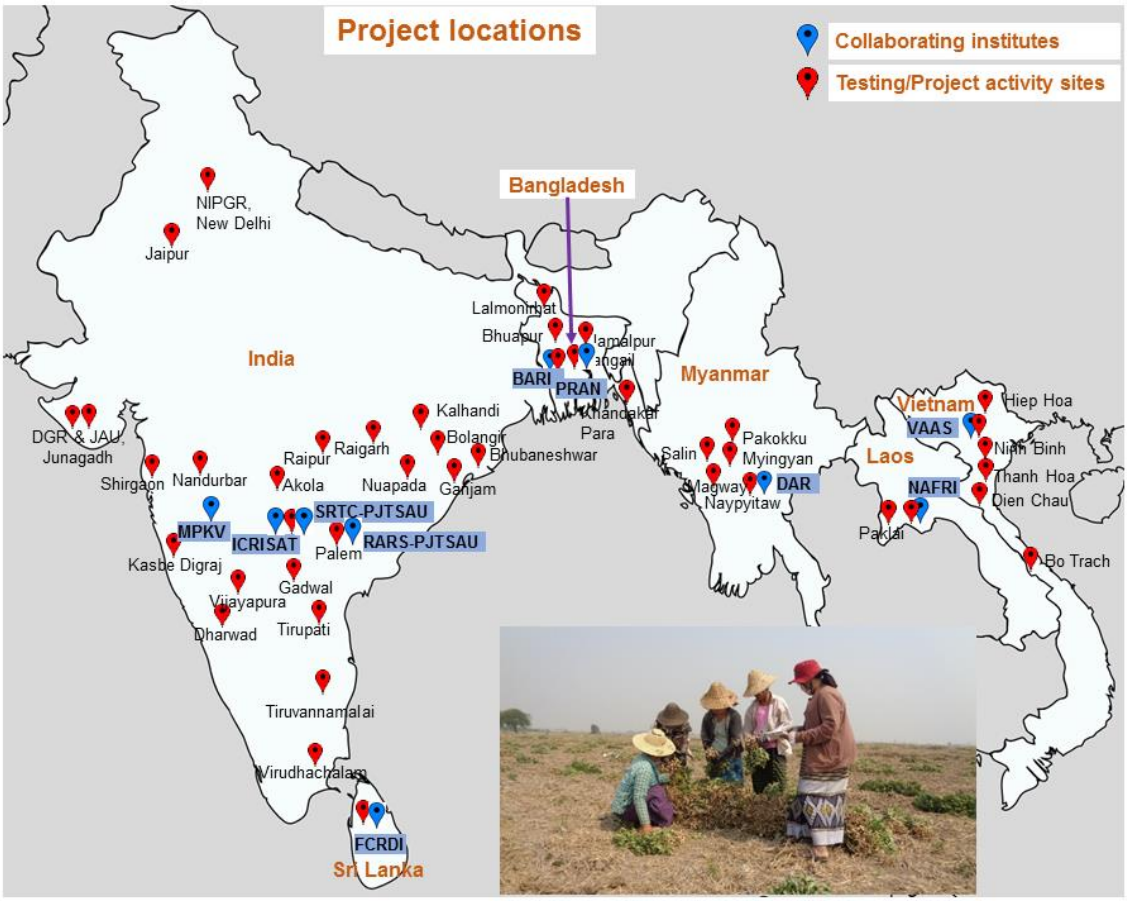
Progress Report
January 2018 to December 2019

Enhancing groundnut productivity and profitability for smallholder farmers in Asia through varietal technologies



Submitted to

The OPEC Fund for International Development (OFID)

ICRISAT INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

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Acknowledgments: *The financial assistance provided by the OPEC Fund for International Development (OFID) for supporting groundnut improvement in Asia and partnership with collaborators from the target countries is gratefully acknowledged.*

Contents

Acronyms:

AAGB	Advances in Groundnut Research through Advances in Genomics and Biotechnology
AICRP-G	All India Co-ordinated Research Project on Groundnut
ANGRAU	Acharya N. G. Ranga Agricultural University
ARS	Agriculture Research Station
BADC	Bangladesh Agricultural Development Corporation
BARI	Bangladesh Agriculture Research Institute
BMS	Breeding Management System
BNF	Biological Nitrogen Fixation
CAPS	Cleaved Amplified Polymorphic Sequence
CASRAD	Centre of Agrarian Systems Research and Development
CDZ	Central Dry Zones
CoA	College of Agriculture
CRP-GLDC	CGIAR Research Program on Grain Legumes and Dryland Cereals
DAR	Department of Agriculture Research, Myanmar
DoA	Department of Agriculture, Myanmar
DoAC&FW	Department of Agriculture Co-operation and Farmers Welfare, Government of India
Dr. PDKV	Dr. Panjabrao Deshmukh Krishi Vidyapeeth
ELISA	Enzyme-Linked Immunosorbent Assay
FCRDI	Field Crop Research & Development Institute
FDR	Foliar Disease Resistance
FPVS	Farmers Participatory Varietal Selection
G×E×Y	Genotype × Environment × Year interactions
GAPs	Good Agricultural Practices
GNG-A	Groundnut Network Group-Asia
GNI	Gross National Income
GP	Germination Percent
GSTP	Genomic Selection Training Population
HTPG	High Throughput Genotyping Platform
ICAR-DGR	Indian Council of Agricultural Research - Directorate of Groundnut Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IGKV	Indira Gandhi Krishi Vishwavidyalaya
JAU	Junagadh Agricultural University
KASP	Kompetitive Allele Specific PCR
LLS	Late Leaf Spot
LRDC-VAAS	Legume Research and Development Centre, Vietnam Academy of Agricultural Sciences
MABC	Marker-assisted Backcrossing
MAGIC	Multi-parent Advance Generation Inter-Cross
MAS	Marker-assisted Selection
MEL	Monitoring, Evaluation and Learning
MLT	Multi-Location Trial
MPKV	Mahatma Phule Krishi Vidyapeeth
NAFRI	National Agriculture and Forestry Research Institute

NARS	National Agricultural Research System
NGO	Non-Governmental Organization
NIPGR	National Institute of Plant Genome Research
OFID	OPEC Fund for International Development
OUA&T	Odisha University of Agriculture & Technology
PICS	Purdue Improved Crop Storage
PJTSAU	Professor Jayashankar Telangana State Agricultural University
PPP	Public-Private Partnership
PPRI	Plant Protection Research Institute
RARI	Rajasthan Agricultural Research Institute
RARS	Regional Agriculture Research Station
RCBD	Randomized Complete Block Design
RIL	Recombinant Inbred Line
RUFT	Ready-to-use Therapeutic-Food
RVSKVV	Rajmata Vijayaraje Scindia Krishi Vishwavidyalaya
SAU	State Agriculture University
SBV	Seed Business Venture
SFSA	Syngenta Foundation for Sustainable Agriculture
SKNAU	Sri Karan Narendra Agriculture University
SRTC, PJTSAU	Seed Research and Technology Centre, Professor Jayashankar Telangana State Agricultural University
TNAU	Tamil Nadu Agricultural University
UAS	University of Agricultural Sciences
USA	United States of America
USAID-IKP	United States Agency for International Development (USAID) and IKP Knowledge Park
VI	Vigor Index
WHO	World Health Organization

1. Executive Summary

The public-private partnership (PPP) with the food industry and seed sector in Bangladesh, India, Myanmar and Vietnam promoted groundnut seed and commodity value chains resulting in economic benefits to the farmers and all the value chain actors, and health benefits for consumers. Seed business ventures (SBV) were successfully piloted in Myanmar and India to develop seed entrepreneurship among smallholder farmers, and the consortium approach enabled engagement with small- and medium- seed companies in Myanmar and India to enhance access to improved varieties of groundnut seeds for smallholder farmers.

The commercialization of high oleic groundnut varieties is an exemplar of varietal technologies meeting the food industry demand, and is a result of the collaborative research efforts of ICRISAT and its partners supported by the OFID grant and other co-investments. India released its first high oleic groundnut varieties, Girnar 4 (ICGV 15083) and Girnar 5 (ICGV 15090) in 2019, and new high oleic lines were advanced to variety release testing in Myanmar and India. High yield potential and disease resistance resulted in enhanced adoption of a recently released high oil groundnut variety GJG 32 (ICGV 03043) in Maharashtra and Telangana states of India. It led to increased profitability for farmers, enhanced environmental sustainability through reduced use of chemicals owing to genetic resistance, and is currently driving new industry opportunities.

The project activities reached 16,982 direct and 226,229 indirect beneficiaries during 2018 and 2019 through 46 on-farm demonstrations, 23 Farmer Participatory Varietal Selection (FPVS) trials and 24 minikit trials. To enhance adoption of new varieties, 2124 small seed packets were distributed to farmers. The project partners and ICRISAT produced 66,344 kgs of Nucleus/Breeder Seed (N/BS) of 17 groundnut varieties to strengthen the formal seed chain and to distribute seeds to the farmers. Famers' awareness was conducted through over 80 farmers' field days/meetings/training during 2018-19 in the target countries.

The Groundnut Network Group-Asia (GNG-A), a multi-stakeholder platform of NARS, ICRISAT, NGOs and the private sector from six target countries, was established and furthered the strengthening of the 'groundnut breeding, testing, and delivery pipelines' in Asia through innovations along the groundnut value chain. The GNG-A network meets the continuous capacity building needs of the stakeholders. In Myanmar and Vietnam, stakeholder consultations provided feedback on designing groundnut product profiles, and current and emerging market needs. National groundnut breeding programs were strengthened by sharing 3519 advanced breeding lines/populations with collaborators from 11 countries and training 16 researchers from six target countries. Cost-efficient genomic tools and robust and non-destructive phenotyping tools enhanced operational efficiency and optimized resources. The project's progress, the news and resources are available on the CGIAR's MEL (Monitoring, Evaluation and Learning) platform (https://mel.cgiar.org/projects/838).

Way forward: Upscaling and/or sustaining the leads achieved during 2018 and 2019 in the target countries, specifically in Bangladesh, Myanmar and India is needed, and there is a strong commitment from government bodies and the private sector in these countries to enhance the profitability of groundnut cultivation, and promote groundnut value chains. Thus, the project proponents submitted a Phase II proposal to OFID seeking co-investment for 2020 and 2021.

2. Highlights of the project outputs

Following is a summary of the key project outputs during 2018 and 2019:

1. The project activities reached 16,982 direct and 226,229 indirect beneficiaries in the target countries of Asia through awareness programs such as farmers' field days and training programs, distribution of small seed packets of improved groundnut varieties, and distribution of Purdue Improved Crop Storage (PICS) bags for own-seed storage, and engaging with farmers through digital technologies.
2. Public-private partnership *(*PPP) between BARI, ICRISAT and PRAN Agro Industries (Dhaka) piloted two groundnut-based food products for treating malnutrition in Bangladesh and deployed value chain innovations from production through processing and consumption, including food safety.
3. First commercialization of high oleic groundnut varieties in India; Girnar 4 (ICGV 15083) and Girnar 5 (ICGV 15090) were released in India during 2019 (https://www.icrisat.org/indias-first-high-oleic-groundnut-varieties-ready-to-go-commercial/).
4. PPPs in Myanmar and India with food processing industries and the seed sector increased access to improved variety seeds for farmers and strengthened commodity supply chains to meet the quality standards of processors.
5. Commercialization of high oleic groundnut lines in Asia has generated industry interest from both oil extraction and confectionery industries.
6. In Myanmar, high oleic lines ICGVs 15090 and 15064; foliar fungal disease-resistant lines ICGVs 14141, 14169, 14175, and 14176 with >35% higher pod yield, and high-yielding lines ICGVs 14284, 14293, 14295, 14306, and 14358 with 70% higher pod yield over Sinpedetha 10 were advanced to the next stage of testing.
7. In Bangladesh, early-maturing and drought-tolerant lines ICGVs 00338, 07219, and 02038 were advanced to variety release testing.
8. Yield advantage and disease resistance resulted in enhanced adoption of a recently released high oil groundnut variety GJG 32 (ICGV 03043) in Maharashtra (https://www.icrisat.org/new-high-oil-variant-draws-farmers-to-groundnut-production-in-western-india/) and Telangana states of India (https://www.icrisat.org/oil-super-rich-groundnut-icgv-03043-ready-to-quench-indias-thirst-for-peanut-oil/) to increase profitability for farmers, enhance environmental sustainability through the reduced use of chemicals owing to genetic resistance, and drive new industry opportunities.
9. Process innovations in groundnut improvement were successfully deployed to enhance genetic gain and operational efficiency and optimize resources; further improvements are in progress.
10. Groundnut-based food products in a feeding pilot in Bangladesh resulted in reduction in anaemia by 40% in adolescent females and 88% in adolescent males; a sharper shift towards recommended population distribution as recommended by the World Health Organization (WHO) was observed in the treatment population for both wasting and stunting.

11. The Groundnut Network Group-Asia (GNG-A), a multi-stakeholder platform represented by NARS, ICRISAT, NGOs and the private sector strengthened public-private partnership to deliver groundnut variety and food product innovations in Asia.
12. The project's progress and the resources developed under it are available on the CGIAR's MEL platform (Monitoring, Evaluation and Learning). (https://mel.cgiar.org/) (https://mel.cgiar.org/projects/838)

3. Background

Groundnut is an important crop in the target countries for food, feed and oil purposes. The total groundnut area in the target countries is about 6 million ha; that amounts to 22% of the global groundnut area. The yield in target countries varies from 1.3 to 2.2 t/ha, and has immense scope to increase by 0.5 to 1.0 ton/ha; which can contribute to an increase of the total production by 2.7 million tons. Adoption of new improved varieties is very low in the target countries and thus, the release of new varieties adapted to the target regions and promoting adoption can contribute to increase in yield in an environmentally sustainable manner, which is one of the best approaches for the resource-poor groundnut farmers of targeted countries. The target countries, Bangladesh, India, Lao People's Democratic Republic (Lao PDR), Myanmar, Sri Lanka, and Vietnam are categorized as lower-middle income countries by the World Bank based on per capita gross national income (GNI) in 2015.

Groundnut-based food products meet the key criteria of availability, affordability, acceptability, nutritional quality and business interest, the necessary criteria for foods to contribute to reducing under-nutrition. Groundnut was identified as one of the important crops having the potential for contributing to nutritional security. Ready-to-use-therapeutic-food (RUTF) products based on groundnut are low in cost and are proven solutions in treating malnutrition among children and women (Janila et al. 2016). Domestic access holds the key to use groundnut for treating malnutrition; thus, in the target countries, there is scope to increase groundnut production and utilization.

In Asia, the use of groundnut mainly for food is gaining precedence over its use for oil; and the role of the domestic food processing and export industry will be significant in the future. It will be useful to develop varieties with farmer preferred traits and enhanced shelf life (high oleic trait) to meet industry demand. Using modern genomic tools, ICRISAT, in collaboration with NARS partners of India, has developed high oleic groundnut varieties in Spanish and Virginia Bunch types, the two botanical types that are cultivated in Africa and Asia (Janila et al. 2015). Spanish Bunch types are mostly preferred owing to their early maturity and drought tolerance, and breeding Spanish Bunch types with a high oleic trait is a significant research breakthrough. The development and release of 'high oleic' groundnut varieties were identified as one of the key priority traits of different groundnut growing ecologies during GNG-A. This is one of the important interventions that will benefit groundnut producers, processors and consumers of the targeted countries. To meet the need for ecology specific requirements, the 'high oleic' trait is in the process of being introgressed into the background of drought-tolerant, FDR, medium maturity, and fresh seed dormant varieties.

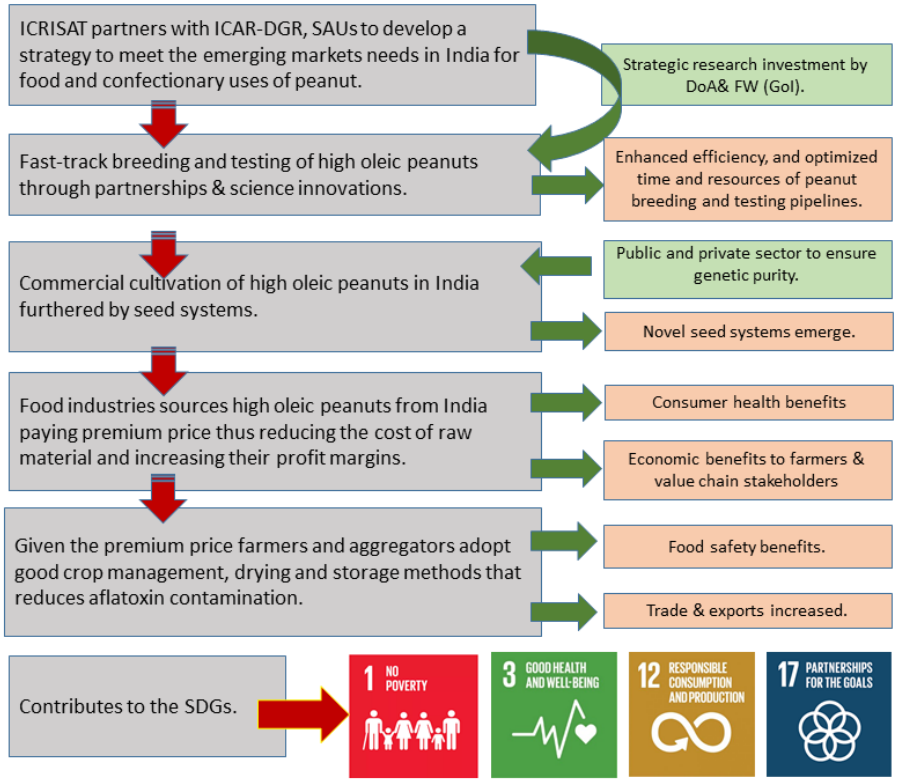
Along with technologies that are adaptable, affordable and accessible to the farmers and create impact, farmer preferred varieties are identified through the farmer participatory varietal selection (FPVS) trials. The quality of research and its outputs depends on the knowledge and skills of human resources engaged in research and development, and the support of the OPEC Fund has contributed significantly in upgrading the technical skills of the professionals and support staff in the targeted countries.

The project goal is to achieve increased productivity and profitability of groundnut cultivation in Asia, through development and deployment of new groundnut varieties with novel trait combinations that meet the needs of the farmers, traders, and the industry in partnership with public and private sector in Asia.

4. Success stories of 2018 and 2019

Success story 1: Commercialization of the first high oleic groundnut varieties in India

High oleic groundnuts offer longer shelf life benefits to the food processing industry, health benefits to consumers and increase profitability to farmers through premium prices compared to normal groundnuts. The oleic acid content in high oleic groundnuts is 80±2% as against 45-50% in normal groundnuts. The collaborative research efforts of ICAR-DGR, SAUs and ICRISAT resulted in the identification of two high oleic groundnut varieties, Girnar 4 (ICGV 15083) and Girnar 5 (ICGV 15090) for release in India. The first commercialization of these two lines is the result of a continued research collaboration led by ICRISAT in India since 2011. Over 100 high oleic groundnut lines are shared with collaborators in 11 countries -- Bangladesh, Myanmar, Vietnam, India, Ethiopia, Nigeria, Mali, Malawi, Tanzania, Uganda, and Australia. The work is supported by CRP-GLDC, DoAC&FW of GOI, OFID and MARS Inc.



A schematic representation of the process of developing and commercializing high oleic groundnut varieties and anticipated outcomes.

1. https://www.scienceforum2018.org/sites/default/files/2018-09/SF18_case_study_peanuts_asia_africa_0.pdf
2. https://www.icrisat.org/indias-first-high-oleic-groundnut-varieties-ready-to-go-commercial/
3. https://www.thehindubusinessline.com/economy/agri-business/two-groundnut-varieties-with-high-oleic-acid-ready-for-release/article27354266.ece)

Success story 2: Public-private partnerships and Seed Business Venture (SBV) increase access to new variety seeds in Myanmar and India

To address these gaps and strengthen the groundnut seed system by creating seed entrepreneurs, ICRISAT along with NARS partners initiated a Seed Business Venture (SBV) model for farmers who could be trained and supported in setting up decentralized seed hubs for their communities. The SBV develops and promotes rural seed business ventures at the village level in order to bridge the demand-supply gap for quality seeds.

The NARS partners and ICRISAT are engaging with small- and medium-sized seed companies to enhance access to improved groundnut seeds of high quality. Such partnerships were established in Myanmar and India.

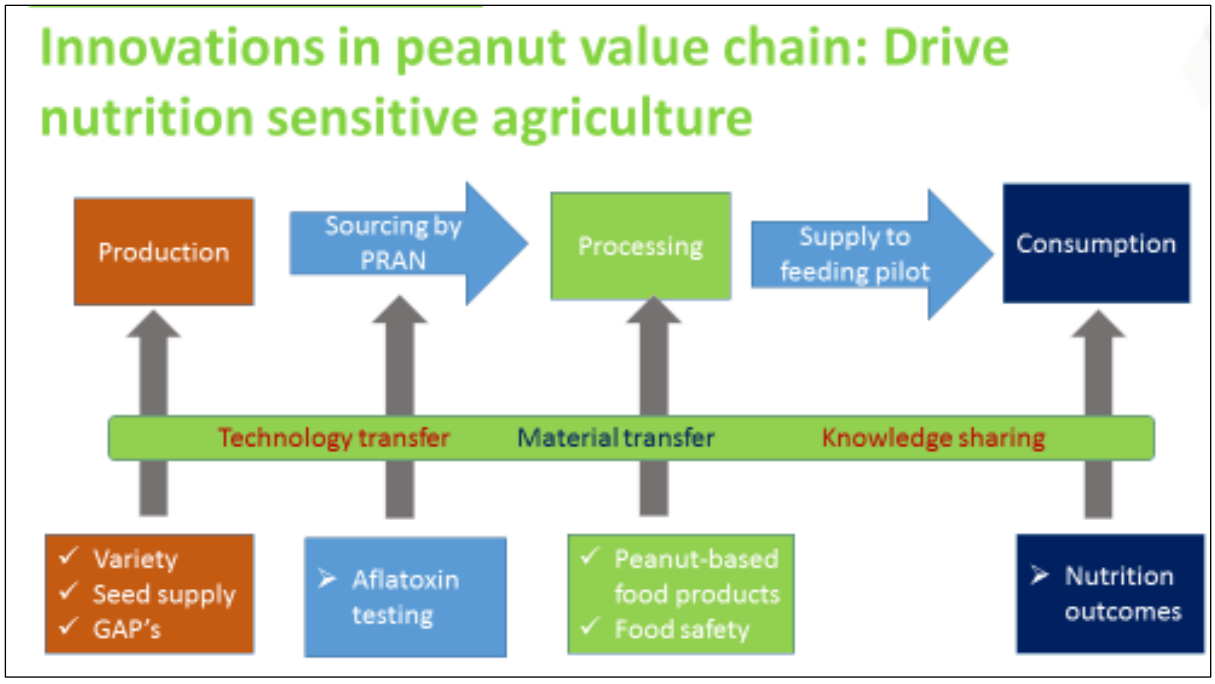
In Myanmar, 999 Mahar Thamardi Seed Company is now producing large quantities of seed of improved groundnut variety Sinpadetha-11 in Myingyan township in Mandalay region to enhancing production and profitability in the Central Dry Zone area. Thirty-five farmers, 14 from Magway and 21 from Naypyitaw Division were engaged in groundnut seed production on 20 ha during rainy season 2019. In India, 21 farmer entrepreneurs are now engaged in seed production of GJG 32 (ICGV 03043). The work is supported by OFID and CRP-GLDC.

(A) Private seed industry partner Mr Jagdish Patel from Vishwas Agriseeds Pvt Ltd. selecting lines based on pod and kernel features from early-maturing varieties at a GNG-A workshop 2019; (B) Seed processing by a seed entrepreneur in Myanmar; and (C) Groundnut seed production plots at Magway township of Myanmar during rainy season 2019.

1. https://www.icrisat.org/seeding-entrepreneurship-in-groundnut-farmers-of-south-india/
2. https://www.icrisat.org/nars-partners-in-asia-pick-up-advanced-groundnut-breeding-lines-with-market-traits-for-their-national-trials/
3. https://www.icrisat.org/stakeholders-meet-discusses-solutions-to-unshackle-myanmars-groundnut-value-chain/

Success story 3: Public-private partnership deploys innovations in groundnut value chain in Bangladesh leading to nutritional outcomes

Groundnut is an important food legume crop of Bangladesh, widely grown in the 'Char' areas after the flood waters recede. Innovations deployed along the groundnut value chain in select districts of Bangladesh through the public-private partnership (PPP) between ICRISAT, BARI and PRAN Agro Industries delivered nutritional outcomes besides positively impacting livelihoods of groundnut value chain actors, including producers. The study results established the nutritional benefits of groundnut-based food supplements among school children. Reduction of anaemia by 30% in female children and 40% in adolescent females and 88% in adolescent males was observed; along with a sharper shift towards recommended/ideal population distribution as recommended by WHO in the treatment population for both wasting and stunting in the end-line survey. The work in Bangladesh is supported by USAID-IKP, OFID, and CRP-GLDC.



A schematic representation of the groundnut value chain innovation in Bangladesh.

1. https://www.icrisat.org/peanut-based-nutritional-supplement-for-school-children-in-bangladesh/
2. https://www.icrisat.org/hands-on-training-program-on-aflatoxin-detection/
3. https://www.icrisat.org/tablet-based-nutritional-assessment-survey-in-bangladesh/

Success story 4: High oil groundnut variety GJG 32 (ICGV 03043) boosts oil industry in India

'High oil' groundnut varieties benefit the oil milling value chain, bring economic benefits to farmers and help cut down on vegetable oil imports in India. Yield advantage and disease resistance resulted in the enhanced adoption of a recently released high oil groundnut variety GJG 32 (ICGV 03043) in Maharashtra and Telangana states of India. This led to increased profitability for farmers, enhanced environmental sustainability through reduced use of chemicals owing to genetic resistance, and drove new industry opportunities. The work is supported by DoAC&FW of GOI, OFID and CRP-GLDC.

Mr Narasimha Reddy from Telangana, India conducted the demonstration comparing GJG 32 (ICGV 03043) with local variety K6, and noted that GJG 32 performed much better than K6 as it resisted leaf spot disease (tikka). GJG 32 has evergreen foliage; hence it is a good source of quality fodder. It is also climate resilient with a higher number of pegs (up to 40 against 15) and a slightly longer growing cycle (140 days against 120 days in the post-rainy season) resulting in higher chances of recovery.

1. http://www.icrisat.org/oil-super-rich-groundnut-icgv-03043-ready-to-quench-indias-thirst-for-peanut-oil/
2. https://www.icrisat.org/new-high-oil-variant-draws-farmers-to-groundnut-production-in-western-india/
3. https://www.icrisat.org/high-oil-and-high-oleate-groundnuts-to-meet-the-growing-demand-in-india/

5. Report of work done

The report presents the details of the work done during the two-year period, from January 2018 to December 2019. The activity-wise progress under the five objectives with seven outputs is presented here, and the progress against the milestones is presented in Table 23.

Objective 1. To develop new groundnut varieties that are suitable for current and emerging production challenges, and meet the needs of the farmers, traders, and industry. The target traits include drought tolerance, disease resistance, fresh seed dormancy, shelling outturn, kernel traits, high oil, and high oleic acid content in early and medium maturity duration backgrounds.

Output 1.1. High yielding, disease resistant, drought tolerant groundnut varieties developed having fresh seed dormancy, high shelling outturn, and quality traits to meet the needs of oil and food uses and suitable for target regions in Asia.

Activity 1.1.1. Constitute trait-specific international nurseries following hybridization, and advancing of generation based on genotyping and phenotyping, selection of bulks for trials, and yield evaluation trials

(a) Release of first high oleic groundnut varieties in India

The collaborative research efforts of ICAR-DGR, SAUs and ICRISAT resulted in the identification of two high oleic groundnut varieties, Girnar 4 (ICGV 15083) and Girnar 5 (ICGV 15090) for release in India (https://www.icrisat.org/indias-first-high-oleic-groundnut-varieties-ready-to-go-commercial/; https://www.thehindubusinessline.com/economy/agri-business/two-groundnut-varieties-with-high-oleic-acid-ready-for-release/article27354266.ece) (Figure 1). The first commercialization of these two lines is the result of a continued research collaboration led by ICRISAT in India since 2011. There is a strong pipeline of promising high oleic lines under different stages of testing across the project partner countries (Figure 2).

(b) Cost-effective genomic tools for advancement decisions

With the development of single nucleotide polymorphic (SNPs) markers for mutant alleles of FAD2B along with resistance to rust and LLS, a high throughput genotyping platform (HTGP) is being used at ICRISAT for selecting target traits. The 10 SNP markers' panel with the cost of genotyping @2.5 USD per sample including DNA isolation was used (Figure 3) to genotype 22,736 individuals during 2018-19 (Table 1). The disease reaction was confirmed in the field by artificial inoculation and detached leaf techniques in the dew chamber (Figure 4). Using the 58K SNP array, 741 lines of MAGIC population and breeding were genotyped to undertake genome-wide association and molecular diversity studies. The protocol for DNA isolation using seed chip approach was standardized to enhance operational efficiency and optimize resources (Figure 5), and 3000 individuals were genotyped using the approach.

Table 1. Parents, advanced breeding lines, genetic populations and individuals of early generations genotyped during 2018-19.

S. No	Season	Generation/Population	Number of Samples	Markers/Array
1	Post-rainy season 2017-18	F_3 and parents	943	10 SNPs
2	Rainy season 2018	$BC_3F_2F_2$ and parents	3008	10 SNPs
3		BC_1F_2 and BC_2F_2	300	5 SSRs
4	Post-rainy season 2018-19	F_2s and parents	10058	10 SNPs
5		F_1, Parents, HOA_CAPS	1504	10 SNPs
6		Drought MAGIC Population, advanced breeding lines	741	58k SNPs
7		High oleic advanced breeding lines	288	CAPS markers
8	Rainy season 2019	F_1 with parents	1504	10 SNPs
9		F_2* with parents	3008	10 SNPs
10		Founder parents	258	48 SNPs
11		High oleic advanced breeding lines	184	CAPS markers
12	Post-rainy season 2019-20	F_1 and advanced breeding lines	940	20 SNPs
		Total	**22736**	

** DNA was isolated using seed chip approach.*

(c) Robust non-destructive phenotyping using near-infra red reflectance spectroscopy (NIRS) for early generation selection

NIRS, a non-destructive approach, was employed to estimate kernel nutritional quality parameters such as oil and protein content and fatty acid profile for early generation selection. A single seed calibration equation was developed to enable selection by scanning an individual F_2 seed resulting in better resource utilization and increased efficiency. NIRS was used for regular phenotyping of 25,303 samples confirmed by the genotype based selected plants (Figure 6, Table 2) and was also supported with the assessment of 5000 samples from eight NARS partners: UAS, Dharwad (3036 samples), RVSKVV Gwalior (267), ARS, Vijayapura (750), UAS Raichur (365), ARS Kasbe Digraj (124), JAU Junagadh (20), RARS Palem (20) and CoA Thiruvannamalai (72) (Table 2).

Table 2. Individuals of early generations and advanced breeding lines phenotyped for nutritional quality traits using NIRS at ICRISAT.

S. No	Breeding programs	Prediction equation	Year	Number of samples
1	ICRISAT	Full cup	2018	547
2			2019	2074
3		Half cup	2018	2387
4			2019	12208
5		Single seed	2019	3433
NARS Partners				
6	UAS, Dharwad	Half cup	2018	1432
7			2019	1604
8	RVSKVV, Gwalior		2019	267
9	UAS, Raichur		2018	365
10	CoA Vijayapura		2018	350
11			2019	400
12	ARS, Kasbe Digraj		2019	124
13	CoA Thiruvannamalai		2019	72
14	JAU, Junagadh		2019	20
15	RARS Palem		2019	20
			Total	**25303**

(d) Groundnut segregating populations and trials

During 2018-19, 136 new crosses were attempted and the segregating populations were evaluated based on genotyping and phenotyping data (Table 3) to develop breeding lines for different agro-ecologies and that met industry needs. Decisions on the advancement of breeding lines were made based on the quantitative and qualitative data from 140 yield trials conducted during the reporting period. A total of 7867 groundnut breeding lines were tested in 178 trials during 2018 and 2019 (Table 4). Eight trials with 3056 genotypes of different genetic populations were evaluated separately to generate phenotypic data for development of genomic resources for the breeding program. The phenotyping of all the trait-specific lines mentioned in the above trial was done after the monsoons in 2017-18, during the rainy season in 2018, post rainy season in 2018-19, and during the rainy season in 2019; whereas phenotyping for trials planted in post-rainy season 2019-20 is underway. The phenotypic data recorded from individuals across trials and seasons are being uploaded in the breeding management system. A total of 12030 individuals/lines of different generations were evaluated/advanced during 2018 (5295 lines) and 2019 (6735 lines).

Table 3. New crosses attempted during 2018-19 at ICRISAT.

S. No	Season	Number of crosses attempted		
		Combining high oleic traits	Other traits	Total
1	Post-rainy season 2017-18	33	6	39
2	Rainy season 2018	17	7	24
3	Post-rainy season 2018-19	32	5	37
4	Rainy season 2019	12	24	36
	Total	94	42	136

Table 4. Yield evaluation trials conducted across different seasons during 2018 and 2019 at ICRISAT.

Season	Stage of testing	Number of trials	Total number of entries
Post-rainy season 2017-18	Preliminary Yield Trials	10	248
	Advance Yield Trials	6	208
	Elite Yield Trials	8	107
	Phenotyping of genetic populations	1	148
	Total	25	711
Rainy season 2018	Preliminary Yield Trials	14	514
	Advance Yield Trials	11	276
	Elite Yield Trials	10	285
	Phenotyping of genetic populations	1	468
	Total	36	1543
Post-rainy season 2018-19	Preliminary Yield Trials	14	438
	Advance Yield Trials	15	478
	Elite Yield Trials	11	334
	Total	40	1250
Rainy season 2019	Preliminary Yield Trials	13	279
	Advance Yield Trials	12	343
	Elite Yield Trials	13	378
	Phenotyping of genetic populations	5	1816
	Total	43	2816
Post-rainy season 2019-20	Preliminary Yield Trials	11	273
	Advance Yield Trials	14	429
	Elite Yield Trials	8	221
	Phenotyping of genetic populations	1	624
	Total	34	1547
	Grand total	178	7867

(e) Seedling vigor as selection criteria for drought tolerance

Seedling vigor and plant canopy traits of over 700 genotypes were recorded under the high throughput phenotyping platform, Leasy scan (Figure 7) to identify traits that could be used in making a selection for drought tolerance. The identified traits will be deployed in breeding programs for screening against drought tolerance. An investigation on 20 'high oleic' and 30 'normal oleic' lines indicate that the germination percentage (GP) and seedling vigor index (VI) of 66.42% and 355.94, respectively, in high oleic lines is comparable with 76.5% GP and 440.58 VI, respectively, in normal lines (Figure 8).

(f) Screening for biological nitrogen fixation efficiency

Biological nitrogen fixation (BNF) efficient lines, ICGVs 171180 and 13189 were identified (Figure 9) and used as parents to develop new genotypes efficient in BNF along with other trait combinations. The genotypes identified as efficient, moderate and poor lines for BNF will be used to validate the genes identified for root nodulation and BNF in collaboration with the

National Institute of Plant Genome Research (NIPGR). The non-nodulating mutant lines, ICGLs 1, 2, 3, 4 and 5 available at ICRISAT are used for understanding the genetic mechanism of BNF in groundnut to target efficiency of BNF.

Output 1.2. High oleic varieties with good shelling outturn, blanchability, uniform seed size to meet the industry needs in Asia

Activity 1.2.1. Constitute and test high oleic trials following hybridization, backcrossing, genotyping to select FAD mutant alleles and confirm phenotype using NIRS

(a) Assessment of sensory and flavor attributes of selected 'high oleic' peanut lines in collaboration with MARS:

Sensory and flavor attributes are important for the food processing industry and the assessment of these properties was carried out in partnership with MARS Inc. In 2019, five high oleic lines were evaluated at a sensory laboratory in USA. Other criteria used for selection of lines for the industry are seed size distribution (grading), and seed mass measured as counts per ounce.

(b) Constitute high oleic trials and advancements

- Twelve high oleic yield trials were conducted during 2018; of which seven preliminary trials with 131 high oleic entries (three with 51 entries in post-rainy season 2017-18 and 4 with 70 entries in rainy season 2018), and five advanced trials (one with 44 entries in post-rainy season 2017-18 and four with 87 entries during rainy season 2018).
- Nine high oleic trials included five preliminary trials with 113 entries, and four advance trials with 89 entries conducted during post-rainy season 2018-19.
- One hundred and thirty-two new high oleic lines developed during 2018-19 under different stages of evaluation at ICRISAT are being shared with NARS partners.
- Advancement of high oleic lines to variety release trials in 2019 in two countries: Two high oleic lines ICGVs 15090 and 15064 were advanced in Myanmar, and three were recommended for testing in All India Co-ordinated Research Project on Groundnut (AICRP-G) trials during rainy season 2019; and two high oleic lines ICGVs 171040 and 181024 were proposed for testing through multi-location trials in Maharashtra, India.
- The promising short duration advance breeding lines with medium-large kernel size and high oleic lines with large kernels will be proposed for evaluation under AICRP-G during 2020.
- A total of 133 high oleic entries involving 12 elite parents (ICGVs 06110, 07368, 06420, 00350, 06142, 03042, 05100, GJGHPS 1, GJG 9, 02266, 00351, Dh 86) are under evaluation in two elite and four advanced trials at ICRISAT (Table 5).

Table 5. Ongoing trials involving high oleic lines at ICRISAT- Patancheru during rainy season 2019.

S. No	No of entries	Design	Habit group	Trial name
1	19	5×5 Lattice	Spanish Bunch (Bold)	Elite Yield Trial High Oleic Acid
2	29	7×5 Lattice	Spanish Bunch	Elite Yield Trial High Oleic Acid
3	5	7 RBD	Spanish Runner	Advanced Yield Trial High Oleic Acid
4	20	5×5 Lattice	Virginia Runner	Advanced Yield Trial High Oleic Acid
5	14	20 RBD	Virginia Bunch	Advanced Yield Trial High Oleic Acid
6	46	7×7 Lattice	Spanish Bunch	Advanced Yield Trial High Oleic Acid

(c) Furthering the high oleic breeding pipeline using popular and elite lines as parents

To strengthen the high oleic breeding pipeline, 94 crosses were attempted at ICRISAT with recycled elite high oleic parents to enhance the rate of genetic gain (Table 6). Farmer-preferred varieties such as, KDG 123, KDG 128, JL 286, SB XI, Dhanlakshmi, GAUG10, GG20, GJG 9, GJGHPS-1 and K6 were used as parents. Generation advancement involved early generation selection using genomic tools and NIRS. In the rainy season of 2019, ICGVs 16687, 16688 and 16700 were proposed by JAU for AICRP-G testing; and ICGVs 15090 and 15065 were identified as potential high oleic lines in Myanmar for variety release testing. Around 70 high oleic lines were tested for foliar disease resistance under artificial disease screening nursery at ICRISAT during rainy season 2019.

Table 6. Elite high oleic parents recycled in the breeding pipeline.

Sl No	Year	Elite lines recycled as parents	No. of high oleic parents used
1	PR 2016/17	ICGVs 15033, 15044, 15017, 15054, 15055, 15001, 15002, 15003, 15004, 15005	10
2	R 2017	ICGVs 15073, 15074, 16022, 16045	4
3	PR 2017/18	ICGVs 171001, 171002, 171008, 171019, 171027, 171035, 171040, 171041, 171042, 15006, 15016, 15064, 15065, 15090, 16705, 16005, 16038, 16027, 16703, 171043, 171044, 171048, 171051, 171052	24
4	R 2018	ICGVs 171021, 181038, 181005, 181002, 181004, 181034, 181036, 181003, 171020	9
5	PR 2018/19	ICGVs 171050, 171024, 171053	3
6	R 2019	ICGVs 181065, 181075, 181490	3
		Total	53

(d) Seed size distribution and blanchability to meet food industry demand

A kernel size distribution of 38/42, 40/50 and 50/60 counts per ounce are preferred by the food industry for salted/roasted/fried groundnuts. The high oleic lines developed at ICRISAT were phenotyped for kernel size distribution along with kernel features (shape, size and color) to select lines that meet industry requirements (Table 7). The industry prefers a greater proportion of grades 1 and 2 for selecting a commercial lot. Easy blanchability is another important trait preferred by the confectionery industry; therefore the phenotyping procedure for blanchability was standardized and deployed to evaluate promising high oleic genotypes (Figure 10).

Table 7. Kernel size distribution of high oleic lines recorded at ICRISAT during post-rainy season 2018-19.

Entry	Pod yield/ha (Kg/ha)	Grades 1 & 2* (%)
ICGV 171002	5633	40
ICGV 171008	4767	73
ICGV 171021	3633	60
ICGV 171024	3667	84

** Grade 1 = 40/50 counts/ounce (100-seed mass of 71-57 g) and Grade 2 = 50/60 counts/ounce (100-seed mass of 56-47 g).*

Objective 2. To identify groundnut varieties adapted to target production ecologies and different cropping systems of Asia through on-station testing and farmer participatory varietal selection (FPVS) trials in collaboration with National Agricultural Research Systems (NARS) partners

Output 2.1. Share trait-specific international nurseries, advanced breeding lines, segregating populations with NARS in Asia

Activity 2.1.1. Multiply international nurseries, and develop segregating population for key traits

- To strengthen breeding programs of NARS, 3519 advanced breeding lines/genetic populations were shared during 2018-19. Details of the over 700 trait-specific advanced breeding lines shared with NARS partners of 11 countries are presented in Table 8.
- A Multi-parent Advance Generation Inter-Cross (MAGIC) and genomic selection training population (2761 lines) were shared with the University of Agricultural Sciences, Dharwad, India, as genetic material to work with in different projects.
- Twenty backcross lines (BC_1F_4 and BC_2F_3) in K6 backgrounds with high oleic content, resistant to foliar disease; and six populations were shared with RARS Palem, PJTSAU.
- The improved varieties -- KDG 128 and KDG 123 -- released from ARS Kasbe Digraj, MPKV, Rahuri were targeted to introgress high oleic and foliar disease-resistant traits at ICRISAT. Eleven segregating populations and 51 F_3 single plant selections of KDG 123 and KDG 128 upon confirmation on target alleles and phenotyping using NIRS were shared with ARS Kasbe Digraj, for evaluation during rainy season 2019.

- Fifty and 32 advanced breeding lines were shared with Acharya NG Ranga Agriculture University, Bapatla and PJTSAU, Hyderabad, respectively for use in their research programs.
- Nine advanced breeding lines were shared with UAS Dharwad for use as parents in their hybridization program.
- Nine lines were shared with NIPGR, New Delhi for genomic studies on biological nitrogen fixation.
- Thirteen short-duration Valencia lines were shared with Dr PDKV Akola, Maharashtra for use in their breeding programs.

Table 8. Groundnut breeding lines and populations shared with national collaborators during 2018 and 2019.

S. No,	Country	No. of genotypes/population shared
1	Myanmar (DAR, Yezin)	141
2	Australia	4
3	Mali	94
4	Bangladesh (BARI)	33
5	Malawi	33
6	Laos (NAFRI)	25
7	Turkmenistan	3
8	Ethiopia	13
9	Vietnam (LRDC, VAAS)	63
10	Namibia	12
11	India (OUA&T, Odisha)	40
12	India (UAS, Dharwad)	2761*#
13	India (MPKV Rahuri)	67
14	India (IGKV, Raipur)	8
15	India (RARS, Palem)	6
16	India (Agricultural College and Research Institute, Vazhavachanur, TN)	15
17	India (RARS, Palem)	263#
18	India (UAS, Dharwad)	9
19	India (Dr PDKV, Akola)	13
20	India (ANGRAU, Bapatla)	50
21	India (PJTSAU, Rajendra Nagar)	32
22	India (NIPGR, New Delhi)	9
23	India (MPKV, Rahuri)	62#
	Total	**3519**

* 2421 lines of MAGIC population, 340 of Genomic Selection Training Population.

#Segregating populations and early generations.

(a) Multiply international nurseries and develop segregating populations for key target traits

To share lines with collaborators globally and to conduct MLTs, 7742 advance breeding lines/ individual lines were multiplied that included 824 trait-specific international nurseries and advance breeding lines to conduct MLTs and FPVS trials in target countries. A Multi-Parent Advanced Generation Intercross (MAGIC) population, Recombinant Inbred Line (RIL), and Genomic Selection Training Population (GSTP) making a total of 6918 lines were multiplied and shared with collaborators to develop genomic resources (Table 9). Over 120 lines were multiplied post-rainy season 2018-19 and 908 lines in summer 2019 at ICRISAT. Around 3649 lines were multiplied during rainy season 2019 to keep in the seed inventory for long term storage and to share with collaborators. The segregating populations for key target traits such a high oleic and FDR are shared with NARS partners (Jaipur, Rajasthan, Palem and Kasbe Digraj, Maharashtra) for early generation testing at target sites. The lines sent to Myanmar, Vietnam, Bangladesh and Lao PDR were multiplied to conduct on-station and multi-locations yield evaluation trials. The seeds of 20 lines were shared with Syngenta Foundation for Sustainable Agriculture (SFSA) by DAR Myanmar to conduct multi-location yield evaluation trials.

Table 9. International trials and advanced breeding lines multiplied during 2018-19.

S. No	Name	Number of Entries
Rainy season 2018		
1	XII International Short Duration Groundnut Varietal Trial	15
2	XIII International Short Duration Groundnut Varietal Trial	15
3	VIII International Drought Tolerance Groundnut Varietal Trial	15
4	XI International Drought Tolerance Groundnut Varietal Trial	15
5	X International Drought Tolerance Groundnut Varietal Trial	15
6	Elite Short Duration Groundnut Varietal Trial-Bold	16
7	Advance Short Duration Groundnut Varietal Trial-Bold	10
8	International Medium Duration Groundnut Varietal Trial	30
9	International Foliar Disease Resistance Groundnut Varietal Trial	47
10	Foliar Disease Resistance Advance Breeding lines	10
11	High Oleic Advance Breeding Lines	84
12	Fresh Seed Dormancy Advance Breeding Lines	25
13	MAGIC And GSTP Populations	2761
Total		3058
Post-rainy season 2018-19		
1	Elite Short Duration Groundnut Varietal Trial Bold	16
2	Advance Short Duration Groundnut Varietal Trial Bold	9
3	International Medium Duration Groundnut Varietal Trial	13
4	International Foliar Disease Resistance Groundnut Varietal Trial	4
5	MABC Lines	4
6	High Oleic Advance Breeding Lines	81
7	Total	127
Summer 2019 (February to June 2019)		
1	Fe and Zn RIL_F7 (ICGV 00440 x ICGV 06040)	328

S. No	Name	Number of Entries
2	NAMF-RIL F7 (ICGV 02266 x ICGV 97045)	158
3	Founder Parents	123
4	High Oleic Lines For DNA	216
5	Amphidiploid	10
6	High Oleic (Rajasthan) Population	6
7	F 6 SSD (ICGV 06040 x ICGV 87141)	1
8	F7 SSD (High Oil Population)	19
9	High Oleic Lines	47
	Total	908
Rainy season 2019		
1	High Oleic Lines	4
2	Early Maturing FDR Lines	5
3	Short Duration Large Kernel Lines	5
4	Drought MAGIC Population	3635
	Total	3649
	Grand total	7742

(b) Testing the new varieties in collaboration with NARS for adaptability and suitability to different production environments and market demand in Asia

Multi-location testing of promising advance breeding lines with different trait combinations is a must to identify genotypes with better performance across locations. The key highlights were:

1. Two genotypes, i.e., ICGV 14421 (a foliar disease resistant line) and ICGV 02266 (a promising drought tolerant line) were evaluated in state multi-location trials at seven locations in Maharashtra during rainy season 2018-19 along with standard check cultivars. Based on superiority over the checks, the entries will be recommended for release and cultivation in Maharashtra.
2. State MLTs in Chhattisgarh identified a promising high oil line, ICGV 06420, for release in the state. State MLTs with eight lines -- ICGVs 07222, 03042, 06420, 07220, 06146, 02266, 06424 and 03043 -- were conducted in collaboration with Indira Gandhi Krishi Vishwavidyalaya (IGKVV) at three locations, Raigarh, Ambikapur and Rajnandgaon during 2018 and 2019 (two additional locations in 2019).
3. Two hundred and twelve advance breeding lines were evaluated under multi-location trials across the target production environments. Another 950 lines which include 624 lines of MAGIC population and 326 lines of RIL population were evaluated for LLS and rust resistance at ARS Kasbe Digraj and for iron and zinc chlorosis at ARS, Vijayapura. (Table 10).
4. Five new MLTs were constituted during rainy season 2019 (Table 10 and Figures 11 & 12). Based on their growth habits, the entries were categorized into Spanish Bunch, Spanish Runner, Virginia Bunch and Virginia runner with different genetic backgrounds. The recording of pre-harvest observations for all the trials has been completed and post-harvest data recording is in progress. The generated data will be

used to propose at least two to three high oleic lines from each location for state or national testing.

Table 10. Multi-location trials conducted across locations during rainy 2019.

S. No	Trial name	No of entries	Design	No. of locations	Proposed locations
Rainy season 2019					
1	Multi-location testing (MLT) of Spanish Bunch High Oleic lines	36	Alpha Lattice	5	Tiruvannamalai, Tamil Nadu; Raigarh Chhattisgarh; Kasbe Digraj, MH; Tirupati, Andhra Pradesh; Dharwad, Karnataka
2	MLT of Spanish Bunch High Oleic lines (Large Kernel Size)	20	RCBD*	2	Junagadh, Gujarat (JAU) and Palem, Telangana
3	MLT of Virginia runner High Oleic lines (D1 and D2 type)	20	RCBD	2	Jaipur, Rajasthan; Junagadh, Gujarat (ICAR-DGR)
4	MLT of Virginia Bunch High Oleic lines (D3 type)	20	RCBD	3	Junagadh, Gujarat (JAU); Vridhachalam, Tamil Nadu; Patancheru, Hyderabad (ICRISAT)
5	MLT of Spanish Bunch High Oleic lines (D2 type)	7	RCBD	2	Jaipur, Rajasthan; Patancheru, Hyderabad (ICRISAT)
6	MLT of Spanish Bunch Foliar Disease Resistance lines	15	RCBD	1	UAS, Dharwad
7	Evaluation of Recombinant Inbred Lines of Fe and Zn	326**	Alpha Lattice	2	UAS, Vijayapura; ICRISAT, Hyderabad
8	Screening of drought MAGIC population for LLS and rust	624**	Alpha Lattice	2	ARS, Kasbe Digraj; ICRISAT, Hyderabad
9	State Multi-location Trial of Promising advance breeding lines in Chhattisgarh	8	RCBD	5	Locations of state MLTs of Chhattisgarh
10	State Multi-location Trial of Promising advance breeding lines in Maharashtra	2	RCBD	7	Locations of state MLTs of Maharashtra
Post-rainy season 2019-20					

S. No	Trial name	No of entries	Design	No. of locations	Proposed locations
11	MLT-Heat tolerance	64	Alpha Lattice	3 (Under two environments; normal and heat stress)	Dr PDKV Akola, Maharashtra; RARS Palem, Telangana; ICRISAT, Hyderabad, Telangana
12	MLT Foliar disease resistance	20	RCBD	1	ARS, Shirgoan, Maharashtra
Total number of entries		**1162**			

* RCBD = Randomized Complete Block Design.
** = Genetic populations.

Output 2.2. Testing the new varieties in collaboration with NARS for adaptability and suitability to different production environments and market demand in Asia

Activity 2.2.1. Conduct farmer participatory varietal selection (FPVS) trials and on-farm demonstrations with NARS:

Myanmar: Around 18 on-station, multi-location yield evaluation trials and farmers' participatory varietal selection trials were conducted at five townships in three selected sites of the Central Dry Zone areas namely, Naypyitaw, Mandalay and Magway Divisions during 2018-19. Eleven FPVS trials were conducted in different townships of Naypyitaw, Mandalay and Magway Divisions (Table 11, Figures 13 & 14). An international short-duration varietal trial was also conducted at DAR after the monsoon in 2019 (Figure 15). The details of promising varieties and their performance tested under FPVS trials are given in Table 12 and 13, respectively. Among the promising varieties, YZG 13014 was identified as superior over popular varieties from the FPVS trials conducted in Salin township; and ICGVs 06151, 06143, and 00005 from the trials conducted in Myingyan and Nyaung Oo townships. ICGVs 07395 and 07390 were identified as superior over popular variety Sinpadetha-11 from the FPVS trials conducted in Magway township. Two on-farm demonstration trials of the best varieties of Sinpadetha-11 were also conducted by DAR, Myanmar.

Table 11. Details of farmers' participatory varietal selection trials conducted in Naypyitaw, Mandalay and Magway divisions, Myanmar.

S. No	Division/ Region	Township	Experi-ments (no.)	No of Farmers	Date of sowing	Date of harvest	Duration
2018							
1	Naypyitaw	Popepathiri	2	2	22.11.18	24.03.19	122
					22.11.18	24.03.19	122
2	Mandalay	Nyaung Oo	1	1	06.12.18	07.04.19	122
3	Magway	Salin	2	2	21.11.18	22.03.19	121
					12.12.18	-	-

	Total		**5**	**5**			
2019							
1	Mandalay	Myingyan	2	2	20.10.2019	-	-
					23.10.2019	-	-
2	Mandalay	Nyaung Oo	2	2	13.12.2019	-	-
					23.12.2019	-	-
3	Magway	Pakokku	2	2	05.11.2019	-	-
					13.11.2019	-	-
	Total		6				
	Grand total		**11**				

Table 12. Promising entries evaluated under FPVS trials to seek farmers' feedback in comparison with Sinpadetha-11 (popular variety) in Myanmar during 2018-19.

S. No	Variety	Source	Salient characters
2018			
1	YZG-13012	DAR	High yield
2	YZG-14022	DAR	High yield, drought tolerant
3	YZG-14031	DAR	High yield, drought tolerant
4	YZG-13014	DAR	High yield
5	ICGV 07273	ICRISAT	Drought tolerant
6	Sinpadetha-11	DAR	High yield
2019			
1	ICGV 06151	ICRISAT	High yield and Foliar disease resistance
2	ICGV 06143	ICRISAT	High yield and Foliar disease resistance
3	ICGV 00005	ICRISAT	High yield and Collar rot
4	YZG-13048	DAR	High yield
5	Sinpadetha-11	DAR	High yield
6	Tontarni	Local	High yield

Table 13. Performance of promising entries in comparison with Sinpadetha-11 (popular variety) evaluated under FPVS trials in different townships of Myanmar during 2018-19.

S No	Variety	Yield (number of baskets/acre)		Yield (Kg/acre)	
		Farmer 1	Farmer 2	Farmer 1	Farmer 2
1	ICGV 07270	47	40	537	454
2	ICGV 07273	49	39	557	438
3	YZG-13012	56	51	638	583
4	YZG-14031	25	28	284	318
5	Sinpadetha-11	60	52	683	591
	Mean	48	42	540	477
1	ICGV 06151	78	65	886	738
2	ICGV 06143	71	55	807	625
3	ICGV 00005	84	65	954	738

S No	Variety	Yield (number of baskets/acre)		Yield (Kg/acre)	
		Farmer 1	Farmer 2	Farmer 1	Farmer 2
4	YZG-13048	69	52	784	591
5	Sinpadetha-11	65	45	738	511
6	Tontarni	52	26	591	295
	Mean	**70**	**51**	**793**	**583**
1	ICGV 06151	28	41	319	466
2	ICGV 06143	24	41	273	466
3	ICGV 00005	30	45	341	511
4	YZG-13048	26	40	295	454
5	Sinpadetha-11	17	36	193	409
6	Tontarni	15	28	170	318
	Mean	**23**	**39**	**265**	**437**
1	ICGV 07395	68	50	772	568
2	ICGV 07390	55	48	625	545
3	ICGV 07392	46	39	523	443
4	YZG-13048	27	30	307	341
5	Sinpadetha-11	47	42	534	477
	Mean	**49**	**42**	**552**	**475**

Bangladesh: Four FPVS trial with four varieties (BARI Chinabadam-8, BARI Chinabadam-9, BARI Chinabadam-10 and Local Dhaka-1) and six on-farm demonstrations were conducted in different districts of Bangladesh.

India: Thirty three on-farm demonstrations, five FPVS trials and 24 minikit trials were conducted during 2018-19. The FPVS trial with eight varieties, namely ICGV 03043, Kadiri-6, Kadiri-9, Kadiri Harithandhra, Kadiri Chithravathi, Dharani, KDG-123 and KDG-128 was conducted during the rainy season of 2018 at RARS, Palem, to demonstrate the varietal technology and to identify the variety preferred by farmers. Progressive farmers from different villages of Mahbubnagar, Wanaparthy, Nagarkurnool and Gadwal districts were invited for their feedback on the respective varieties. Most of the farmers opined that KDG128 was the best yielder having more number of pods (>35 average, maximum 56) with medium size kernels. Two FPVS trials each at RARS, Palem and at farmers' fields with six best MABC lines *i.e.* ICGVs 13189, 13207, 13229, 13200, 14421 and 13193 were conducted during the post-rainy season of 2018-19. The farmers' response regarding these MABC-derived lines in comparison to the popular varieties was collected through a questionnaire (Figure 16). Progressive farmers from different villages of Mahbubnagar, Wanaparthy, Nagarkurnool and Gadwal districts were invited for their opinions on 8th November 2019 (Figure 17). JCG-2141, KDG-123, KDG-128, Kadiri-6, Kadiri-9, Kadiri Chitravathi, Kadiri Harithandhra, Dharani were sown as part of FPVS. Most of the farmers opined JCG-2141 to be the best yielder having more number of pods (>35 average, maximum 56) with medium bold seed. Two FPVS trials with four MABC-derived foliar fungal disease resistance lines (ICGVs 14421, 13189, 13207 and 13229) along with popular varieties conducted at ARS, Kasbe Digraj.

In Maharashtra, four on-farm demonstrations of ICGV 02266 (2) and GJG 32 (ICGV 03043) (2) were conducted in Sangli and Satara districts (Figure 18), and in Nandurbar district, tribal

women conducted two on-farm demonstrations for the variety, Phule Chaitanya (KDG 160) (Figure 19). The improved groundnut variety, GJG 32 (ICGV 03043) is preferred and adopted by most of the farmers in the targeted ecologies (Figure 20). A trial with six groundnut genotypes *viz.,* Dhanalaxmi, Unap, JL 24, Western local bulk, GJG 32 (ICGV 03043) and ICGV 02266 under high input management at Pujam Farm was conducted to demonstrate the high yield potential of improved varieties. In this trial, GJG 32 (ICGV 03043) produced maximum pod yield of 58.14 q/ha followed by ICGV 02266 (54.28 q/ha), and both the lines are characterized by its dark green foliage, profuse pods and resistance to diseases. Farmers recorded good pod yield from twenty-five on-farm demonstration of GJG 32 (ICGV 03043) conducted in Rainy 2019 in Pune (12), Satara (11) and Sangli (2) districts.

Five minikit trials of one elite line ICGV 02266 was also given to IGKV, Raipur, India to demonstrate variety to farmers during 2018. Nineteen minikits of ICGV 03043, ICGV 07222 and ICGV 02266 were distributed to farmers for varietal demonstration in Chattishgarh during June 2019.

Lao PDR: The 25 advanced breeding lines received from ICRISAT are under seeds increase and testing at NAFRI, Lao PDR. After the selection of promising lines from pre-yield trails and, the farmer participatory varietal selection (FPVS) trial will be conducted in the Paklai district, Xayabouly province of central Laos.

Vietnam: Three FPVS trials and five on-farm demonstrations were conducted in different provinces of Vietnam during 2018-19. Twelve promising groundnut genotypes selected by the Legumes Research and Development Center were tested in farmers' fields to identify high-yielding varieties in the main growing region in Northern Vietnam. The average yield of 12 promising groundnut varieties ranged from 3.67 to 4.31 tons/ha; among them were two varieties, T4 and T7 recorded high pod yield of over 4 tons/ha, which is 22-23% superiority, respectively over the control variety, L14 (Table 14). Farmers harvested good pod yield from the two on-farm demonstrations of new groundnut variety (L29) in Dien Chau district, Nghe An province (Figure 21). Out of three on-farm demonstration trials, two were conducted each in Ninh Binh and Thanh Hoa province during 2018 and another conducted in Bac Giang province during 2019 (Figure 22).

Table 14. Pod yield of promising groundnut varieties tested under FPVS trials in Northern Vietnam (2018 and 2019).

No	Groundnut variety	Pod yield of promising groundnut varieties (t/ha)			
		2018	2019	Mean	% increase over L14
1	T1	3.88	3.71	3.80	9.8
2	T2	3.93	3.62	3.78	9.2
3	T3	3.63	3.83	3.73	7.8
4	T4	4.23	4.38	4.31	24.5
5	T5	3.80	3.76	3.78	9.2
6	T6	3.76	3.84	3.80	9.8
7	T7	4.16	4.25	4.21	21.6
8	T8	3.66	3.82	3.74	8.0

No	Groundnut variety	Pod yield of promising groundnut varieties (t/ha)			
		2018	2019	Mean	% increase over L14
9	T9	3.57	3.77	3.67	6.0
10	T10	3.69	3.66	3.68	6.1
11	T11	3.75	3.84	3.80	9.8
12	T12	3.77	3.69	3.73	7.8
15	L14 (c)	3.40	3.52	3.46	-
	CV (%)	9,0	7,9	-	
	$LSD_{0.05}$	0,53	0,50	-	

Objective 3. To promote formal and informal seed systems in partner countries in collaboration with NARS partners.

Output 3.1. Develop and promote alternate seed models to ensure the availability of new improved groundnut varieties to farmers

Activity 3.1.1. Distribute small seed packets and support informal and formal seed systems through seed production of NS and BS class of seeds

(a) Distribution of small seed packets:

1. Fifteen farmers of Popepathiri, Salin, and Nyaung Oo representing the Napyitaw, Magway and Mandalay divisions of Myanmar received 22 kgs of seeds of Sinpadetha-11 and Magway 16 varieties.
2. Two thousand one hundred and twenty four seed packets of the best varieties were distributed to the farmers. Of these, 1660 seed packets of ICGVs 03043 and 02266 were distributed among farmers in Maharashtra and Telangana whereas 220 seed packets of new groundnut variety L29 were distributed to farmers by the Legumes Research and Development Center – Field Crop Research Institute (LRDC-FCRI) Vietnam. Two hundred seed packets of BARI Chinabadam-8 and BARI Chinabadam-9 have been distributed to 200 farmers in different districts of Bangladesh (Figure 23). The seeds received back from the farmers will be distributed to other farmers during subsequent seasons.
3. Seven tons of Breeder Seed (BS) of the recently released high oil groundnut variety ICGV 03043 and one ton of BS of a promising line -- ICGV 02266 -- were supplied to two NARS partners i.e. MPKV, Rahuri and PJTSAU, Hyderabad for distribution to the farmers after rainy season 2017-18.
4. Four tons of seeds (three tons of ICGV 03043 and one ton of ICGV 02266) supplied to MPKV, Rahuri were distributed among 380 farmers in three different regions *viz.*, Sangli (132), Satara (158) and Kolhapur (90) (Figure 24). The seeds received back from the farmers were supplied to 380 other farmers in the respective areas in the post-rainy season 2018-19.
5. Four tons of BS of ICGV 03043 supplied to PJTSAU, Hyderabad were distributed among 400 farmers of different regions of Telangana. The 10 kg seeds received back from the farmers have been given to around 400 other farmers in the post-rainy season 2018.
6. Four hundred kg of BS of GJG 32 (CGV 03043) was distributed to 28 progressive farmers in Uppununthala village of Nagarkurnool district during October 2018 to produce around 5000 kg seeds for distribution during the next season.

7. Twenty-five farmers including 12 from Pune, 11 from Satara and two from Sangli districts were given 25 kg seeds of GJG 32 (ICGV 03043) for demonstration in the rainy season 2019. Around 19 farmers were given seeds of ICGVs 03043, 07222 and 02266 as minikits in Chhattisgarh (Figure 25).

(b) Nucleus/Breeder Seed Production

1. Nucleus/Breeder Seeds: A total of 66,344 kgs of 17 improved groundnut varieties were produced during 2018-19; 25600 kgs NS was produced at ICRISAT, 2040 kgs at BARI Bangladesh, 2000 kgs at ARS, Kasbe Digraj, 10000 kgs at SRTC, PJTSAU, 454 kgs at DAR, Myanmar and 24100 kgs at LRDC, Vietnam. Among the varieties, ICGV 02266 (1700 kgs), ICGV 03043 (12000 kgs), ICGV 00351 (3000 kgs) and ICGV 07222 (2000 kgs) were produced at ICRISAT to strengthen the seed production chain and to distribute seeds to farmers. (Table 15).
2. Breeder seed production of farmer preferred varieties YZG-13012 and YZG-14022 was undertaken at Oilseed Crops Section, DAR in rainy season 2019. Around 227 kgs of nucleus seeds of Sinpadetha-11 and Magway-16 were produced at DAR, Yezin, Myanmar. Apart from NS/BS, seed production of three acres of foundation seed of Sinpadetha-11 at the Oilseed Crops Section in Department of Agricultural Research and Magway 16 at Magway Central Research Farm during rainy season 2019 were also undertaken.
3. Seed production of Magway 16 was done over 20 acres (14 farmers) in Magway Division and of Sinpadetha-11 on 30 acres (21 farmers) during rainy season 2019 in collaboration with DAR, DoA and private seed companies in Myanmar.
4. The BS production of Phule Warna (1300 kgs), Phule Morna (500 kgs) and Phule Chaitanya (200 kgs) was done at the Agricultural Research Station, Kasbe Digraj (Figure 26). A total of 2040 kg of Breeder Seed -- BARI Chinabadam-8 (1650 kgs), BARI Chinabadam-9 (2000 kgs), BARI Chinabadam-10 (40 kgs) and BINA Chinabadam-4 (500 kgs) was produced at BARI, Bangladesh and supplied to the public seed producing authority, Bangladesh Agricultural Development Corporation (BADC), for multiplication as foundation seed during 2018-19. PRAN Agro Business Ltd and Partex Agro Ltd have been engaged in groundnut seed production in Bangladesh. Around 8500 kgs of seeds of Kadiri-9 and 1500 kgs of ICGV 03043 were produced by SRTC, PJTSAU, Hyderabad.

Table 15. Nucleus/Breeder seed production of best varieties across the partner organization during 2018-19.

Location	Season/year	Variety	Quantity Produced (Kgs)
ICRISAT, Patancheru	2018	ICGV 02266	1500
		ICGV 03043	8000
		ICGV 07222	2000
		ICGV 03043	4000
		ICGV 00351	2000
		ICGV 00350	4500
	2019	ICGV 00351	1000
		ICGV 02266	200

Location	Season/year	Variety	Quantity Produced (Kgs)
		ICGV 91114	1100
		ICGV 02266	400
		ICGV 03043	900
		Total	**25600**
BARI, Bangladesh	2018-19	BARI Chinabadam-8	1650
		BARI Chinabadam-9	2000
		BARI Chinabadam-10	40
		BINA Chinabadam-4	500
		Total	**4190**
ARS, Kasbe Digraj, Maharashtra	2018-19	Phule Warna (KDG-128)	1300
		Phule Morna (KDG-123)	500
		Phule Chaityana (KDG-160)	200
		Total	**2000**
SRTC, PJTSAU	2019	Kadiri 9	8500
		ICGV 03043	1500
		Total	**10000**
DAR, Myanmar	2019	Sinpadetha 11	227
		Magway 16	227
		Total	**454**
LRDC, Vietnam	2018	L 27	5000
	2019	L 27	19100
		Total	**24100**
		Grand Total	**66,344**

(c) Seed increase of promising lines for national testing

Three high oleic entries -- ICGVs 16687, 16688 and 16700 were proposed by JAU, Junagadh for AICRP-G testing during the rainy season of 2019 in the AICRP-G workshop held from 25-27 May 2019. Also, eight high oleic entries, ICGVs 16024, 16041, 16690, 16668, 16679, 16692, 16697 and 16704 tested under AICRP-G during the rainy season of 2018 were advanced to AVT-2 during rainy season 2019. Seed multiplication of seven high oleic entries -- ICGVs 16668, 16679, 16688, 16687, 16690, 16697, and 16700 that are under evaluation in AICRP-G is being carried out at ICRISAT. Seed increase of best performing high oleic lines that are currently under MLT during rainy season 2019 will be done based on pod yield data. These lines will be multiplied after rainy season 2019-20 to generate sufficient quantity of seed for AICRP-G testing.

(e) Piloted Seed Business Venture (SBV) for entrepreneurship programs in India and Myanmar

To strengthen the groundnut seed system by creating seed entrepreneurs, ICRISAT along with NARS partners initiated a Seed Business Venture (SBV) model for farmers who could be trained and supported in setting up decentralized seed hubs for their community. The SBV

develops and promotes rural seed business ventures at the village level in order to bridge the demand-supply gap for quality seeds. (https://www.icrisat.org/seeding-entrepreneurship-in-groundnut-farmers-of-south-india/)

A groundnut entrepreneurs' identification workshop at ICRISAT in April 2019 (Annexure I & Figure 27) followed by a scouting trip to Palem and Nagarkurnool on 6 and 13 May 2019, identified ten farmers for seed entrepreneurship training. The training on groundnut seed production, post-harvest management, and business plans was conducted on 20 May 2019. The ten farmers engaged in seed production of GJG 32 (ICGV 03043) variety in the rainy season 2019 season (Annexure II) (Table 16). Twenty-eight other farmers of the Primary Agricultural Cooperative Society (PACS) were trained in seed production of GJG 32 (ICGV 03043) by SRTC, PJTSAU, Hyderabad. PACS is one of the successful societies running several farmer schemes to promote profitable agriculture. A second training program-cum- workshop on 15 November 2019 in RARS, Palem (Figure 28) identified 11 farmers for seed entrepreneurship in seed production (Table 17).

SBV pilot in Myanmar: 999 Mahar Thamardi Seed Company is now producing large quantities of seeds of improved groundnut variety Sinpadetha-11 at Myingyan township in Mandalay region. The company's staff and their contract farmers participated in the groundnut field day and groundnut seed production technology training held in Myingyan township in 2019. Enhancing groundnut production and profitability in the Central Dry Zone areas requires the promotion of stronger and closer cooperation and collaboration with all stakeholders for development of improved varieties and seed systems in CDZ. Thirty-five farmers, 14 from Magway and 21 from Naypyitaw Division were engaged in groundnut seed production on 20 ha during rainy season 2019 (Table 18).

Table 16. Literature in the local language provided to the farmers.

S. No.	Literature provided in Telugu
1	Techniques to follow at farmers level for groundnut seed production
2	Improved cultivation practices for groundnut
3	Groundnut plant protection, nutrient deficiencies
4	Aflatoxin contamination in groundnut- Management practices to follow

Table 17. List of farmers trained in seed entrepreneurship and engaged in groundnut seed production in Telangana, India.

S. No.	Name of the Farmer	Village	Mandal	District	Contact Number
Rainy 2019					
1	Chandrasekhar Reddy Nelli	Peddakarpamula	Peddakothapally	Nagarkurnool	9182774018
2	Ganesh Rao Venepalli	Mushtipally	Pedakothapally	Nagarkurnool	9493441499
3	Govind Padala	Peddakarpamula	Pedakothapally	Nagarkurnool	8464834835
4	Srikanth Reddy Naredla	Peddakarpamula	Pedakothapally	Nagarkurnool	9177141390

S. No.	Name of the Farmer	Village	Mandal	District	Contact Number
5	Papi Reddy Aderla	Peddakarpamula	Pedakothapally	Nagarkurnool	9703863059
6	Sudarshan Reddy Kusireddy	Pedakothapally	Pedakothapally	Nagarkurnool	9848077764
7	Raju Surapaga	Bawajipally	Thimmajipet	Nagarkurnool	9640941498
8	Prameela Kongari	Shaina Palle	Bijinapally	Nagarkurnool	6305733631
9	Pratap Bantroth	Gurampally	Dharur	Jogulamba Gadwal	9491389188
10	Mallesh Gadwal	Jampally	Dharur	Jogulamba Gadwal	9963625281
Post-rainy 2019-20					
11	Bandi Chennaiah	Nakkalapally	Peddakothapally	Nagarkurnool	9949318004
12	Kalla Swamulu, no edu	Nakkalapally	Peddakothapally	Nagarkurnool	9542257955
13	Katapaga Narsimha, degree	Chinnakothapally	Peddakothaplly	Nagarkurnool	9010180635
14	A. Chandraiah	Chinnakothapally	Peddakothaplly	Nagarkurnool	9010180635
15	Kaniki Narsimha	Bavajipally	Thimmajiet	Nagarkurnool	9542143518
16	V.Tirupathaiah, no edu	Bavajipally	Thimmajiet	Nagarkurnool	7731934121
17	G.Krishnaiah, no edu	Bavajipally	Timmajipet	Nagarkurnool	8008312522
18	Venkata Rama Reddy C/O Dr. Ramanjaneyulu	Potharam	Husnabad	Siddipet	9395538853
19	B.Thirupathi Reddy	Chanchal Cherlapally	Koyda	Siddipet	9989132353
20	Ram Prasad C/O Dr. G.V. Singh	Madanapalle	Madanapalle	Chittor	7993486449 9848346669
21	Chandrashekhar Reddy	Paddakarpamula	Peddakothapally	Nagarkurnool	9182774018

Table 18. List of farmers trained and engaged in groundnut seed production in collaboration with 999 Seed Company in Myanmar.

S. No	Name	Village	Sown area (acre)	Date of sowing
	Magway division			
1	U Kauk Kyi	Thaphansate	1	2.5.2019
2	U Zaw Min Oo	Gwaydauksan	1	29.5.2019
3	U Tin Aung Lwin	Thityakauk	1	6.6.2019
4	U Thein Yu	Kyetsonpway	1	29.5.2019
5	U Thaung Ngwe	Kyetsonpway	1	29.5.2019
6	U Soe Thein	Folaylone	1	30.5.2019
7	U Aung Naing	Kanywalay	1	1.6.2019
8	U Myint Shwe	Ywathitkyi	1	30.5.2019
9	U Aung Zaw	Nyanpinywa	1	29.5.2019
10	U Nyan Htwe	Chaungphyu	1	31.5.2019
11	U Kyaw Win	Kanpyar	3	29.5.2019
12	U Myo Htay	Magyikan	3	29.5.2019
13	U Tun Win	Kanpyar	2	29.5.2019
14	Daw Gwan	Nyaungpin	2	29.5.2019
		Total area	**20**	
	Naypyitaw Division			
15	U Sein Htay	Tharyarkone	1	19.4..2019
16	Daw Swe SweOo	Tharyarkone	2.5	19.4.2019
17	U Thein Lwin	Tharyarkone	1	11.4.2019
18	U Hla Win	Tharyarkone	1	15.5.2019
19	U Sein Win	Tharyarkone	3	7.5.2019
20	U Soe Lin	Tharyarkone	1	16.5.2019
21	U Nyunt Hlaing	Tharyarkone	1	16.5.2019
22	U Aung Soe	Tharyarkone	1	10.5.2019
23	U Htay Lwin	Tharyarkone	2	18.5.2019
24	U Win Myint	Tharyarkone	2	19.5.2019
25	U Myint Lwin	Tharyarkone	1	5.5.2019
26	U Myint Naing	Tharyarkone	1	15.5.2019
27	U Zayyar Min	Tharyarkone	1	15.5.2019
28	U Tint Lwin	Tharyarkone	1	15.5.2019
29	U Pyae Thein	Tharyarkone	1.5	19.4.2019
30	U Soe Thein Win	Tharyarkone	2.5	17.5.2019
31	U Soe win	Tharyarkone	2	18.5.2019
32	U Kyaw Myint	Thuyethamain	1	19.4.2019
33	U Ye Ko	Thayethamain	1	5.5.2019
34	U Zaw Tun	Thuyethamain	1	17.5.2019
35	Daw Ngwe Yi	Thuyethamain	1.5	18.5.2019
		Total Area	**30**	
		Grand Total	**50**	

Objective 4. To enhance human capacities of NARS personnel in integrated plant breeding techniques and seed production technologies through training at ICRISAT

Output 4.1. NARS personal enabled with enhanced skills in conventional and modern tools and seed production technologies

Activity 4.1.1. Conduct training programs and groundnut field days

(a) Groundnut value chain stakeholders' consultation meeting in Myanmar

Mapping of the whole groundnut value chain i.e., from field to plate is critical for designing groundnut product profiles and targeting breeding programs in the country. A multi-stakeholder meeting was conducted at the Department of Agricultural Research (DAR), Yezin on 19-20 February 2019 along with the OFID on-going training program on 'Groundnut Testing Pipeline and Seed Production Technology' (Annexures III and IV). Groundnut researchers from DAR and other provinces, groundnut traders, oil processors, private seed companies, NGOs, progressive farmers and representatives from other value-adding industries were invited to brainstorm and map the whole groundnut value chain in the country. Approximately 49 stakeholders actively participated and deliberated in the discussions (Figure 29).

A comprehensive market survey was conducted in collaboration with DAR and ICRISAT from 7-17 September 2019 to collect information from producer farmers, traders, wholesalers, processors, seed companies and exporters in three major provinces, namely Magway, Sagaing and Mandalay. The key findings from the study are:

1. Oilseeds are the third largest crop group in Myanmar and groundnut, sesame and sunflower are major oilseed crops. Nearly one million ha of cropped area is under groundnut cultivation. Myanmar has witnessed area expansion under groundnut since 1998 owing to growing domestic demand and high profitability. The mean productivity gain/annum was estimated @ 18 kg per ha due to the research and development efforts by various stakeholders. Oil and confectionery take the lion's share of the total demand in the country followed by food and seed.
2. Climate change, irregular rainfall, drought and market price fluctuations are the major constraints to groundnut cultivation as perceived by the stakeholders.
3. Poor seed systems/seed purity are other major reasons for lower productivity levels in the country. Strengthening the formal and informal seed systems are the need of the hour.
4. In the absence of public market systems and quality parameters, traders play a major role and offer non-remunerative prices.
5. The preferred market traits are – high yield, high oil content, and kernels that are medium sized. The potential value opportunities in the country are – edible oil, confectionery, candy, roasted groundnut, etc. The oil processing companies prefer to procure high oil varieties whereas food companies preferred varieties with rose colored kernel testa. Moisture content and aflatoxin contamination were other issues in the export market.
6. Groundnut is the preferred crop to grow during the rainy and post-rainy seasons. During the rainy season, it is normally cultivated immediately after the harvest of sesame. Often it is intercropped with pigeonpea but this proportion has declined in recent times. Seed availability of improved groundnut is limited (< 1%) and farmers are highly dependent on farm saved seed or farmer-to-farmer seed exchange.

7. Based on their feedback, 50-60% of the country's total is exported, 10-20% is processed for oil, and the remaining is used in confectionery. Owing to high export demand the domestic groundnut seed price is high in the country.
8. Totani (red kernel) type followed by Sinpadetha-11 and Magway 16 are major cultivars grown in the CDZ region.
9. Mechanization is limited to land preparation. High labor costs are the major constraints in groundnut cultivation and area expansion. Usage of portable driers and on-farm seed storage technologies are very limited. Sale of produce immediately after harvest is the common practice due to lack of storage space.
10. Among the biotic challenges, leaf miner and leaf spots are widespread. Awareness about aflatoxin and its management is very limited. High moisture content and aflatoxin management in kernels are the biggest challenge in the groundnut market.
11. The preferred traits are: medium and uniform size kernels, low moisture (8.5%) content, red/tan colored kernels and 42% oil content (Figure 30). Second grade kernels are preferred for oil pressing. The oil refineries are traditional in nature.
12. Tan/white medium sized kernels of good quality are preferred for the export market. Tan/white kernels with large sized kernels are preferred for the confectionery market or for export to Thailand. The red kernel type is highly preferred for exporting to China.
13. Border trade is preferred with China because of the short transportation time and simple informal processes. Exporters confirm that there is a huge demand for Myanmar's groundnut because of its sweetish taste that is preferred in the international market. The preferred traits for export are: softness, round size, uniform, little sweetness, oil content and tan color.

(a) Groundnut value chain stakeholders' consultation meeting in Vietnam

Understanding the groundnut value chain from field to plate enables the design of groundnut product profiles and strategic breeding program in a target country. A multi-stakeholder consultation meeting and a training program on 'Groundnut Testing Pipeline and Seed Production Technology' organized at Legume Research and Development Centre (LRDC), Vietnam Academy of Agricultural Sciences (VAAS), Hanoi on 4-5 June 2019 was represented by 56 participants; researchers from different divisions of VAAS and Plant Protection Research Institute (PPRI), Department of Extension, progressive farmers, and representatives from private seed companies. (Annexures V and VI; Figure 31).

Structured discussions documented groundnut ecologies, current and future traits of demand, value addition opportunities and export potential etc. The following key points were highlighted:

1. In Vietnam, groundnut is mainly grown on 210,000 ha in six major regions. North Central and Central Coastal region (45%), Northern Midlands and Mountain region (23%) and the Red River Delta (13%) account for >70% of the total groundnut area in the country.
2. Predominant groundnut ecologies are; (a) rainfed system (cultivated during spring) and (b) intensive farming system (cultivated during both, spring and autumn seasons).

3. Vietnam was a key exporter of groundnut to neighboring countries till 2005, but not anymore owing to domestic demand; it now depends on imports from USA, India, Argentina, Senegal, Malaysia and China.
4. The growth in its productivity, an increase of 26 kg per ha/annum during the last six decades, came from the cultivation of new varieties that supported domestic demand to some extent despite the decline in area by about 60,000 ha, where corn and vegetables in spring and potato in winter are major competing crops.
5. About 72% of the total groundnut production in the country is used for food purposes followed by oil processing (19%). Over time, its demand for food consumption has exponentially increased compared to oil processing.
6. Groundnut production challenges are bacterial wilt, early and late leaf spot, and rust among biotic constraints along with aflatoxin contamination which causes serious health issues and export restrictions; and abiotic stresses such as low temperature during early spring season, soil salinity, water deficit stress in mid-season and heavy rains in the late season leading to quality deterioration and germination of seeds in the soil before harvesting.
7. Access to quality seeds is another key challenge and >80% of the farmers use own saved seeds and suggest the need to strengthen groundnut seed systems in the country.
8. The price fluctuation in the market is the biggest concern expressed by stakeholders.
9. A detailed study on groundnut value chain will be conducted by ICRISAT and LRDC in collaboration with the Center of Agrarian Systems Research and Development (CASRAD) of VAAS in the country.

(c) Groundnut Network Group-Asia (GNG-A)

The Groundnut Network Group-Asia (GNG-A) represented by multi-disciplinary teams from CGIAR, NARS, NGOs and the private sector, plans to strengthen the 'crop breeding, testing and delivery pipelines' of groundnut in Asia. The network is a platform for (a) product design and trait prioritization through feedback from target ecologies; (b) deploying breeding strategies for enhanced selection efficiency and optimized operational efficiency in terms of time and resources; (c) testing at target sites to address G×E×Y interactions; (d) delivery through partnerships that include linking products to commercial entities (industry) and applying models that would ensure rapid adoption to scale by farmers; (e) decision support for product advancement and (f) exchange of knowledge, resources and continuous capacity building.

Groundnut Network Group-Asia meeting, 2018: The GNG-A annual meeting was held at ICRISAT from 30 to 31 March 2018. There were 63 participants, of which 28 were NARS partners from different target countries (19 from India, 5 from Vietnam and 1 each from Myanmar, Lao PDR, Sri Lanka and Bangladesh, Figures 32 & 33). The list of participants in GNG-A and the detailed program schedule are given in annexures VII and VIII, respectively. All the presentations delivered in GNG-A were shared with the participants and are accessible using the link cited in the last page of the report. The product design was made by a team of crop breeders, socioeconomists, pathologists, extension specialists and researchers of other disciplines based on the varietal needs of the target ecologies and market needs. The annual meeting of GNG-A will identify/deliberate/develop one/more of the following:

1. Product designs for target ecologies through a feedback mechanism.
2. Target ecology-specific trials (regional or international) to be conducted during the year (one or two seasons, depending on the ecology).
3. Early generation testing at target sites to enable selection of better allele combinations for adaptability.
4. Decisions on product advancement.
5. Sharing/deploying delivery models that would ensure rapid adoption of scale by farmers.
6. Delivery through partnerships that include linking products to commercial entities (industry).
7. Capacity building and knowledge sharing on methodologies of breeding and testing, experimental design, layout, recording observation, use of data capturing devices and data management tools (BMS) and others based on the need.

The GNG-A will enable the crop improvement program of ICRISAT and NARS to: (a) leverage resources; (b) engage ICRISAT/NARS/NGO/private sector through product prioritization, development, testing to delivery; (c) further the breeding and testing pipelines; (d) serve as a platform for knowledge sharing and best practices; and (e) meet continuous capacity building needs of the NARS.

Groundnut Network Group-Asia 2019: The Groundnut Network Group-Asia (GNG-A) workshop was held at ICRISAT on 26-27 September 2019 with >60 NARS partners from five Asian countries (Bangladesh, Myanmar, India, Laos PDR and Vietnam) and industry partners from food processing and seed sectors of India (Annexure IX & X, Figure 34).

Panel discussion on the groundnut industry: A panel discussion on 'what's new in the groundnut industry' was moderated by Dr Kumaracharyulu with the following panelists: Mr Tushar Thumar Patel, Director, Khedut Feeds & Foods Pvt. Ltd., Rajkot; Mr Rangamanner Chetty, R & D Manager, VNKC Agricom, Ahmedabad; and Dr Hemang Baxi, Bombay Super Hybrid Seeds, Rajkot, India, with the following key highlights:

1. Kernel size distribution is one of the industry's criterion for selecting produce and it prefers 38/42, 40/50 and 50/60 counts per ounce for salted/roasted/fried peanuts. Light tan and rose testa are preferred over dark tan. The large-seeded type will fetch premium prices compared to regular sized kernels. Elongated kernels (Chinese flat peanuts) over round seed shape are preferred for the confectionery industry.
2. Farmers usually fetch premium prices for their products based on oil content as high kernel oil is preferred by oil extracting industries.
3. The use of groundnut kernels for oil extraction has significantly reduced due to the availability of other cheaper vegetable oils such as palm, sunflower and soybean.
4. The industries are keen to adopt high oleic groundnuts as they offer several health benefits to the consumers, and enhanced flavor and extended shelf life to their food products. There is a huge demand for high oleic groundnuts in European countries supplied by Argentina, USA and Brazil. Argentina could export more to international markets because of their lower cost of production compared to other countries. The release of high oleic groundnut varieties will increase India's ability to export to

European countries, noted Mr Tushar Patel. Currently, industries in India are ready to pay a premium of 5000 INR/ton for high oleic groundnut grown in India.

5. Aflatoxin contamination due to poor crop management, drying and lack of storage facilities, and mixture of varieties are key constraints to the industry.
6. A huge opportunity exists for seed industries as farmer's demand seeds of newer varieties.
7. Market preferred traits include: (a) round seeded type as they are preferred for chocolate-coated products; (b) low to normal oil content (~45-48%) is preferred for peanut butter; (c) Valencia three-seeded type groundnut is in demand for boiling purposes; (d) easy blanchability is preferred for salted/roasted uses; (e) less shrinkage of kernels in the bold-type groundnut is a requirement for long term storage and export; and (f) sensory attributes are important for confectionery purposes.

(d) Capacity building of researchers from target countries

Key highlights from the training programs:

1. Two long-term training programs were conducted during 2018-19; the first training program with six researchers was on advances in groundnut research and seed production technology organized at ICRISAT from 24 September to 5 October 2018 (Table 19 & Figure 35). The second training program for six researchers was conducted from 16-27 September 2019 at ICRISAT (Figure 35). Both aimed to build capacity among researchers of partner institutes for modern breeding tools such as marker-assisted backcrossing (MABC) and marker-assisted selection (MAS), high throughput genotyping and phenotyping for target traits, seed production technology, mechanization in research and data management and analysis using digital tools like Breeding Management System (BMS) and Genstat (Annexure XI & XII).
2. Two stakeholder consultation meetings were held in Myanmar and Vietnam to study the groundnut market and value chain and design groundnut product profiles. It was conducted in Myanmar from 19- 21 February 2019 at DAR with 35 participants from DAR and other sub-centers, Extension Officers of DoA, Syngenta Foundation, private seed and food industry representatives, and scientists from ICRISAT, India. In Vietnam, it was conducted from 4-5 June 2019 with 56 participants comprising researchers from different divisions of VAAS and the Plant Protection Research Institute (PPRI), Department of Extension, representatives from private seed companies and scientists from ICRISAT, India.
3. In Lao PDR, the groundnut breeding programs need to be strengthened. Therefore, two research technicians were trained at LRDC-FCRI, Vietnam, for a period of three months during the crop season. They have learned all the activities related to groundnut breeding, which they will share with other teams in Lao PDR.
4. Two NARS scientist, Dr MP Deshmukh, Associate Professor, ARS, Kasbe Digraj and Dr Truong Thi, Acting Director, LRDC-FCRI, Vietnam attended the 10th International Conference on Advances in Groundnut Research through Advances in Genomics and Biotechnology (AAGB) held at Saly Senegal during 12-16 November 2018.
5. Ph.D. scholar Ankush Wankhede was trained at the University of Georgia for three months on advance genomic technologies in groundnut research. One training session

on groundnut seed production with 20 extension officers was conducted at BARI, Bangladesh.

6. A training program was organized on the detection of aflatoxin contamination through ELISA method at BARI, Bangladesh. There were 20 trainees including 10 researchers from BARI, 5 from PRAN Agro-Business Ltd, 2 from Bombay Sweets and 3 from Partex Agro Ltd (Figure 36). Another training program was organized on groundnut seed production technology at BARI, Bangladesh, with 30 trainees including 5 extension officers, 15 researchers from BARI, 5 seed production officers of PRAN Agro-Business Ltd, 2 from Bombay Sweets and 3 from Partex Agro-Business Ltd.
7. Standard operating procedures for groundnut breeding and testing pipelines were prepared for NARS partners (http://oar.icrisat.org/10653/1/Standard%20Operating%20Procedures.pdf)
8. Training program on aflatoxin detection: An aflatoxin detection program using the commercial ELISA kit (Helica Biosystems) was organized at BARI headquarters, Joydebpur on 8 April 2019 by researchers from ICRISAT. A total of 36 participants attended the training which included staff of PRAN Agro-Business Ltd, Partex Agro Chemicals, Bombay Sweets, government staff from BADC, DAE (Department of Agricultural and Extension) and BARI staff. A total of 15 participants which included 5 staff members from PRAN Agro-Business Ltd and 10 participants from BARI were given hands on training in the use of the ELISA kit to estimate aflatoxin content in groundnuts.

Table 19. Trainees who attended the training program at ICRISAT in 2018 and 2019.

S. No	Name	Country	Institute
Long-term training program conducted during 2018			
1	Ms Maw Maw Niang	Myanmar	Department of Agriculture Research, Yezin
2	Mr Mehbub Ul Islam	Bangladesh	Bangladesh Agricultural Research Institute, Rajshahi, Bangladesh
3	Mr Wanga Maliata Athon	Namibia	Crop Research and Production, Ministry of Agriculture, Water and Forestry Mannheim Research Station, Tsumeb, Namibia
4	Dr Rajendra L Bhakre	India	Agriculture Research Station, Mahatma Phule Krishi Vidyapeeth, Kasbe Digraj, Sangli, Maharashtra
5	Mr B V Pandhare	India	Agriculture Research Station, Mahatma Phule Krishi Vidyapeeth, Kasbe Digraj, Sangli, Maharashtra
6	Dr G Sheshu	India	Regional Agriculture Research Station, Professor Jayashankar Telangana State Agricultural University, Palem Telangana
Long-term training program conducted during 2019			
7	Ms Linh Trin	Vietnam	Legume Research and Development Center, VAAS, Hanoi, Vietnam
8	Mr Krishna Chandra Saha	Bangladesh	Bangladesh Agricultural Research Institute, Rajshahi, Bangladesh

S. No	Name	Country	Institute
9	Mr Mukaddasul Islam Riad	Bangladesh	Bangladesh Agricultural Research Institute, Rajshahi, Bangladesh
10	Mr Khamphanh Xayyalat	Lao PDR	Maize and Cash Crop Research Center National Agriculture Forestry and Rural Development Research Institute
11	Mr Sidhdhnath	India	PJTSAU, Rajendra Nagar, Hyderabad, India
12	Ms Rachna Begudam	India	PJTSAU, Rajendra Nagar, Hyderabad, India

(e) Training on Groundnut testing pipeline and seed production technology

1. A training program on groundnut seed production technology was conducted at DAR, Yezin, Myanmar on 20 February 2019 with around 30 participants including the seed production officers of DAR, DoA, NGOs, and private seed companies (Figure 37). A similar training program was conducted at Legume Research and Development Center, VAAS, Hanoi, Vietnam.
2. Two training programs were organized for groundnut researchers of BARI, Bangladesh. The subject matter expert from ICRISAT shared knowledge on groundnut seed production, improved crop management and seed storage technology along with insights into groundnut breeding and testing pipelines. The detailed agenda and program schedule for both the training programs are given in annexures IX and XI.
3. Two training programs in Bac Giang and Quang Binh provinces of Vietnam were organized by LRDC during January 2019 (Figure 38).
4. One training program and three progressive farmer-scientist meetings were conducted at ARS Kasbe Digraj to train farmers in seed production technology and good agriculture practices (Figure 39). A training program for farmers on groundnut seed production technology and seed distribution of GJG 32 (ICGV 03043) was conducted at RARS Palem during November 2019.
5. In Bangladesh, training programs were organized by BARI to train the staff of the Department of Agriculture and farmers on improved management practices, seed production and good agriculture practices (GAPs) to reduce the contamination of aflatoxin in the produce. A total of 40 officers and staff from the Department of Agriculture extension took part in two training sessions; 200 farmers attended four training sessions, and ~230 farmers took part in two field days.

(g) Promoting groundnut-based food supplements to treat malnutrition in Bangladesh

Groundnut-based food supplements have long been used in the preparation of therapeutic foods to treat malnutrition in children and the elderly. Keeping the therapeutic/health benefits of groundnut in mind, a project to address malnutrition in select districts of Bangladesh, through novel interventions, involving public-private partnership and strengthening of the peanut-based food value chain system was proposed. Two products -- multi-grain peanut bars and peanut cookies were selected based on preferences by school children in Jamalpur and Lalmonirhat districts of Bangladesh. The production and distribution of groundnut biscuits (70 g) and groundnut bars (60 g) (Figures 40 & 41) was initiated jointly by a team from ICRISAT, BARI and PRAN Agro Ltd from 8 January to 15 June 2019. Groundnut biscuit and bar production were taken up at the PRAN manufacturing unit of Habiganj Agro

Ltd. for biscuits and PRAN Agro- Ltd., Eakdala, Natore for bars, as per the guidelines and specifications provided by ICRISAT. The groundnut products were analyzed for nutritional parameters at an external laboratory in Bangladesh and for aflatoxin contamination at ICRISAT. All the tested products recorded below the minimum permissible limit of 15 ppb for aflatoxin.

The analysis of baseline and endline survey results indicated higher incidences of anaemia in female children compared to their male counterparts. On completion of the feeding pilot, there was a reduction in anaemia by 88% in adolescent males, 30% in female children and 40% in adolescent females; and a sharper shift towards recommended/ideal population distribution as recommended by WHO in the treatment population for both wasting and stunting in the endline survey.

Objective 5. To disseminate information on improved farmer-preferred groundnut varieties and integrated crop management technologies through the use of new technologies

Output 5.1. Enhanced awareness among the farmers on improved groundnut varieties and seed production technologies.

Activity 5.1.1 .Conduct farmer and extension awareness programs through NARS and digital technologies

(a) Groundnut field days and farmer training:

1. Four farmer training programs (each with ~50 farmers) on groundnut seed production technology was organized each at Vagoldi Ghar-Shepur; Belgasa-Jamalpur; Razarhat-Kurigram and Char Gokunda-Lalmonirhat, Bangladesh. The farmers were also trained in improved crop and post-harvest management practices and the role of good quality seeds of improved varieties in enhancing production and profitability.
2. A training program on groundnut seed production technology was held at Myingyan township in August 2019 by DAR in collaboration with DOA and 999 Mahar Thamardi Seed Company.
3. In the rainy season of 2019, two groundnut farmer field days each were conducted at Thityone village, Myingyan township in the Mandalay region on 31 August 2019 (38 male and 37 female participants) and Magyikan village, Magway township on 21 September 2019 (53 male and 22 female participants). Staff of the Department of Agricultural Research and Department of Agriculture, groundnut production farmers, traders, 999 Mahar Thamardi Seed Company staff and township level officials participated in the field day to demonstrate new technologies for groundnut production (Figures 42 & 43). Another field day will be held at Nyaung Pin village, Pakokku township in Magway region in the second week of February 2020.
4. Two mega field days were held in India, one with about 300 farmers on the performance of groundnut variety GJG 32 (ICGV 03043) at Pebbair, Wanaparthi district of Telangana on 25 January 2019; and the second ARS Kasbe Digraj on 30 March 2019 with about 250 farmers. The farmers were addressed by Dr K P Vishvanatha, Vice Chancellor, MPKV, Rahuri on recent techniques to enhance the profitability of the farmers along with the role of new varieties in improving the productivity of different crops (Figure 44).

5. Two field day-cum-training programs, one on the new groundnut variety GJG 32 (ICGV 03043), seed rate usage, importance of seed treatment and sowing methods and mechanization; and a second on the mid-season training on fertilizer management, plant protection measures, mechanical harvesting and post-harvest management were conducted for the farmers of Uppununthala PACS with around 120 farmers in each program.
6. A field day on groundnut crop was organized in the field of Mr. P. Balaswamy, Palem village, Bijinapalli mandal of Nagarkurnool District, Telangana on 1 May 2019 by RARS Palem. A mega farmers' field day was organized at Islampur, Jamalpur, Bangladesh (Figure 45). A field day was organized at Nallavelli village, Nagarkurnool District in co-ordination with PJTSAU and the Ministry of Agriculture and Farmers welfare (Figure 46).
7. Farmer's field day-cum-training programs were organized at the four project districts f Bolangir, Nuapada, Kalahandi and Ganjam to train farmers and seed entrepreneurs in improved groundnut production, storage and use of the Kalgudi app (mobile-based software application). About 30 training sessions each involving ~200 farmers were conducted in 2018-19 (Table 20).
8. For seed storage, training on the use of Purdue Improved Crop Storage (PICS) bags was imparted. Also, use of the mobile-based Kalgudi app to link groundnut farmers working in Odisha district was discussed as part of the training program (Figure 47).
9. The recently released high oil groundnut variety (ICGV 03043) has been drawing farmers to groundnut production in Maharashtra and Telangana states of India (https://www.icrisat.org/new-high-oil-variant-draws-farmers-to-groundnut-production-in-western-india/).
10. Four farmers' meetings each at Alate and Kapuskhedi inSangli district, and Kalwade and Janugawadi in Satara district were held for interactions on the challenges being faced in groundnut cultivation, and their feedback on ICGV 03043 (seed distributed to the farmers during rainy season 2018) (Figure 48). Pod and fodder yield and tolerance to foliar fungal diseases (late leaf spot and rust) were appreciated by farmers in all the villages (Figure 49). This high oil variety empowers women, as stated by Ms Savita Janugade of Janugadewadi village in Satara district to visiting scientists that one can easily harvest ICGV 03043, unlike other varieties in use. For women whose work involves drudgery, an easy-to-harvest crop is important to reduce workload. "Harvesting is seen as a woman's job. Women keep the earnings from the portion of harvest sold as seed. With this variant being easier to pull out and peel, a woman can get her share of money without working too hard for it," says Ms Janugade, who chairs a self-help group for women. The SHG supports the village's economy by lending money at low rates. With government support, increasing demand, changing climate and farmers' need for new varieties that can withstand unseasonal rain, groundnut is finding more takers in western Maharashtra.
11. A training program on groundnut seed production technology for extension officers and progressive farmers was held on 10 April 2019 at TSF Saudapur, Karad.

12. A farmers' meeting was conducted at CARS, Raigarh on 26 June 2018 (Figure 64). Two training programs on improved groundnut production technology with 40 extension officers were conducted at BARI, Jamalpur.

Table 20. Farmers' field day-cum-training programs on improved groundnut cultivation practices, storage and linkage with Kalgudi App, 2018-19.

S. No	Date	Venue (District/Block, Village)	Number of farmers
1	12 Feb 2018	Nuapada/Kariar, Chhata	211
2	13 Feb 2018	Bolangir/Bangomunda, Balikhamar	209
3	14 Feb 2018	Bolangir/Muribahal, Lebada	222
4	15 Feb 2018	Nuapada/Komna, Sialati	206
5	16 Feb 2018	Bolangir/Bangomunda, Purniapali	225
6	17 Feb 2018	Bolangir/Patnagarh, Thakpada	211
7	20 Feb 2018	Ganjam/Sorada, Sorada Block HQ	217
8	21 Feb 2018	Ganjam/Sorada, Muliapali	215
9	23 Feb 2018	Ganjam/Khallikota, Kumbhidhipa	214
10	24 Feb 2018	Ganjam/Khallikote, Ramachandrapur	211
11	25 Feb 2018	Ganjam/Khallikote, Danapur	224
12	26 Feb 2018	Kalahandi/Bhawanipatna, Bhawanipatna	208
13	27 Feb 2018	Kalahandi/Bhawanipatna, Khairibhadi	221
14	28 Feb 2018	Kalahandi/Golamunda, Mermahul	212
15	5 Mar 2018	Bolangir/Muribahal, Makripada	217
16	7 Mar 2018	Nuapada/Boden, Palsada	218
17	10 Mar 2018	Nuapada/Khariar, Kuligoan	283
18	11 Mar 2018	Kalahandi/Junagarh, Labanipur	205
19	14 Mar 2018	Kalahandi/Kesinga, Burdipada,Belamal	211
20	12 Mar 2018	Bolangir/Titilagarh, Sialjhudengi	228
21	15 Mar 2018	Kalahandi/Bhawanipatna, Gananthpur	206
22	21 Mar 2018	Ganjam/Khalikote, Ulapur	204
23	21 Mar 2018	Nuapada/Khariar, Chechair	270
24	22 Mar 2018	Bolangir/Bangomunda, Jampada	219
25	22 Mar 2018	Ganjam/Khalikote, Kairashi	210
26	23 Mar 2018	Nuapada/Khariar, Sargadi	220
27	24 Mar 2018	Ganjam/Belaguntha, Badapada	206
28	24 Mar 2018	Nuapada/Komna, Belgaon	202
29	25 Mar 2018	Nuapada/Sinapali, Kapsi	214
30	26 Mar 2018	Bolangir/Bangomunda, Themra	203
		Total	**6522**

(b) Training on mechanization for groundnut cultivation

To facilitate post-harvest operations such as threshing in groundnut, two dry plant threshers were given to farmers' self-help groups (Figure 50). These machines are kept at Ganjam and Kalahandi districts of Odisha. A farmers group was formed and is involved in the operation and maintenance of the thresher. To train farmers on the use of the machine, eight trainings were conducted at different villages in the four districts (Table 21).

Table 21. Special training programs conducted to demonstrate mechanization in groundnut cultivation in farmers' fields using dry plant threshers.

Sl No	Date	Venue (District/Block, Village)	Number of participants
1	23 Mar 2018	Kalahandi/Kesinga, Bisudi	75
2	25 Mar 2018	Kalahandi/Golamunda, Karmath	78
3	26 Mar 2018	Kalahandi/Junagarh, Makarsola	74
4	27 Mar 2018	Nuapada/Khariar, Tikhali	107
5	28 Mar 2018	Kalahandi/Bhawanipatna, Parimal	82
6	28 Mar 2018	Bolangir/Bangomunda, Badmula	88
7	29 Mar 2018	Bolangir/Muribahal, Lebeda	61
8	30 Mar 2018	Bolangir/Bangomunda, Barakani	70
		Total	635

4. Direct and indirect beneficiaries

The current OFID project has strengthened the existing collaboration between ICRISAT and NARS partners of Myanmar, Vietnam Bangladesh, Lao PDR, Sri Lanka and India. Sharing knowledge and breeding material helped NARS partners strengthen groundnut breeding and testing pipelines and contributed to enhanced profitability of groundnut cultivation. It helped to leverage the expertise and resources among the existing NARS partners, and also supported the evaluation of promising lines across different locations to identify the best adaptable varieties to release for commercial cultivation. However, the project helped to set up a new collaboration with the National Agriculture and Forestry Research Institute (NAFRI), Lao PDR and to start a groundnut breeding program in the country. The emphasis on strengthening formal seed systems through supplying quality seed to seed production chains and developing informal groundnut seed system by creating seed entrepreneurs will help increase the varietal adoption rate and seed replacement ratio across the groundnut growing regions in the target countries. The value chain studies conducted in India, Myanmar and Bangladesh helped to understand the needs of different stakeholders in the groundnut value chain which were considered in designing product profiles for different target ecologies with defined timelines of delivery. The execution of project activities and milestones enabled us to reach 16,982 direct and 226,229 indirect beneficiaries (Table 22).

Table 22. Direct and indirect beneficiaries of the project from January 2018 to December 2019.

S. No	Activities	No of events	Direct Beneficiaries	Indirect Beneficiaries
1	Distribution of Seed Packets of Improved Varieties (10 kgs)	-	2124	6372
2	Nucleus/Breeder Seed Production of Improved Varieties	66344	-	132688
3	Farmers Participatory Varietal Selection Trials (FPVS)	23	1380	4140
4	Groundnut Network Group-Asia Meetings	2	127	6350
5	Long term training of NARS Partners at ICRISAT/Vietnam	4	16	800
6	Research Scholars Completed/Pursuing Ph.D. Research at ICRISAT	4	4	
7	Farmers Field Days	12	2150	10750
8	Farmers Trainings/Meetings	42	7864	39320
9	Demonstration of Mechanization	8	894	4470
10	Training of Extension Officers	5	170	8500
11	Stakeholders Meetings for Groundnut Value Chains and Product Profiles	2	105	2100
12	Training under Seed Business Ventures Program	5	109	545
13	Training program on Aflatoxin detection	1	36	180
14	Training on Seed Production Technology	8	315	1575
15	On-farm demonstrations	46	46	2300
16	Minikit trials	24	24	1200
17	Participation in International Conferences/Meetings	2	5	100
18	Distribution of Purdue Improved Crop Storage Bags	-	1000	3000
19	Food supplements to School Children's in Bangladesh through IKP project	-	613	1839
	Total	-	**16982**	**226,229**

6. Milestone-wise work done summary

The milestones completed during the project period are summarized in Table 23.

Table 23. Milestone-wise work done from January 2018 to December 2019.

Objectives	Milestones/ Activities	Work done from January 2018 to December 2019	Work is done/ in progress
1. To develop new groundnut varieties that are suitable to current and emerging production challenges, and meet the needs of the farmers, traders and the industry. The target traits include drought tolerance, diseases resistance, fresh seed dormancy, shelling outturn, kernel traits, high oil, and high oleic acid content in early and medium maturity duration backgrounds	1.1.1.1. Attempt 80 new crosses annually	136 crosses have been done, the parentage of 28 cross combination are planted in crossing block during PR19-20	✓
	1.1.1.2. Constitute new preliminary/observation trials with 500 new lines annually	Trait-specific preliminary/observatory yield trials are conducted with >1400 entries	✓
	1.1.1.3. Genotype early generation populations, 10000 plants annually	Completed genotyping of 22736 individual plants/lines	✓
	1.1.1.4. Phenotype 200 lines for drought tolerance, disease resistance and early maturity in respective nurseries	Phenotyping of >1000 trait-specific lines was done	✓
	1.1.1.5. Conduct 50 yield evaluation trials that include preliminary, advanced and elite trials	178 trials were conducted	✓
	1.1.1.6. Constitute three International Nurseries annually	Three international nurseries were constituted, namely XIV IFDRGVT, XIII ISGVT, X IDRGVT with 15 lines in each	✓
	1.2.1.1. Initiate backcross program with the 1-2 popular varieties of target countries	The farmer-preferred varieties KDG 123, KDG 128, JL 286, SB XI, Dhalakshmi, GAUG 10, GG 20, GJG 9, GJGHPS-1, K6 etc. are incorporated in the crossing program	✓
	1.2.1.2. Attempt 20 new crosses annually to combine traits with high oleic trait	94 crosses attempted to combines high oleic trait into different backgrounds	✓
	1.2.1.3. NIRS phenotyping of populations (10000 annually) for oil, protein and high oleic trait	Over 25000 individual plants/lines were phenotyped for oil, protein and fatty acid concentration including ~5000 samples from NARS partners	✓

Objectives	Milestones/ Activities	Work done from January 2018 to December 2019	Work is done/ in progress
	1.2.1.4. Develop 100 high oleic lines annually for yield evaluation trials and for processing quality parameters	Over 500 new high oleic lines were evaluated for fatty acid profile and processing quality parameters	✓
2. To identify groundnut varieties adapted to target production ecologies and different cropping systems of Asia through on-station testing and farmer-participatory varietal selection (FPVS) trials in collaboration with NARS partners	2.1.1.1 Share at least 12 International nurseries annually	Trait-specific international nurseries are constituted and shared with partners from different target countries	✓
	2.1.1.2. Share at least 100 trait-specific lines and 20 segregating populations annually	3519 genotypes/populations shared with NARS partners of 11 countries which include over 700 trait-specific advanced breeding lines and 20 segregating populations	✓
	2.2.2.1. Conduct at least 24 FPVS trials annually with NARS	23 FPVS trials conducted	✓
	2.2.2.2. Conduct 12 on-farm trials annually with NARS	21 on-farm demonstration and 24 minikit trials conducted to demonstrate best variety to farmers	✓
	2.2.2.3. Arrange 10000 kg of seed production annually of entries in the FPVS trials, and on-farm demonstrations	>10000 kgs seeds of promising entries produced for FPVS and on-farm demonstrations	✓
3. To promote formal and informal seed systems in partner countries in collaboration with NARS partners	3.1.1.1. Distribute 5000 seed packets of 10 Kg pods of new improved varieties (2500 annually)	2124 seed packets of 10 Kg seeds of best varieties were distributed. The farmers will share the 10 kgs of seeds with neibouring farmers	✓
	3.1.1.2. Produce 12,000 kg of Nucleus Seed and Breeder Seed	Over 64000 kgs of Nucleus/Breeder Seed of 17 varieties produced	✓
	3.1.1.3. At least 60 seed producing entrepreneurs engaged in groundnut seed production	Around 100 progressive farmers were trained and engaged in seed production to be seed entrepreneurs	✓
4. To enhance human capacities of NARS	4.1.1.1. At least 6 researchers trained at ICRISAT annually	16 researchers undergo long term training	✓

Objectives	Milestones/ Activities	Work done from January 2018 to December 2019	Work is done/ in progress
personnel in integrated plant breeding techniques and seed production technologies through training at ICRISAT	4.1.1.2. Conduct groundnut field day annually at ICRISAT	Scientist field and GNG-A workshops held during 2018 and 2019 with >120 participants	✓
5. To disseminate information on improved farmer-preferred groundnut varieties and integrated crop management technologies through use of new technologies	5.1.1.1. Train extension staff	1. Five training were conducted across project partner countries 2. Two stakeholder consultation meeting were conducted in Myanmar (19-20 Feb 2019) and Vietnam (4-6 June 2019)	✓
	5.1.1.2. Conduct 20 farmer field days at on-farm sites	19 farmer's field days; eight trainings on mechanization in groundnut and 20 farmers meetings were conducted	✓
	5.1.1.3. Enhance capacities of farmers in target countries using digital technologies	38 training programs on improved groundnut production technology and use of digital tools such as Kalgudi app conducted	✓

✓ work done

7. References

First-ever High oleic peanuts in India https://www.youtube.com/watch?v=JQIIdGBWiu0

Groundnut researchers in Asia move towards modernization of breeding program http://www.icrisat.org/groundnut-researchers-in-asia-move-towards-modernization-of-breeding-program/

New high-oil variant draws farmers to groundnut production in Western India https://www.icrisat.org/new-high-oil-variant-draws-farmers-to-groundnut-production-in-western-india/

Oil super rich groundnut ICGV 03043 ready to quench India's thirst for peanut oil https://www.icrisat.org/oil-super-rich-groundnut-icgv-03043-ready-to-quench-indias-thirst-for-peanut-oil/

Standard operating procedures for groundnut breeding and testing pipeline was prepared for NARS partners http://oar.icrisat.org/10653/1/Standard%20Operating%20Procedures.pdf

Release of two high oleic varieties for the first time in India https://www.icrisat.org/indias-first-high-oleic-groundnut-varieties-ready-to-go-commercial/; https://www.thehindubusinessline.com/economy/agri-business/two-groundnut-varieties-with-high-oleic-acid-ready-for-release/article27354266.ece

Two groundnut varieties with high oleic acid ready for release https://www.thehindubusinessline.com/economy/agri-business/two-groundnut-varieties-with-high-oleic-acid-ready-for-release/article27354266.ece

India's first 'high oleic' groundnut ready to go commercial https://ruralmarketing.in/industry/agriculture/indias-first-high-oleic-groundnut-ready-to-go-commercial

Hyderabad scientists develop new groundnut varieties https://timesofindia.indiatimes.com/city/hyderabad/hyderabad-scientists-develop-new-groundnut-varieties/articleshow/69584415.cms

Industry plans to reach consumers with high oleic groundnut oil in 2-3 years https://www.icrisat.org/industry-plans-to-reach-consumers-with-high-oleic-groundnut-oil-in 2-3-years/

NARS partners in Asia pick up advanced groundnut breeding lines with market traits for their national trials https://www.icrisat.org/nars-partners-in-asia-pick-up-advanced-groundnut-breeding-lines with-market-traits-for-their-national-trials/

Stakeholders meet discusses solutions to unshackle Myanmar's groundnut value chain https://www.icrisat.org/stakeholders-meet-discusses-solutions-to-unshackle-myanmars-groundnut-value-chain/

Janila P, MK Pandey, Y Shasidhar, M Sriswathi, P Khera, SS Manohar, P Nagesh, MK Vishwakarma, GP Mishra, T Radhakrishnan, N Manivannan, KL Dobariya, RP Vasanthi, RK Varshney (2016). Molecular breeding for introgression of fatty acid desaturase mutant alleles (*ahFAD2A* and *ahFAD2B*) enhances oil quality in high and low oil containing peanut genotypes. *Plant Science* **242**: 203-213.

Janila P, Pandey MK, Shasidhar Y, Variath MT, Sriswathi M, Khera P, Manohar SS, Nagesh P, Vishwakarma MK, Mishra GP, Radhakrishnan T, Manivannan N, Dobariya KL, Vasanthi RP and Varshney RK. 2015. Molecular breeding for introgression of fatty acid desaturase mutant alleles (a*hFAD2A* and *ahFAD2B*) enhances oil quality in high and low oil containing peanut genotypes. *Plant Science.* 01-42.

Bera SK, Manohar SS, Variath MT, Chaudhari S, Yaduru S, Thankappan R, Narayana M, Kurapati S, Pandey MK, Sudini HK, Shanmugavel S. (2018) Assessing variability for disease resistance and nutritional quality traits in an interspecific collection of groundnut (*Arachis hypogaea*). Plant breeding. 137(6):883-94.

Jadhav Y, Surendra SM, Sunkad Gururaj, Viswanatha KP, Pandey MK, Murali TV, Yaduru Shasidhar, Praveen Kona, Rajeev KV and Pasupuleti Janila (2019) Genomic Regions Associated with Resistance to Peanut Bud Necrosis Disease (PBND) in a Recombinant Inbred Line (RIL) Population. 2019, Plant breeding. (Accepted)

Deshmukh M.P., S.N. Nigam, D.K. Kathmale, B.P. Kurndkar, S.R. Shinde, S.B. Mahajan and R.G. Jadhav (2018) Promising Virginia bunch groundnut varieties for target ecologies of India at 10th International Conference on Advances in Groundnut Research through Advances in Genomics and Biotechnology (AAGB) held during 12 to 16 November 2018 (https://www.isra.sn/aagb2018/wp-content/uploads/2018/11/AAGB-2018-abstracts-posters.pdf)

Truong T T, N. X. Thu, and Bui Q. Dang (2018) Present status and future possibilities of peanut cultivation in different zones of Vietnam at 10th International Conference on Advances in Groundnut Research through Advances in Genomics and Biotechnology (AAGB) held during 12 to 16 November 2018 (https://www.isra.sn/aagb2018/wp-content/uploads/2018/11/AAGB-2018-abstracts-posters.pdf)

Janila, P, T.V. Murali, SS. Manohar, Sunil Chauddhari (2018) Modernizing the Peanut Breeding Program at ICRISAT at 10th International Conference on Advances in Groundnut Research through Advances in Genomics and Biotechnology (AAGB) held during 12 to 16 November 2018 (https://www.isra.sn/aagb2018/wp-content/uploads/2018/11/AAGB-2018-abstracts-posters.pdf)

Chaudhari S, Khare D, Murali TV, Pandey MK and Janila P (2018) Molecular Diversity and Marker-trait Association for Resistance to Foliar Fungal Diseases and Nutritional Quality Traits in Genomic Selection Training Population of Groundnut at 10th International Conference on Advances in Groundnut Research through Advances in Genomics and Biotechnology (AAGB) held during 12 to 16 November 2018 (https://www.isra.sn/aagb2018/wp-content/uploads/2018/11/AAGB-2018-abstracts-posters.pdf)

Deshmukh Dnyaneshwar, Murali TV, Marathi Balram, Chaudhari Sunil, Bhatnagar PM and Janila P (2018) Fatty Acid Accumulation in ahFAD Mutant High Oleic Groundnut Lines Across Developmental Stages and its Effect on Seed Quality Parameters at 10th International Conference on Advances in Groundnut Research through Advances in Genomics and Biotechnology (AAGB) held during 12 to 16 November 2018 (https://www.isra.sn/aagb2018/wp-content/uploads/2018/11/AAGB-2018-abstracts-posters.pdf)

Su Htwe Nge, Khin Mar Mar Nwe, Maw Maw Niang, Sunil Chaudhari, Dnyneshwer Deshmukh and P Janila (2018) Association of Pod Shell Thickness and Kernel Weight with Shelling Outturn in a MAGIC Population of Groundnut at 10th International Conference on Advances in Groundnut Research through Advances in Genomics and Biotechnology (AAGB) held during 12 to 16 November 2018 (https://www.isra.sn/aagb2018/wp-content/uploads/2018/11/AAGB-2018-abstracts-posters.pdf)