and new areas likely to come under groundnut cultivation
- Understanding the crop biology under conditions of elevated temperature in terms of germination, vegetative growth, floral biology, crop duration and quality of produce
- Identification of varieties suitable for cultivating at high-temperature to withstand heat stress during pod filling stages
- Understanding of the behavioral and incidence pattern of insect-pests and diseases under conditions of elevated CO_2 and increased ambient temperature and RH etc.
- Understanding of soil microbe vis-à-vis nutrient availability and impact on biological nitrogen fixation

Short term strategies

Improvement in Crop Varieties

- Varietal development through marker-assisted breeding, site-directed mutagenesis and trans- and cis-genic approaches for:



- Early maturing and drought tolerance, high-yield coupled with desirable quality traits and in-built tolerance of biotic and abiotic stresses
- Nutrient-efficiency, cold, soil acidity and salinity tolerance, herbicide resistance and fresh-seed dormancy
- Bold-seeded with high sucrose and oleic/linoleic ratio, and free from allergen and aflatoxin
- Development of designer groundnut with nutraceutical properties
- Bringing down duration of crop by 10 days to diversify cropping system and bringing groundnut crop into new cropping system and niches

Improvement in Crop Production Technologies

- Soil-management for altered physical properties and nutrient composition, refinement of fertigation technology and nanotechnology, site specific and sensor based input management for yield maximization
- Enhancement of carbon sequestration through conservation agriculture and increasing nutrient availability with interventions in cultivation practices in changing climate
- Development of highly-efficient and competitive strains of rhizobia,

PGPR and phosphate solubilizing microbes to reduce the use of chemical fertilizers
- Synchronization of nutrient supply with crop demand pattern through integrating different sources of nutrients

Management of Biotic and Abiotic Stresses

- Plant ideotypes for affording tolerance to biotic and abiotic stresses
- Application of endophytes and RNAi technology for management of biotic stresses
- Enhanced resistance to foliar fungal diseases (rust, leaf spots, *Alternaria*), viral diseases (PBND and PSND) and defoliating insect pests (leaf miner, tobacco caterpillar and gram pod borer)
- Identification of new and more efficient bio-control agents for their use in management of biotic stresses
- Development of strong forewarning system for timely and effective management of biotic stresses
- Development of varieties and package of cultivation, harvesting, and post-harvest handling for producing aflatoxin free groundnuts
- Use of nano-formulations as efficient delivery system

IPR and PPVFR

- DNA fingerprint database of cultivars and germplasm accessions
- Revamping of seed production system to ensure timely and adequate supply of quality seeds

Mechanization of Cultivation

- Development of implement and machines for intercultural, harvest and post-harvest operations

Post-Harvest Storage and Utilization

- Identification of packaging material as well as temperature and RH conditions for on-farm storage and warehouse for material to be exported
- Application of seed encapsulation for storing seeds as such instead of storing in-shell. This would greatly reduce the volume for storing and transporting seeds
- Value addition and creation of new and diverse products for domestic consumption

Long term strategies

Genetic Improvement

- Identification of useful genes and their novel variants in the germplasm for developing transgenics tolerant to stresses and gene pyramiding to confer multiple stress tolerance.
- Introgression of the desirable traits available in the germplasm to develop stress tolerant cultivars in agronomic background employing molecular and biotechnological approaches.
- Next-generation sequencing technologies and improvement of genotyping platforms with powerful tools for characterizing the genetic composition of the groundnut germplasm/breeding lines along with improved statistical machinery will provide quantitatively and qualitatively different information (e.g., copy number and epigenetic variation) in a faster way.
- Open platforms for data and information generation and sharing in genomics, proteomics, trait mapping for climate change, and disease-resistant traits would help to mitigate the crisis at global level in war-footing to save/sustain the groundnut crop from epidemics.

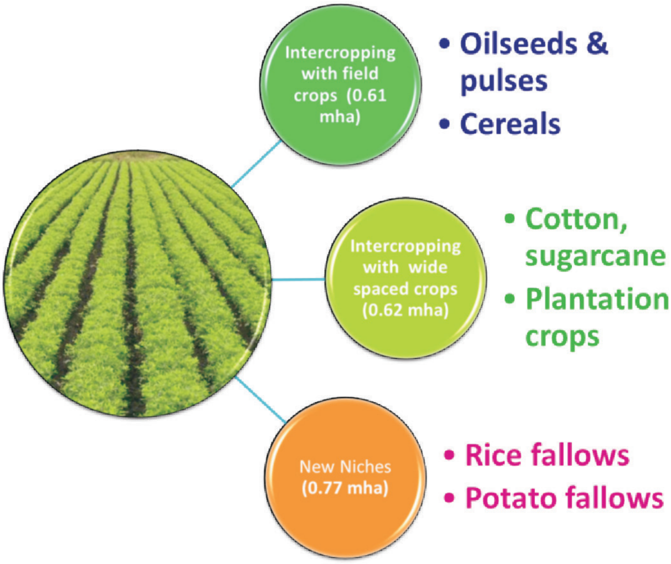
Basic and Strategic Research

- Evaluation of germplasm for various desirable traits at hot spots
- Creation of data-base on the basis of evaluation of germplasm at multi-locations for a large array of traits (agronomical, morphological, anatomical traits and response to various biotic and abiotic stresses)
- Identification of morpho-physiological and biochemical traits imparting tolerance of water-deficit, high temperatures and salinity for use in trait based breeding
- Ionomics and metabolomics to identify genotypes for climate resilience
- Development of elite transgenic events for addressing the resistance to complex traits like drought, viral resistance etc.
- Identification of new bio control agents for insect-pests and pathogens
- Understanding of host-parasite relationship in respect of diseases and insect pest as well as production of phytoalexins and operation of genetic switches

Expansion of Area

- Scope exists for bringing some additional new areas under groundnut crop through:

- Further spread of *kharif*-groundnut in Rajasthan, *rabi*-groundnut in West Bengal, Orissa and NEH region and introduction of its cultivation in rice-fallows in the peninsular India and NEH region, potato fallows in Uttar Pradesh, Punjab and Gujarat for spring groundnut as an intercrop with several widely spaced field crops and plantation crops



Ways to increase the total area under groundnut cultivation by 2050

Policy Interventions

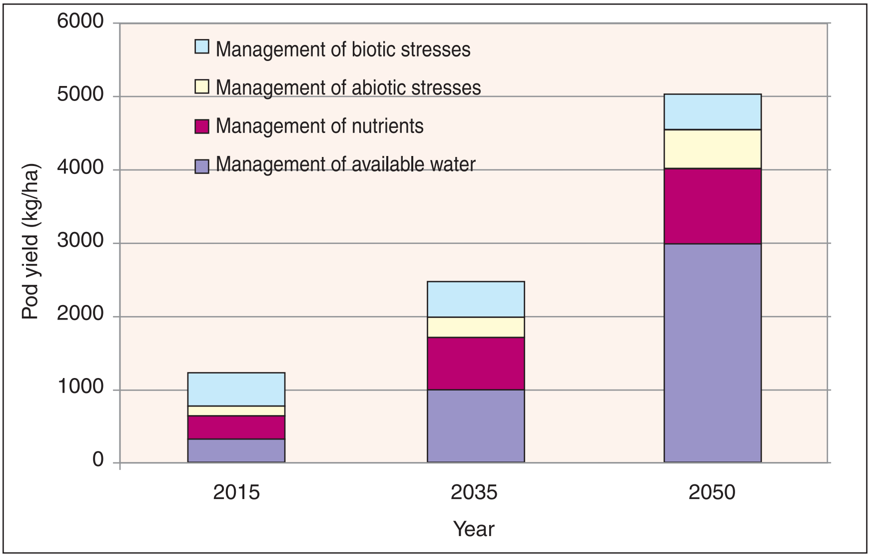
- Ensuring accessibility to international germplasm collection
- Measures to ensure multiplication of breeder seed through five-stage seed multiplication chain. Production of foundation seed onwards to be undertaken only in high productivity areas
- Timely announcement of remunerative minimum support price to ensure that groundnut cultivation remains a profitable venture
- Manufacture and supply of region specific composite fertilizers fortified with micronutrients in major groundnut growing areas
- Manufacture and supply of genuine biofertilizers and biocontrol agents in viable forms (with at least 10^8-10^{10} cfu or spores/g preparation)
- Incentive to farmers for adopting new groundnut varieties and institutionalization of contract farming system for cultivating groundnut for specific end use e.g. processing for peanut butter,

S. No.	Potential crop/cropping systems/niche	Specific area	Potential area (m ha)	Target area (m ha) 2020	Target area (m ha) 2025	Target area (m ha) 2050
1. Intercropping with field crops						
i	Pulses Pigeon Pea	Andhra Pradesh (Prakasham, Mehboobnagar, Warangal, Nalgonda), Tamil Nadu, Karnataka, Uttar Pradesh (Bundelkhand), Gujarat and Maharashtra	0.5	0.1	0.20	0.22
ii	Oilseeds Castor and Soyabean	Andhra Pradesh, Tamil Nadu, Gujarat and Madhya Pradesh	0.3	0.1	0.10	0.14
iii	Cereals Maize, Sorghum and Bajra	Rajasthan, Bihar, Punjab, NEH region, Karnataka, Maharashtra, Uttar Pradesh and Gujarat	0.5	0.1	0.20	0.25
2. Intercropping with wide spaced field crops						
i	Cotton (rainfed uplands and irrigated)	Gujarat Maharashtra, Andhra Pradesh and Tamil Nadu	0.50	0.15	0.20	0.22
ii	Sugarcane	Maharashtra, Uttar Pradesh and Bihar	0.20	0.05	0.10	0.15
3. Intercropping with wide spaced plantation/horticultural crops						
i.	Coconut and Cassava	Kerala, Andhra Pradesh and Tamil Nadu	0.50	0.05	0.20	0.25
4. New niches						
i.	Rice fallows	Tamil Nadu, Andhra Pradesh, Orissa, West Bengal and Goa,	0.50	0.1	0.20	0.22
ii.	Potato fallows	Western and Central Uttar Pradesh, Gujarat and West Bengal (Hooghly)	0.50	0.2	0.30	0.35
iii.	River bed and uplands	Assam- Brahmaputra	0.01	0.01	0.01	0.10

using as biofortified food, functional food or as nutraceutical. Likewise a tag of 'Low oil', 'High protein', 'Free from aflatoxin', 'Free from allergen' should be able to fetch a premium price
- Promotion of public-private partnership and community based seed production societies for seed production of new varieties

Up-gradation of Infrastructure for Research

The existing infrastructure of ICAR-DGR and AICRP-Groundnut would need augmentation in human, physical and financial resources in a span of a few years. Facilities will be required for:
- Phenotyping and work on genomics, proteomics and transcriptomics,
- Containment for evaluation of transgenics, glasshouses with controlled RH and temperature for basic and applied research, rhizotron for studies on root



Current and future crop production technology: change in relative contributions of various components of management

- Hybridization under controlled RH and temperature
- Screening facilities for evaluation of resistance to diseases
- Quality evaluation laboratory at 2-3 centres of AICRP-Groundnut

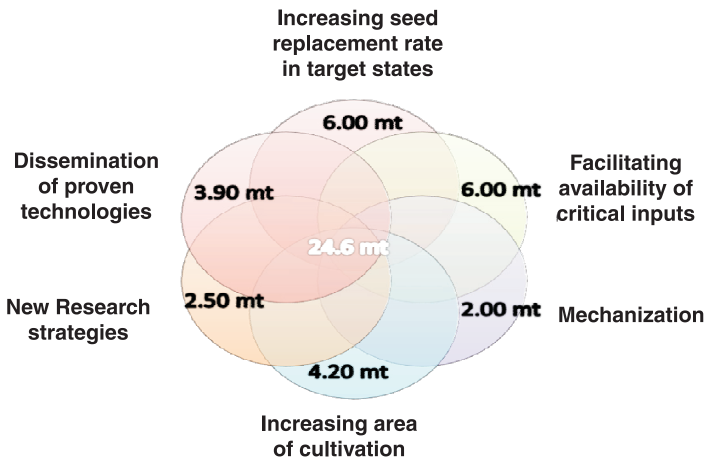
It is thus envisioned that in the year 2050, as an output of sustained scientific research, several modules of production technologies would be available for individual-farmer-field level. With backstopping of a dependable weather forecasting system and a robust quality seed supply system, the application of new technologies will help India realize average yield of 5000 kg ha^{-1} under rain fed situations and 7000 kg ha^{-1} under irrigated situations and thus once again make India the largest producer and exporter of groundnut. The new-age groundnut varieties (conventionally bred or transgenics) grown under new age package of production and protection practices would substantially improve water and land productivity.

The projected contributions of various components of technologies which would help attain the cherished goal are indicated in the figure above.

Marketing

At present the farmers sell their produce at the nearest marketing yard popularly known as *mandi*. These marketing yards are generally established at sun-district levels where the buyers purchase the produce through auction. The small farmers who need cash immediately and are not capable of holding the produce bring the same to market as soon as possible while well-to-do farmers bring their produce to market when the prices go up. Contract farming though practiced at insignificant scale for only organically produced groundnut can be developed further and institutionalized to safeguard the interest of both farmers and traders or processors alike. Necessary steps need to be taken by the state governments backed by mandatory provisions of insurance.

Organically cultivated groundnut which fetch premium price, is already being practiced by a small number of farmers. The produce is purchased in the village itself by the agents of firms concerned. The farmers are often forced to sell their produce at normal rates as the produce does not conform to the norms of organic food by certification agencies or offer of prices without any premium due to lack of demand of such groundnuts. This sector needs to be much more organized. Formation of co-operative societies by the farmers for production and disposal of organically grown groundnut may play a crucial role in protecting the interest of farmers.Since groundnut pods are of semi-perishable nature, the farmers are not constrained to resort to distress sales ever. The produce, however, is not only bulky but also prone to infestation by storage insect-pests. Hence the farmers cannot hold the produce for long as buffer time is not more than 30-40 days.



Possible ways to increase the total groundnut production by 2050

As most edible oils would continue to be available at a cheaper price, markets for value-addition in groundnut would grow for diverting the produce for direct consumption in domestic as well as international markets. By 2020-25, technology would be available to avoid contamination of groundnuts with aflatoxin. The adoption of good agricultural practices (GAP) through "contract farming" or producer companies supported and nurtured by export oriented processing units and hygienic post-harvest handling and storage of produce in the processing units will help India emerge as the largest player in the international trade of groundnut.

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Goals and Targets

The ICAR-DGR was established in 1979 by the name National Research Centre for Groundnut (NRCG). The NRCG made its humble beginning in a small building with 18 ha farm land on Junagadh-Veraval highway. Later, NRCG acquired another area of 105 ha land on Junagadh-Gir state highway. Soon after construction of a four-storey laboratory-cum-office building at the new site, the entire establishment was shifted to the new location. This was followed by shifting of headquarters of All India Coordinated Research Project on Groundnut (AICRPG) from Akola to Junagadh in 1992 and bringing the AICRPG under the administrative control of NRCG. Subsequently, the infrastructure has been growing gradually and now this Directorate occupies an enviable position among various crop commodity research institutions.During the eleventh Five-Year Plan, the NRCG was upgraded from level of a 'NRC' to level of a 'Directorate' and the erstwhile NRCG thus became 'Directorate of Groundnut Research' or 'DGR' in short.

Mandate of ICAR-DGR

- Conduct basic and strategic research to enhance production, productivity and quality of groundnut
- Act as the national repository of working collection of groundnut germplasm and information on groundnut research
- Establish relevant institutional linkages
- Offer consultancy and training
- Provide logistic support and coordination mechanism for generation of location-specific technology through the All India Coordinated Research Project on Groundnut

Human Resource

The sanctioned cadre strength of ICAR-DGR is 115, which comprises one RMP, 39 scientific, 40 technical, 157 administrative, and 26 skilled supporting staff. In addition, there are about 25 temporary status laborers. The total number (about 60) of employees engaged on *ad hoc* basis as Senior Research Associate, Research Associate, Senior Research Fellow, Hindi Translator, Accounts Assistant, Electrician, Plumber, Skilled Helpers, etc. keeps on varying depending upon the availability of core budget and the positions available in the ongoing externally funded projects.

The research activities are pursued through multidisciplinary research projects. The research projects are conceived and formulated after thorough discussion in the Institute Research Committee (IRC) meetings. The IRC meetings are chaired by the Director and attended by all the scientists. The number of projects running at a given time remains 25-30. The Research Advisory Committee (RAC), which is chaired by an eminent scientist from outside ICAR system, reviews the progress of the projects and the future plan of work every year. The recommendations of RAC are submitted to the Council along with the remarks of the Director. Mid-course correction, if any, approved by the ICAR is then incorporated in the future work plans of the research projects.

All India Coordinated Research Project on Groundnut

An All India Coordinated Research Project on Groundnut (AICRPG) exists for multi-location evaluation of technologies developed by ICAR-DGR and SAUs and a few ICAR institutes and KVKs. At present there are five main and seventeen supporting centres under AICRPG. For the purpose of locating the centres, keeping in view the prevailing agro-climate and cropping density of groundnut, the country is classified into five zones for identifying the problems and prioritizing research under AICRP-G.

Mandate of AICRP-Groundnut

- Conducting multidisciplinary research on Crop Improvement, Crop Production and Crop Protection at regular and voluntary centers
- 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
- Development of high-yielding groundnut varieties possessing resistance/field tolerance to drought; diseases and insect-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 groundnut varieties
- Demonstration of proven production and protection technologies on quality aspects through on-farm demonstrations in target areas
- Production of nucleus and breeder seed of important groundnut varieties

Human Resource of AICRP-G

There are 27 Plant Breeders, 13 Agronomists, 10 Plant Pathologists, 8 Entomologists, two Physiologists, and one Cytogeneticist in addition to 85 technical and five ministerial positions. The Director, ICAR-DGR also functions as the Project Coordinator. The research programmes are developed during the annual national level technical meetings of the AICRP-G.

Since its inception, the Directorate of Groundnut Research has been addressing various issues concerning productivity of groundnut crop and has developed technologies to overcome the adverse effects of various biotic and abiotic stresses through multi-disciplinary approach. The efforts in future would be for further improving productivity, quality, and utilization of groundnut under changing scenarios of climate and global market.

Missionary vision

Development and dissemination of technologies which would enhance average productivity of groundnut in India from the current 1200 kg/ha to at least 3500 kg/ha by 2050 and have groundnut cultivation, more sustainable, remunerative and globally competitive.

Goals and targets for productivity enhancement

The following broad goals are proposed to for productivity enhancement in groundnut along with different agencies to be involved:

Goals	Targets	Agencies involved
Increasing seed replacement rate in target states	Large scale seed multiplication of promising high yielding varieties (in high productive regions) to saturate the target states having yields lower than the national average in *kharif* (Andhra Pradesh and Karnataka) Large scale seed multiplication of promising high yielding varieties to saturate the states having high productivity but deficient in quality seeds for cultivation in *rabi*-summer (Odisha, West Bengal and NEH Region) and spring (Punjab and Western Uttar Pradesh) Creation of large scale facilities to cold-store the produce of *rabi*-summer and spring seasons for use as seeds in the ensuing seasons during the subsequent year Increasing the efficiency of conversion of Breeder to Foundation and Certified seeds through technological back stoppings and taking up seed production in high productive regions through PPP Mass multiplication seeds of new varieties through farmers participatory Approach by following PDKVV Akola model (Annexure-I) and through seed villages for rapid farmer-farmer spread	DAC, NSC, HIL, SAUs, selected KVKs located in high productive areas, Public-Private partnerships, NMOOP
Dissemination of proven improved technologies	Large scale on-farm demonstration oftestedimproved production and protection technologies for adoption by farmers of different groundnut growing states (Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra, Gujarat, Rajasthan and Uttar Pradesh)	Extension agencies of ICAR, SAUs and KVKs
Facilitating availability of critical inputs including irrigation water	Large scale watershed development through rain water harvesting structures (Check dams, farm and community ponds, reservoirs) Micro-irrigation and drips for drought prone ground nut growing states/regions like Andhra Pradesh, Karnataka, Maharashtra, Uttar Pradesh and Rajasthan Supply of bio-fertilizers (Rhizobium, Plant Growth Promoting Rhizobacteria, Phosphorous Solubilizing Micro-organisms and bio-control agents (Trichoderma and Pseudomonads) Supply of secondary and micro-nutrients to states deficient in micro-nutrients like **Zn**: Andhra Pradesh, Bihar, Haryana, Karnataka, Madhya Pradesh and Uttar Pradesh; **Boron**: Bihar, Karnataka, **Fe**: Gujarat, Tamil Nadu and Maharashtra	DAC, State Dept. of Agriculture, State Irrigation Departments, DAC, State Dept. of Agriculture, NGOs, PSUs on Fertilizers and chemicals

Mechanization	Mini-Tractors and tractor drawn farm machineries like bed formers, seed cum fertilizer drill, intercultural tools, harvester, thresher, decorticators for six major groundnut growing states (Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Rajasthan)	DAC, State Dept. of Agriculture and Engineering, Cooperatives
Export policy support	Identification of agencies; Capacity building of staff to handle detection of aflatoxins in export samples Establishing Referral Labs matching International Standards to estimate aflatoxins Establishing 'cold-store houses in major areas targeted for export-quality groundnut production (Gujarat, Andhra Pradesh, Tamil Nadu) Promoting contract farming and good agriculture and management practices to minimise aflatoxin problem	APEDA, IOPEPC, ICAR, DAC, Marketing Federations and Seed Industries
Minimum Price Support	Prices go down both due to very high production levels in a good crop year and low production in a bad crop year. Better procurement policy need to be developed and implemented Premium pricing for export quality and organically produced groundnut	DAC, NAFED, APMCs and States
New technologies	Directed breeding programmes using tools like MAS to develop groundnut varieties with better confectionary/ food qualities	ICAR-DGR and SAUs
Planting methods and fertigation through drips and use of liquid fertilizers	Enhances resources use efficiency, and improves groundnut yield by 20%	PSUs on Fertilizers and chemicals, DAC and States
Planned crop rotation	Groundnut-groundnut in the same field is not advisable as inoculum of soil borne and foliar fungal diseases build up. A proper crop sequence suitable for the growing areas results in higher yields and substantial savings in disease control and cash earnings	DAC, Agricultural extension and line departments
Capacity Building of stakeholders	This would apprise the extension functionaries about new technologies and need for their transfer to farmers	Directorate of Groundnut Research, SAUsAICRP-G centres
	This would enhance awareness among the farmers about the benefits of new technologies and also getting the feedback on the problems being faced by them	SAUs, KVKs, State Dept. of Agriculture

Focus

- Identification of trait specific donors in the germplasm collection
- Pre-breeding lines possessing novel genes for resistance to major biotic and abiotic stresses
- New pests and diseases which may emerge under the changing scenario of climate
- Management of water resources, especially of rain-water for enhanced water-productivity
- Genetic enhancement for yield and quality traits as well as stress tolerance

- Resource-use efficiency in rain-fed and irrigated conditions
- Cropping systems, crop diversification and precision farming
- Adverse impact, if any, of climate change and its amelioration measures
- Resource integration for efficient input utilization including Integrated Nutrient Management (INM), Integrated Disease and Pest Management (IDPM)
- Production of aflatoxin free groundnuts
- Development of models and forecasting tools for a dependable crop advisory service
- Product diversification, bio-fortification and value-addition and economic use of byproducts
- Development of varieties for specific end users: high oil varieties for crushing, low oil varieties for direct consumption, high protein varieties as functional food etc.
- Conservation agriculture
- Identification of the socio-economic constraints in adopting new technologies and other bottlenecks
- Marketing and export issues

Way Forward

Technology-led improvement, sustainability and profitability of various groundnut based production systems in India and better and economic utilization of the by-products of groundnut industry i.e. shell and oil- or deoiled-cakes are the major future thrusts in enhancing productivity of groundnut. The technologies available today have the potential of enhancing average national yield to the level of 1500-2000 kg ha^{-1} by the year 2020. The continued refinement of technology developed during the decades to come by convergence of progresses made in other fields of science would gradually enhance the average national productivity potential to around 4000 kg ha^{-1} by the year 2050. The cherished target of attaining national average productivity of 4000 kg ha^{-1} by 2050 would be attained by adopting the following strategy:

- Production of quality seed of recommended varieties in farmer participatory mode to achieve desirable seed replacement rate and rapid spread of new varieties.
- During the decade to follow, irrigated summer and spring groundnut cultivations offer a great opportunity with a yield potential of 4000 kg ha^{-1} and hence necessitates total package support.
- Use of biodegradable films to facilitate early sowing and economic use of irrigation water for enhancing water productivity and to achieve 'more crop per drop'.
- Introduction of early-maturing groundnut varieties for *rabi* rice-

Pillars of hope

- Ample scope for exploitation of genetic diversity in the available germplasm
- Possibility of development of specific stress resistant varieties (conventionally bred or transgenic)
- Wild species: a reservoir of useful genes especially for stress resistance
- Scope exists for expansion of area in *rabi*-summer (Odisha and West Bengal) and *kharif* (Rajasthan, NEH) and in spring (Uttar Pradesh, Punjab)
- Large-scale production of biological control agents and site specific fertilizers
- Greater adoption of micro-irrigation and fertigation systems to enhance input use efficiency
- Scope for development of an array of new value-added products
- Intercropping in wide-spaced plantation crops
- Potential for a positive response to increasing levels of atmospheric CO_2
- Expansion of area under irrigated crop

fallows and river beds and also in traditional summer areas, and expansion of area in spring season in potato-fallows which will result into a quantum jump in production.

- The release of varieties with enhanced insect-pest, disease and drought-tolerance would help in augmenting production.
- Introduction of large-seeded varieties in sandy-soil areas with assured irrigation and appropriate inputsto increase production of export quality groundnut.
- Plant protection technologies with enhanced use of bio-control agents to make groundnut cultivation more eco-friendly.
- In the longer run, use of new formulations coupled with nanotechnology would dramatically reduce the quantities of agro-chemicals used in groundnut cultivation. Promotion of soil-test based fertilizer application and fertigation at a large scale will enhance factor productivity.
- The total area under groundnut is likely to increase a little. The area lost in certain states may even be regained besides some gain in other states.
- The Information and Communication Technology (ICT) and Geographic Information System (GIS) would play an important role in rapid transfer of technology and releasing advisory to the farmers without loss of time. The farmers will be connected with advisory services while being anywhere.
- The synergies amongst the research organizations (ICAR and SAUs), seed production agencies and the line departments of central and state governments to attain the projected yields.
- Tailor-made varieties for specific end use for use as functional food, nutraceutical, high energy food etc.
- Utilization of *Arachis* genome data for development of tools for devising strategies for effective management of biotic and abiotic stresses.
- Exploring pathogen and *Arachis* genome interaction for developing diagnostic tools for management of existing and emerging diseases and pests.

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