DGR

वार्षिक प्रतिवेदन

ANNUAL REPORT 2010-11

भाकृअनुप
ICAR

मूंगफली अनुसंधान निदेशालय

पो. बो. नं. ५, जूनागढ - ३६२ ००१, गुजरात, भारत

Directorate of Groundnut Research

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(Indian Council of Agricultural Research)
P. B. No. 5, Ivnagar Road, Junagadh, Gujarat, India

Citation :

Annual Report 2010-11, Directorate of Groundnut Research,
Junagadh-362001, Gujarat, India

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Cover illustration :

Groundnut crop in farmers' field

Published by:

Director
Directorate of Groundnut Research
P.O. Box 5, Ivnagar Road,
Junagadh-362001, Gujarat, India

Printed at :

Radhika Printers, Ahmedabad.
Ph. (079) 2658 5504, Cell - 90999 11139

Preface

After one of the worst droughts in 2009, the early arrival of monsoon in 2010 raised the hopes of one and all for a good year for agriculture. But the euphoria was short-lived for it rained and rained and rained – a total rainfall of 1690 mm was recorded in Junagadh against the normal 650 mm. The result – groundnut crop in the field suffered due to these excessive un-seasonal rains. Besides Gujarat, the saga was nearly the same for Andhra Pradesh. These two states together comprise nearly 60% *kharif* groundnut area in the country. According to the first advanced estimates for *kharif* 2010, groundnut production in India would be about 56 lakh tonnes from an area of about 50 lakh tonnes. The productivity would be 1120 kg ha^{-1}.

At DGR, almost all the field experiments in *kharif* 2010 were spoilt by the excessive rains as water stagnated in the fields for days together. Some consolation was there as the laboratory based experiments progressed well and in most cases encouraging results were obtained. There was good progress in the areas of developing transgenic groundnut, possessing resistance to drought and viral diseases. Novel findings were there on aflatoxin contamination of groundnut kernels during various stages of industrial processing. The data generated on the survival probabilities of various technologies transferred earlier to the farmers, was quite revealing. The list is long.

During the year two genotypes 'ICGV 00350' and 'HNG 123' were identified at AICRPG workshops for release even as three varieties identified earlier viz. 'Girnar 3', 'Kadiri Harit Andhra', and 'GPBD 5' were notified by Govt. of India. In addition, one variety 'GJG-HPS-1' was released by Govt. of Gujarat. During the period under report a total of 16,407 q breeder seed comprising 47 varieties was produced.

I compliment the scientists of DGR and AICRP-G on their contributions.

During this year, there was a consolidation of scientific manpower as eight young scientists, recruited through ARS-examination, were posted at DGR. In addition, one Principal Scientist in Agronomy discipline was recruited through direct selection by ASRB. DGR also bid farewell to its three scientists – one Senior Scientist in the discipline of Extension and two Scientists – one in the discipline of Agronomy and another in the discipline of Plant Biotechnology.

The plan budget utilization in 2010-11 was nearly cent per cent for both DGR and AICRP-G.

All the scientists of DGR have contributed towards the compilation of this report and so have the administration and accounts sections. Dr. R. Dey and Dr. K.K. Pal have been working untiringly to compile and edit the contents and oversee the printing of this report. Several other officials have also contributed to preparation of this report. I thankfully acknowledge the contribution of one and all.

J. B. Misra

Director

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Executive Summary

In the year 2010, Junagadh received nearly three times the normal rainfall. As a result water stagnated in the fields for days together and most of the field experiments were vitiated. The laboratory based experiments, however, progressed uninterrupted. The summary of the results of various experiments and related scientific activities are described here.

- A wide range of variation was found amongst 188 RILs of a mapping population phenotyped for traits related to early maturity, pod and seed yields and drought tolerance.
- Ten fresh crosses were attempted for incorporating resistance/tolerance of different abiotic stresses into superior agronomic background.
- In summer, seed enhancement of 23 advanced breeding lines from plant-to-row was taken up for evaluation in station trials.
- Two preliminary yield evaluation trials (one each of Spanish and Virginia) and another two advanced trials (one each of Spanish and Virginia) were conducted in *kharif*.
- In various yield evaluation trials of Spanish groundnut, the yield of TG 37A (a variety fast becoming popular among farmers in Saurashtra region over the ruling variety GG 20), was the highest.
- Of the seven early maturing Virginia lines evaluated in the *kharif* and summer seasons, six were identified for early flowering.
- Under All India Coordinated Varietal Trials, JUN 27 was found promising at locations characterized for occurrence of mid- and end-of-season droughts. Another advanced breeding line PBS 30086 was tested in second year of initial varietal trials for Spanish groundnut.
- Nucleus seed (240 kg) of varieties Girnar 2 and Girnar 3 was produced.
- Ten crosses were effected in *kharif* 2010 to develop improved varieties resistant/tolerant of collar rot and stem rot, foliar diseases (rust and Late Leaf Spot, LLS) and PBND. The success rate was in the range of 5.1 to 22.8%.
- Interspecific crosses were made and the segregating and advanced breeding lines of these crosses were distributed to the eight centres of AICRP-G for making location specific selections. A total of 210 selections were made.
- A sick plot for large scale screening of groundnut genotypes against collar rot (*Aspergillus niger*) and stem rot (*Sclerotium rolfsii*) fungi was developed.
- It was revealed through scanning electron microscopy (SEM) that the genotype, CS 19 resistant to stem rot, possessed solid stem trichomes, wax deposits and compact arrangement of vascular cells while in the susceptible genotype GG 20 both solid stem trichomes and wax deposits were absent and the vascular cells were loosely arranged.
- SEM revealed that the testa of variety J 11 (possessing seed coat resistance) was rough on which conidia of *Aspergillus flavus* failed to germinate while on the testa of variety GG 20 (susceptible) conidia not only did germinate but also produced profuse mycelia.

- In *kharif*, compared to sole groundnut crop, the population of jassids in 'groundnut + Bt-cotton' showed an increasing trend from 30 DAG to 60 DAG. The population of thrips was smaller in 'groundnut + castor' while it was larger in 'groundnut + red gram' and 'groundnut + desi cotton' at 30 DAS. The highest yield of groundnut was, however, recorded in 'groundnut + cluster bean'.
- In *kharif*, seed treatment with imidacloprid (0.0035%) + 2 spray of 0.008% imidacloprid (30 and 45 DAG) was found the best in lowering jassid and thrips populations. The highest pod yield (1662 kg ha^{-1}) was, however obtained with 2 sprays of thiamethoxam at 30 and 45 DAG compared to that of control (1583 kg ha^{-1}) and other treatments.
- In *kharif*, seed treatment with acetamiprid @ 1 g kg^{-1} was most effective in reducing the incidence of jassids at 30 DAS and seed treatment with fipronil @ 1ml kg^{-1} was found most effective in reducing the incidence of thrips at 30 DAS. Highest pod yield and net returns were recorded in seed dressing with thiamethoxam @ 1g kg^{-1} seeds.
- Among various doses of imidachloprid used for seed treatment in *rabi*-summer, the dose of 5.0 g kg^{-1} seed was found not only most effective in reducing incidence of jassids (at 40 DAS) and thrips (at 30 and 40 DAS) but also gave the highest pod yield and net returns
- In *rabi*-summer, seed treatment with thiamethoxam @ 1g kg^{-1} seed was found superior in reducing jassid population while the seed treatment with fipronil @ 1 ml kg^{-1} seed proved best in reducing thrips population. The highest pod yield of groundnut (1179 kg ha^{-1}) was, however, recorded when seeds were treated with imidachloprid @ 2 g kg^{-1} seed. Two sprays (at 30 and 45 DAS) with 0.008% imidachloprid proved the best in reducing jassid population and 2 sprays (30 & 45 DAG) with 0.01% thiamethoxam was effective in managing thrips. Moreover, the highest pod yield (2032 kg ha^{-1}) was recorded with two sprays (at 30 and 45 DAS) with 0.01% thiamethoxam as compared to control (1630 kg ha^{-1})
- Biocontrol agent *Trichoderma harzianum* (DGR T-170) effectively reduced the stem rot disease. It was, however, not effective in suppressing afla-root disease.
- Occurrence of Alternaria leaf disease was seen on 60-day old groundnut crop in the areas surveyed in Kadavasan, Kodinar, Devali and Junagadh.
- The genotypes CS 168, code 1-1, CS 296 and ICGV 86590 showed less than 20% incidence of stem rot incidence while the genotypes CS 164, CS 104 and CS 316 showed less than 10% incidence of collar rot.
- The excessive rains in *kharif* 2010 did not permit full expression of soil borne diseases even in artificially inoculated conditions. But for foliar diseases, incidences up to 80% for early leaf spot, 30% for late leaf spot and 20% for rust were recorded.
- Results of several experiments and field trials including root studies were analyzed to propose the architecture of efficient root and shoot systems in groundnut for cultivation under both irrigated and rain-dependent conditions.

- Among various carriers evaluated for application of a consortium of beneficial bacteria, application through seed coating was found to be most effective.
- Application of AM fungi, viz., *Glomus etunicatum*, *Glomus fasciculatum*, *Glomus mosseae* and *Gigaspora scutellospora* improved growth, yield and nutrient uptake of groundnut cultivar TG 37A.
- Newly identified strain of groundnut rhizobia PAS 17-2 enhanced the pod yield of groundnut variety Girnar 2 by nearly 25% over the standard culture NC92.
- Seven DAPG-producing fluorescent pseudomonads were identified for having antifungal activities against major soil-borne fungal pathogens of groundnut
- In groundnut P, K, B and Zn were found to be important nutrients for pod-filling.
- Application of small doses (0.05 and 0.10 kg ha^{-1}) of nickel (Ni) and cobalt (Co) increased nodulation and pod yield of all cultivars
- The seed dressing with Mo showed synergistic effect with Ca, K and P in groundnut.
- Zn- and B-responsive groundnut cultivars were identified by screening 110 cultivars
- High Fe and Zn density cultivars were identified.
- For NEH region, cultivars GG 7, GG 13, ICGS 76 and CSMG 84-1 were identified as the high yielding ones.
- Cultivars NRCG 11551, NRCG 2538, NRCG 11656 were identified as tolerant to Al-toxicity
- Use of organic or 50% organic + 50% inorganic fertilizers was found to be superior over use of inorganic fertilizers alone
- Intercropping of maize, rice, sesame and mung was feasible in NEH.
- In NEH region groundnut could be grown on even discarded and highly eroded soils even if organic matter and fertility was too low.
- Varieties ICGV 86590 and TKG 19A were found to be most suitable for intercropping with maize, sesame, mung and rice in NEH region.
- The climate of NEH favoured cultivation of large seeded groundnut varieties like BAU 13, GG 20, CSMG 84-1 and ICGS 76.
- Groundnut fertilized with FYM (5 t ha^{-1})+50% RDF, wheat with FYM (5 t ha^{-1}) + 50% RDF and green manuring with green gram under 'groundnut-wheat-green gram' cropping system recorded the highest total system productivity (2451 kg ha^{-1}) and net returns (Rs 33541/-ha^{-1}).
- Application of 2 kg citric acid + 2 t FYM ha^{-1} significantly improved the pod yield (2605 kg ha^{-1})
- Maximum pod yield (1772 kg ha^{-1}) and net returns (Rs 25037/- ha^{-1}) were realized under 15 t FYM ha^{-1} with biofertilizers *(Rhizobium* and PSB) and biopesticides (*Trichoderma* and castor cake).
- Maximum pod yields of variety TG 37A and GG 2 were obtained with the application of 50 kg N, 80 kg P_2O_5, 100 kg K_2O, 150 kg Ca, 40 kg S, 50 kg Mg, 4 kg Zn and 1.5 kg B ha^{-1}.
- Pod and haulm yields improved significantly with successive increase in levels of N up to 37.5 kg, P up to 70 kg P_2O_5 and K up to 30 kg K_2O ha^{-1}.

- Pod and haulm yields improved significantly with application of 40-60-60 kg ammonium sulphate + SSP + MOP + 10:2:1 kg Fe Zn B ha^{-1}.
- For varieties GG 7 and GG 20, the highest pod and haulm yields were obtained with application of 60 kg N, 100 kg P_2O_5, 125 kg K_2O, 200 kg Ca, 50 kg S, 60 kg Mg, 5 kg Zn and 2 kg B ha^{-1}.
- Application of 100% RDF in furrows with flat bed check basin method of irrigation, being at par with 100% RDF through drip and 100% RDF in furrow with flat bed drip irrigation, significantly improved pod and haulm yield over 50 and 75% RDF through drip.
- Among various combinations of sources of nutrients, application of '20-40-30 kg urea-DAP-MOP + 250 kg gypsum + 10:2:1 kg Fe:Zn: B ha^{-1}' recorded the highest pod yield. The highest haulm yield was, however, obtained with 20-40-30 kg ammonium sulphate-SSP-MOP + 10:2:1 kg Fe:Zn:B ha^{-1}.
- Compared to lower levels, application of 25 kg N, 80 kg P_2O_5 and 60 kg K_2O ha^{-1} resulted in significant improvement in pod and haulm yields of *kharif* groundnut
- It was observed that water of up to 2-3 dS m^{-1} salinity could be used for optimum yield of groundnut but the yield were lower than those obtained with non-saline (normal) water.
- Among the various varieties tested in saline soil, under Spanish group SG 99 gave the highest yield.
- A total of 89 accessions under 6 sections viz *Arachis* (66), Caulorhizae (1), Erectoides (7), Heteranthae (7), Procumbentes (10) and Rhizomatosae (39) were maintained in the field gene bank. Another 1398 germplasm accessions including wild relatives of groundnut were supplied to 36 indenters for use in the crop improvement programme.
- For flowering behavior, both location and genotypic variations were found significant.
- Out of 67 Spanish bunch accessions evaluated for the presence of fresh seed dormancy, four accessions were registered as 'genetic stocks, with NBPGR. Two accessions possessed a long period of fresh seed dormancy of 60 days while two other accessions had fresh seed dormancy for 40 days.
- At Raichur, a hot spot centre, the incidence of PBND was high (50.3%) in the susceptible variety GG 11. One NRCG (NRCG 14625, 7.8%) and two ICRISAT (ICG 171, 8.5) mini core accessions had the least incidence (<10%). Besides, five NRCG mini core accessions and six ICRISAT mini core accessions recorded quite low (<20%) incidence of PBND.
- Nine transgenics were tested by RT-PCR for the expression of the *mtl*D gene sequence and 8 events of transgene expression were confirmed.
- Nine PCR positive plants were identified from the putative transgenics generated with annexin gene.
- Analysis by PCR using defensin gene-specific primers revealed the presence of the transgene in 14 putative transgenics.
- Sixty four polymorphic markers for parents JL 24 and ICGV 86590 were identified.

- One sequence of oxalate oxidase gene was isolated from barley and submitted to GenBank (Accession no. HQ634345).
- The oil content of a large number of samples analysed was in the range of 40.2 to 55.8%.
- Preliminary calibration of FT-NIR spectroscopy was completed to predict the oil content of groundnut samples in a non-destructive manner.
- The pattern of change due to drought in the methanol soluble and methanol insoluble seed proteins differed between Spanish and Virginia cultivars.
- Seven proteolytic bacterial cultures, tolerant to high temperature, salinity and heavy metals were isolated and evaluated.
- Two highly efficient proteolytic isolates of *Bacillus* sp. (SP8-14 and F1) were identified for slurry fermentation of de-oiled groundnut cake for producing proteases.
- The soil-population of *Aspergillus flavus* was higher in *kharif* than in *rabi*-summer conversely the seed infection of *A. flavus* was higher in *rabi*-summer produce than that in *kharif* produce.
- Soil population of *Aspergillus flavus* decreased when groundnut was grown in rotation with garlic, onion, or fallow land than that in groundnut-groundnut rotation
- It was shown that the practice of 'conditioning' of pods in groundnut processing units contributes to enhanced levels of aflatoxin in groundnut.
- Ten fresh crosses were made to incorporate large-seed size in high-yield varieties.
- For obtaining adequate seeds for different station trials, 22 advanced breeding lines were multiplied even as 49 lines (8 Spanish, 41 Virginia) were maintained.
- Hybridization for 12 back crosses was carried out at RRS, Virdhachalam during *rabi* seasons and more than 100 probable cross-pods were harvested for each cross combination. Hybridization for 13 fresh crosses was carried out during *kharif* season at Junagadh.
- In advanced yield trials, the pod yield of genotype NRCGCS401 was significantly higher than those of the best checks TG 26 (in summer) and GG 7 (in *kharif*).
- Two large-seeded Spanish groundnut genotypes were evaluated in AICRP-G trials during *rabi*-2009 and *rabi*-2010 seasons at seven locations.
- The Plant Germplasm Registration Committee approved registration of eight multiple disease resistant groundnut breeding lines germplasm (NRCGCS 21, NRCGCS 77, NRCGCS 83, NRCGCS 85, NRCGCS 86, NRCGCS 124, NRCGCS 180, NRCGCS 22) developed at DGR.
- Among the interspecific breeding lines (434) screened at MARS, UAS, Raichur, 77 and 111 lines scored less than 5% incidence for stem rot and PBND, respectively. For LLS, 26 lines and for rust 25 lines scored below 3 on a 1-9 scale. Besides, 55 genotypes showed multiple diseases resistance (stem rot, PBND, rust and LLS).
- Molecular diversity among 30 accessions of *A. glabrata* accessions was determined using RAPD and SSR primers.
- Salt responsive transcripts isolated from *A. glabrata* accessions showed similarity to a large number of stress responsive genes.

- Two nucleotide sequences 'bankit1384528HQ191219' (from TMV NLM-2) and 'bankit1384538HQ191220' (from *Arachis glabrata* accession ICG 8902) were submitted to the GenBank.
- The estimate of growth in groundnut area for the period 1991-2008 revealed that, the area under this crop has been declining in all the major groundnut growing states except Rajasthan where the area was in increasing trend. The rate of deceleration of area was highest in Tamil Nadu followed by Maharashtra, Karnataka and Andhra Pradesh.
- At AICRPG workshops, two genotypes 'ICGV 00350' and 'HNG 123' were identified for release. Three varieties identified earlier viz. 'Girnar 3', 'Kadiri Harit Andhra', and 'GPBD 5', were notified by Govt. of India. While one variety 'GJG-HPS-1' was notified by Govt. of Gujarat.
- A total of 16,407 q breeder seed comprising 47 varieties was produced.

During 2010-11 nine scientists joined DGR even as three left. The plan budget utilization in 2010-11 was nearly cent per cent for both DGR and AICRP-G.

PROJECT 01 : BREEDING AND GENETIC STUDIES ON TOLERANCE OF BIOTIC AND ABIOTIC STRESSES IN GROUNDNUT

(CHUNI LAL, A.L. RATHNAKUMAR, NARENDRA KUMAR*, AJAY B.C. **, K. S. JADON*, HARISH G. *, P.C. NAUTIYAL AND A. L. SINGH)

*Since May 2010 **Since January 2011

Sub-project 01: Breeding and genetic studies on tolerance of abiotic stresses in groundnut

(CHUNI LAL, AJAY B. C., P. C. NAUTIYAL AND A. L. SINGH)

Hybridization

During *kharif* 2010, ten crosses were attempted to incorporate tolerance of different *abiotic* stresses and yield attributes. Cross-wise hybridization success achieved is given in Table 1. An over all success rate of 26% was achieved.

Table 1. Cross-wise pollinations attempted, hybrid pods harvested and crossing success (*kharif* 2010)

Sr.. No	Parents	Desired traits	Buds pollinated (no.)	F_1 pods harvested (no.)	Success Rate (%)
1	Girnar 2 x Girnar 3	Fresh seed dormancy	407	93	23
2	Girnar 2 x Girnar 1	Drought tolerance	352	85	24
3	Girnar 2 x PBS 14081	High yield	308	65	21
4	PBS 14081 x TMV 2 NLM	Drought tolerance (high SCMR)	242	32	13
5	PBS 14081 x PBS 15031	High HI	615	72	12
6	Girnar 3 x NRCG 14425	Uniform maturity	388	65	17
7	PBS 14081 x NRCG 14405	High shelling	78	78	14
8	PBS 21095 x CS 303	Drought tolerance (high SCMR)	14	14	22
9	PBS 21087 x CS 1	Drought tolerance (low SLA)	90	90	21
10	PBS 16038 x CS 1	Drought tolerance (Low SLA)	60	60	11
		Total	**2554**	**654**	**26**

Selection and generation advancement in F_2 and successive generations

Since *kharif* 2010 was not a normal year due to excessive and prolonged rains, the yields were extremely poor and hence selections were not done. The segregating breeding material in different filial generations was advanced as such to the successive generations. The number of crosses in different filial generations was 9, 8, 20, 4, and 1 in F_3, F_4, F_5, F_6 and F_7, respectively.

Evaluation of segregating material at AICRP-G centre ARS, Durgapura, Jaipur

Seeds of 29 cross combinations supplied earlier to ARS Durgapura, were evaluated in *kharif* 2010 and advanced to next generations. Number of lines and single plants selections were made for further evaluation.

- An advanced breeding line RG 576 was derived through selection at ARS, Durgapura from the segregating material of a cross 'ICG 6766 x ICG 11524'. This line is being evaluated under AICRP-G.
- Lines derived from another cross 'ICG 913 x ICG 9346' through selection at ARS, Durgapura not only were resistant to collar rot but also recorded significantly higher pod yield over the checks in last couple of years.
- Lines developed at DGR from two cross combinations 'PBS 20176 x Code 26' and '(TKG 19A x Kadiri 3) x TKG 19A' evaluated at ARS, Durgapura in *kharif* 2010. These lines have shown superiority over checks for pod yield.
- 'TKG 19 A x Kadiri 3' in F_7 having high oil content and 'ICGS 11 x SB XI' in F_8 having fresh seed dormancy showed superiority for pod yield will be further evaluated in *kharif* 2011.

Maintenance breeding

In *kharif* 2010, 205 advanced breeding lines developed under different breeding programmes were maintained. These lines included 11 mutants of Girnar 1 and 17 WUE lines.

Station trials for yield evaluation

Advanced breeding lines developed for tolerance of various abiotic stresses were evaluated under preliminary yield evaluation trial for one year and advanced yield evaluation trial for two years. Observations were recorded on WUE (SCMR and SLA). In *kharif* 2010, due to prolonged and excessive rains the yields were very poor. Very few pods were formed and many plants did not bear any pod. The maturity was prolonged and kernel development was badly affected. Hence the trials were considered vitiated and it was decided to repeat these trials as such next year (*kharif* 2011). Besides WUE traits, only pod yield was recorded, and these traits are discussed trial wise hereunder.

Preliminary yield evaluation trial of breeding lines of Spanish groundnut

Twenty-three advanced breeding lines of Spanish groundnut along with three check varieties (GG 2, GG 7 and TG 37A) were evaluated for yield, besides surrogates of water-use efficiency (SLA and SCMR) in RBD with three replications. The plot size was of five rows of 5 m each. The planting geometry was 10 cm (plant to plant within a row) and 45 cm (row to row). Analysis of variance indicated highly significant differences due to genotypes. Among the check varieties, the highest SCMR and pod yield and the lowest SLA were observed for TG 37A. The results indicated that TG 37A has edge over GG 2 for yield. Out of seven advanced breeding lines found superior for SCMR, the SLA values of six were also significantly lower than the best check. In addition, the SLA of two more lines was significantly low. The pod yield of PBS 15027 and PBS 15029 was above one tonne yet was statistically at par with the best check variety (Table 2). The mean values for SCMR, SLA and pod yield were 22, 190 cm^2 $plant^{-1}$ and 679 kg ha^{-1}, respectively.

Table 2. Performance of selected advanced Spanish breeding lines for SCMR, SLA and yield in preliminary yield evaluation trial (*kharif* 2010)

Genotypes	SCMR	SLA	PY (kg ha^{-1})
Test entry			
PBS 11091	25*	160*	836
PBS 15018	25*	161*	590
PBS 15019	27*	163*	639
PBS 15020	25*	184	862
PBS 15022	23	172*	897
PBS 15023	24	156*	664
PBS 15027	25*	162*	1062
PBS 15029	24	194	1096
PBS 15030	23	161*	406
PBS 15034	27*	155*	794
PBS 15044	26*	176*	701
PBS 16046	22	166*	612
Check			
GG 2	17	208	454
GG 7	17	234	669
TG 37 A	22	200	900
Mean	22	190	679
CV %	9.9	8.8	23.5
CD (5%)	3	24	227

Advanced yield evaluation trial of breeding lines of Spanish groundnut

Twenty-three advanced breeding lines of Spanish groundnut along with three check varieties (GG 2, GG 7 and TG 37A) were evaluated for yield, besides surrogates of water-use efficiency (SLA and SCMR) in a RBD with three replications in *kharif* 2010. The plot size was five rows of 5 m each. The planting geometry was 10 cm (plant to plant in a row) 45 cm (row to row). Analysis of variance indicated highly significant differences due to genotypes. The highest SCMR and pod yield and the lowest SLA among the check varieties were observed for TG 37A. Compared to the best check variety, for three genotypes (PBS 16039, PBS 16044 and SE 8) significantly higher SCMR and lower SLA values were recorded (Table 3). In addition, the SCMR of genotype PBS 15045 was high. The pod yields were quite low (389 to 786 kg ha^{-1}).

Table 3. **Performance of selected advanced Spanish breeding lines for SCMR, SLA and yield in advanced yield evaluation trial (*kharif* 2010)**

Genotypes	SCMR	SLA	PY (kg ha^{-1})
Test entry			
PBS 15045	28*	209	627
PBS 16039	30*	165*	785
PBS 16044	33*	176*	786
SE 8	29*	183*	630
Check			
GG 2	23	228	365
GG 7	19	226	519
TG 37 A	23	205	933
Mean	24	212	607
CV (%)	13	6	25
CD (5%)	5	22	245

Preliminary yield evaluation trial of breeding lines of Virginia groundnut

Thirty-two advanced breeding lines of Virginia bunch groundnut along with two check varieties (GG 20 and Somnath) were evaluated for yield and surrogates of water-use efficiency (SLA and SCMR) in RBD with three replications. The plot size was of five rows of 5 m each. The planting geometry was 10 cm (plant to plant within a row) and 60 cm (row to row). Analysis of variance indicated highly significant genotypic differences for all the traits. The check variety Somnath was adjudged to be the best for all the three traits. Three entries PBS 24127, PBS 25046 and PBS 25054 out performed the best check variety for SCMR. For SLA none was significantly superior to the best check variety. The yields were very poor for all the test entries and the check varieties. The pod yield of Somnath, which was the best check variety, was only 549 kg ha^{-1}. Although the pod yields of two test entries PBS 24115 (721 kg ha^{-1}) and PBS 24119 (723 kg ha^{-1}) were significantly higher, yet the values were lower than the national average (Table 4).

Table 4. **Performance of selected advanced Virginia breeding lines for SCMR, SLA and yield in preliminary yield evaluation trial (*kharif* 2010)**

Genotypes	SCMR	SLA	PY (kg ha^{-1})
Test entry			
PBS 24115	22	175	721*
PBS 24119	22	177	723*
PBS 24127	26*	178	437
PBS 25046	26*	161	383
PBS 25054	26*	164	376
Check			
GG 20	22	166	468
Somnath	24	156	549
Mean	22	174	507
CV (%)	7	7	16
CD (5%)	2	17	106

Advanced yield evaluation trial of breeding lines of Virginia groundnut

Thirty groundnut genotypes comprising twenty-eight advanced breeding lines of Virginia bunch groundnut and two check varieties (GG 20 and Somnath) were evaluated for their performance in *kharif* 2010 under rainfed conditions. All the thirty genotypes were grown in a RBD with three replications. The plot size was of five rows of 5 m each. The plant-to-plant distance within a row was 10 while the rows were spaced 60 cm from each other. Highly significant genotypic differences were found for all the traits. GG 20 was found to be the best check variety for SCMR and pod yield, however, for SLA, Somanath was the best check variety. Six advanced breeding lines namely, PBS 15039, PBS 15040, PBS 25017, PBS 25047, PBS 25049 and PBS 29100 were rated significantly superior to the best check variety for SCMR. For SLA and pod yield, however, none of the test entries was found superior to the best check (Table 5).

Table 5. Performance of selected advanced Virginia breeding lines for SCMR, SLA and yield in advanced yield evaluation trial (*kharif* 2010)

Genotypes	SCMR	SLA cm^2g^{-1}	PY ($kg\ ha^{-1}$)
Test entry			
PBS 15039	26*	180	344
PBS 15040	30*	149	411
PBS 22066	22	203	1010
PBS 25017	25*	163	535
PBS 25047	27*	155	614
PBS 25049	25*	163	442
PBS 29100	26*	149	665
Check			
GG 20 22	180	839	
Somnath	21	171	684
Mean 23	183	625	
Cv (%)8	9	25	
CD (5%)	3	22	211

Evaluation of early maturing advanced breeding Virginia groundnut lines under rainfed conditions of *kharif* season

Seven advanced Virginia breeding lines derived from a cross chico x R 33-1 which were selected for early maturity, were evaluated in a RBD with three replications along with a variety Somnath as a check for early maturity in Virginia groundnut group. The line SE 32 was significantly early in flower initiation (FI) and days to 50% flowering (F_{50}) – components for early maturity- and SE 37 and SE 38 for days to 50% flowering only (Table 6). For WUE traits and pod yield no test entry was superior over the check variety. The highest yield (875 $kg\ ha^{-1}$) recorded was in Somnath variety, which was very poor compared to the national average.

Table 6. Evaluation of early maturing advanced breeding Virginia groundnut lines in *kharif* 2010 (high rainfall conditions)

Genotypes	SCMR	SLA cm^2g^{-1}	PY ($kg\ ha^{-1}$)	FI	F_{50}
Test entry					
SE 6	26	170	659	27	32
SE 23	23	205	265	27	30*
SE 32	24	232	356	24*	28*
SE 34	26	216	402	25	29*
SE 35	25	218	392	25	29*
SE 37	26	227	443	25	28*
SE 38	27	216	322	25	28*
Check					
Somnath	29	175	875	26	31
Mean	26	207	464	26	29
CV (%)	9	11	13	4	2
CD (5%)	5	50	137	2	1

Drought screening nursery

Along with 3 drought tolerant checks, 120 advanced breeding lines (identified for end of season drought tolerance in the previous season) were sown in drought screening nursery. This trial was, however, vitiated due to excessive rains throughout the crop season and hence will be repeated in *kharif* 2011.

Phenotyping of RILs (188 line) derived from a cross TAG 24 x TMV2 NLM for surrogate of water-use efficiency under rainfed conditions

Along with two parental lines, 188 RILs were raised in two replications for phenotyping for WUE traits (SLA and SCMR) and yield attributes under rainfed conditions. Due to excessive rains throughout the crop season the trial was also vitiated and hence will be repeated in *kharif* 2011.

Seed enhancement for AICRPG trials

Seed enhancement activity was undertaken for eight breeding lines (PBS 16034, PBS 16035, PBS 16039, PBS 16040, PBS 15031, PBS 11056, SE 28 and SE 25) for their entry in AICRPG Trials. The seeds of two breeding lines PBS 30086 and JUN 27, which are already under AICRP-G trials, were also multiplied.

PBS 16040

PBS 15031

Advanced lines in AICRP-G trials

Considering the good performance of test entry JUG 27 under mid- and end-of-season drought situations in 2008 and 2009, this entry was evaluated in advanced drought tolerance varietal trials in *kharif* 2010 under above drought situations. Another advanced-line, PBS 30086 was tested in IVT II under Spanish groundnut trials.

Nucleus seed production of DGR-groundnut varieties

In *kharif* 2010, 125 kg and 115 kg nucleus seed of Girnar 2 and Girnar 3, respectively was produced.

Supply of segregating material to AICRP-G centres

Detailed information on the crosses available in F_4 to F_6 generations (harvested in kharif 2009) was sent to different AICRP-G centres along with performa for Material Transfer Agreement. Accordingly, the segregating material of 19 crosses (15 crosses in F_4, 3 crosses in F_5 and 1 cross in F_6) was supplied to ARS, Durgapura and JAU, Junagadh centres.

Evaluation of early maturing advanced Spanish breeding lines for their suitability for summer cultivation

Single year of evaluation

Along with four checks (GG 2, Dh 86, TG 26 and TAG 24), 15 advanced breeding lines (11 selections derived from a single cross Chico x R 33-1) were evaluated in a randomized block design in summer 2010. Each genotype was sown in five rows (5 m each) and replicated thrice. Most of the test entries were the progenies of the early maturing cultivars Chico (Spanish) and R 33-1 (Virginia). The objective of the experiment was also to identify early maturing line(s) for summer situations i.e. the ones which could be harvested before onset of monsoon.

Observations were recorded on days to flower initiation and 50% plants to flower. SCMR and SLA values were recorded at 55th day after sowing on second fully opened leaf from the top of five randomly selected plants (irrigation was given a day before recording the values). Specific leaf area was determined in two ways, one before allowing the sampled leaves to float in water (SLA1) and another after allowing the sampled leaves to float in water (in petriplates) for 3 hrs (SLA2) (to compare two approaches). From these sampled leaves the water saturation deficit (WSD) was worked out. On attaining maturity, the crop was harvested. After drying the produce the pod yield/plot was recorded and expressed as kg ha^{-1}. Observations on harvest index (HI, %), hundred seed mass (HSM, g), mass of hundred selected (sound and mature) seeds (SMHSS, g), and shelling out turn (SOT, %) were recorded. Harvest index was expressed for both pod (HI_p) and kernel (HI_k).

Significant genotypic differences were observed for most of the traits studied. Among the check varieties, GG 2 was found the best for days to flower initiation and 50% flowering, and water saturation deficit (WSD); TG 26 was found the best for SCMR; and Dh 86 the best for pod yield; and TAG 24 was the best for kernel yield and the remaining traits. The pod and kernel yields of advanced breeding lines SE 28 were 3456 and 2488 kg ha^{-1}, respectively, and were significantly higher than those of the best check varieties (Table 7). Although, both DF_I and DF_{50} of this genotype were short (indicating early maturity), the genotype actually attained maturity in 107 days (medium maturity). DF_{50} values of advanced breeding lines SE 21 and SE 27 were significantly short. The SCMR values of the advanced breeding line PBS 11056 were high (Table 7).

Table 7. Descriptive statistics of various crop attributes and the promising Spanish genotypes (evaluation for one year)

Traits	Mean	Min	Max	CV %	CD 5%	Best Check	Promising advanced breeding lines
Days to FI	39	34	43	3.1	2	GG 2 (37)	SE 28 (34)
Days to 50% flowering	44	41	50	2.9	2.2	TAG 24 (45)	SE 21 (42), SE 27 (43), SE 28(41)
SPAD (SCMR)	39	33	46	7.1	4.6	TAG 24 (41)	PBS 11056 (46)
SLA1(cm^2g^{-1})	163	147	187	8.5	17.2	TAG 24 (149)	-
SLA2 (cm^2g^{-1})	167	150	193	9.3	15.2	TAG 24 (154)	-
WSD (%)	13	11	16	14.9	2.6	GG 2(12)	-
PY (kg ha^{-1})	2694	2044	3456	15.4	418.5	Dh 86(2953)	SE 28 (3456)
KY (kg ha^{-1})	1690	1267	2488	15.9	389.5	TAG 24(2094)	SE 28 (2488)
Hi_p(%)	40	33	50	21.4	14	TAG 24 (50)	-
Hi_k(%)	31	24	42	26.7	13.5	TAG 24(42)	-
HKW (g)	32	20	43	9.2	4.9	TAG 24(43)	-
HSMK (g)	42	26	55	8.8	6.2	TAG 24(52)	-
SMK (%)	39	32	50	13.9	9	TAG 24(48)	-
Shelling %	66	57	73	3.8	4.1	TAG 24(73	-
DM	105	100	111	1.8	3.1	TAG 24(102)	-

Two years of evaluation

The above experiment on 'evaluation of early maturing advanced breeding lines of Spanish type for their suitability for summer cultivation' was also conducted in summer 2009 (first year data already reported). However, in summer 2009 for recording SLA the sampled leaves were not floated in water for 3-h as done in summer 2010. Similarly, WSD was not recorded in summer 2009. Combined analysis of variance of the data pooled over two years (summer 2009 and summer 2010) for traits common in both the years revealed that differences due to years were significant only for SCMR and SMK. For all the traits studied, the genotypic differences were highly significant, however, genotype x year interactions were significant only for DF1, DF50, HI_p, SOT and DM. When means across the years for various traits were compared, a few test entries (SE 21 and SE 28 for DF1; PBS 11056, PBS 15031 for SCMR; and SE 28 for PY) were found to be significantly superior to the best check variety (Table 8). The entry SE 28, being consistent for high pod yield is to be tested under AICRP-G trials for summer situations.

Table 8. Descriptive statistics of various crop attributes and promising genotypes identified (evaluation for two years-summer 2009 and summer 2010)

Traits	Mean	Min	Max	CV %	CD 5%	Best check	Promising advanced breeding lines
Days to FI	34	30	36	4	2	TAG 24 (32)	SE 21(30), SE 28 (30)
Days to 50% flowering	45	41	49	4	2	Dh 86 (41)	-
SCMR	39	34	45	6	3	TAG 24 (40)	PBS 11056 (45), PBS 15031 (43)
SLA (cm^2g^{-1})	163	145	182	7	14	TAG 24 (145)	-
DM	2608	2035	3228	15	452	TAG 24 (2768)	-
PY (kg ha^{-1})	1748	1305	2098	16	317	TAG 24 (1992)	SE 28 (3228)
KY (kg ha^{-1})	38	30	49	19	8	TAG 24 (49)	-
Hi_p(%)	27	21	38	24	8	TAG 24 (38)	-
Hi_k(%)	32	20	41	12	5	TAG 24 (41)	-
HKW (g)	42	27	55	11	5	TAG 24 (51)	-
HSMK (g)	47	37	57	20	11	TAG 24 (57)	-
Shelling %	67	59	72	5	4	TAG 24 (72)	-

Evaluation of early maturing advanced Virginia breeding lines under summer conditions

In summer 2010, along with the early maturing Virginia check variety Somnath, seven advanced breeding sister lines derived from a cross of Chico and Robout 33-1 (early maturing Spanish and Virginia germplasm lines respectively) were evaluated in RBD with 3-replications. Except for SCMR, genotypic differences were highly significant for all the traits. Results indicated among the advanced breeding lines one or more were superior to the check variety-SE 37 for DF50; SE 23 for PY; SE 23, SE 34, SE 37 and SE 38 for KY; and SE 37 for SMK. Except SE 6, all the lines were significantly superior to check in respect of HIp, HIk and SOT. For DM, interestingly the values of all the lines were significantly smaller than that of check (Table 9). This trial will be repeated for one more season.

Table 9. Performance of early-maturing Virginia genotypes in summer 2010

Traits	SE 6	SE 23	SE 32	SE 34	SE 35	SE 37	SE 38	Somnath	CV (%)	CD (5%)
DFI	44	43	41	42	41	43	41	42	4	3
DF50	52	50	50	50	50	49*	50	50	2	1
PY (kg ha^{-1})	2018	4817*	3993	4299	3516	4347	4142	2960	24	1600
KY (kg ha^{-1})	983	3410*	2908	3150*	2547	3128*	2987*	1754	26	1196
HI_p (%)	20	47*	45*	42*	36*	45*	51*	25	11	7
HI_k (%)	12	38*	37*	35*	30*	38*	43*	16	13	7
SPAD	37	39	40	39	40	40	41	42	6	5
SLA1 (cm^2g^{-1})	173	180	156	157	157	159	152	135	6	17
SLA2 (cm^2g^{-1})	178	181	159	161	159	165	154	140	6	16
WSD (%)	17	16	14	14	14	13	14	16	14	4
HSM (g)	46	30	25	23	27	25	27	45	13	7
HSMK (g)	54	39	33	34	32	32	32	58	5	3
SMK (%)	47	39	38	48	33	56*	37	43	14	10
SOT (%)	49	71*	73*	73*	72*	72*	72*	60	2	3
DM	110*	105*	105*	105*	105*	102*	102*	115	2	1.9

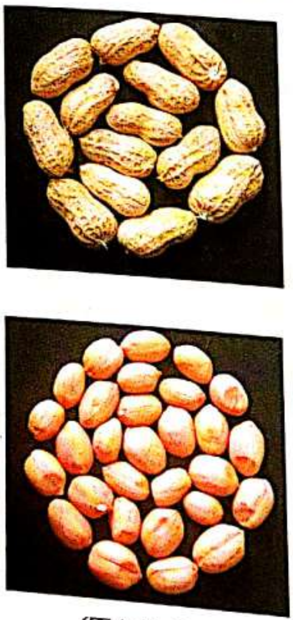
Phenotyping of RILs (188 line) derived from a cross (TAG 24 x TMV2 NLM) for surrogate of water-use efficiency under irrigated and drought situations

In summer 2010, the mapping population comprising 188 RILs derived from a cross (TAG 24 x TMV2 NLM) and developed for water-use efficiency traits were sown in a split plot design with two treatments (irrigated and drought) as main plot treatments and 190 genotypes comprising 188 RILs and the two parental lines (plot size: 2 rows of 5 m each). Soil moisture content at 0-5 and 5-10 cm soil depths was recorded regularly on alternate days and also before and after giving irrigation. The soil temperature was recorded daily at 8 am, 12 am and 4 pm at 0-5 and 5-10 cm soil depths. Observations on different traits were recorded by following standard procedures (SLA was recorded without floating the samples leaves in water as SLA1 and after floating same leaves in water for 3 hrs as SLA 2). Mid season drought was imposed.

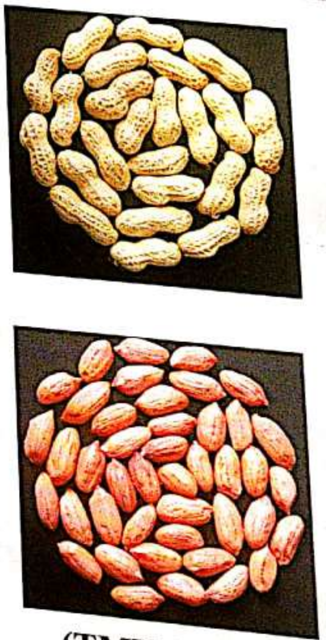
Highly significant effect of irrigation treatments was observed on all the traits studied except DFI and DF_{50}. In case of subplot treatment (genotypes) except for SLA 1 and SLA 2, highly significant differences were found for all the traits studied. Interactions between irrigation-levels and genotypes were not significant except for SCMR and pod yield. When the values of range and mean (averaged over 188-RILs) were compared with corresponding values of the parental lines, it was discernible that by crossing TAG 24 and TMV 2NLM, a very large range of variability was unlocked for all the traits. There was not much difference between the values of various means for RILs and those for parents (Table 10).

When comparison was made between the main plot treatments, it was observed that there was significant increase in the mean values of SCMR, WSD, HSM, SMK and SOT across the RILs and parents when drought was imposed (Table 11). However, in case of SLA1, HSMK, KL, KW, KL/KW, PY and KY under drought conditions there was significant decline in the mean values of these traits. There was no significant impact of drought on traits namely, DFI, DF_{50} and SLA2.

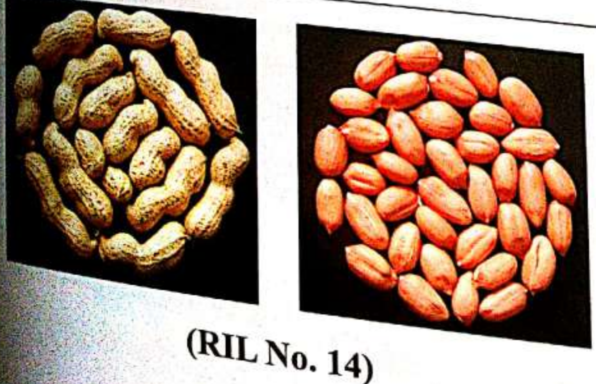
TAG 24 and TMV 2NLM with its RIL



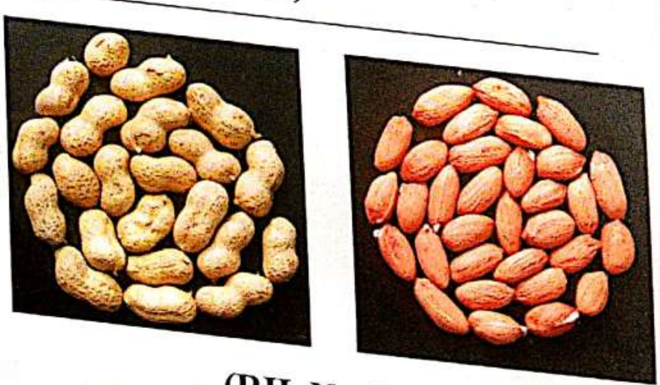
(TAG 24)



(TMV 2NLM)



(RIL No. 14)



(RIL No. 72)

Table 10. Descriptive statistics of various attributes of parental lines (TAG 24 and TMV 2NLM) and 188 RILs under irrigated and drought situations

Traits	Parents			RILs	
	TAG 24	TMV2 NLM	Mean	Range	Mean
DFI	44	41	42	39-49	43
DF50	47	52	49	45-54	48
SCMR	40	49	44	34-53	41
SLA1 (cm^2g^{-1})	153	165	159	134-223	165
SLA2 (cm^2g^{-1})	160	181	170	140-228	170
WSD (%)	18	23	21	8-27	16
HSM (g)	37	38	37	23-66	41
HSMK (g)	49	50	49	30-75	52
SMK (%)	48	33	41	26-71	43
SOT (%)	70	63	67	47-75	66
KL (mm)	12.7	15.7	14	9.4-18.2	14.0
KW (mm)	8.4	7.5	8	5.5-9.9	8.3
KL/KW	1.5	2.1	2	1.3-2.0	1.7
PY (kg ha^{-1})	3681	1944	2812	1182-6840	3757
KY (kg ha^{-1})	2567	1245	1906	771-4494	2475

Table 11. Mean values of different traits under irrigated and drought conditions across 188 RILs and the two-parental-lines.

Trait	Irrigated	Drought	CD (5%)
DFI	43	43	NS
DF50	48	48	NS
SCMR	39	43	0.4
SLA1 (cm^2g^{-1})	183	157	18.5
SLA2 (cm^2g^{-1})	180	170	17.7
WSD (%)	14	19	0.6
HSM (g)	40	42	1.5
HSMK (g)	53	51	0.7
SMK (g)	42	44	1.3
SOT (%)	65	67	0.8
KL (mm)	14	14	0.2
KW (mm)	8	8	0.1
KL/KW	2	2	0.0
PY (kg ha^{-1})	4223	3271	122.9
KY (kg ha^{-1})	2757	2182	84.8

Raising of F_1 generation and selection of true hybrids

Ten crosses attempted in *kharif* 2009 for different objectives were raised in summer 2010 and cross wise true hybrid plants were selected. In cross 'SE 22 x VG 9816', not even a single hybrid plant could be identified. In other crosses, though the number of true hybrids identified was very small yet a very high number of F_2 pods were produced.

Raising of advanced breeding lines and DGR-varieties

Single plant progenies of 23 new advanced breeding lines developed in *kharif* 2009 were raised in summer 2010 for seed enhancement for their evaluation the station trials in coming seasons. Three varieties, Girnar 1, Girnar 2 and Girnar 3, developed at DGR were raised for exhibition.

Sub-project 02 : Breeding and genetic studies for tolerance of biotic stresses in groundnut

Crosses effected

In *kharif* 2010, for developing improved varieties resistant/tolerant of collar rot and stem rot, foliar diseases (rust and Late Leaf Spot, LLS) and Peanut Bud Necrosis Disease (PBND), ten crosses were effected (Table 1 and 2). The number of cross-pods was between 19 and 82 with a success rate of 5.1 to 22.8%. Of these, three crosses were made for developing mapping populations (RILs) for stem rot, collar rot and foliar diseases. The success rate in two crosses was quite low 5.1% in 'GG 20 x JSP 19' and 9.2% in 'GPBD 4 x VG9816'.

Table 1. Particulars of crosses effected in *kharif* 2010

	Parents	Objective	F_1 pods obtained	Success (%)
1	GG 20 x ICGV 87846	Tolerance of stem rot	32	9.6
2	GG 20 x JSP 39	Tolerance of stem rot	19	5.1
3	TG 37 A x SGL 4233	Tolerance of collar rot	69	13.6
4	ICGV 00350 x ICGS 44	Tolerance of PBND	37	10.4
5	ICGV 00351 x ICGS 44	Tolerance of PBND	68	22.8
6	TMV Gn 13 x VG 9816	Tolerance of rust, LLS and PBND	72	18.6
7	GPBD 4 x VG 9816	Tolerance of rust, LLS and PBND	38	9.2
		Total	**335**	

Table 2. Particulars of crosses effected in *kharif* 2010 to develop mapping populations (RILs)

	Parents	Objective	F_1 pods obtained	Success (%)
1	CS 158 x CS 19	Tolerance of stem rot	73	18.3
2	GG 7 x SGL 4233	Tolerance of collar rot	82	22.1
3	TMV (Gn) 13 x VG 9816	Tolerance of rust, LLS and PBND	72	18.6
		Total	**227**	

Advancement of filial generations

Progenies of 70 crosses were advanced to their next filial generations, of which seven crosses were rejected due to a large proportion of poor recombinants. The number of crosses in early generations were 30 and in advanced generation 40.

Since, the *kharif* 2010 season was not favourable due to excessive rains at peak flowering, pod formation, and pod filling stages the selections could not be made. Hence, from F_3 to F_6, a total of 44 progeny bulks could be made from 48 crosses. In F_6, 19 crosses were advanced and a total of 19 progeny bulks were selected.

Development of mapping populations

Development of mapping populations (RILs) was attempted with the objectives of:

- Screening of the spectrum of genetic variability generated in the F_2 generation from the crosses of contrasting parents, in hot spots for target diseases
- Identification of DNA markers associated with the resistance/susceptibility to target diseases.

In *kharif* season, the F_1s of four crosses (three for tolerance of stem rot and one for collar rot) were raised (Table 3) while from F_2s of three crosses (two for stem rot and one for both LLS and rust) 137, 129 and 82 RILs, respectively, were obtained (Table 4). In cross 'JL 24 x VG 9816', the number of F_2s obtained, however, was small (82)

Table 3. True F_1s identified among the crosses in mapping population (RILs)

Cross	No. of true F_1s identified
For tolerance of stem rot:	
GG 20 x CS 19	44
GG 20 x CS 75	59
GG 20 x CS 83	45
For tolerance of collar rot:	
GG 20 x SGL 4233	48

Table 4. RILs (F_2s) obtained in various crosses made for developing mapping populations

Cross	RILs obtained
For tolerance of stem rot:	
GG 20 x CS 19	137
GG 20 x JSP 39	129
For tolerance of rust, LLS:	
JL 24 x VG 9816	82

Yield evaluation trials

Ten promising genotypes, PBS 21085, PBS 22059, PBS 22062, PBS 22063, PBS 22064, PBS 22065, PBS 22066, PBS 22067 and PBS 22074 were in different stages of yield evaluation. Over two years, the pod yield of three genotypes, PBS 22059, 22066, and 22067 was significantly higher that of the best check, GG 20. These entries will be multiplied in *kharif* 2011 for multi-location testing of AICRP-G.

Release of varieties

The genotype PBS 12030, developed earlier was released as a new variety Girnar 3 for cultivation in *kharif* in Orissa, West Bengal and Jharkhand. The pedigree of this variety included Girnar 1, a multiple diseases resistant variety, as an ovule parent and ICGS 11, a PBND resistant variety, as a male parent.

Multiplication, distribution of breeding materials to different AICRP-G centres:

Multiplication of breeding materials

A total of 91 advanced generation breeding materials (40 Spanish and 51 Virginia) developed earlier for tolerance of various biotic stresses, were multiplied in *kharif* season 2010.

Distribution of breeding materials to AICRP-G centres

Specific crosses were made to strengthen the breeding programme of the centres of AICRP-G and for supplying the breeding materials of interspecific hybrid origin. The segregating and advanced breeding lines of these crosses were distributed to eight centres to effect location specific selections (Table 5). A total of 210 selections were made in different filial generations at various centres of AICRP-G.

Development of sick plot for collar rot disease

In *kharif* 2010, a sick plot was developed to facilitate screening of segregating and advanced generation breeding materials for collar rot disease. The initial soil microflora was studied in all the plots. The inoculums of virulent isolates were mass multiplied and mixed with FYM and applied separately to each of the micro plots. The growth and multiplication of *Asergillus niger*, the causal organism of collar rot, was monitored in the soil regularly at monthly intervals before subsequent addition of inoculum. Similar observations were also made in the sick plot for stem rot disease.

The study indicated that the soil population of *A. niger* increased steadily from 1.8 to 23.4 X 10^3 cfu during June to October (Figure 1) in spite of the heavy rainfall. While the soil population of *Sclerotium rolfsii* decreased drastically during June to August and subsequently increased gradually up to October (Figure 1).

Thus, the build up of population of *A. niger* was unaffected by heavy rainfall. This indicated that if the rains cease and the optimal conditions is restored, there would be a sudden spurt of occurrence of collar rot while in case of stem rot, the development of disease would be quite slow. Thus, for stem rot, the chemical control would be possible while genetic resistance and seed treatment with systemic insecticides would be required before sowing to control occurrence of collar rot.

Table 5. **Particulars of segregating and advanced breeding lines (F_3-F_6) supplied to AICRP-G centres**

Sr. No.	Crosses	Centres
F_3: Multiple diseases resistance (rust, LLS, stem rot) breeding lines		
1	GG 20 x CS 19	UAS, Dharwad, JAU, Junagadh
2	SG 99 x CS 19	RAU, Durgapura
F_3:Multiple diseases resistance (rust, LLS, PBND) breeding lines		
3	TG 37 A x VG 9816	OUA&T, Bhubaneshwar
4	TMV 2 x ICGV 86590	ANGRAU, Kadiri
F_4: Foliar diseases resistance (rust, LLS) breeding lines		
1	SG 99 x GPBD 4	NAU, Vyara
2	TG 37 A x ICGV 86590	ANGRAU, Kadiri
F_4: Foliar diseases resistance (rust, LLS) breeding lines and adaptability to *kharif* and rabi-summer seasons		
1	R 2001- 2 x SG 99	TNAU, Vridhachalam
2	SG 99 x TG 37 A	NAU, Vyara
3	Dh 86 x TG 37 A	OUA&T, Bhubaneshwar
F_5: Foliar disease resistance (rust, LLS) breeding lines with tolerance of sucking pests (jassids and aphids)		
1	SG 99 x TAG 24	OUA&T, Bhubaneshwar
2	Dh 86 x CS 19	OUA&T, Bhubaneshwar
F_6: Foliar diseases (rust, LLS) and stem rot tolerant breeding lines		
1	GG 20 x CS 19	JAU, Junagadh
2	CS 19 x GG 20	
3	CS 19 x PBS 24030	
4	GG 20 x GPBD 4	NAU, Vyara
5	PBS 24030 x CS 19	
F_6: PBND tolerant breeding lines		
6	PBS 24030 x GG 20	RAU, Durgapura

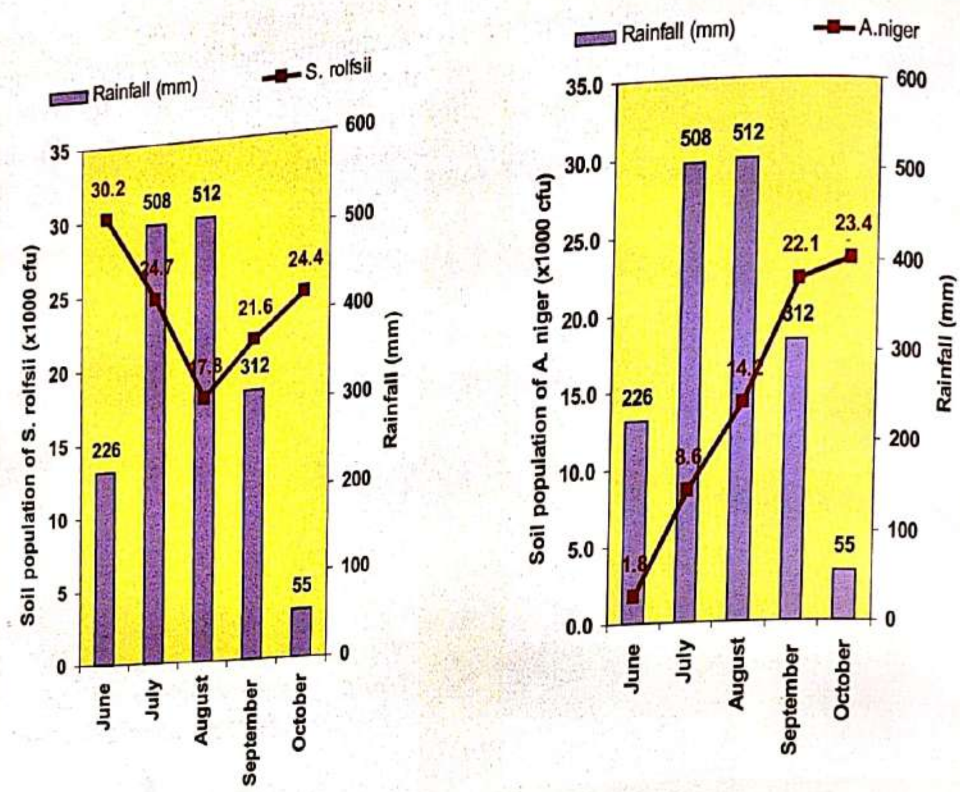


Figure 1. Build-up of soil population of *Sclerotium rolfsii* and *Aspergillus niger* in the sick plot

Studies on the mechanisms of resistance:

In the control of stem rot disease

Since, stem rot is rampant not only in rainfed *kharif*, but also in irrigated *rabi* and summer production systems, the genetic resistance to the disease is very important. Among the few sources available, CS 19, an interspecific derivative developed at DGR is a registered novel source of resistance. Understanding of the mechanisms of resistance will be very useful for proper exploitation of resistance in CS 19. Since the fungus secretes oxalic acid and penetrates the host tissue, either structural barrier or antibiosis would be the expected cause of resistance in CS 19. The scanning electron microscope (SEM) available at CSMCRI, Bhavnagar, was used for the purpose. *In priori*, the time of infection and entry of the fungus was standardised and it was observed that within 3 days the fungus gained entry in to the host cell of both susceptible variety, GG 20 and the resistant genotype CS 19.

Scanning electron microscopy of cross section of stems revealed the resistant genotype, CS 19, possessed i) solid trichomes ii) wax deposits and iii) compact arrangement of vascular cells (Figure 3) which could be affording it resistance to stem rot. While the susceptible variety, GG 20, lacked solid trichomes and wax deposits (Figure 4) and had loosely arranged vascular cells which could predispose it for heavy incidence of stem rot.

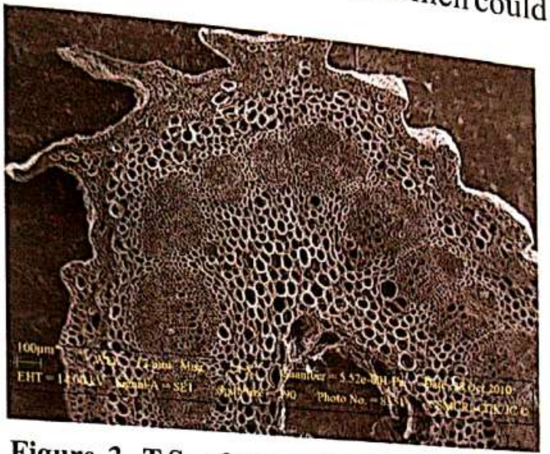


Figure 3. T.S. of stem of genotype CS 19 showing solid stem trichomes and compact arrangement of vascular bundles

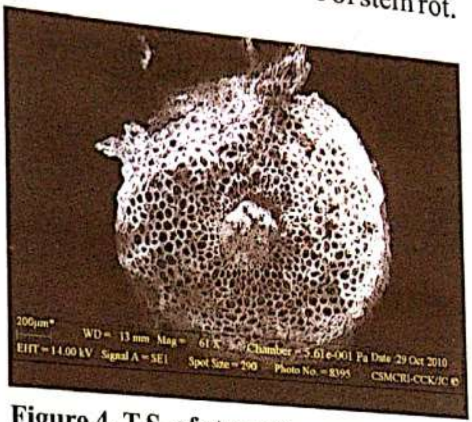


Figure 4. T.S. of stem of genotype GG 20 showing absence of trichomes and loose arrangement of vascular bundles

Control of *Aspergillus flavus*:

The fungus, *Aspergillus flavus* is a ubiquitous fungus which infects pods and kernels and produces aflatoxin. There are only very few sources of resistance to *A. flavus*. Cultivar J 11 has been reported to be a source of seed coat resistance.

It was revealed through electron microscopy that seed coat of the kernels of J 11 was rough and the conidia of *A. flavus* failed to germinate even after three days of inoculation (Figure 5) whereas in GG 20 (a susceptible cultivar) numerous conidia germinated and grew profusely to completely cover the testa (Figure 6). The study confirmed the seed coat resistance of J 11.

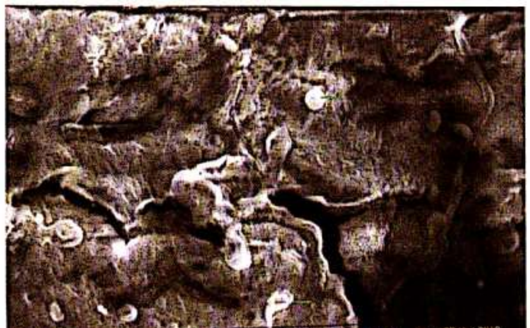


Figure 5: Rough seed coat of J 11 showing a spore of *A. flavus* which failed to germinate

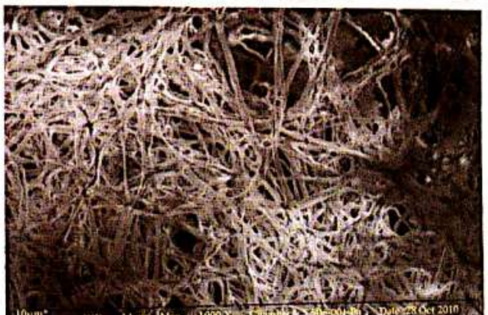


Figure 6: Profuse growth of mycelia of *A. flavus* which completely covered the seed of GG 20

Screening of advanced breeding materials for stem rot and *Aspergillus flavus* seed colonisation and infection:

Along with the susceptible variety TAG 24, twenty advanced breeding lines were screened in the sick plot in summer 2010 for their reaction to stem rot and also *in vitro* seed colonisation by *Aspergillus flavus*.

In sick plot, the highest incidence (67.1%) of stem rot was observed in genotype CS 421, which was followed by the check variety, TAG 24 (64.3%) and the genotype PBS 14068 (63.1%). Thus under high disease pressure, none of the genotypes was found resistant. Three genotypes, VG 0107 (21.6%), PBS 14060 (26.5%) and PBS 14064 (27.3%), however, showed tolerance reaction.

In vitro studies on seed infection and colonisation by AF 111, a virulent strain of *Aspergillus flavus*, indicated that the accessions differed significantly for seed infection and colonisation by *Aspergillus flavus*.

PROJECT 02 : INTEGRATED PEST MANAGEMENT (IPM) IN GROUNDNUT BASED PRODUCTION SYSTEM

(P. P. THIRUMALAISAMY, HARISH, G*, K. S. JADON* AND PRASANNA, H.**)

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** Included as an associate since February, 2011

Sub-project 01: Management of insect pests in groundnut based production system

Integrated Pest Management in groundnut based inter cropping system

An experiment on integrated insect pest management (IPM) in groundnut based intercropping system was conducted during *kharif* 2010. The cultivar GG 20 was sown in replicated trial in plot size of 6 x 5 m at 45 cm distance between the rows. There were 10 treatments and three replications. Groundnut was intercropped with sunflower (local), castor (GAUCH-4), pigeon pea (BDN-2), soybean (local), green gram (K-851), cluster bean (local), Bt cotton (MRC 6301), desi cotton (Deviraj) and hybrid cotton (G Cot 10) in a row ratio of 3:1.

The result indicated that the intercrops like sunflower harboured significantly smaller population of jassids compared to other intercrops at 30, 45 and 60 DAS. The results indicated that with red gram as intercrop, the population of thrips was the largest while with castor it was the least at 30, 45 and 60 DAS.

The intercrops had a significant effect on the pod yield of groundnut. The highest pod yield of groundnut was recorded in 'groundnut + cluster bean' which was followed by 'groundnut + castor', and the lowest pod yield was recorded in 'groundnut + soybean'.

Efficacy of new molecules for controlling sucking insect pests of groundnut (*kharif*)

T1:	Seed treatment with 0.0035% imidachloprid
T2:	T1 + 1 spray (30 DAG) with 0.008% imidachloprid
T3:	T1 + 2 sprays (30 & 45 DAG) with 0.008% imidachloprid
T4:	1 spray (30 DAG) with 0.008% imidachloprid
T5 :	2 sprays (30 & 45 DAG) with 0.008% imidachloprid
T6:	1 spray (30 DAG) with 0.05% carbosulfan
T7:	2 sprays (30 & 45 DAG) with 0.05% carbosulfan
T8:	1 spray (30 DAG) with 0.05% acetamiprid
T9:	2 sprays (30 & 45 DAG) with 0.05% acetamiprid
T10:	1 spray (30 DAG) with 0.05% profenophos
T11:	2 sprays (30 & 45 DAG) with 0.05% profenophos
T12:	1 spray (30 DAG) with 0.01% thiomethoxam
T13:	2 sprays (30 & 45 DAG) with 0.01% thiomethoxam
T14:	2 sprays (30 & 45 DAG) with 0.04% monocrotophos
T15:	Untreated control

Compared to control and other treatments, T3 was found the best in controlling the populations of jassids. The highest pod yield of 1662 kg ha^{-1} was, however, obtained with T13 while the lowest pod yield of 1583 kg ha^{-1} was in control.

Figure 1. Soybean intercropped with groundnut

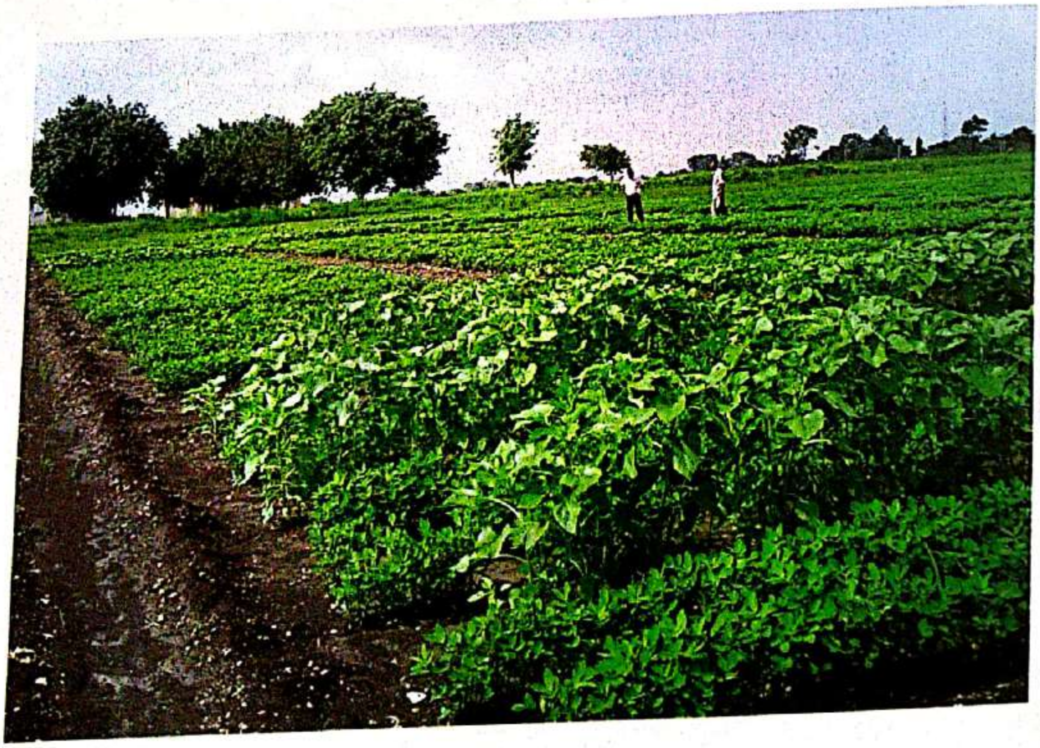

Figure 2. Sunflower intercropped with groundnut

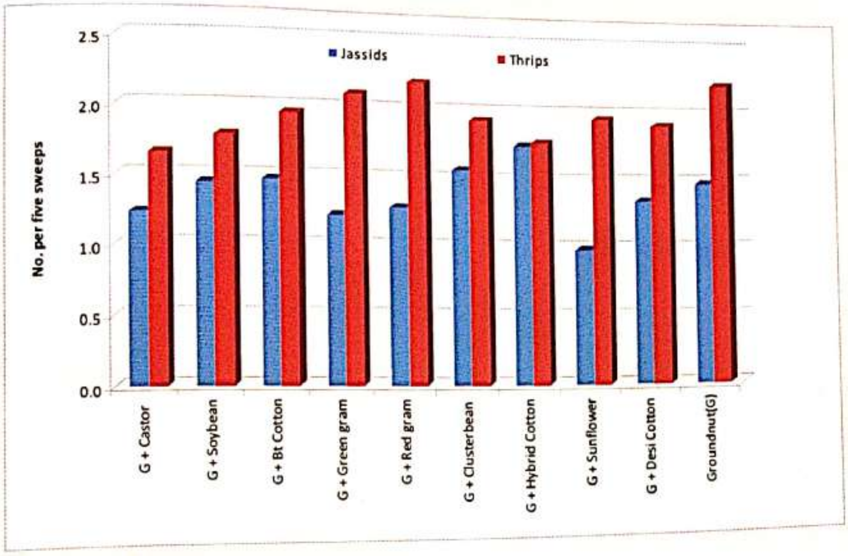

Figure 3. Effect of intercrops on sucking pests of groundnut

Effect of treatment of seeds with insecticides on sucking pests of groundnut during *kharif*

An experiment was conducted during *kharif* 2010 to test efficacy of seed treatment of insecticides for the management of sucking pests of groundnut. The treatments were,

- T1: Fipronil @ 1ml kg^{-1};
- T2: Imidacloprid @ 2mlkg^{-1};
- T3: Acetamiprid @ 1g kg^{-1};
- T4: Carbosulfan @ 5mlkg^{-1};
- T5: Thiamethoxam @ 1g kg^{-1};
- T6: Chlorpyriphos @ 6ml kg^{-1};
- T7: Foliar spray of monocrotophos 0.04 % at 30 and 45 DAS and
- T8: Untreated control

The treatment T3 was found to be the most effective in reducing the incidence of jassids at 30 DAS and T1 found most effective in reducing the incidence of thrips at 30 DAS. Highest pod yield and net returns were, however, recorded in T5.

Effect of treatment of seeds with imidacloprid on sucking pests of groundnut during *kharif*

An experiment was conducted during *kharif* 2010 to test efficacy of seed treatment of insecticides for the management of sucking pests of groundnut with the following treatments, T1: Imidacloprid @ 0.5 g kg^{-1}; T2: Imidacloprid @ 1.0 g kg^{-1}; T3: Imidacloprid @ 2.0 gkg^{-1}; T4: Imidacloprid @ 3.0 gkg^{-1}; T5: Imidacloprid @ 4.0 gkg^{-1}; T6: Imidacloprid @ 5.0 g kg^{-1}; T7: Foliar spray with monocrotophos 0.04 % at 30 and 45 DAS and T8: Untreated control. Among different treatments, seed treatment with Imidacloprid @ 5.0 g kg$_{1}$ was found superior in reducing the jassids incidence at 40 DAS and also was found superior in reducing the thrips incidence at 30 and 40 DAS. Highest pod yield and net returns was recorded in Imidacloprid @ 5.0 g kg^{-1} treated plots.

Effect of seed treatment of imidacloprid (70% WS) on the infestation of sucking pests of groundnut, cultivar GG 2 during summer

Among various doses evaluated, seed treatment with imidachloprid (70 % WS) @ 5g kg^{-1}; seed was found to be the best in controlling the infestation of jassids and thrips and the pod yield (1964 kg ha^{-1}) was also highest in this treatment and was on par with the pod yield (1976 kg ha^{-1}) obtained with the standard practice of spray of monocrotophos (0.04 % at 30 and 45 DAS).

Effect of spray of new insecticides on infestation of sucking pests of groundnut in summer 2010

Seed treatment of new insecticides was effective in reducing the population of jassid and thrips. Among the new molecules tested, seed treatment with Thiamethoxam @ 1g kg^{-1} seed was found superior in reducing jassid population and seed treatment with Fipronil @ 1 ml kg^{-1} seed proved best in reducing thrips population. However, the highest yield (1179 kg ha^{-1}) was recorded when seed was treated with imidachloprid @ 2g kg^{-1} seed as compared to control (799 kg ha^{-1}).

Effect of New molecules against sucking pests of groundnut during summer

Two sprays (at 30 and 45 DAS) of 0.008% imidachloprid proved best in reducing jassids population and 2 sprays (at 30 and 45 DAG) of 0.01% thiamethoxam was effective in managing thrips. The highest pod yield of 2032 kg ha^{-1} was, however, recorded in the two sprays of thiamethoxam. The yield of control was 1630 kg ha^{-1}.

Sub-project 02: Integrated management of major diseases (ELS, LLS, Rust, Collar Rot, Stem rot, PBND) of groundnut

Management of *Sclerotium rolfsii* through biocontrol agent during summer

The biocontrol agent *Trichoderma harzianum* (DGR T-170) was multiplied initially on sorghum grains and then further enriched on FYM. The FYM enriched with bio control agent was applied along the seed placement row. The stem rot pathogen, *S. rolfsii* multiplied on sorghum grains was also applied in the same seed placement row. In the control trial, only *S. rolfsii* was applied. The incidence of stem rot in the plot treated with *Trichoderma* was 7.4% and the pod yield was 1935 kg ha^{-1} while the corresponding values in control plot were 14.1% and 1661 kg ha^{-1}, respectively.

Management of *Aspergillus flavus* through biocontrol agent during summer

The incidence of afla-root disease caused by *A. flavus* was 4.8% in the plots which were treated with *Trichoderma harzianum* (DGR T-170) while it was 4.9% in the control plot. Thus it was indicated that it may not be possible to manage *A. flavus* by using bio-control agent.

Survey of incidence of *Alternaria* leaf disease of groundnut in the Saurashtra region of Gujarat during summer

Areas of Kadavasan, Kodinar, Devali and Junagadh were surveyed during the first fortnight of April, 2010 for recording the incidence of *Alternaria* leaf disease.

The disease was not seen on 60-day old crop in the fields. In the DGR experimental plot, however, the disease appeared slowly on 70-day old crop and the severity reached up to of 20% (4 in 1-9 scale) at the time of harvest. It seems, that the pathogen could not establish itself due to very high temperatures and low relative humidity in the atmosphere. Sporadic incidences of collar rot, stem rot and bacterial leaf spot were observed during the survey.

Management of *Alternaria* leaf disease in groundnut using fungicides during summer

Due to late appearance (70 DAS) and low severity (<20%) of the *Alternaria* disease in the field, the experiment was abandoned.

Evaluation of genotypes for reaction to soil borne diseases (stem rot and collar rot) in artificially inoculated conditions during summer

The check variety GG 2, along with nineteen genotypes was evaluated for incidence of stem rot (*Sclerotium rolfsii*) under artificially inoculated conditions. Four genotypes, CS 168, code 1-1, CS 296 and ICGV 86590 exhibited lower than 20% incidence of stem rot. The pod yield was, however, highest in CS 160 (173 g 2m^{-1} row). In another experiment, nineteen genotypes and check variety GG 2 were evaluated for the incidence of collar rot disease (*Aspergillus niger*). Three genotypes CS 164, CS 104 and CS 316 showed less than 10% incidence of collar rot. The pod yield was highest in CS 164 (322 g 2m^{-1} row).

Screening of genotype in concrete block under artificially inoculated conditions during *kharif*

A total of nineteen genotypes and check variety GG 2 were evaluated for the incidence of stem rot (*Sclerotium rolfsii*) under artificially inoculated conditions. The incidence was in the range of 8.50 to 47.02%. In five genotypes, CS-323, Code-1, CS-296, CS-334 and CS-160 the incidence was low with values of 8.50, 10.83, 12.50, 13.82 and 15.00%, respectively. In another experiment, nineteen genotypes and check variety GG 2 were evaluated for the incidence of collar rot (*Aspergillus niger*). The genotypes CS-316 (8.66%) and CS-81 (8.82%) has shown less than 10% incidence.

Screening of genotypes for disease resistance in sick plots during *kharif*

Due to heavy rains and continued water-logged condition in the fields, screening for soil-borne diseases (stem rot, collar rot and afla-root) could not be done. The severity of early leaf spot was as high as 80% (8 in 1-9 scale) while the severity of late leaf spot and rust were relatively as low as 30% and 20% (5 and 4 in 1-9 rating scale), respectively.

Biological control of soil borne and foliar fungal diseases during *kharif*

A field experiment was conducted to study the effect of bio-agents on soil-borne and foliar fungal diseases. Since the incidences of soil-borne diseases viz., afla-root, collar rot and stem rot were lowest (2.00, 4.98, and 4.68 percent respectively) in the control, the values were not statistically different from the treatments. This was due to heavy rainfall and water-logged condition in fields up to 70 days in which pathogen could not establish itself in the soil. Whereas foliar disease ELS, was quite severe (up to 8 in 1-9 rating scale) in the first 70 days of the crop, and this was followed by LLS and rust up to the maturity of the crop. Although the disease severity was very high, continuous and excessive rains smothered the disease suppressive effect of bio-agents.

Integrated Disease Management of major diseases of groundnut during *kharif*

An integrated approach for the management of major diseases namely stem rot, collar rot, afla-root, ELS, LLS and rust was tried in field conditions using the susceptible cultivar GG 2. As the incidences of soil borne diseases viz., afla-root, collar rot and stem rot, were quite low (1.08, 2.67, and 1.81%, respectively) even in the susceptible cultivar the differences between control and treatments were not significant. This was due to heavy rainfall and water-logged condition of fields up to 70 days which did not permit the pathogen to establish itself in soil. Whereas, ELS appeared very severely (upto 8 in 1-9 rating scale) in the first 70 days of the crop, followed by LLS and rust during maturity of the crop. Though disease severity was very high, continuous rain hindered the effect of different treatments on disease suppression.

Evaluation of new fungicides against soil-borne diseases during *kharif*

For management of stem rot, collar rot and afla-root diseases, various fungicides: Hexaconazole (2 ml kg^{-1}), Hexaconazole (1 ml kg^{-1}) + Captan (3 g kg^{-1}), Carbendazim + Mancozeb (3 g kg^{-1}), Tebuconazole (1.5 g kg^{-1}), Propiconazole (2 ml kg^{-1}), Difenconazole (2 ml kg^{-1}), Vitavax (2 gkg^{-1}), Carbendazim (2 gkg^{-1}), Mancozeb (3 gkg^{-1}), and Captan (3 gkg^{-1}) were used for treating seeds of groundnut. Due to heavy rainfall and continuous water logged conditions in the field upto 70 days, the incidence of soil-borne diseases was very low and hence the experiment was wound up without any conclusion.

Management of *Sclerotium rolfsii* through bio-agent, *Trichoderma* spp. (isolates of Dharwad and DGR T-170) during *kharif*

The crops raised after treating the seeds and soil with various isolates of *Trichoderma,* differed in the incidence of stem rot. The incidence was 12.96% with 'DGR 170' while it was 12.65% with 'Dharwad' and 11.77% with the control. Excessive rainfall and continuous water logged field conditions adversely affected the potential of bio-agents to suppress the stem rot pathogen.

Figure 4. Survey of incidence/severity of diseases in the Saurashtra region of Gujarat

Figure 5. Multiplication of *Trichoderma harzianum* (DGR T-170) on FYM

PROJECT 03 : PHYSIOLOGICAL STUDIES ON ENVIRONMENTAL STRESSES IN GROUNDNUT

(P. C. NAUTIYAL, RADHAKRISHNAN T., S. K. BISHI, K. CHAKRABORTY AND K. A. KALARIYA)

A conceptual model for drought tolerance in groundnut

Morphological traits

In groundnut, a compact canopy architecture was found to be directly associated with leaf and canopy temperatures, whereas plant height was inversely associated with net photosynthetic rate (P_N). Among the leaf characteristics, specific leaf area (SLA), distance between two leaflets and petiole length were found to be inversely associated with P_N and water-use efficiency. In addition, groundnut crop is known for leaf folding to avoid the incidental radiations, especially under water deficit conditions. Thus the degree of leaf folding under water deficit is indicative of the potential of plant to avoid the water loss through leaf surfaces, i.e., higher the degree of leaf folding the higher the drought tolerance. Number of branch and leaf area index during vegetative and early reproductive stages is also directly associated with higher productivity, and maintenance of higher leaf area index during the vegetative and early reproductive stages was higher in JAL 42. This potential of JAL 42 needs to be utilized under irrigated conditions during summer season. The association between number of branch and pod yield was quite significant (r=0.62**), while plant height was associated with leaflet length and width (r= 0.55**), petiole length (r=0.41**), P_N (r= -0.45**), g_s (r= -0.55**), total sink number (r= -0.42**), petiole length with leaflet length (r=0.54**) and width (r=0.77**), P_N (r=0.-44**) and g_s (r= -0.33*). Thus to increase productivity, number of branches need to be increased, while, plant height, petiole length, leaflet length and width need to be decreased, i.e., a compact canopy architecture could be developed and the variability in morphological traits could be utilized for this purpose (Table 1).

Anatomical traits

Among the anatomical traits large water storage cells, higher stomatal density with small stomatal cell on the upper and lower surfaces of the leaf, more palisade and spongy parenchyma cell thickness, higher number of xylem rows and number of cells in each row seems to be associated with drought tolerance, in groundnut. In addition, the epicuticular wax load accumulated under water deficit conditions seems to be associated with drought avoidance mechanism. Various associations were worked out, such as, SLA and thickness of upper epidermis (r=-0.30*), thickness of epidermis and HI (r=-0.33*), and pod yield (r= -0.33*) , thickness of palisade cells and leaflet width (r=-0.40**) and length (r=-0.42**), thickness of water storage cell and number of mature pods (r=0.34**), total sink number (r=0.31*) and weight of immature pods (r=0.39*). Plant height was associated directly with thickness of epidermis and inversely with thickness of palisade cell and number of xylem rows, but these associations were statistically non-significant. Thus in groundnut thickness of epidermis, palisade and spongy parenchyma and water storage cell seems to be closely associated with the water-use efficiency or drought tolerance.

Crop phenology

In India, for cultivation of groundnut, moderate crop maturity period needs to be 110-125 days after sowing during summer and 120-135 days after sowing during rainy seasons. In addition, cultivars possessing fresh-seed dormancy could be preferred over the cultivars without fresh-seed dormancy under rain-dependent conditions, and contrary to this during summer season cultivars without fresh-seed dormancy could be preferred. Because in groundnut, seed dormancy and crop maturity period are directly associated. The traits, such as uniform field emergence, early ground cover and synchronized flowering are desirable for cultivation under both irrigated and rain-dependent conditions. Furthermore, crop maturity period was associated inversely with harvest index (HI) and directly with total biomass production. Thus increase in pod yield, so far in groundnut, has been achieved basically due to increased HI. Indeed to develop suitable plant for both irrigated and rain-dependent conditions there is need for increasing both HI and biomass production. Thus to increase groundnut productivity, genotypes with low SLA and high leaf area index during vegetative and early reproductive stages could be a desirable trait. Thus a cultivar with a high rate of biomass production and high pod yield is required. Further, a maturity that is neither shorter nor longer than the duration of the crop growing season is desirable.

Seed and seedling vigour

Utilization of reserve food material, evaluated in 10 cultivars, belonging to three different seed weight groups of Virginia and Spanish market types, indicated that both medium and high seed-weight groups are efficient in utilization of reserve food material. Thus the desirable traits or parameters related with seed and seedling vigour in groundnut seems to be the maintenance of seed membrane permeability during aging, uniformity in germination and growth rate, rapid opening of cotyledons, development of secondary roots, adequate food supply from cotyledons (100-seed weight >30 g) during germination and early seedling establishment, and lower SLA. These traits may contribute significantly to establishing vigours and uniform crop stands both under irrigated and rain-dependent conditions. In addition, optimum seed Ca content, i.e., between 250 and 300 ppm is essential to maintain seed viability and vigour in groundnut.

Pre-adaptation to heat stress

Since in field conditions water deficit stress or drought is always associated with high temperature and there could be variation in leaf temperature of 2 to 3°C in the canopy temperature, under normal irrigation and 50% water-deficit stress. In groundnut, including the wild *Arachis* species and their accessions, leaf cell membrane stability test showed that a tolerant type is efficient in maintaining cell membrane integrity under high temperature stress. Also the tolerant types accumulate less food-reserve in stem but high proline content under water-deficit stress. Work on efficient ABA cascade and oxidative enzymes need to be intensified to understand the exact mechanism of drought tolerance in groundnut at the molecular level. Such studies may lead to identification of the molecular markers and QTLs for drought tolerance in groundnut.

Photosynthetic efficiency

Spanish market type groundnut possesses relatively a short crop duration hence preferred for cultivation under limited water-availability environments. Field trials conducted during three contrasting seasons with 30 Spanish groundnut cultivars, showed wide genetic variability in physiological and yield components. The associations between leaf area index during early stages of crop growth and pod yield, P_N and number of reproductive sink, and P_N and the difference between Tleaf and Tair , especially during pegging stage, pointed out that the source is not a limiting factor in productivity. Hence, photosynthetic efficiency could be increased both directly and indirectly by increasing the P_N per unit leaf area and/or per unit ground area and increasing reproductive sink-size, respectively. Strategies are required to increase productivity by utilizing the genetic variability among the existing cultivars by developing new cultivars suitable for semi-arid regions. For illustration, the low SLA cultivars could be utilized under limited water-availability environments. On the other hand, the high SLA types could be utilized in increasing early leaf area index and biomass, especially under irrigated condition. In addition, several cultivars with desirable traits were identified for the use as donor parents. Moreover, average P_N was high during full-pod (R4) (18.11 μmol $m^{-2}s^{-1}$), followed by beginning seed (R7) (17.08 μmol $m^{-2}s^{-1}$) and was low during full-seed (R6) (8.70 μmol $m^{-2}s^{-1}$) and harvest maturity (R8) (8.32 μmol $m^{-2}s^{-1}$). This showed a perfect source-sink relationship, i.e., enhanced P_N during beginning pod, to meet the additional requirement of photosynthates to developing reproductive sink.

Maintenance of leaf water relations

Field experiments conducted during two rainy seasons to study the effect of soil moisture deficit on total biomass production, pod yield, HI and drought tolerance index, in groundnut cultivars possessing a wide range of SLA. Under increasing moisture-deficit, the low SLA types were able to maintain high relative water content (RWC), P_N and stomatal conductance (g_s) during both the seasons. The relationship between RWC and P_N (r= 0.91, $P<0.01$), and RWC and g_s (r=0.65, $P<0.01$) were significant. It is concluded that under water-limited conditions there is a significant inverse association between SLA and RWC. The low SLA types (wateruse efficient) were found to be drought tolerant in terms of total dry mass production and maintenance of higher RWC under water-deficit. It is suggested that drought tolerant cultivars with higher biomass and pod yield could be made by combining high HI and WUE in terms of lower SLA. In addition, it was also seen that a remarkable positive correlation between 'increase in yield' and increase in P_N, g_s, T or TE and *vis-a-vis* WUE. The cultivars developed for WUE are being analyzed for molecular markers associated with WUE. Finally, there is need for superior rate of biomass accumulation, a superior rate of actual yield accumulation in order to acquire a higher HI.

Analysis of the genetic background of the promising cultivars

Cultivar TAG 24 was found to be the most promising for cultivation under summer season as it has shown high P_N, g_s, HI and lower ΔT. In addition, stability in pod yield was also high indicating its adaptation for cultivation during summer season. This cultivar was developed through mutation breeding by BARC and was released in 1991. The variety 'Spanish Improved' is the original parental material, from which a mutant "TG 18A" was obtained through irradiation. From a landrace "Samrala Local", variety M 13 was developed. TAG 24 was eventually developed by crossing "TG 18A" and "Samrala Local". This cultivar stands close to the ideotype and hence could serve the purpose of ideal plant type, suitable for cultivation during summer season. Another example is cultivar J 11 which showed stability in P_N, g_s, and ΔT, plant height, shelling outturn, total biomass and pod yield. This cultivar was released in 1964 and developed through hybridization between Ah 4218 and Ah 4354 "introduced material". This cultivar was used as national check for several years and seems to be adapted for varying environmental conditions. Third example is cultivar ICGS 11, which showed stability in P_N, g_s, plant height, HI and shelling outturn. This was released by the ICRISAT in 1986 for cultivation during post-rainy season. It is a single plant selection from natural hybrid population of an Indian variety "Robut 33-1 (Kadiri 3). Robut 33-1 is a secondary selection from an exotic germplasm of Israel "Rehovut". It has broad genetic base imparted by the exotic blood and further by recombination with unknown pollen source. This cultivar could serve the purpose of ideal plant type for cultivation under rain-dependent conditions.

Root architecture under normal and water-deficit stress

Several root physio-morphological traits are related to pod yield and improvement of these traits should lead to increased productivity (Fig. 1). To generate basic biological information it is important to measure spatial and temporal inter conversions of root architecture under normal and water deficit conditions. An underlying assumption of these studies is that roots would contribute to higher water uptake and then to higher yield. Yet, the relation between rooting and water uptake is not adequately studied and the available information is controvertial. In what drought scenarios, soils, and crops roots can contribute to water uptake and yield still remains an open question. Our understanding is that water uptake is crucial during key stages like flowering, peg initiation and pod development and small differences in water uptake at these stages could lead to large differences in yield. Experiments were conducted with cultivars and germplasm accessions in root-study-blocks. Various associations between root and shoot traits and among the root traits were established such as root length and plant height, root volume and number of branches and tap root length and degree of leaf folding. For example, primary root length (cm) was directly associated with secondary root length (r=0.85**), secondary root length density (cm root m^{-3} soil) (r= 0.28*), root weight density between 61-75 cm (g root m-3 soil) (r= 0.41**), shoot weight (r=0.22*), total biomass (r=0.21*) and inversely with degree of leaf folding (r =-0.19). Thus primary root length seems to be a desirable trait to increase biomass productivity under rain-dependent condition. Further, specific root length (cm root g^{-1} m^{-2} soil) was inversely associated with secondary dense root length (r=-0.42**), root volume (r= -0. 69**), number of branches (r=-0.30*), root weight density (r=-0.85**) though the association was higher in deeper soil layers and also with shoot weight (r=-0.54**), total biomass and root:shoot ratio (r=-0.35*). Specific root length indicates about thickness of root, i.e., higher the thickness of the root the lower the specific root length. Whether higher or lower specific root length is desirable trait for groundnut cultivation under water deficit condition need to be explored further.

Also, secondary root length was directly associated with secondary dense root length (r= 0.51**), root volume (r=0.35**), plant height (r=0.37**), root weight density (g root m^{-3} soil) (r= 0.53**) in deeper soil layers, shoot weight (r=0.36**), total biomass (r=0.37**) and inversely with degree of leaf folding (r=-0.24*). Higher secondary root length seems to be a desirable trait under rain dependent cultivation of groundnut. Secondary dense root length (cm) was associated with root volume (r=0.52**), root weight density (r= 0.51**), shoot weight (r=0.42**), total biomass (r=0.44**) and inversely with degree of leaf folding. Root volume (ml) was directly associated with number of branches (r=0.28*), root weight density in upper soil layers (r= 0.83**), shoot weight (r= 0.46**), total biomass (r=0.52**) and root shoot ratio (r=0.41**) but non-significant with degree of leaf folding. Thus both root and shoot desirable traits associated with drought tolerance need to be utilised for pyramiding of the gene and developing ideotype for water use efficiency or drought tolerance in groundnut.

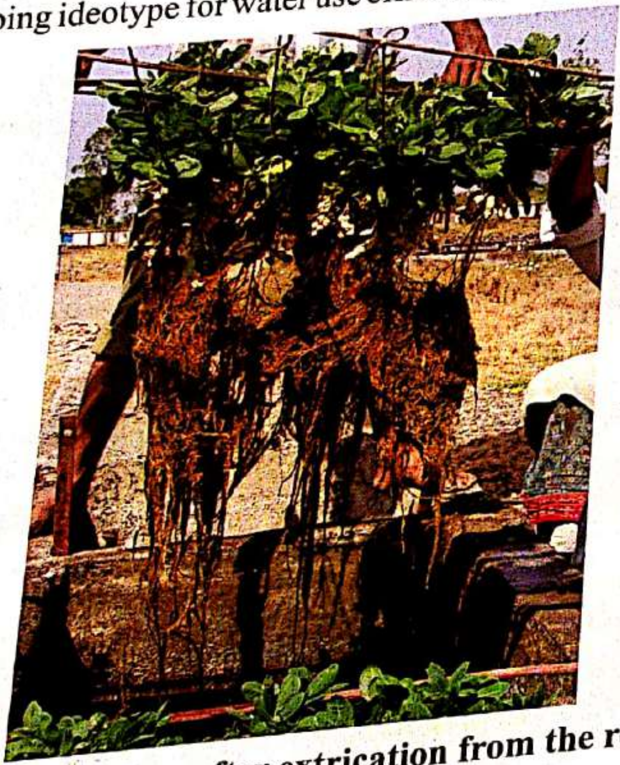

Figure 1. Groundnut root system after extrication from the root-study-block

Table 1: Variations in various morphological traits among 30 Spanish groundnut cultivars

Parameter/trait	Range	Average	Diversity index
Plant height (cm)	17.53-29.10	24.47	0.473
Number of branch (plant^{-1})	7.87-12.63	9.80	0.486
Petiole length (cm)	5.17-8.50	6.90	0.483
Distance between upper and lower pair of leaflet (cm)	0.87-2.17	1.66	0.783
Leaflet length (upper pair) (cm)	5.17-7.62	6.18	0.396
Leaflet length (lower pair) (cm)	4.60-6.83	5.57	0.393
Leaflet width (upper pair) (cm)	2.30-3.40	3.03	0.363
Leaflet width (lower pair) (cm)	1.82-3.10	2.64	0.485

PROJECT 04: MICROORGANISMS IN RELATION TO SOIL HEALTH AND PLANT NUTRITION IN GROUNDNUT

(K. K. PAL AND R. DEY)

Consortium of beneficial bacteria

Evaluation of delivery systems of a consortium of microorganisms for enhancing the growth and yield of groundnut

Seven delivery systems for a consortium of beneficial bacteria were evaluated in a field trial with groundnut cultivar TG 37A during summer season. The bacterial consortium consisted of PGPR (*Pseudomonas fluorescens* BHU1 and *Pseudomonas maculicola* S1(6)), PSM (*Pseudomonas* sp. BM8 and *Bacillus polymyxa* H5) and groundnut rhizobia (NRCG 4 and NC 92). FYM, talcum powder, kaoline, sterile farm soil, charcoal, groundnut seed, and irrigation water were used as carrier/delivery systems.

Except for charcoal all the delivery systems evaluated enhanced the shoot dry weight of groundnut. The maximum dry biomass was produced when FYM was used for delivering the consortium. In most of the treatments, there was enhancement in the root length of the plants. Although all the delivery systems enhanced the pod and haulm yields, the differences were, however, not significant.

Table 1. Effect of various bacterial-consortium delivery-systems on growth and yield of groundnut cultivar TG 37A (summer 2010)

Delivery system	SDW ($g\ p^{-1}$)	HY ($kg\ ha^{-1}$)	PY ($kg\ ha^{-1}$)	Shelling turn-over (%)	HSM (g)
Seed	17.12	4505	2862	66.6	41.7
FYM	19.85	5110	3040	69.3	42.1
Talcum	17.12	4965	2965	66.4	44.5
Irrigation	18.06	4880	3260	67.8	44.1
Kaoline	16.99	4695	2817	68.1	44.3
Soil	18.62	4722	2835	70.4	44.3
Charcoal	15.72	4680	2745	70.0	45.0
Control	14.57	4487	2695	66.2	41.2
CD (5%)	1.70	NS	NS	1.24	NS

In the trial conducted in *kharif* 2010 with cultivar Girnar 2, compared to uninoculated control, an improvement of 28% in pod yield was obtained by application of consortium through seed coating. While use of FYM, farm soil, kaoline and charcoal as carriers, resulted in 25%, 22%, 18% and 14% improvement of pod yield, respectively.

Table 2. Effect of various bacterial-consortium delivery-systems on growth and yield of groundnut, cultivar Girnar 2 (*kharif* 2010)

Delivery system	SL (cmp^{-1})	HY ($kg\ ha^{-1}$)	PY ($kg\ ha^{-1}$)	Shelling turn-over (%)	HSM (g)
Seed	41.4	4195	1900	58.6	31.8
FYM	40.9	4200	1847	58.0	32.3
Talcum	41.3	4200	1547	58.3	32.6
Irrigation	38.5	3559	1487	58.5	31.9
Kaoline	40.8	4112	1747	58.7	32.9
Soil	41.2	4525	1812	57.8	31.2
Charcoal	41.3	3985	1690	58.0	30.8
Control	39.1	3820	1482	56.8	30.6
CD (5%)	1.76	371	140	1.03	1.48

Evaluation of various AM fungi for promoting the growth and yield of groundnut

A field trial was conducted during the summer 2010 to study the effects of inoculation of AM fungi on the growth and yield of groundnut cultivar TG 37A. Four AM fungal cultures *viz.*, *Glomus etunicatum*, *Glomus fasciculatum*, *Glomus mosseae*, and *Gigaspora scutellospora* were evaluated. Inoculation with AM fungi significantly improved the growth of groundnut in terms of biomass of shoot and root, and number and mass of nodules. *G. fasciculatum* was identified as the best culture for enhancing both pod and haulm yields. There was an increase in root volume due to AM fungi infection (Table 3). In the pot trial, application of *Glomus etunicatum* significantly enhanced pod yield and biomass of shoot and root.

During *kharif* 2010, in a pot trial, inoculation with *Glomus etunicatum* and *Glomus mosseae* significantly improved root volume, pod yield and VAM root-colonization.

Table 3. Effect of inoculation of AM fungi on the growth and yield of groundnut cultivar TG 37A (summer 2010)

AM fungus	PY ($kg\ ha^{-1}$)	SDW ($g\ p^{-1}$)	HY ($kg\ ha^{-1}$)	NDW ($mg\ p^{-1}$)	HSM (g)
G. etunicatum	2840	17.4	4583	31.2	46.6
G. fasciculatum	2997	15.7	5223	31.0	47.7
G. mosseae	2443	17.0	4927	31.6	48.1
G. scutellospora	2950	16.1	4407	32.6	46.5
Un-inoculated control	2693	14.0	4727	23.0	44.7
CD (5%)	NS	1.3	437	3.7	1.80

Groundnut-rhizobia

Evaluation of new strains of groundnut rhizobia

A field trial conducted during *kharif* 2010 to evaluate the newly isolated nod$^+$nif$^+$ competitive strains of groundnut rhizobia. Six strains viz., RH17, RH29, SRR7, RH11, PAS17-2, and RH20 having additional traits like production of siderophore and IAA like substances, were tested along with standard culture NC 92. Compared to control (un-inoculated), the inoculation with the newly isolated strains of groundnut rhizobia SRR7, RH17, PAS17-2, RH11 and NC 92 enhanced the pod yield of cultivar Girnar 2 and the strain PAS17-2 was adjudged the best (Table 4). Inoculation with rhizobia also improved the BNF parameters.

Table 4. Effect on inoculation of newly isolated rhizobia on the growth, yield and BNF parameters in groundnut, cultivar Girnar 2 (*kharif* 2010)

Treatment	PY (kg ha^{-1})	HY (kg ha^{-1})	Shelling turn-over (%)	HSM (g)
Control	1044	4725	58.3	33.5
NC92	1187	4210	60.0	35.4
RH17	1287	4062	59.9	32.9
RH29	1039	3825	59.1	33.7
SRR7	1245	4777	60.8	35.2
RH11	1474	4542	56.3	32.0
PAS17-2	1480	4045	62.0	36.8
RH20	1097	4270	62.5	34.8
CD (5%)	161	373	NS	2.37

Development of suppressive soils

Isolation and testing of DAPG-producing fluorescent pseudomonads for suppression of soil-borne fungal pathogens

The fluorescent pseudomonads are known to produce 2, 4-diacetylphloroglucinol (2, 4-DAPG) which is antifungal and inhibits the soil-borne fungal pathogens. To develop suppressive soils to naturally suppress the fungal pathogens, an attempt was made to isolate DAPG-producing fluorescent pseudomonads from the rhizosphere of groundnut. Seventy fluorescent pseudomonads were isolated and tested *in vitro* for their inhibitory effect on soil-borne fungal pathogens like *A. niger*, *A. flavus* and *S. rolfsii*. Out of 70, only seven isolates viz., DAPG 1, DAPG 2, DAPG 3, DAPG 4, DAPG 5, DAPG 6, and DAPG 7 showed antifungal activity against *A. niger* and *S. rolfsii*. The presence of genes responsible for production of DAPG in these isolates was also confirmed by PCR amplification of *phl*D genes by phl2aF and phl2aR primers and an amplicon size of 746 bp was obtained. Identity of these isolates revealed that DAPG-producing trait can also be present in other species of *Pseudomonas* like *Pseudomonas putida* and may not restricted to *P. fluorescens* and *P. aeruginosa*. Application of DAPG-producing fluorescent pseudomonads, reduced the population of *A. flavus* and *A. niger* in soil in pots (Table 5 and 6). An experiment was conducted in field during *kharif* 2010 to develop suppressive soils by applying these bacteria. Due to water stagnating in the fields as a result of excessive rains in the season, the experiment was inconclusive.

Table 5. Population of *Aspergillus flavus* in soil as influenced by the application of DAPG-producing groundnut rhizobacteria

Isolate	Population in CFU g^{-1} soil			
	Before application	Inoculum load (CFU g^{-1} carrier)	After 15 days	After 30 days
Control	25×10^1	-	ND	ND
+ Pathogen	25×10^1	57×10^6	110×10^3	80×10^3
+ DAPG2	25×10^1	57×10^6	38×10^3	20×10^3
+ DAPG3	25×10^1	57×10^6	71×10^3	28×10^3
+ DAPG4	25×10^1	57×10^6	48×10^3	33×10^3
+ DAPG7	25×10^1	57×10^6	54×10^3	13×10^3
+ DAPG1	25×10^1	57×10^6	80×10^3	28×10^3
+ DAPG5	25×10^1	57×10^6	30×10^3	24×10^3
+ DAPG6	25×10^1	57×10^6	70×10^3	11×10^3

Table 6. Population of *Aspergillus niger* in soil as influenced by the application of DAPG-producing groundnut rhizobacteria

Isolate	Population in CFU g^{-1} soil			
	Before application	Inoculum load (CFU g^{-1} carrier)	After 15 days	After 30 days
Control	25×10^1	-	ND	ND
+ Pathogen	25×10^1	28×10^6	360×10^3	110×10^3
+ DAPG2	25×10^1	28×10^6	55×10^3	30×10^3
+ DAPG3	25×10^1	28×10^6	50×10^3	20×10^3
+ DAPG4	25×10^1	28×10^6	60×10^3	30×10^3
+ DAPG7	25×10^1	28×10^6	58×10^3	44×10^3
+ DAPG1	25×10^1	28×10^6	67×10^3	26×10^3
+ DAPG5	25×10^1	28×10^6	70×10^3	33×10^3
+ DAPG6	25×10^1	28×10^6	38×10^3	21×10^3

Effect of application of different doses of Mo on the parameters of BNF and yield of groundnut

In a pot trial, application of Mo improved the BNF and yield attributes like number of nodules and biomass; length and dry weight of shoot and root; and pod yield. Maximum benefit was observed when Mo was applied @ 0.50 kg ha^{-1}. The doses need further optimization and validation.

Testing the compatibility of recommended biofertilizers with other seed treatment practices

Fluorescent pseudomonads and *Rhizobium* cultures in the beneficial bacterial consortium were tested for compatibility with seed treatment chemical Bavistin from 0 to 2500 ppm. All the bacterial cultures tested were found to be compatible with Bavistin @2500 ppm.

16S rDNA sequencing of important cultures

Samples of 16S rDNA isolated from seven DAPG-producing fluorescent pseudomonads were sequenced and on the basis of sequence homology five cultures were identified as *P. putida* and the remaining two as *P. aeruginosa*.

PROJECT 05 : MANAGEMENT OF MINERAL NUTRITION AND ASSOCIATED STRESSES IN GROUNDNUT

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Sub-Project 01: Mineral nutrient requirements and related disorders in groundnut (A. L. Singh)

P, K, Zn and B nutrition in various seed-size groundnuts

The pod nutrition of cultivars with various sizes of seeds was studied for macronutrient (P and K) and micronutrients (Zn and B) in a field experiment taking 43 groundnut genotypes varying in pod structure and sizes. The genotypes were grown by applying fertilizers in combinations ($P_{50} + K_{100}$, $P_{50} + K_{100}$ + 2 kg ha^{-1} Zn + 1 kg ha^{-1} B). The results indicated a large variation in the response depending upon the seed size. The genotypes NRCG 11057, ICGV 86590, NRCG 12085, 11073, and 2063 showed high response to all these nutrients. However the genotypes NRCG 7599, 11057, 11535, 2063, JSP 19 and JL 24 showed a more pronounced response to B and Zn. The large seed-size genotypes required more P, Ca and K as these showed high P and Ca in their seeds and shell than those of small seed-size genotypes. With the application of Boron and Zn, the content of these elements increased in both seed and shell with a more pronounced effect in large seeded ones. The P, K, Zn and B increased pod yield by increasing the size (length and width) of pod and seed.

Two-year data revealed that P, K, B and Zn are required for proper pod-filling and their application is crucial for maintaining proper pod and seed size for the production of export quality large-seeded groundnuts.

Studies on the Ni and Co nutrition in groundnut

The effect of application of low doses (0.05 and 0.10 kg ha^{-1}) of nickel (Ni) and cobalt (Co) on the nodulation, growth and pod yield was studied using four cultivars (GG 2, GG 7, ICGS 76 and GG 20) in micro-plots. A significant increase in nodulation, growth and pod yield in all the cultivars was seen with application of both Ni and Co. All the cultivars responded well to application of 0.10 kg ha^{-1} Ni. However, the response to Co, varied with cultivars and was up to 0.05 kg ha^{-1} in ICGS 76 and up to 0.10 kg ha^{-1} in GG 2, GG 7 and TG 37. Thus, application of Ni and Co not only increased the nodulation but also pod yield irrespective of cultivars.

Seed treatment with micronutrients

The effect of seed treatment with Mo (ammonium molybdate at 0.5 kg ha^{-1}) along with and without Ca, K and P (as potassium dihydrogen orthophosphate, calcium chloride, each at 5 kg ha^{-1}) was studied in micro plots using four cultivars GG 2, GG 7, ICGS 76 and GG 20.

The results indicated that all the cultivars responded well to application of Mo as seed treatment and there was a significant increase in yield.

The application of Ca, K and P showed synergistic effect with Mo in all the cultivars. Though all the cultivars responded well to seed dressing of these nutrients, the extent of response to individual element varied with cultivars. Three cultivars showed maximum response to application of calcium chloride while ICGS 76 showed maximum response to potassium dihydrogen orthophosphate.

Yield potential of various nutrient efficient lines

A total of 26 groundnut varieties, mostly the nutrient efficient ones and 5 inefficient ones were grown in field under high management to ascertain their yield potential in summer season besides conducting some basic studies. The root exudates and leaf sap of these genotypes, when analyzed for cation and anion contents a wide variation was observed among the cultivars. Under high management, the cultivars showed their yield potential in the range of 2131-6713 kg ha^{-1}.

Screening of DGR-core-germplasm and ICRISAT-mini-core germplasm for response to fertilizer application and its effect on kernel nutrient density

The core-gemplasm collection of DGR and the mini-core gemplasm collection of ICRISAT were evaluated for response to fertilizer application and its effect on kernel micronutrient density. In kharif season, 120 DGR-core germplasm were grown under both unfertilized and fertilized conditions for evaluation while 166 ICRISAT-mini-core germplasm lines were planted for multiplication. The pod yields were poor due to excessive and protracted rain resulting in prolonged stagnation of water in the fields. In the ICRISAT-mini-core collection, the pod yield varied from none to as high as 116 g m^{-2} with an average of 34 g m^{-2}. In DGR-core-germplasm collection the pod yield varied from 2.5 to 99.0 g m^{-2} with an average of 38 g m^{-2} without fertilizers and from 6.5 to 111 g m^{-2} and with an average of 43 g m^{-2} with fertilizers.

On the basis of the studies conducted for three years on fertilizer response of DGR-core-germplasm collection using 179-194 lines under both unfertilized and fertilized conditions the following accessions were identified:

- Fertilizer-responsive high-yielding genotypes with more than 200 g pod m^{-2} : NRCG 11711, NRCG 11942, NRCG 11693, NRCG 1913, NRCG 6064, NRCG 12272, NRCG 10911, NRCG 10496, NRCG 3198, NRCG 11866
- Fertilizer non-responsive and low-yielding genotypes with less than 60 g pod/m^{2} : NRCG 11996, NRCG 168, NRCG 7306, NRCG 12329, NRCG 12881, RCG 12748, NRCG 12879, NRCG 11701, NRCG 11868
- The kernels of 194 DGR-core-germplasm lines grown during *kharif* season were analyzed for various micronutrients and the genotypes with high micronutrient density were identified:
- High Fe lines (>150 ppm): NRCG 6236, 7063, 7306, 11246, 11700, 12326, 12581, 12899
- High Zn lines (> 60 ppm): NRCG 3533, 8423, 10820, 11157, 11868, 11925, 11297 and 12305

Studies on response of Zn and B application on groundnut cultivars

A total of 110 groundnut cultivars were grown with and without application of Zn and B to study their effect on pod yield and density of these nutrients in the kernels. Due to excessive and continuous rains during the season, in general, the pod yields were low with an average of 810 kg pod ha^{-1}. The results indicated that the average yield increased to 910 kg ha^{-1} with application of Zn and 880 kg pod ha^{-1} with application of B. All the cultivars, however, did not respond to application of these micronutrients. Some of the high- or low-yielding cultivars responsive to these micronutrients are:

- Zn-responsive high yielding cultivars (>150 g pod m^{-2}): JSP 19, CSMG 84-1, CSMG 9510, CSMG 884, ICGS 76, B 95, M 335, GG 13, Chitra, ICGS 76, M 522, M 13, GG 16, Girnar 2, and CSMG 9510.
- B-responsive high yielding cultivars (>150 g pod m^{-2}): CSMG 84-1, GG 16, GG 13, CSMG 884, M 522, ICGS 76, Chitra, CSMG 9510, JSP 19 and Girnar 2.
- Cultivars responsive to both Zn and B: JSP 19, ICGS 76, CSMG 9510, Chitra, CSMG 884, and Girnar 2
- Low- to non-responsive cultivars: Chico, TG 3, MH 1, Jyoti, MH 4, CO1, and Jawan.

Screening groundnut cultivars for high Zn content in seed

Kernels of 103 groundnut cultivars were analyzed for Zn, Fe, and other nutrients. In the first year, the Zn concentration in kernels was in the range of 20-90 mg kg^{-1} with a mean value of 45 mg kg^{-1}. In the subsequent year, however the range of Zn concentration was 30-124 mg kg^{-1} with a mean value of 58 mg kg^{-1}. Similarly the Fe concentration in kernels was in the range of 30-190 mg kg^{-1} with a mean value of 90 mg kg^{-1} in the first year of experimentation. In the subsequent year the Fe concentration in kernels was in the range of 60-250 mg kg^{-1} with a mean value of 120 mg kg^{-1}. Of these, 10-15 high Zn and Fe containing cultivars were listed.

- High Zn genotypes (more than 70 ppm): Gangapuri, M145, AK12-24, Kissan, Jyothi, VRI 3, BG 3, BAU 19, TAG 24, and NRCG 6155.
- High Fe genotypes (more than 150 ppm): M 145, M13, DSG 1, AK12-24, TAG 24, ALR 3 JS 19, MH 4, Somnath, ICGV 86031, ICGV 86325, Tirupati 3, and GG 2.

In another study the spray of aqueous solution of Zn (as zinc sulfate) on the foliage 3-4 times during cropping season, in 60 groundnut cultivars, influenced yield and yield attributes, checked over growth of the foliage. The nutrient content of the same when analyzed there was significant increase in Zn content in seed of most of the varieties with the maximum response in GG 2, Tirupati 4, JL 220, VRI 2 K 134, BAU 13, GG 7 and MH 1 cultivars.

Screening, maintenance and multiplication of nutrient-efficient and -inefficient lines

A total of 120 nutrient-efficient and in-efficient groundnut genotypes were grown for multiplying the seed of these genotypes for testing in NEH region and various other studies.

Sub-project 02: Management of soil acidity and related problems of groundnut

(A. L. Singh, M. Datta, S. Biswas, Y. Ramakrishna, and K. A. Pathak)

Screening of groundnut genotypes for Al-toxicity tolerance

In sand culture

For evaluation of tolerance of Al-toxicity (1000 µM of Al as $AlCl_3$), 34 groundnut varieties were screened by raising these in sand culture (in pots). The symptoms of Al-toxicity on roots and on plant growth were noticed 25-30 days after sowing. There was a reduction in growth and yield. On the basis of their relative performance, the groundnut varieties GG7, M 335, ICGV 86590, HNG 69, R 9251 and GG 16 were identified to be tolerant to Al-toxicity.

Field Screening in acid soils

A large number of germplasm lines were tested in NEH region in the acid soils at Tripura, Mizorum, and Nagaland in fertilized (lime 500 kg ha^{-1}, FYM 10 t ha^{-1} and P_2O_5 50 kg ha^{-1}) and unfertilized conditions. The promising lines identified to possess tolerance to Al-toxicity were NRCG 11551, NRCG 2538 and NRCG 11656.

In Tripura, 60 genotypes of core collection were evaluated under fertilized and unfertilized conditions for tolerance of soil acidity and Al-toxicity besides recording observations on occurrence of diseases under natural conditions. The genotypes showed a very wide range of response (pod yield 0 to 920 g $3m^{-1}$ row). The pod yield of most of the genotypes increased with application (Table 1). Several genotypes, however, did not show any response to the applied fertilizers.

Table1. Performance of DGR core collection of groundnut germplasms in Tripura during 2009-10 under fertilized (F) and unfertilized (UF) conditions

	NRCG accession no.	Occurrence of diseases: Late leaf spot (1-9 scale)		Rust (1-9 scale)		Wilt (%)		Pod yield (g $3m^{-1}$ row)	
		F	UF	F	UF	F	UF	F	UF
1	12518	4.4	4.4	1.0	1.0	0	0	420	490
2	955	2.4	2.2	1.0	1.0	0	0	450	320
3	11811	2.8	3.2	1.0	1.0	4	2	190	260
4	12256	3.2	4.2	1.0	1.0	0	0	290	490
5	17	3.2	3.2	1.0	1.0	0	0	300	500
6	12581	4.4	4.4	1.0	1.0	0	0	240	490
7	12174	3.2	3.4	1.0	1.0	0	0	520	690
8	201	2.6	3.4	1.0	1.0	1	0	290	590
9	11088	3.6	4.4	1.0	1.0	0	2	920	750
10	12339	3.2	3.2	1.0	1.0	0	0	150	340
11	11275	5.4	6.0	1.0	1.0	0	0	300	130
12	11276	5.8	5.8	1.0	1.0	0	2	120	100
13	10572	6.0	6.0	1.0	1.0	4	3	220	200
14	12543	4.0	4.0	1.0	1.0	2	2	440	330
15	11450	6.6	6.6	1.0	1.0	3	2	200	340
16	12148	5.8	5.6	1.0	1.0	0	1	340	420

	NRCG accession no.	Occurrence of diseases: Late leaf spot (1-9 scale)		Rust (1-9 scale)		Wilt (%)		Pod yield (g 3m^{-1} row)	
		F	UF	F	UF	F	UF	F	UF
17	11700	7.4	7.8	1.0	1.0	1	0	50	240
18	9966	6.4	6.6	1.0	1.0	0	2	170	220
19	12049	4.4	5.4	1.0	1.0	0	0	370	340
20	11646	6.0	6.8	1.0	1.0	2	0	140	90
21	8963	3.2	2.6	1.0	1.0	0	0	320	740
22	12423	4.8	5.8	1.0	1.0	0	1	170	200
23	11711	7.2	7.4	1.0	1.0	1	0	250	270
24	11346	4.0	4.2	1.0	1.0	0	0	90	220
25	12691	6.8	7.4	1.0	1.0	3	1	140	120
26	12297	2.2	2.0	1.0	1.0	0	0	370	370
27	12264	3.8	4.4	1.0	1.0	5	4	220	190
28	12713	3.2	2.8	1.0	1.0	0	0	300	250
29	10564	2.6	3.6	1.0	1.0	0	0	440	440
30	11154	7.6	7.4	1.0	1.0	2	0	80	70
31	11175	6.8	6.8	1.0	1.0	1	0	260	340
32	10967	6.6	6.6	1.0	1.0	0	0	340	220
33	11942	6.6	6.8	1.0	1.0	0	0	220	170
34	10191	3.2	4.0	1.0	1.0	0	0	740	600
35	11126	5.6	5.6	1.0	1.0	4	1	250	290
36	12478	2.2	2.4	1.0	1.0	0	0	470	470
37	12291	2.2	2.0	1.0	1.0	0	0	450	400
38	12393	2.6	2.4	1.0	1.0	0	0	70	80
39	11289	6.6	6.8	1.0	1.0	1	1	250	75
40	12255	3.0	3.4	1.0	1.0	0	0	70	80
41	10429	5.8	5.4	1.0	1.0	0	1	250	10
42	10969	4.6	3.8	1.0	1.0	0	0	350	130
43	12700	4.8	4.0	1.0	1.0	7	1	90	20
44	11551	5.2	5.2	1.0	1.0	0	0	270	20
45	8956	3.0	3.2	1.0	1.0	0	0	250	200
46	12630	4.0	4.0	1.0	1.0	0	0	20	30
47	3198	3.0	2.6	1.0	1.0	0	0	230	150
48	12334	0	4.2	0	1.0	0	0	0	20
49	7443	4.6	4.2	1.0	1.0	0	0	50	50
50	12968	2.4	2.0	1.0	1.0	0	0	20	30
51	12437	7.0	7.2	1.0	1.0	0	0	90	70
52	11693	3.2	2.8	1.0	1.0	0	0	250	250
53	12879	5.2	5.2	2.6	4.0	3	0	10	130
54	2190	5.8	5.8	2.8	2.2	0	0	50	90
55	11236	5.2	5.8	1.0	1.0	1	0	50	120
56	1086	7.4	6.2	1.0	1.0	0	0	170	130
57	11197	5.2	4.2	3.2	2.4	0	0	50	100
58	11985	2.6	2.2	1.0	1.0	0	0	170	180
59	11656	0	3.6	0	4.0	0	0	0	120

The results of some experiments conducted earlier which could not be included in the previous annual reports are also being reported here.

The data showing the occurrence of diseases on DGR-core germplasm collection during *kharif* 2009 is given in Table 1. During this year late leaf spot disease affected all the genotypes of core collection though the incidence was low enough (2-3 score in 1-9 scale) indicating resistance under fertilized as well as unfertilized condition. The noteworthy genotypes were NRCG 955, NRCG 12297, NRCG 12487, NRCG 12291, NRCG 12393, NRCG 12968 and NRCG 11985. Incidence of rust was high in the genotypes NRCG 12879, NRCG 2190, NRCG 11197 and NRCG 11656. The genotypes, NRCG 11811, NRCG 10572, NRCG 11450, NRCG 12264, NRCG 11126 and NRCG 12700 were affected more by wilt disease than by other diseases.

Experiment on organic farming

To reduce the cost of cultivation and provide an alternative for poor availability of lime and chemical fertilizers in NEH region, the various organic farming approaches compatible with the traditional practices of farmers, were evaluated. For the poor farmers in Nagaland and Mizorum, the *bun* farming is close to nature and easy to practice.

In a field experiment conducted during *kharif* 2009 at the Main-Scheme farm of the Nagaland centre, the effect of inorganic and organic sources of nutrient on different varieties of groundnut was studied. The soil of the experimental site was sandy loam, acidic (pH = 4.7), medium in organic carbon (0.66 %), deficient in available nitrogen (178.8 kg ha^{-1}), medium in phosphorous (15.4 kg ha^{-1}), and medium in available potash (177 kg ha^{-1}). The experiment was laid down in a Randomized Block Design with three replications. The treatments consisted of various combinations of organic and inorganic sources, *viz.*, organic (F1), recommended NPK (F2), 25% organic + 75% NPK (F3) and 50% organic and 50% NPK. Groundnut genotypes FeSeG-8 (V1), FeSeG 10 (V2), JL 24 (V3) and ICGS 76(V4) were evaluated. The crop was sown during the last week of May and harvested at maturity. The data (Table 2) revealed that use of organic (F1) and use of 50% organic and 50% NPK were both superior to inorganic NPK (F2) and 25% organic + 75% inorganic NPK (F3) treatment.

Table 2. Effect of organic sources and fertility levels on the growth and yield attributes of groundnut genotypes (FeSeG 8 (V1), FeSeG 10 (V2), JL 24 (V3) and ICGS 76 (V4) in Nagaland

Varieties and treatments	Plant height (cm)	No. of branches	Plant fresh wt (g)	Plant dry wt (g)	CGR at various stages			Pods plant^{-1}	Pod wt (g plant^{-1})	Seeds pod^{-1}	Test wt (g)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})
					30-45 DAS	45-75 DAS	75-123 DAS						
V1F1	116	14	200	45	1.95	3.62	0.15	11	14.7	2	692	1602	4557
V1F2	110	12	172	40	2.20	1.79	1.13	12	14.1	2	727	1336	3168
V1F3	119	14	223	53	1.62	1.30	0.35	14	19.1	2	626	1716	4629
V1F4	127	15	271	51	1.04	2.13	0.76	10	21.9	1	651	1893	3532
V2F1	114	10	155	35	1.93	2.80	1.76	12	14.8	3	377	802	1232
V2F2	113	10	122	23	2.23	1.22	1.11	9	10.9	3	350	667	1429
V2F3	109	10	164	37	1.30	2.90	1.61	8	11.1	2	350	709	1036
V2F4	128	9	143	35	1.41	1.54	0.83	8	11.6	3	353	662	1482
V3F1	95	9	155	38	2.79	0.44	0.52	10	14.6	2	466	716	1286
V3F2	103	8	132	33	2.26	0.84	0.66	8	9.5	1	493	518	1625
V3F3	105	9	153	34	2.35	0.79	0.68	8	7.9	2	483	616	947
V3F4	103	10	143	42	1.28	1.39	0.56	12	11.3	2	510	764	1375
V4F1	121	15	395	76	1.78	3.19	1.16	13	23.4	2	639	2295	4379
V4F2	111	13	228	54	1.79	2.15	0.99	12	6.36	2	640	1843	3532
V4F3	108	13	234	51	1.83	2.35	1.16	9	14.4	2	649	1362	3036
V4F4	113	12	227	52	1.74	2.09	0.93	11	14.5	2	642	1919	3329

In highly eroded soils of discarded land where organic matter is too low, the groundnut was the only crop that could be grown and the organic fertilizers always elicited better response over inorganic ones. Among the promising organic sources were vermicompost, poultry manure, green leaf of *Gliricidia* and subabul, and slurry of waste from piggery. Application of FYM alone (10 t ha^{-1}) was enough for alleviating Al-toxicity in the highly eroded soils of NEH region. Growing of *Tefrosia microphylla*, *Crotalaria microphylla*, *Plemengia* and *Glirricidia* on the bunds as hedge and subsequently incorporating their foliage as organic manure in fields for groundnut and rice and their intercrop showed excellent response in Nagaland, Meghalaya and Tripura.

Nutrient management in bold-seeded groundnut

The NEH region, where water is not a limiting factor and the low temperatures that prevail during reproductive phase, provide a congenial environment for proper pod-filling and high yield of groundnut. This makes the NEH region a potential area for production of bold-seeded groundnut provided the fertilizers required are applied and soil acidity and Al-toxicity is overcome. For developing technology for successful production of large-seeded groundnuts in this region, field experiments were conducted by applying organic and inorganic fertilizers in various combinations to provide the key nutrients and to overcome the adverse effect of soil acidity and Al-toxicity.

In Tripura, very poor yield (only 290 kg pod ha^{-1} and 220 kg haulm ha^{-1}) was obtained in unfertilized control plots with the variety GG 20. With the application of lime, P and K the yields increased to 780 kg pod ha^{-1} and 930 kg haulm ha^{-1}. Application of FYM in addition to inorganic fertilizers further enhanced yield to 1120 kg pod ha^{-1} and 1030 kg haulm ha^{-1}.

Table 3: Effect of nutrition on yield attributes of bold-seeded groundnut in acid soils of Tripura

Treatments	Pods $plant^{-1}$	Pod wt g $plant^{-1}$	Seed wt g $plant^{-1}$	Plant wt g $plant^{-1}$	100-seed wt (g)	Shelling (%)	Yield ($kg\ ha^{-1}$)	
							Pod	Haulm
T_1- Control	9	12.4	3.9	6.4	56.6	48.8	290	220
T_2- P_{50}	15	15.1	7.7	16.0	50.0	43.7	350	440
T_3- K_{100}	11	11.8	6.3	7.6	66.6	60.0	290	210
T_4- Lime (2.5 t ha^{-1})	11	13.9	9.1	11.1	46.6	43.9	520	340
T_5- P_{50} + Lime	14	24.6	16.2	21.2	53.3	46.7	750	760
T_6- P_{50} + K_{100} + Lime	17	24.9	12.4	25.1	46.6	48.7	780	930
T_7- P_{50} + K_{100} + Lime + 13 kg Boric acid ha^{-1}	15	21.1	10.8	23.0	43.3	42.1	730	760
T_8- P_{50} + K_{100} + Lime + 10 t ha^{-1} cow dung	15	19.6	13.6	20.2	56.6	41.2	1120	1030
SE (±)	1.80	1.97	0.99	1.85	6.9	4.25	44	60
CD (0.05)	2.34	2.45	1.73	2.37	14.5	3.29	360	420

In Mizorum, the experiment on Integrated Nutrient Management (INM) in groundnut was conducted in *kharif* 2009 using bold-seeded variety ICGS 76 using different source of nutrient for the sustainable production of groundnut. The groundnut was sown on 13th Aug 2009 in randomized block design with three replications. The treatments comprised of different fertilizer sources either alone or in combinations where maximum pod yield of 2310 (q ha^{-1}) was obtained with P50 + Ca100 + BF + B + Mo which is significantly superior to P50+BF, P50 and control (Table 4). In another experiment at Mizorum the groundnut varieties ICGS 76 and TG 37A when evaluated under different fertility levels maximum pod yield of 1570 and 2110 kg ha^{-1}, were recorded with ICGS 76 and TG 37A, respectively, with application of P50 + K100 + Lime 2.5 t ha^{-1} + FYM 10 t ha^{-1}. The performance of TG 37A was better than ICGS 76 in response to the nutrient application.

Several years of study reveals that P, Ca, K and B and many a time N also are the key nutrients in acid soils of the NEH-region where these deficiencies are induced and for achieving required yield and quality in large-seeded groundnut application of P, Ca and B and organic fertilizers are most critical. The study with various fertilizers, lime and FYM have shown that it is essential to fertilize the large-seeded groundnut with essential elements and with proper management it was possible to harvest about 2000 kg ha^{-1} pod yield. The, combination of organic with inorganic sources was better than the lone use of inorganic fertilizers in acid soils.

Table 4. Influence of various nutrients sources and INM in ICGS 76 groundnut during *kharif* 2009 in Mizorum

Treatment	Height (cm)	Branches plant^{-1}	Pods plant^{-1}	100 pod wt (g)	100 kernel wt (g)	Yield (kg ha^{-1})
control	22.3	6.6	9.2	158.7	65.3	1210
10 t ha^{-1} FYM	24.5	8.9	11.8	154.4	62.1	2150
P50	22.6	8.1	12.5	140.2	57.4	1560
Ca 100	21.0	6.7	13.0	146.8	59.1	1910
Ca 100 through local source	25.9	8.8	17.1	170.7	62.6	2240
P50+ Ca 100	24.3	7.1	13.0	159.3	62.3	2110
P50+ Ca 100 + boron	28.7	8.7	19.6	164.5	64.5	2180
P50+ Ca 100 + boron + Mo	30.4	9.3	15.2	166.1	65.3	2280
P50 + BF	23.7	8.3	11.6	174.4	67.6	2310
Ca 100+ BF	23.5	6.7	9.9	158.6	62.9	1270
P50+ Ca 100+ BF	24.8	7.7	10.1	148.9	60.4	2190
P50+ Ca 100 + boron + Mo + BF	27.9	8.5	15.1	141.2	59.6	2310
SEm (±5)	2.0	0.8	1.1	8.3	3.7	24
C.D. (5%)	5.7	2.3	3.2	23.9	10.5	70

Local Ca source was Sun grass @ 2 kg m^{-2}, Boron as 2 kg Borax ha^{-1}, BF as *Rhizobium*, Mo as 500 g Sodiu molybdate ha^{-1}

Sub-Project 03 : Development of sustainable production technologies for north-eastern India

(A.L. Singh, J.B. Misra, S. Biswas, K.A. Pathak, Y. Ramakrishna, M. Singh, B. P. Bhatt (ICAR Res. Complex for NEH-region)

Evaluation of released cultivars and nutrient efficient lines

Evaluation of groundnut varieties for their tolerance of soil acidity and Al-toxicity and finally pod yield in NEH region has been a regular feature of this project and by the year 2010 more than 100 groundnut varieties were evaluated and some of them recommended for cultivation in this region. In the recent years over 40 groundnut genotypes comprising released cultivars and nutrient-efficient lines were evaluated for four years in NEH region and the high yielding groundnut genotypes with a fairly good degree of tolerance to soil acidity, insect pests and foliar diseases were identified for various states:

- Mizorum: ICGS 76, ICGV 88448, CSMG 84-1, ICGV 86590, TKG 19A, GG 20, M 13.
- Tripura: ICGS 76, GG 13, M 13, TG 37A, Kaushal, NRCG 7599, 6450, 6155
- Arunachal pradesh: ICGV 86590, GG 7, NRCG 1308, and 7599.
- Nagaland: ICGS 76, CSMG 84-1 GG 7, FeESG 8 and 10 and NRCGCS 268 and 148

Identification of groundnut varieties suitable for various intercropping systems

The field experiment in Manipur for three years demonstrated highest groundnut yield in maize + groundnut intercropping and the varieties ICGV 86590 and TKG 19A were most suited. In Tripura intercropping system using three groundnut genotypes (FeESG 8, FeESG 10 and GG 7) intercropped with sesame, mung and rice in various combinations, the FeESG 10 groundnut in combination with rice at 2:2 produced highest yield of 1570 kg ha^{-1} followed by the combination of GG 7 + mung (970 kg ha^{-1}) at 1:1 and FeESG 8 + Rice (1080 kg ha^{-1}).

Evaluation of confectionery groundnut genotypes in NEH region

The NEH region, with no limitation of water, has high potential for growing confectionery groundnut. Accordingly 10-15 confectionery/large seeded groundnut varieties, viz., GG 20, HNG 10, ICGS 76, BAU 13, TPG 41, GG 7, Somnath, NRCGCS 148, 268 and 281 were evaluated for their yield potential in NEH region under high management conditions of (FYM 10 t ha^{-1} + PSM + PGPR and all fertilizers). Three years of study in Mizorum, Tripura, Barapani and Nagaland revealed that though all these groundnut genotypes performed well in NEH and hence any one of these could be used, however BAU 13, GG 20, CSMG 84-1, ICGS 76 and NRCGCS 148 were superior yielding one. But the large-seeded groundnut should not be grown in low fertility soils, where the performance of all these was very poor.

In Tripura, seven cultivars were grown during *kharif.* The incidence of late leaf spot disease was comparatively low in GG 20 and ICGS 76 with disease scores of 2.87 and 4.1, respectively. The variety, ICGS 76, was, however, more prone to rust (Table 5). The genotypes FeESG 10 and FeESG 8 showed high incidence late leaf spot (disease score: 6.33 – 6.70) although the former one was resistant to rust (disease score 1.9). The rest of the varieties were intermediate in disease reaction. Both GG 20 and ICGS 76 gave high yield during the season.

Table 5. Disease incidence and yield performances in groundnut genotypes in Tripura during *kharif* 2009

Genotype	Disease score (1-9 scale)		Yield plot^{-1} (kg 5 sq m^{-1})
	Late leaf spot	Rust	
FeESG 8	6.70	3.40	1.300
FeESG 10	6.33	1.90	1.050
GG 5	5.23	2.00	0.750
GG 7	4.47	1.80	1.350
GG 11	5.37	1.76	0.500
GG 20	2.87	1.80	1.820
ICGS 76	4.10	3.57	1.627

PROJECT 06: DEVELOPMENT OF SUSTAINABLE PACKAGES OF PRACTICES FOR GROUNDNUT BASED CROPPING SYSTEMS

(N. K. JAIN*, R. S. JAT**, H. N. MEENA, D. BHADURI AND K. K. PAL)

* Since 20th October, 2010 **Upto 28th February, 2011

Permanent experiment on nutrient dynamics and sustainability under groundnut based cropping system

A long-term experiment with five popular groundnut based cropping systems viz: sole groundnut, two intercropping systems (with pearl millet and pigeon pea) and two sequential cropping systems (groundnut–wheat and groundnut–wheat–green gram) was initiated during *kharif* 1998 under different fertilizer regimes created through combinations of organic and inorganic fertilizers to study the nutrient dynamics and sustainability of the systems.

The performance of groundnut under different cropping systems is presented below (Table 1): All the cropping systems had a positive effect on pod yield of groundnut and the total system productivity (TSP) in terms of groundnut pod equivalent yield. The highest TSP (2451 kg ha^{-1}) and net returns (Rs 33541/-ha^{-1}) were obtained with groundnut with FYM (5 t ha^{-1}) + 50% RDF, wheat with FYM (5 t ha^{-1}) + 50% RDF, and green manuring with green gram in the groundnut-wheat-green gram cropping system. The sustainable yield index was highest (SYI=0.92) in groundnut (FYM+50% RDF)-wheat (100% RDF). The ten-year soil-fertility data on organic carbon analysis revealed a slight improvement with integrated use of organic and inorganic fertilizers and it was highest in the groundnut with FYM (5 t ha^{-1}) + 50% RDF-wheat with FYM (5 t ha^{-1}) + 50% RDF-green gram cropping system (0.56%).

Table. 1. TSP (averaged over ten years in terms of groundnut pod equivalent yield) and soil organic carbon status (after 10 years) in various cropping systems and nutrient management practices (initial soil organic carbon = 0.36%)

Treatment	Groundnut (100% RDF)				Groundnut (FYM + 50% RDF)			
	TSP (kg ha^{-1})	Sd	SYI	OC (%)	TSP (kg ha^{-1})	Sd	SYI	OC (%)
Sole groundnut	1044	0.28	0.61	0.44	1097	0.05	0.65	0.47
Wheat (100% RDF)	2105	0.32	0.75	0.46	2368	0.06	0.92	0.48
Wheat (50% RDF)	1943	0.20	0.77	0.46	2343	0.11	0.89	0.47
Wheat (FYM + 50% RDF)	2230	0.15	0.87	0.48	2354	0.12	0.89	0.50
Wheat (100% RDF)-green gram	2152	0.17	0.84	0.46	2334	0.03	0.88	0.55
Wheat (50% RDF)-green gram	1937	0.21	0.83	0.46	2362	0.13	0.88	0.52
Wheat (FYM+50% RDF)-green gram	2222	0.003	0.74	0.48	2451	0.01	0.80	0.56
Pigeon pea (100% RDF)	1274	0.17	0.77	0.48	1260	0.24	0.73	0.51
Pigeon pea (50% RDF	1153	0.05	0.78	0.49	1275	0.26	0.72	0.49
Pearl millet (100% RDF)	627	0.12	0.64	0.46	653	0.24	0.63	0.49
Pearl millet (50 % RDF)	632	0.06	0.72	0.49	639	0.001	0.69	0.49

TSP = groundnut equivalent yield averaged over 10 years; OC = soil organic carbon content; SD = standard deviation; and SYI = sustainable yield index.

Development of technology for application of citric acid in groundnut to enhance the P availability

The experiment was conducted during summer 2010 to increase the soil phosphorus availability by application of citric acid (CA) and to find out the suitable mode of application of CA in groundnut. The treatment consisted of four levels of CA (control, 2, 4 and 6 kg ha^{-1}) and five modes of applications (CA alone, CA with FYM 2t ha^{-1}, CA with FYM 1t ha^{-1}, CA with SSP 250 kg ha^{-1}, and CA with SSP 125 kg ha^{-1}).

The results (Table 2) revealed that application of CA with either FYM or SSP significantly increased the pod yield of groundnut over no application. The significantly highest pod yield (2605 kg ha^{-1}) was obtained with the application of '2 kg CA + 2 t FYM ha^{-1}. The magnitude of response, however, decreased with the increasing doses of CA (4 and 6 kg ha^{-1}). There was no significant effect on haulm yield and harvest index (Table 3). Maximum value of organic carbon (0.93%) was recorded with 2 t FYM ha^{-1} while P status (14 kg ha^{-1}) was higher with 250 kg SSP ha^{-1}. Due to application of citric acid both soil organic content and available-P increased. Maximum soil organic carbon and available-P status was recorded under 6 kg ha^{-1} citric acid.

Table 2. Interaction effect of levels and mode of application of citric acid on pod yield (kg ha^{-1}) of groundnut

Levels of citric acid	Mode of application				
	Control	FYM (2 t ha^{-1})	FYM (1 t ha^{-1})	SSP (250 kg ha^{-1})	
Control	1593	1805	1821	1860	1617
Citric acid (2 kg ha^{-1})	1745	2605	1665	1868	1677
Citric acid (4 kg ha^{-1})	1709	1756	1822	1677	2143
Citric acid (6 kg ha^{-1})	1622	1778	1893	1807	1703
Mean	1667	1986	1800	1803	1785
CD (P=0.05) main-plot			165		
CD (P=0.05) sub-plot			122		
CD (P=0.05) main-plot at same sub-plot			288		
CD (P=0.05) sub-plot at same main-plot			273		
CV % (a)			10		
CV % (b)			9		

Table 3. Effect of levels and mode of application of citric acid on haulm yield, harvest index, organic carbon and soil P-status after harvest of groundnut

Treatment	Haulm yield (kg ha^{-1})	HI (%)	OC (%)	P (kg ha^{-1})
Control	4434	28	0.83	7
FYM (2 t ha^{-1})	4469	31	0.93	11
FYM (1 t ha^{-1})	4523	29	0.92	10
SSP (250 kg ha^{-1})	4113	31	0.91	14
SSP (125 kg ha^{-1})	4345	29	0.87	10
CD (P=0.05)	NS	NS	0.05	2
CV (%)	11	10	5.77	18
Control	4587	28	0.86	8
Citric acid (2 kg ha^{-1})	4558	29	0.89	11
Citric acid (4 kg ha^{-1})	4188	31	0.90	11
Citric acid (6 kg ha^{-1})	4174	30	0.91	12
CD (P=0.05)	NS	NS	0.03	1
CV (%)	14	11	4.82	15

Organic groundnut production practices

The experiment on organic farming was initiated during summer 2009 with the 14 combinations of organic treatments and one unfertilized control and one RDF. In this experiment some new nutrient sources of organic origin such as sea weed (Biozyme) and Panchagavya were also evaluated.

The results (Summer 2010) indicated that the highest pod yield (1772 kg ha^{-1}) was recorded with application of 15 t FYM ha^{-1} along with biofertilizers (*Rhizobium* and PSB) and biopesticides (*Trichoderma* and castor cake) and the pod yield was significantly superior only to T1, T2, T6, T7, T11, T14 and T16 (Table 4). On the other hand, application of different organic treatments did not differ significantly with each other in their effect on haulm yield, shelling out turn and HKM.

Due to application of different organic sources, the P-status of soil was significantly affected while the differences in organic carbon and K content were non-significant. Maximum net returns (Rs 25037 ha^{-1}) were realized with the application of 15 t FYM ha^{-1} along with biofertilizers (*Rhizobium* and PSB) and biopesticides (*Trichoderma* and castor cake).

Table 4. Effect of various sources of organic nutrition on groundnut productivity, soil fertility and the economics of cultivation

S.N	Treatment	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	SP (%)	HKM (g)	OC (%)	Soil P (kg ha^{-1})	Soil K (kg ha^{-1})	OC (%)	GR (Rs. ha^{-1})	TC (Rs. ha^{-1})	NR (Rs. ha^{-1})
T1	Control	1204	5417	70	35	0.8	6	269	0.8	30094	14500	15594
T2	RDF	1357	5000	71	32	0.9	15	243	0.9	33933	16160	17773
T3	FYM + BF + BP	1772	6250	70	34	0.9	17	355	0.9	44305	19268	25037
T4	Vermicompost +BF+BP	1562	5694	73	35	0.8	8	336	0.8	39062	19268	19794
T5	T3 + gypsum + RP	1631	5972	73	35	0.8	9	325	0.8	40785	21502	19283
T6	T4 + gypsum + RP	1296	5000	73	35	0.9	12	302	0.9	32396	21502	10894
T7	Sea weed	1374	5556	70	32	0.7	15	254	0.7	34347	15625	18722
T8	Panchagavya	1581	6111	72	35	0.8	11	287	0.8	39528	17972	21556
T9	T3 + T7	1618	5972	70	34	0.8	12	325	0.8	40458	20393	20065
T10	T4 + T7	1601	6528	72	34	0.8	14	261	0.8	40021	20393	19628
T11	T5 + T7	1357	5694	73	34	0.9	5	347	0.9	33917	22627	11290
T12	T6 + T7	1628	5972	66	33	0.8	8	231	0.8	40708	22627	18081
T13	T3 + T8	1533	5972	74	34	0.8	9	343	0.8	38319	22740	15579
T14	T4 + T8	1132	5139	72	36	0.9	13	273	0.9	28298	22740	15558
T15	T5 + T8	1570	5417	73	34	0.9	14	265	0.9	39250	24974	14276
T16	T6 + T8	1487	5278	73	35	0.8	7	273	0.8	37187	24974	12213
CD (p = 0.05)		275	NS	NS	NS	NS	3	NS	NS			

Optimization of doses of application of fertilizers for attaining specific yield targets through IPNS in summer groundnut

A field experiment was initiated during summer 2010 to generate equations of fertilizers application for attaining the set targets of yield and to proportionate the nutrient requirements from integrated plant nutrient system (IPNS). In the first step, a fertility gradient was created to generate basic data on: nutrient (N, P, K, S, Ca, B) requirements (kg t^{-1}), and the extent of contribution from soil, fertilizers and FYM, and then to calculate soil and fertilizer efficiency. For this, seven different levels of nutrients were applied. Two groundnut varieties TG 37A and GG 2 were used in the experiment. One season data (Table 5) revealed that maximum pod yields of both the varieties were obtained with the application of 50 kg N, 80 kg P_2O_5, 100 kg K_2O, 150 kg Ca, 40 kg S, 50 kg Mg, 4 kg Zn and 1.5 kg B ha^{-1}.

Compared to control, with application of different levels of nutrients there was a significant improvement in the contents of N and P of soil while there was no significant change in organic carbon and K contents. The highest soil-N (after harvest) was observed with the application of 50 kg N, 80 kg P_2O_5, 100 kg K_2O, 150 kg Ca, 40 kg S, 50 kg Mg, 4 kg Zn and 1.5 kg B ha^{-1} while the highest available-P was recorded with the application of 12 t FYM ha^{-1} in both the varieties.

Table 5. Groundnut productivity and soil fertility status as influenced by various treatments

Treatments	GG 2				TG 37A				OC (%)			Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
										After			After			After			After	
	Pod yield (kg ha^{-1})	HI (%)	SP (%)	HKM (g)	Pod yield (kg ha^{-1})	HI (%)	SP (%)	HKM (g)	Initial	V_1	V_2	Initial	V_1	V_2	Initial	V_1	V_2	Initial	V_1	V_2
T1	2443	25	71	41	2668	31	68	41	0.83	0.76	0.83	52	69	76	6	8	9	388	265	317
T2	2908	29	70	39	3082	32	67	39	0.81	0.88	0.85	65	71	78	18	13	20	422	261	310
T3	2778	27	72	41	2863	30	70	43	0.84	0.87	0.84	42	71	93	19	18	21	448	250	306
T4	2450	27	70	40	3159	32	67	40	0.83	0.84	0.86	79	95	87	12	16	20	464	258	269
T5	2805	31	70	41	3182	32	67	44	0.79	0.88	0.91	79	93	82	16	18	21	444	310	321
T6	3454	37	71	42	3258	35	67	43	0.78	0.87	0.97	59	109	103	10	19	22	452	284	287
T7	3290	36	71	43	2807	33	71	45	0.78	0.83	0.86	64	92	81	13	22	25	396	269	280
CD (P=0.05)	570	NS	NS	NS	490	NS	NS	NS	NS	NS	NS	11	21	17	3	4	4	NS	NS	NS
CV (%)	11	-	-	-	12	-		-	-											

T1 (Control); T2 (Farmer's practice 41-46-25); T3 (30-40-50-80-25-30-2-1 NPKCaSMgZnB), T4 (40-60-75-125-30-40-3-1); T5 (50-80-100-150-40-50-4-1.5), T6 (60-100-125-200-50-60-5-2) and T7 (12 t FYM ha^{-1}) and V1: GG 2 and V2: TG 37A.

Revalidation of doses of fertilizers (N:P:K) for summer groundnut production

The experiment was carried out during summer 2010 to revisit the response of groundnut to application of nitrogen, phosphorus and potassium fertilizers under the irrigated conditions at DGR farm. The experiment consisted of three levels each of nitrogen (25, 37.5 and 50 kg N ha^{-1}), phosphorus (50, 70 and 90 kg P_2O_5 ha^{-1}) and potassium (0, 30 and 60 kg K_2O ha^{-1}). Thus, in all 27 combinations of doses of N, P and K with three replications were evaluated.

Results indicated that application of nitrogen up to 37.5 kg ha^{-1} significantly improved the yields of pod and haulm over the control (25 kg N ha^{-1}) while there was a slight decline in yield with the application of nitrogen at higher doses (Table 6).

Successive increase in levels of phosphorus up to 70 kg P_2O_5 ha^{-1} improved the yields of pod and haulm significantly and thereafter a declining trend was observed.

Similar to nitrogen and phosphorus, application of potassium up to 30 kg K_2O ha^{-1} significantly enhanced the pod and haulm yields and with higher doses the yield decreased slightly.

The changes in all the parameters of growth and yield followed the same trend. Compared to the initial status, the soil-fertility improved with the addition of nutrients.

Table 6. Effect of application of nitrogen, phosphorus and potassium fertilizers on yield of pod and haulm of summer groundnut

Level of application	Pod yield	Haulm yield
N (kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1})
25	1417	4218
37.5	1565	4591
50	1426	4501
CD (P=0.05)	123	160
P_2O_5 (kg ha^{-1})		
50	1401	4321
70	1553	4514
90	1454	4475
CD (P=0.05)	123	160
K_2O (kg ha^{-1})		
0	1369	4321
30	1624	4552
60	1414	4437
CD (P=0.05)	123	160

Effect of different combinations of sources of nutrients on growth, yield and quality of summer groundnut

The experiment was conducted during summer 2010 in randomized block design with three replications and a net plot size of 8 m x 5 m. The treatments comprised

- T_1 Control
- T_2 FYM 10 t ha^{-1}
- T_3 25:50:0 kg ha^{-1} recommended N:P:K + FYM 5 t ha^{-1} + 500 kg gypsum ha^{-1}
- T_4 Farmers' practice (45-70-40 kg ha^{-1})
- T_5 40-60-60 kg urea + SSP + MOP ha^{-1}
- T_6 40-60-60 kg urea + DAP + MOP + 250 kg gypsum ha^{-1}
- T_7 40-60-60 kg ammonium sulphate + SSP + MOP ha^{-1}
- T_8 40-60-60 kg ammonium sulphate + DAP + MOP + 250 kg gypsum ha^{-1}
- T_9 40-60-60 kg urea + SSP + MOP + 10:2:1 kg Fe Zn B ha^{-1}
- T_{10} 40-60-60 kg urea + DAP + MOP + 250 kg gypsum + 10:2:1 kg Fe Zn B ha^{-1}
- T_{11} 40-60-60 kg ammonium sulphate + SSP + MOP + 10:2:1 kg Fe Zn B ha^{-1}
- T_{12} 40-60-60 kg ammonium sulphate + DAP + MOP + 250 kg gypsum +10:2:1 kg Fe Zn B ha^{-1}

Growth attributes

Plant height was influenced significantly by application of various combinations of fertilizers. At 45 DAS, application of ammonium sulphate + DAP + MOP + micronutrients (T12) resulted in maximum height (25.53 cm) but at harvest, maximum height was observed with urea + SSP + MOP, while the minimum height was in control (T1).

The combination of urea + SSP + MOP + micronutrients (T9) recorded maximum leaf area (139.05 cm^2), which was statistically significant, while the minimum leaf area was recorded in the control. The significantly highest root length was observed in combination of urea+DAP+MOP+gypsum+micronutrient (T10).

Yield attributes

There were no significant differences in number of pegs and pods $plant^{-1}$ at 45 DAS, 100-kernel mass, shelling outturn and SMK due to application of various combinations of nutrients. Highest number of mature pods $plant^{-1}$ was observed in urea + SSP + MOP + micronutrients (T9) while the maximum 100-pod mass (110.33 g) was recorded in ammonium sulphate+SSP+MOP+micronutrients (T11).

Yield

The pod yield of groundnut improved significantly with the application of 40-60-60 kg ammonium sulphate + SSP + MOP +10:2:1 kg Fe Zn B ha^{-1} (T11) over all the other treatments and was at par with other treatments containing micronutrients and 25:50:0 kg recommended NPK+FYM 5 t+500 kg gypsum ha^{-1} (T3).

Table 7. Effect of different combinations of sources of nutrients on pod and haulm yields of summer groundnut during 2010

Treatments	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
T1	1284	2009
T2	2640	3973
T3	3294	4834
T4	2711	4844
T5	2515	4036
T6	2484	4048
T7	2771	4367
T8	2774	4448
T9	3252	4950
T10	2980	4769
T11	3312	4577
T12	3082	4659
CD (P = 0.05)	499	380
CV (%)	10.7	5.23

Optimization of fertilizer doses for specific yield targets through IPNS in groundnut

A field experiment was initiated during *kharif* 2009 to optimize fertilizer doses for attaining specific yield targets through IPNS. The fertility gradient in the field was created the same way as has been described for summer season. The results for variety GG 7 (Table 8) indicated that the yields of pod and haulm were highest in treatment

T6 i.e., 60 kg N, 100 kg P_2O_5, 125 kg K_2O, 200 kg Ca, 50 kg S, 60 kg Mg, 5 kg Zn and 2 kg B ha^{-1} and the values were significantly higher than those realized in treatments T1, T2, T3, T4 (except haulm yield) and T7. The harvest index, however, did not differ significantly due to various treatments.

The analysis of data pooled for two years, indicated that there was a significant improvement in harvest index with treatment T6 over control only.The pod yield, while being at par with those of T4 and T5, also improved significantly.

Table 8. Effect of different treatments on yields of pod and haulm and harvest index of groundnut (variety GG 7)

Treatment	Pod yield (kg ha^{-1})		Haulm yield (kg ha^{-1})		Harvest index (%)	
	2010	Pooled	2010	Pooled	2010	Pooled
T1	689	1007	1792	3540	27.7	25.1
T2	773	1164	1917	3632	28.7	29.3
T3	771	1129	1847	3598	29.5	28.3
T4	967	1314	2018	3635	32.1	30.1
T5	1148	1417	2027	3488	35.9	29.9
T6	1223	1487	2120	3588	36.4	31.4
T7	884	1178	1940	3646	31.2	28.9
S.Em±	97	60	40	123	2.1	1.2
CD (P = 0.05)	299	174	123	NS	NS	3.2

T1(Control); T2 (Farmer's practice 41-46-25); T3 (30-40-50-80-25-30-2-1 NPKCaSMgZnB), T4 (40-60—75-125-30-40-3-1); T5 (50-80-100-150-40-50-4-1.5), T6 (60-100-125-200-50-60-5-2) and T7 (12 t FYM ha^{-1}).

The results (Table 9) for variety GG 20 revealed that maximum pod yield was recorded in treatment T6 i.e., 60 kg N, 100 kg P_2O_5, 125 kg K_2O, 200 kg Ca, 50 kg S, 60 kg Mg, 5 kg Zn and 2 kg B ha^{-1} and the pod yield was significantly higher than those of only T1 and T3 treatments during *kharif* 2010. Significantly higher haulm yield was also obtained in treatment T6 and the value was at par with T5. Various treatments, however, did not have any significant influence on harvest index. In pooled analysis, the pod yield in T6 was significantly higher than all the other treatments. Also the maximum values for haulm yield and harvest index were in T6.

Table 9. Effect of different treatments on yield and harvest index of groundnut (Variety GG 20)

Treatment	Pod yield (kg ha^{-1})		Haulm yield (kg ha^{-1})		Harvest index (%)	
	2010	Pooled	2010	Pooled	2010	Pooled
T1	701	800	1649	2092	29.8	27.0
T2	1028	1008	1823	1929	36.0	30.7
T3	926	941	1756	1847	34.6	31.3
T4	1079	1083	1916	2025	36.0	32.9
T5	1109	1200	2069	2004	34.5	37.9
T6	1326	1426	2244	2141	36.9	39.7
T7	1071	1074	1883	2010	36.2	32.4
S.Em±	103	58	68	60	2.1	1.4
CD (P = 0.05)	317	169	208	176	NS	4.0

Optimization of water and nutrient requirement for groundnut under drip irrigation system

The experiment was conducted during *kharif* 2010 to optimise the nutrient and water requirements of groundnut under drip irrigation. The experiment consisted of five schedules of fertigation (50, 75 and 100% RDF through drip; 100 % RDF as furrow placement followed by drip irrigation; and 100% RDF as furrow placement followed by check basin method of irrigation) and was laid out in randomised block design with 3 replications. Results revealed that plant dry weight, pod weight and number of mature pods plant^{-1} were maximum in treatment 100% RDF in furrows with check basin method of irrigation and the values were significantly higher than those in 50 and 75% RDF supplied through drip only (Table 10). None of the treatments had significant effect on number of immature pods plant^{-1}, 100-kernel weight, shelling out turn and harvest index. Application of 100% RDF in furrows fb check basin method of irrigation, being at par with 100% RDF through drip and 100% RDF in furrow fb drip irrigation recorded significantly higher pod and haulm yields than those obtained with 50 and 75% RDF through drip.

Table 10. Effect of fertigation on groundnut productivity (*kharif* 2010).

Treatments	Plant wt (g plant^{-1})	Pod wt (g plant^{-1})	Mature pods plant^{-1}	Immature pods plant^{-1}	100-kernel wt (g)	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Shelling out-turn (%)	HI (%)
T1: 50% RDF by drip	7.83	6.18	7.13	8.80	36.66	563	1870	63.33	23.40
T2: 75% RDF by drip	8.66	6.93	8.03	8.07	37.10	713	2079	64.33	25.53
T3: 100% RDF by drip	9.99	8.03	9.93	7.40	37.60	885	2420	64.98	26.70
T4: 100% RDF as furrow placement	10.38	7.93	10.07	7.20	38.08	852	2433	65.82	25.94
Control (T5)*	11.14	8.30	10.27	6.40	38.63	895	2545	66.79	26.03
S.Em.±	0.61	0.29	0.35	0.65	0.47	43	97	1.49	1.42
CD (P=0.05)	1.98	0.94	1.15	NS	NS	142	317	NS	NS
CV (%)	10.98	6.70	6.70	14.77	2.17	9.6	7.4	3.97	9.61

(*Existing practice, Fertilizer as furrow placement with check basin method of irrigation)

Effect of different combinations of nutrient sources on growth, yield and quality of *kharif* groundnut

The experiment was conducted during *kharif* 2010 in the randomized block design having three replications and net plot size of 5 m x 8 m. The experiment comprised of 12 treatments namely

- T1 Control
- T2 FYM 10 t ha^{-1}
- T3 12.5:25:0 kg recommended NPK + FYM 5 t ha^{-1} + 500 kg gypsum
- T4 Farmers' practice (20:50:25)
- T5 20-40-30 kg urea + SSP + MOP ha^{-1}
- T6 20-40-30 kg urea + DAP + MOP + 250 kg gypsum ha^{-1}

T7 20-40-30 kg ammonium sulphate + SSP + MOP ha^{-1}
T8 20-40-30 kg ammonium sulphate + DAP + MOP + 250 kg gypsum ha^{-1},
T9 20-40-30 kg urea + SSP + MOP + 10:2:1 kg Fe Zn B ha^{-1}
T10 20-40-30 kg urea + DAP + MOP + 250 kg gypsum + 10:2:1 kg Fe Zn B ha^{-1}
T11 20-40-30 kg ammonium sulphate + SSP + MOP + 10:2:1 kg Fe Zn B ha^{-1}
T12 20-40-30 kg ammonium sulphate + DAP + MOP + 250 kg gypsum + 10:2:1 kg Fe Zn B ha^{-1}

Results (Table 11) showed that the highest pod yield was obtained with T10, which was followed by T9, T11, T12 and T3 but the values were statistically at par with each other. Haulm yield was, however, significantly higher under T11 over rest of treatments except T7, T9, T10, and T12. Other yield and growth parameters also followed more or less a similar trend. The soil fertility status also improved due to addition of each nutrient.

Table 11. Effect of different combinations of sources of nutrient on pod and haulm yields of *kharif* groundnut during 2010

Treatment	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
T1	337	1171
T2	462	2840
T3	562	2843
T4	536	3512
T5	533	3684
T6	463	3009
T7	536	4013
T8	534	3678
T9	617	4345
T10	645	4013
T11	611	4347
T12	611	4263
CD (P = 0.05)	100	655
CV (%)	11.03	11.13

Optimization of doses of hydrogel for irrigated as well as rainfed *kharif* groundnut

The experiment was conducted during *kharif* 2010. It comprised two irrigation schedules, one fully irrigated and another rainfed (without protective irrigation), which both were allotted to main plots and 4 levels of hydrogel (control, 1.5, 2.0 and 2.5 kg ha^{-1}), allotted to sub plots in split plot design with 3 replications. The crop was raised by following recommended package of practices. Results revealed that compared to control, none of the treatment had any significant effect on yield atributes as well as pod and haulm yields significantly (Table 12). This was due perhaps to the excessive and protracted rains in *kharif* 2010 and as such there was no water-deficit at any of the critical stages of the crop.

Table 12. Effect of hydrogel on yield attributes and yield of irrigated as well as rainfed groundnut (*kharif* 2010)

Treatment	Plant weight (g $plant^{-1}$)	Mature pods $plant^{-1}$	Immature pods $plant^{-1}$	Pod weight (g $plant^{-1}$)	100-kernel wt (g)	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Shelling out-turn (%)	HI (%)
Main Plot-Irrigation schedule									
Fully irrigated (I1)	7.10	6.08	3.43	3.71	27.27	676	1710	63.87	28.27
Rainfed without any protective irrigation (I2)	6.56	6.53	3.20	4.05	27.78	649	1684	64.16	27.75
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	9.19	14.88	6.85	25.97	10.74	38.36	6.37	2.85	27.39
Sub plot-Hydrogel (kg ha^{-1})									
Control (S1)	6.60	5.92	3.60	3.19	27.47	654	1649	61.68	28.41
1.5 (S2)	6.77	5.97	3.37	3.87	27.41	644	1685	63.71	27.61
2.0 (S3)	6.93	6.27	3.10	3.98	27.30	636	1703	64.11	27.04
2.5 (S4)	7.01	7.05	3.20	4.50	27.91	715	1750	66.57	28.97
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	10.3	11.95	27.14	27.72	7.6	11.67	8.81	4.27	13.53

Revalidation of fertilizer doses (N:P:K) for *kharif* groundnut production

The experiment was carried out during *kharif* 2010 to revisit the response of groundnut to applied nitrogen, phosphorus and potassium under irrigated conditions. The treatments consisted of three levels each of nitrogen (12.5, 25, and 37.5 kg ha^{-1}), phosphorus (40, 60 and 80 P_2O_5 kg ha^{-1}) and potassium (0, 30 and 60 kg K_2O ha^{-1}). Thus, in all 27 combinations of doses of N, P and K with three replications were evaluated.

Results (Table 13) reveled that during *kharif* 2010 successive increase in levels of nitrogen significantly enhanced pod and haulm yields of groundnut up to 25 kg ha^{-1} and thereafter increase was non-significant. Pooled data of 2 seasons (*kharif* 2009 and 2010) showed a similar trend. Compared to values corresponding to 12.5 kg N ha^{-1}, the increase in pod and haulm yields due application of 25 kg Nha^{-1} were 9.4% and 8.05% respectively.

Compared to application of 40 kg P_2O_5 ha^{-1}, the pod and haulm yields of the crop fertilized with 80 kg P_2O_5 ha^{-1} were significantly higher. On an average, there was an increase in pod and haulm yields by 12.86 and 10.37%, respectively, over 40 kg P_2O_5 ha^{-1} and 11.26 and 6.21% respectively over 60 kg P_2O_5 ha^{-1}.

There was a significant increase in pod and haulm yields with the application of potassium @ 60 kg K_2O ha^{-1} over lower levels during *kharif* 2010. The analysis of data pooled over two years indicated that there was an improvement in pod and haulm yields by 12.88 and 9.76%, respectively over control and compared 8.62 and 8.16%, respectively over 30 kg K_2O ha^{-1}.

Due to addition of nutrients, the other yield parameters followed more or less a similar trend. Compared to initial status, the soil fertility also improved.

Table 13. Effect of nitrogen, phosphorus and potassium on pod and haulm yields of *kharif* groundnut

Treatment	Pod yield (kg ha^{-1})			Haulm yield (kg ha^{-1})		
	2009	2010	Pooled	2009	2010	Pooled
N levels (kg ha^{-1})						
12.5	1240	450	845	3268	1781	2525
25	1338	528	933	3560	1932	2746
37.5	1379	554	967	3752	1941	2847
CD (P=0.05)	77	31	58	231	143	190
P levels (kg P_2O_5 ha^{-1})						
40	1253	481	867	3350	1783	2567
60	1266	500	883	3457	1914	2686
80	1439	550	995	3772	1956	2864
CD (P=0.05)	77	31	58	231	143	190
K levels (kg K_2O ha^{-1})						
0	1253	465	859	3364	1829	2597
30	1323	478	901	3488	1797	2643
60	1382	589	986	3728	2027	2878
CD (P=0.05)	77	31	58	231	143	190

PROJECT 07: MANAGEMENT OF EXISTING AND EMERGING PROBLEMS OF SOIL AND WATER SALINITY FOR GROUNDNUT PRODUCTION

(H. N. MEENA, D. BHADURI, R. DEY, K. CHAKRABORTY AND K.A. KALARIYA)

Use of saline water in groundnut based cropping systems

Consolidated results of project (2002 to 2010)

Groundwater forms an important source of irrigation next to surfacewater in arid, semi-arid and coastal regions of the country. About one-third of the total utilizable potential of the ground-water in such regions are of poor quality. In Gujarat, particularly in Saurashtra region, the farmers generally raise only one rain-fed crop of groundnut and keep fields fallow in the *rabi* (winter season) as they can not use under ground saline water for irrigation on the one hand and non availability of canal water for irrigation on the other hand. An experiment, which was started in the year 2002 continued up to 2010 with the objective of exploring the possibility of using saline groundwater for irrigation in different crop rotations (groundnut-groundnut, groundnut-wheat, groundnut-mustard, groundnut-bajra and groundnut-cowpea). After ten years of experimentation, it was concluded that instead of taking a single crop of groundnut in coastal area of Saurashtra region, the farmers can take an additional crop in summer season, the farmers can use saline water of 2-3 dS m^{-1} salinity for supplementary irrigation in *kharif* groundnut, and 4-6 dS m^{-1} salinity of water for irrigation of wheat, mustard and bajra crops in *rabi*-summer and can obtain economic yields of these crops (about 1000 kg ha^{-1} of groundnut, 1500 kg ha^{-1} mustard, 3500 kg ha^{-1} wheat and 3300 kg ha^{-1} of bajra). The saline water is not suitable for irrigation of summer groundnut and cowpea because salinity builds up in soil due to application of saline water for irrigation. The build up of salinity in root zone (EC_{iw} = 4 dS m^{-1} in groundnut and EC_{iw} = 6 dS m^{-1} in wheat, mustard and bajra) adversely affected absorption of water by plants even though the soil had enough water. This resulted in stunting of plants and significant decrease in yield. Prolonged use of saline water for irrigation lead to increased the soil pH from 7.8 in 2002 to 8.2 in 2010, which also possibly deteriorated the soil health and adversely affected the yield. The oil content in groundnut kernels and mustard seeds also decreased significantly with increase in salinity of the water from 0.5 to 6 dS m^{-1}.

Detailed results of groundnut-Cowpea rotation (2010-11)

After harvesting groundnut in *kharif* 2009, cowpea was sown in summer by using saline water (salinity levels 0.5, 2, 4 and 6 dS m^{-1}) for irrigation. Results showed that grain yield of cowpea decreased with increase of salinity of water 0.5 to 6 dS m^{-1} and that of soil from 1.1 to 7.5 dS m^{-1}. Compared to control (normal water), the yield was significantly lower with use of saline water for irrigation. After harvest of cowpea, as a result of continuous use of saline water for irrigation, the soil salinity increased gradually to 1.1, 3.1, 5.6 and 7.5 dS m^{-1} with respect to increasing levels of salinity in irrigation water.

Kharif groundnut was taken in 2010 to evaluate eight Spanish varieties namely TPG 41, GG 6, Girnar 3, GG 8, SG 99, TG 37 A, GG 7, and R 2001-3 in the saline environment having salinity levels of 0.5, 2, 4 and 6 dS m^{-1}. Each variety was grown in a single row of five meters without giving any supplementary irrigation. The performance of these varieties was very poor under salinity conditions due not only to salinity but also due to continuous and excessive rainfall through out the season which caused stagnation of water in the field.

It was observed that the pod and haulm yields of all the varieties were at par with use of saline water of 2 dS m^{-1} but significant differences were observed with the use of water salinity of 4 and 6 dS m^{-1} compared to water salinity of 0.5 dS m^{-1} (control). Further, the non-significant difference in pod and haulm yield were also recorded within the varieties under Spanish group but the decreasing order of pod yield were recoded in SG 99, TPG 41 and GG 8, TG 37A, GG 7, Girnar 3, R 2001-3 and GG 6 under saline environment. Almost similar trend was also observed on the performance of other yield contributing characters under saline environment.

Table 1. Effect of salinity on yield and yield contributing characters of summer cowpea

ECiw (dS m^{-1})	ECe (dS m^{-1}) harvest (cm)	Plant height at harvest (cm)	Root length at harvest	Final plant stand at harvest
0.5	1.1	50.2	22.5	3.2
2	3.1	43.5	17.8	2.8
4	5.6	39.8	17.1	1.7
6	7.5	33.1	14.1	1.0
CD at 5%	1.0	8.7	NS	1.1
ECiw (dS m^{-1})	**ECe (dS m^{-1})**	**Dry plant weight (g)**	**Dry root weight (g)**	**Fresh pod yield (kg ha^{-1})**
0.5	1.1	28.4	2.6	2418
2	3.1	18.8	2.8	1753
4	5.6	11.1	1.6	776
6	7.5	6.6	1.3	385
CD at 5%	1.0	8.8	NS	545

Table 2. Effect of saline water irrigation on pod and haulm yields of *kharif* groundnut

Treatment	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
Salinity levels (dS m^{-1})		
0.5	480	1775
2.0	548	1642
4.0	307	1175
6.0	29	251
CD (P= 0.05)	71.7	139.2
Genotype		
TPG 41	361	1148
GG 6	290	1174
Girnar 3	319	1160
GG 8	361	1345
SG 99	403	1172
TG 37 A	350	1288
GG 7	331	1190
R 2001-3	312	1209
CD (P= 0.05)	NS	NS

Evaluation of released cultivars of groundnut (Virginia and Spanish bunch group) under different methods of irrigation in saline environment at JAU Research Station, Khapat

An experiment was conducted at a hot-spot area (JAU Research Station, Khapat) during summer 2010. Sixteen Spanish and ten Virginia cultivars were grown using different methods of irrigation (flood, sprinkler and drip) under saline environment with initial soil and water ECe of 0.92 and 2.52 dS m^{-1}, respectively. After harvest the soil and water ECe were 2.02 and 4.57 dS m^{-1}, respectively. The first irrigation was given at the time of sowing and seven supplementary irrigations were given during the crop growth period. Irrespective of habit groups, there were no pod formation in any cultivar which perhaps was due to combined effect of very high temperature and high water salinity. There was a high rate of mortality due to continual use of saline irrigation water resulting in drastic reduction of population at the time of harvest.

PROJECT 08.: MANAGEMENT OF GERMPLASM OF CULTIVATED GROUNDNUT (*A. hypogaea L.*) AND ITS WILD RELATIVES

(A. L. RATHNAKUMAR, S. K. BERA AND M. C. DAGLA)

Field maintenance of wild *Arachis* germplasm

In field gene bank, 106 accessions belonging to 6 different sections *viz. Arachis* (66 accessions), *Caulorhizae* (1 accession), *Erectoides* (7 accessions), *Heteranthae* (7 accessions), *Procumbentes* (accessions 10), and *Rhizomatosae* (39 accessions) were maintained. The seeds and cuttings of these species were supplied to different indenters.

Acquisition, distribution and utilization of germplasm accessions

For use in various ongoing crop improvement programmes, 1398 germplasm accessions including wild relatives of groundnut, were supplied to 36 indenters for identification of promising lines for WUE, diseases and nematode tolerance, large seeded types and subsequent use in ongoing crossing programmes. The recipients included the scientists of DGR (1059 accessions), State Agricultural Universities (239 accessions) and AICRP-G centres (100 accessions). Three new accessions were acquired.

Multiplication and conservation of germplasm accessions

Voucher samples

In *kharif*-2010, 284 accessions (60 HYB, 40 HYR, 145 VUL, and 39 FST) were sown for multiplication. As poor yields were realized due to excessive rains, the seeds could not be sent for conservation in NBPGR, New Delhi.

Mini-core collection

Out of 184 accessions comprising the mini core collection, 75 accessions (6 HYB, 11 HYR, 30 VUL, and 28 FST) were multiplied in *kharif* 2010.

DUS reference varieties

Thirty DUS reference varieties (7 HYB, 8 HYR, 13 VUL, and 2 FST) were multiplied in *kharif* season to augment their seeds.

General accessions

A set of 159 accessions received from NBPGR was multiplied in *kharif* season.

Released varieties

A set of 173 released varieties (48 HYB, 26 HYR, 95 VUL, and 4 FST) was multiplied in *kharif* season for distribution and conservation.

Variability garden

A set of 45 morphologically unique accessions (15 HYB, 2 HYR, 10 VUL, and 18 FST), identified from the working collection, was multiplied for distribution and conservation.

Sub-set of DGR working collection

In *kharif*, 167 accessions (37 HYB, 9 HYR, 72 VUL, and 49 FST), representing a subset of DGR working collection, were multiplied. Of these, 86 accessions were deposited with NBPGR for conservation.

Repatriated accessions

A set of 185 accessions (HYB: 36; HYR: 28; VUL: 87; FST: 34) repatriated from ICRISAT was multiplied in *kharif* season. Due to poor yields, the quantities of seeds required for depositing with NGB could not be obtained. Hence, these accessions will be further multiplied in ensuing *kharif*.

Composite collection for water use efficiency

A total of 196 diverse germplasm accessions and advanced breeding lines developed through NFBSFARA project were multiplied in *kharif*.

ICRISAT germplasm

For multiplication, a total of 91 (26 HYB, 5 HYR, 24 VUL, and 36 FST) accessions were sown in *kharif* 2010.

Morpho-physiological characterization of mini-core germplasm

Characterisation of new accessions

A total of forty-one new accessions (21 HYB, 3 HYR, 5 VUL, 3 FST, and 9 unidentified) were evaluated and characterised in *kharif* 2010. Due to excessive rainfall during the critical stages of crop growth, only eight qualitative and 12 quantitative traits could be characterised. Pod yield in these accessions ranged from 2.0 g (NRCG 13311) to 11.2 g (NRCG 13307); Shelling turnover ranged from 47.9 (NRCG 743) to 72.2% (NRCG 13313). Hundred seed mass ranged from 16.0 g (NRCG 13192) to 48.6 g (NRCG13000).

Characterisation of exotic collection

Forty exotic collections have been evaluated and characterised in *kharif* 2010. Only eight qualitative and 12 quantitative traits could be characterised.

Among the 40 accessions studied, the pod yield was low (1.7 g plant^{-1}) in NRCG 17239 to 9.9 g plant^{-1} in NRCG 17242. Hundred seed mass ranged from 18.2 g (NRCG 17211) to 44.8 g (NRCG 17241). Shelling turnover ranged from 44.4 (NRCG 17211) to 73.8% (NRCG 17230).

Characterisation of large seeded accessions

Twenty-eight large seeded Virginia accessions (HYB: 18; HYR: 10) were evaluated and characterised for 12 pod and seed traits. The check varieties used were M 13 (HYR) and GG 20 (HYB).

The hundred seed mass ranged from 27.4 g (NRCG 12560) to 48.7 g (NRCG 4775). Pod yield of these accessions ranged from 2.2 g (NRCG 13085) to 11.8 g (NRCG 685) per plant. Shelling turn over in the accessions ranged from 52.5 (NRCG 12447) to 72.3% (NRCG 13085).

Studies on flowering behaviour and yield of large-seeded germplasm accessions

For two consecutive summer seasons (2009 and 2010), 28 large seeded accessions (13 Spanish bunch and 15 Valencia) were evaluated in field for their yield traits in a randomized block design with two replications at two locations DGR, Junagadh and ARS, Shirgaon. The flowering behaviour was studied in both 2009 and 2010 seasons at DGR Junagadh and only in 2010 season at ARS, Shirgaon. The varieties TKG 19A and GG 7 were used as check.

Results of analysis of two-year data generated at DGR, Junagadh

The total number of flowers produced in each of the 30 accessions at four different stages at ten - day intervals beginning at 45 DAS and culminating at 75 DAS (coinciding with flower initiation and peak flowering stages, respectively) were recorded besides recording observations on five yield traits (number of mature pods, pod yield, 100 - seed mass, shelling outturn, and days to maturity). The ANOVA obtained by using data pooled over years indicated that:

- Among the yield traits, the year - to - year and the genotypic variations were significant only for number of mature pods and days to maturity while the variations for pod yield were non-significant and only genotypic variations were significant for 100-seed mass and shelling outturn.
- In case of flower production at the four different stages of growth, the year-to-year variation was not significant at 45 DAS while both year-to-year and genotypic variations were significant at all the other three stages.

The values of mean, range, critical difference and co-efficient of variation calculated by using pooled data for the yield traits are given in Table 1.

Table 1. Mean, range, critical difference (CD) and co-efficient of variation (CV) for the yield traits at DGR Junagah

Trait	Mean	Range	CD (p=0.05)	CV (%)
Mature pods (no. plant^{-1})	12.3	4.3-18.8	6.8	33.1
Pod yield (g plant^{-1})	12.9	5.4-16.9	6.4	35.9
Hundred seed mass (g)	45.4	38.0-55.2	6.2	7.8
Shelling outturn (%)	69.8	56.8-75.6	6.8	13.3
Maturity (no. of days)	114.3	110.5-119.8	5.15	2.2

Results of analysis of one year data of two locations (DGR, Junagadh and ARS, Shirgaon)

In summer 2010, the observations were recorded on flower production (at four stages of crop growth) and five yield traits for 28 germplasm accessions along with two check varieties, TPG 41 and GG 7.

The analysis of pooled data indicated that:

- For flower production, variations due to locations as well as genotypes were significant at all the four stages of crop growth
- Among the yield traits, days to maturity, number of mature pods and hundred seed mass exhibited significant variations due to genotype whereas the variations in pod yield were significant only due to location. The variations in shelling outturn due to location or genotype were, however, non-significant.

Comparison of expression of traits at DGR, Junagadh and ARS Shirgaon

The values of mean (pooled), range, critical difference and co-efficient of variation for yield traits in the two locations are provided in Table 2.

Table 2. Comparison of values of mean (pooled), range, citical difference, and co-efficient of variation for yield traits

Trait	Mean		Range		CD (p=0.05)	CV (%)
	Junagadh	Shirgaon	Junagadh	Shirgaon		
Mature pods (no. plant^{-1})	13.0	9.1	4.8-16.8	6.3-12.7	2.2	23.1
Pod yield (g plant^{-1})	13.6	10.3	4.1-19.4	6.6-14.6		
Hundred seed mass (g)	44.6	54.7	39.0-53.0	41.3-68.4	5.6	4.6
Shelling outturn (%)	69.3	70.9	40.9-75.6	58.4-76.4	3.9	5.6
Days to maturity	112	106	108-119	96-119	6.7	2.5

Thus the values of days to maturity, pod yield and number of pods/plant for 30 genotypes grown at Junagadh were higher than the corresponding values pertaining to Shirgaon. While the values of hundred seed mass and also shelling outturn, were higher for Shirgaon than those for Junagadh.

It was found that the seed filling was rapid in Ratnagiri, which resulted in the high seed mass, but the number of pods and yield/plant were found to be slightly lower at Ratnagiri when compared with the values observed under Junagadh conditions. Temperature seemed to play a role in rapid seed filling at Ratnagiri (Table 3) which was about 25-35°C throughout the crop growth.

Table 3. Weather-data for crop-period in *rabi*-summer 2009-10

Month	Temperature (°C)				Relative Humidity (%)			
	Junagadh		Shirgaon		Junagadh		Shirgaon	
	Min.	Max.	Min.	Max.	Morning	Evening	Morning	Evening
January	13	31	24	33	59	23	61	49
February	15	32	23	32	63	19	76	60
March	22	38	26	33	62	16	83	68
April	24	41	29	33	74	19	78	68
May	26	41	30	35	76	29	73	64

Evaluation of genotypes with low ?[13]C, for yield and physiological traits under moisture-deficit conditions

A total of 28 genotypes comprising 12 released varieties, 7 from ICRISAT mini-core collection and 9 accessions of subset of NRCG working collection and identified for exhibiting low ?[13]C values (around 18.0) were studied for yield and its components and physiological traits (SLA and SCMR) under moisture-deficit conditions in summer 2010.

The genotypes were grown in a randomised block design with two replications. For imposing moisture-deficit stress, the irrigation was withheld for 30 days from 40 DAS to 70 DAS. The soil-moisture content at 15 cm depth was 15.0, 13.5 and 6.2% at 10, 20 and 30 days after imposing stress (DAST), respectively while corresponding values at 30 cm depth were 17.0, 14.2 and 11.1% respectively. These values were indicative of the extent of moisture deficit stress to which the genotypes were subjected. The soil temperature at 15 cm depth was 32.0, 38.7 and 44.1°C at 10, 20 and 30 DAST, respectively.

The ANOVA indicated the significant differences due to genotypes for all the traits studied. The range of per plant pod yield was 4 g (TMV 10) to 34 g (BG 2) for the released varieties and from as low as 1 g (NRCG 404) to as high as 15 g (NRCG 14395) for the germplasm accessions. The varieties giving high pod yield per plant under moisture deficit stress were ICGV 86590 (22 g), Kadiri-3 and M 197 (21 g), and DRG 12 (20 g).

The main cause for the low yields of germplasm accessions appeared to be reduction in both the number of pods per plant and 100-seed mass and thereby indicating an adverse affect of moisture deficit stress on partitioning of assimilates. While among the released varieties, the number of pods was leff affected and hence the yields were much less affected.

The SLA and SCMR were measured 10, 20 and 30 days after imposing the moisture deficit stress in the 28 genotypes. The values of SLA in all the five high-yielding varieties at 20 DAST were much higher than those at 10 DAST and the values decreased subsequently and were the lowest at 30 DAST.

The increase in the SLA 20 DAST could be attributed mainly to increase in leaf area while reduction in SLA observed at 30 DAST could be attributed mainly to increase in leaf weight and reduction in leaf area (Figure 1).

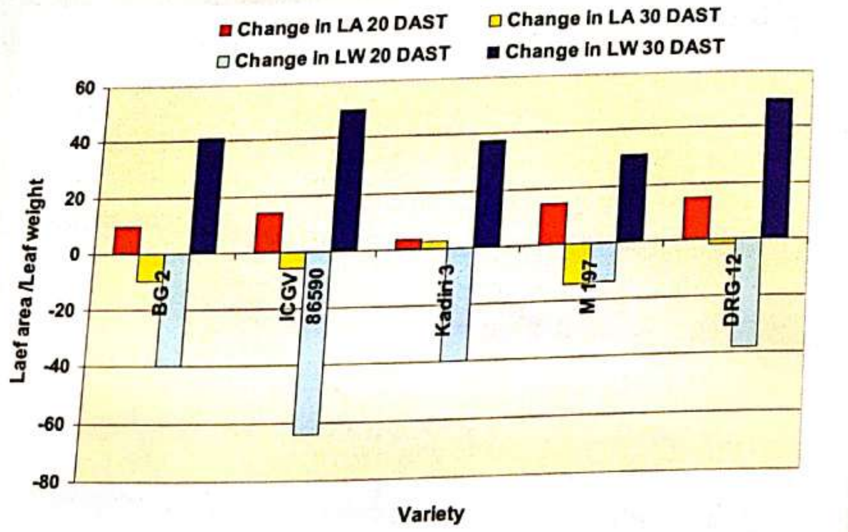

Figure 1. Changes in leaf area and weight (%) under moisture-deficit stress

The largest increase in SLA (from 206.3 to 293.3 cm^2g^{-1}) was in DRG 12 at 20 DAST while the largest reduction in SLA at 30 DAST was in BG 2 (from 186.7 to 157.2 cm^2g^{-1}). Interestingly, the variety Kadiri 3 maintained its leaf area and showed the least reduction at 30 DAST at the same time it regained its leaf weight at 30 DAST almost as much as it lost after 20 days of stress. It was also observed that the SCMR increased gradually during the period of stress in all the varieties (Figure 2).

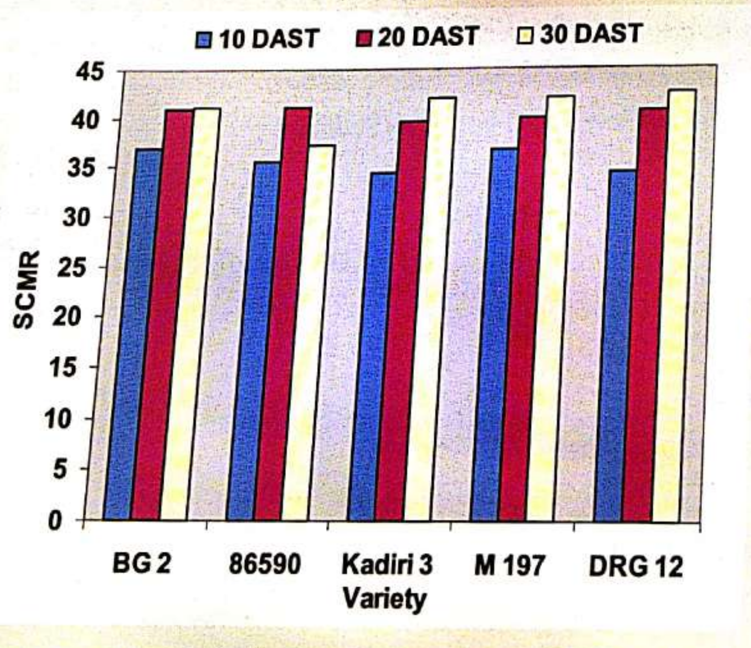

Figure 2. Changes in SCMR under water-deficit

Screening of Spanish mini-core collection for fresh-seed dormancy

Out of 67 Spanish accessions evaluated, four accessions which exhibited fresh-seed dormancy over two seasons were registered as novel 'genetic stock' with the NBPGR. Out of four accessions registered, two possessed fresh seed dormancy for as long a period as 60 days- these are NRCG 14350 (INGR 10034) and NRCG 14409 (INGR 10035). Another two accessions possessed fresh-seed dormancy for relatively a short period of 40 days and these are NRCG 14326 (INGR 10032) and NRCG 14336 (INGR 10033).

Assessment of kernel infection and colonization by *Aspergillus flavus*

Twenty-two accessions, belonging to NRCG subset of working collections, were screened *in vitro* for seed infection and colonization by the highly virulent strain of *A. flavus* (AF-111). Out of these, six accessions showed infection and colonization below 2.33% and 3.33%, respectively while among other genotypes the infection was as high as 100% and colonization up to 56.67% (Table3).

Table 3. Assessment of infection and colonization in groundnut genotypes identified for *in vitro* tolerance of *A. flavus*

Genotype	Infection (%)	Colonization (%)
NRCG 12431	6.67	0.00
NRCG 12591	23.33	3.33
NRCG 12671	23.33	0.00
NRCG 12732	13.33	0.00
NRCG 12899	26.67	3.33
NRCG 12968	13.33	0.00

Screening of mini-core collections of DGR and ICRISAT for major pests and diseases at hot spots

The mini-core collections of DGR and ICRISAT were screened for PBND at Raichur during summer 2010. The incidence of PBND was high (50.3%) in the susceptible variety GG 11 while one NRCG (NRCG 14625) and two ICRISAT (ICG 171 and ICG 85) mini core accessions were identified for showing very low (<10%) incidence.

Five accessions of NRCG mini core, NRCGs 14710 (10.1), 13603 (12.2), 13129 (12.8), 1030 (14.6) and 9225 (15.4); and six accessions of ICRISAT mini-core, ICGs' 17625 (11.1), 11687 (12.2), 9911 and 14105 (12.5), 12370 (13.9) and 4729 (17.8%) recorded low (<20%) incidence.

PROJECT 09: BIOTECHNOLOGICAL APPROACHES TO THE CHARACTERISATION AND GENETIC ENHANCEMENT OF GROUNDNUT

(RADHAKRISHNAN T., A. L RATHNAKUMAR, CHUNI LAL, S. K. BERA AND ABHAY KUMAR)

Genetic transformation

Transformation of groundnut (*A. hypogaea* L. cv. GG 20) with mannitol-1- phosphate dehydrogenase (*mtlD*) gene construct

From the PCR-confirmed T_0 plants, 469 T_1 plants were grown in PII glass house. Among these 264 plants have so far been analyzed for the segregation of the transgene using PCR and gene specific primers and 160 plants were identified to have the transgene (Figure 1).

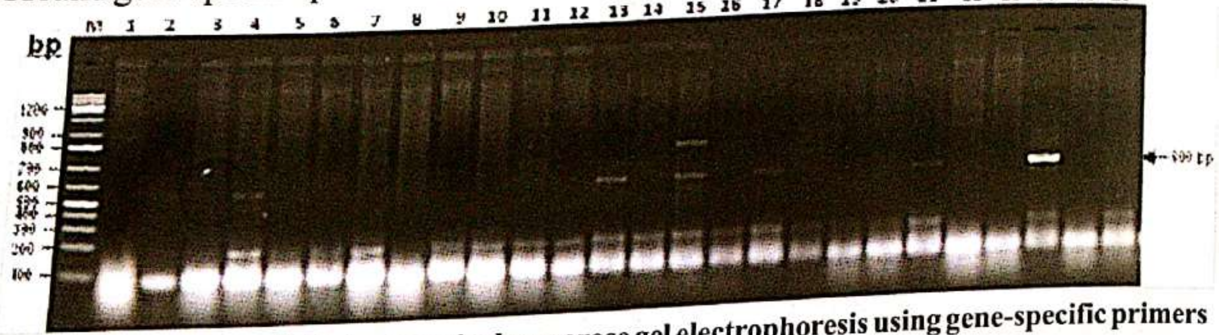

Figure 1. Screening of *mtl*D T_1 transgenics by agarose gel electrophoresis using gene-specific primers

Physiological analysis:

The T_1 generation of *mtlD* transgenics was evaluated for their response to varying levels of salinity (0, 100, 200, and 300 mM NaCl) using leaf disc assay. The leaf discs were floated for 72 h under continuous white light (30 mmol $m^{-2} s^{-1}$) at 28±1°C. Data are the mean of three independent experiments. The total leaf chlorophyll content was also estimated. It was observed that the chlorophyll content of T_1 plants was lower than that of wild type (untransformed groundnut variety GG 20). The chlorophyll content may show improvement in the T_2 generation homozygous plants.

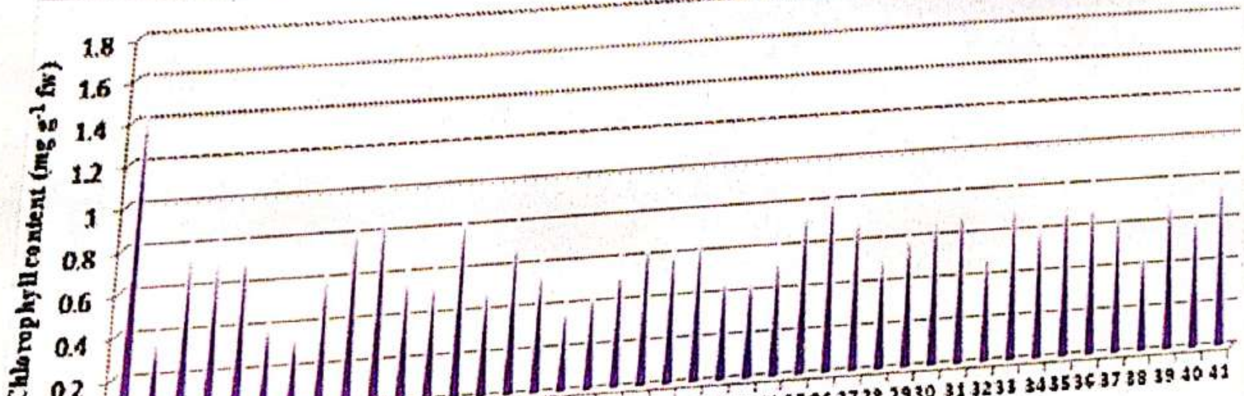

Figure 2. Total chlorophyll content in the leaf-discs from wild and transgenic plants

Of the PCR-positive plants, nine were confirmed with southern hybridization of genomic DNA for the integration of the transgene and the copy number. These plants were tested for the expression of the transgene using RT-PCR and in 8 events were confirmed.

Transgenics (*A. hypogaea* L. cv. GG 20) using annexin gene constructs

In 20 sets, 774 de-embryonated cotyledon-explants were co-cultured and 652 explants were regenerated, 1561 well developed shoots were obtained, and eventually 1023 rooted and healthy plants were transferred to glass house. PCR analysis of these plants using gene-specific primers is in progress and so far 8 PCR positive plants have been identified.

Transformation of groundnut (*A. hypogaea* L. cv. GG 20) using the plant defensin Rs-AFP2 (*Raphanus sativus* Anti fungal protein 2) and Tfgd2 (*Trigonella foenum gracecum* defensin 2) genes

Out of 794 explants were co-cultured with *Agrobacterium* in 20 batches, 672 explants regenerated and 1617 shoots were regenerated. Of these, 1135 shoots were established in glasshouse after hardening. PCR analysis of these shoots by using gene-specific primers revealed the presence of the transgene in 14 putative transgenics.

Development of mapping populations and assessment of molecular diversity Genotyping of the parental lines and populations

Eight parental genotypes viz. TAG 24, R9227, JL 24, ICGV 86590, GG 20, CS 83, CS 75, and CS 19 which were used for developing mapping populations, were analysed for their marker polymorphisms. The PCR products of 250 markers were separated on an on-chip microfluidic electrophoresis system and the profile (Figure 3) revealed 64 markers to be polymorphic between the two parents JL 24 and ICGV 86590.

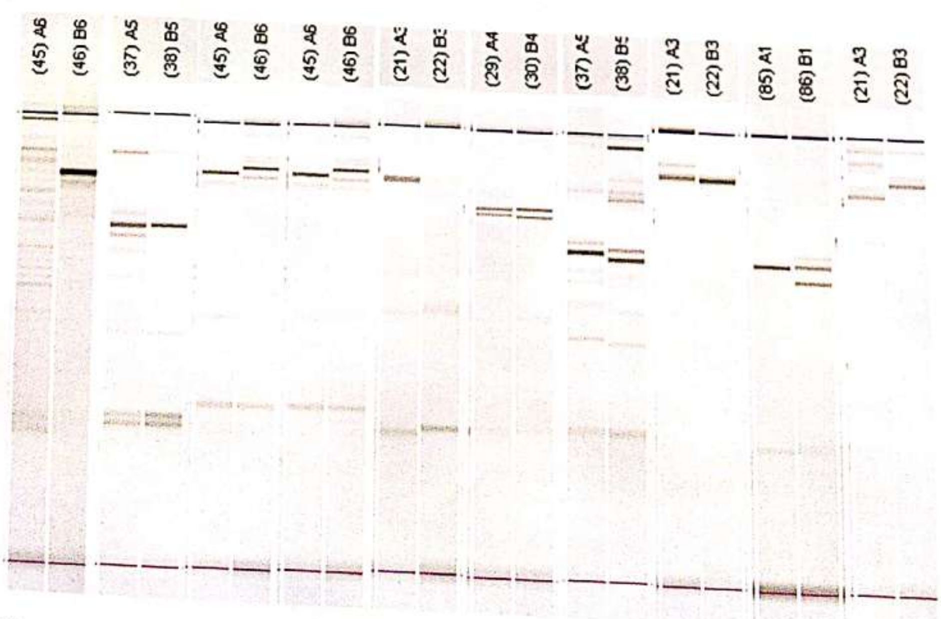

Figure 3. Electropherogram of ten cultivars showing polymorphic amplicons as revealed by automated microfluidic chip electrophoresis

Hybridisations for development of mapping populations

The number of recombinant progenies obtained from four different crosses (three for tolerance of stem rot and one for collar rot) which were in generation F_1 and the three crosses (two for tolerance to stem rot and one for LLS and rust) in F_2 generation produced are given in Table 1 and Table 2.

Table 1. F1s confirmed in crosses for developing mapping population (RILs)

S.No.	Crosses	F_1s confirmed
For tolerance of stem rot:		
1	GG 20 x CS 19	44
2	GG 20 x CS 75	59
3	GG 20 x CS 83	45
For tolerance of collar rot:		
4	GG 20 x SGL 4233	48

Table 2. Number of RILs (F_2s) in different crosses meant for developing mapping populations

S.No.	Crosses	No. of RILs obtained
Tolerance of stem rot:		
1	GG 20 x CS 19	137
2	GG 20 x JSP39	129
Tolerance of rust, LLS:		
3	JL 24 x VG 9816	82

Cloning of oxalate oxidase gene from wild species of groundnut

PCR amplification of oxalate oxidase gene from 18 wild species of groundnut was attempted using gene-specific primers designed from the sequence available for barley (from the NCBI database). Efforts aimed at PCR optimization including designing alternative primers failed to give the desired results. In contrast, the amplification obtained from the barley DNA as template gave excellent amplification at approx. 700bp, as expected. Hence, RD2660 variety of *Hordeum vulgare* was used for isolating the cds (coding sequence) of oxalate oxidase gene. An amplification of 684 bp was obtained. The cds has been cloned into pDrive cloning vector and mobilised into *E. coli* strain XL-1blue. The sequence has been submitted to GenBank (Accession no. HQ634345).

PROJECT 10: ASSESSMENT AND ENHANCEMENT OF QUALITY IN GROUNDNUT AND ITS VALUE ADDED PRODUCTS

(S. K. BISHI)

Assessment of groundnut quality

Evaluation of oil content in the kernels of groundnut cultivars

Oil content of kernel samples of 1026 groundnut genotypes (398 from AICRP-G centers and 628 from DGR) was analyzed. The range of values for oil content in the samples received from various sources is given in Table 1:

Table 1. Oil content (%) of groundnut samples

Source	Samples analyzed (number)	Oil content (%)	
		Maximum	Minimum
AICRPG center			
Tindivanum, Tamil Nadu	64	52.5	41.0
Khargone, MP	60	48.0	41.5
Dharwad, Karnataka	101	54.0	45.0
Anand, Gujarat	24	52.8	42.7
Jagtial, AP	34	51.5	41.2
Akola, Maharashtra	31	55.8	40.2
Kalyani, West Bengal	19	50.4	43.7
Dharwad, Karnataka	65	53.2	40.2
DGR section			
Soil Science	202	52.3	43.6
Cytogenetics	18	55.6	46.3
Soil Science	36	53.4	45.8
Germplasm Resources	44	53.9	46
Plant Physiology	268	54.9	41.9
Plant Breeding	60	52.3	46.5

Preliminary calibration of NIR Spectrophotometer for prediction of oil content of groundnut kernel samples in a non-destructive manner

Kernel oil content of 30 groundnut genotypes was determined by standard Soxhlet procedure (Oil^{sox}). The range of Oil^{sox} was 43.5 to 53.4% with a mean of 48.9%. These samples were then subjected to FT-NIR spectroscopy (800-1400 nm) in several combinations of ranges of wave-length and other factors. The absorption spectra thus generated were used for developing a calibration for predicting oil content (Oil^{NIR}) of kernel samples. The statistical package supplied along with the FT-NIR spectrometer was used for processing the data. A highly significant correlation (r = 0.82) was observed between the values of Oil^{sox} and Oil^{NIR}. The range of Oil^{NIR} was 43.8 to 52.5% with a mean of 48%. Generally, the Oil^{NIR} values were lower than Oil^{sox} values. The maximum magnitude of difference between Oil^{sox} and Oil^{NIR} was -2.8 for the genotype BG 2 while the minimum was -0.1 and 0.1 for the genotypes RS 138 and GG 2, respectively. The results demonstrated that FT-NIR spectroscopy has the potential of predicting oil content of groundnut samples in a non-destructive manner. Some more refinements in the equations may, however, be required to improve the predictability by using a large number of samples (>50) for developing the calibration.

The calibration developed was used for estimation of oil content of 700 groundnut samples. The values were the range of 36% to 56%.

Influence of drought on methanol soluble and insoluble seed proteins of groundnut cultivars

Being a predominantly rain-fed crop, the groundnut plants frequently suffer drought of various spells and intensity which affects both yield and the quality of the produce. A field trial was conducted with 25 Spanish and 20 Virginia cultivars under both well irrigated (T_1) and exclusively rain-dependent (T_2) conditions. The rain-dependent crop suffered drought during pod development phase with a soil moisture content of 7-8% compared to 17-18% in the well irrigated crop. The pods were harvested at physiological maturity and dried to a moisture content of 7-8%. After one month of storage, kernels were analysed for methanol insoluble seed proteins (MISP) and methanol soluble seed proteins (MSSP). Due to influence of drought, in Spanish group, the MISP increased whereas it decreased in most cultivars of the Virginia types. Due to drought, in most of the Spanish type cultivars, the MSSP decreased but in all Virginia cultivars it increased. The difference in pattern of change in MISP and MSSP between Spanish and Virginia cultivars could be due to difference in their respective degrees of drought tolerance.

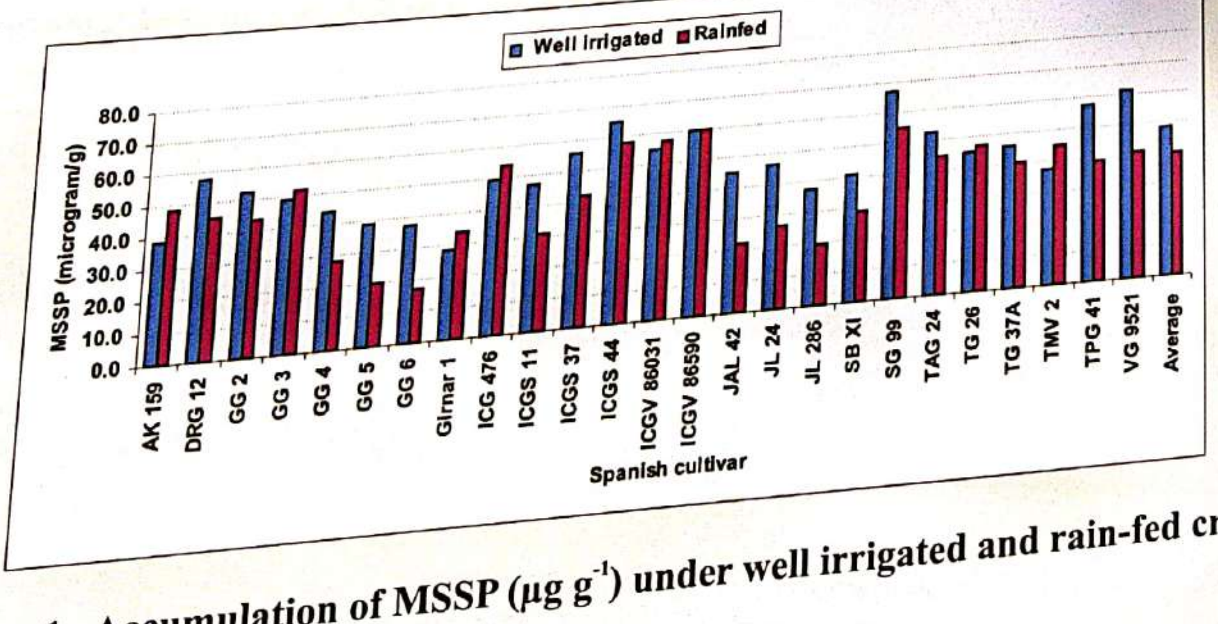

Figure 1. Accumulation of MSSP (μg g^{-1}) under well irrigated and rain-fed crops

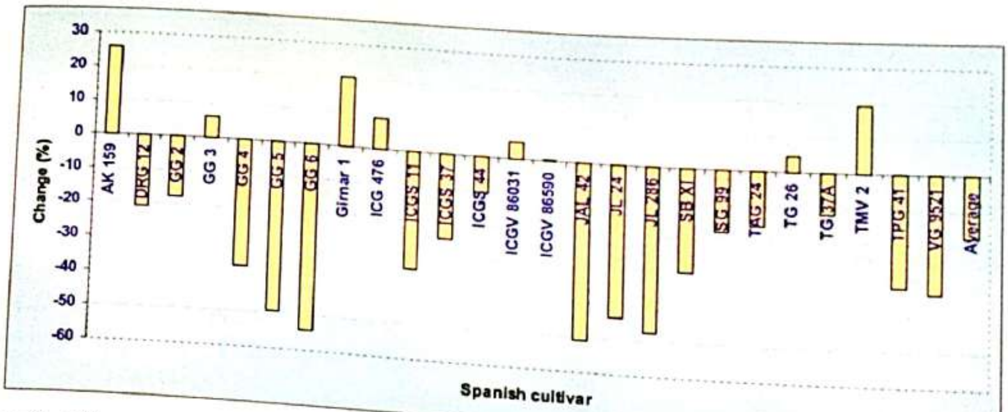

Figure 2. Change in MSSP content under water-deficit stress in Spanish cultivars

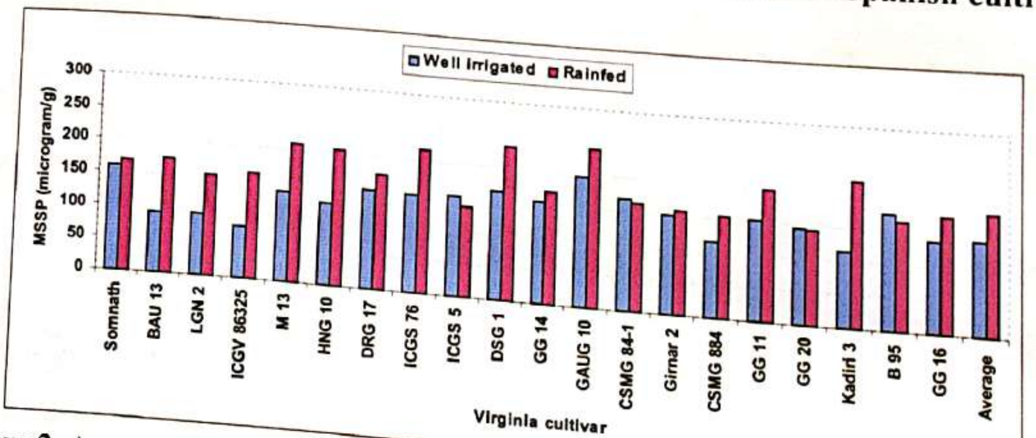

Figure 3. Accumulation of MSSP ($\mu g g^{-1}$) under well irrigated and rain-fed crops

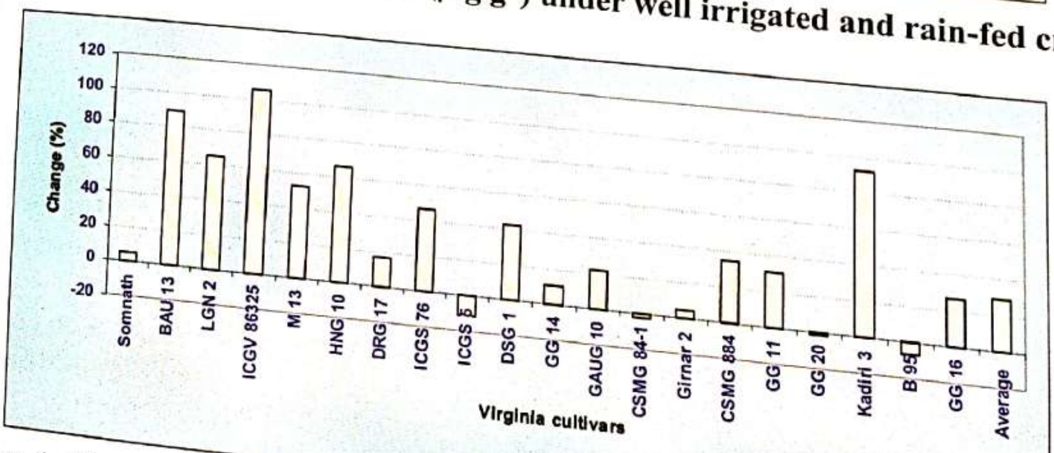

Figure 4. Change in MSSP content under water-deficit stress in Virginia cultivars

PROJECT 11: BIOTRANSFORMATION OF GROUNDNUT BY-PRODUCTS INTO USEFUL PRODUCTS

(R. DEY, K.K. PAL AND S.K. BISHI)

Isolation and evaluation of thermo - tolerant and salinity tolerant proteolytic bacteria

Slurry fermentation of de-oiled groundnut cake

The de-oiled groundnut cake was subjected to slurry-fermentation by seven bacterial cultures at 50°C and in 5% NaCl for evaluating the protease production potential of these cultures selected earlier for their tolerance of high temperatures and salt concentrations, and heavy metals (Ni, Co, Hg, Cd: 0.5 mM to 12.5 mM). *Bacillus* sp. isolate SP8-14, which produced all three types of proteases i.e. acidic, neutral and alkaline, was identified to be the most efficient proteolytic isolate. The maximum activity was obtained after 48 h of fermentation at pH 8.6 (174 IU) (Table 1).

Slurry fermentation was also carried out at 50°C in 10% NaCl. Compared to 5% NaCl, there was a lower production of proteases and the maximum activity was obtained only after 96 h of fermentation. Maximum activity of 165.7 IU protease/g de-oiled groundnut cake was obtained with *Bacillus* sp. isolate SP8-14 at 50°C (Table 2). Slurry fermentation of de-oiled groundnut cake was conducted with three isolates viz. P6, F1 and F6 which could grow even at 60°C in 5% NaCl to study the protease production potential in camparison with *Bacillus subtilis* taken as standard. While F1 produced only neutral (44.0 IU g^{-1} de-oiled cake at pH 7.0) and alkaline proteases (107.1 IU g^{-1} de-oiled cake at pH 9.0), F6 produced all three types: acid, neutral and alkaline (Table 2).

Table 1. Protease production potential of high-temperature tolerant strains of bacteria in slurry fermentation of de-oiled groundnut cake (at 50°C, in 5% NaCl, and 48h of fermentation)

Isolate	Protease (IUg^{-1} de-oiled cake)				
	pH				
	4.6	7.5	8.6	9.6	10.0
P1	ND	12.6	18.9	26.1	23.7
F1	73.9	108.4	64.5	97.0	70.5
SP5-8	5.9	25.9	53.2	33.2	ND
SP8-14	116.5	101.1	174.8	131.4	146.1
Bacillus subtilis	61.4	ND	ND	ND	ND

Table 2. Protease production potential of high temperature tolerant strains of bacteria in slurry fermentation of de-oiled groundnut cake (at 60°C, in 5% NaCl, and 48h of fermentation)

Isolate	Protease (IUg^{-1} de-oiled groundnut cake))						
	pH						
	4.0	5.0	6.0	7.0	8.0	9.0	10.0
P6	0.5	7.1	21.1	44.5	44.2	61.5	39.5
F1	9.2	ND	30.8	44.0	31.7	107.1	42.3
F6	1.1	27.1	16.9	28.2	13.3	15.1	35.0
B. subtilis	ND	ND	ND	18.0	13.0	16.7	17.2

PROJECT 12: PREVENTION AND MANAGEMENT OF MYCOTOXIN CONTAMINATION IN GROUNDNUT

(P. P. THIRUMALAISAMY AND K. S. JADON*)
* Included as an associate since May, 2010

Effect of long-term crop rotation or cropping system on soil population of *Aspergillus flavus* and pre-harvest aflatoxin contamination

Soil population of *Aspergillus flavus* was estimated by serial dilution technique before sowing and also immediately after harvest of garlic, onion, and groundnut crops and also from fallow land during *kharif* and summer.

Table 1. Soil population of *Aspergillus flavus* in crop rotation experiment

Groundnut variety (*kharif*)	Rotation crop	Population of *Aspergillus flavus* ($x10^3$ cfu g^{-1} soil)			
		summer		*kharif*	
		Before sowing	After harvest	Before sowing	After harvest
J 11	Garlic	6.22	6.22	6.2	9.2
	Onion	6.33	6.78	7.9	11.1
	Groundnut (J 11)	7.00	5.44	7.7	13.1
	Fallow	5.89	5.33	6.8	11.1
GG 2	Garlic	6.22	5.67	5.9	10.1
	Onion	5.78	5.78	6.7	9.6
	Groundnut (GG 2)	6.67	4.89	5.1	10.6
	Fallow	7.22	5.00	7.0	12.9

During summer, population of *A. flavus* in soil was lower at the time of harvest than at the time of sowing. Reduction in population of *A. flavus* was, however, also observed in the groundnut-groundnut rotation. The overall reduction in population of *A. flavus* could be due to high soil temperature (up to 44°C) prevailing at the time of harvest. In *kharif*, the estimated population of *A. flavus* was always higher in groundnut when grown in rotation with groundnut than in rotation with onion or garlic or fallow. Groundnut-groundnut crop rotation encouraged the buildup of *A. flavus* population upto $13.1 x 10^3$ cfu g^{-1} soil.

Further, seed infection of *A. flavus* in groundnut kernel was tested by agar plate technique. It was higher in summer groundnut than in *kharif* groundnut. During summer, the estimated seed infection was 30.0 and 35.3% in the varieties J 11 and GG 2, respectively. Aflatoxin contamination (AFB1 in ppb) was estimated by indirect competitive ELISA. It was 8.0 ppb in J 11 and 13.8 ppb in GG 2.

Table 2. Seed infection of *Aspergillus flavus* and aflatoxin contamination in groundnut

Groundnut variety (*kharif*)	Rotation crop (summer)	*Aspergillus flavus* summer Seed infection (%)	summer Aflatoxin (ppb)	*kharif* Seed infection (%)	*kharif* Aflatoxin (ppb)
J 11	Garlic	-	-	14.4	12
	Onion	-	-	13.4	4
	Groundnut	30.0	8.0	10.0	21
	Fallow	-	-	10.0	23
GG 2	Garlic	-	-	10.0	10
	Onion	-	-	16.7	1
	Groundnut	35.5	13.8	17.8	34
	Fallow	-	-	11.1	38

Studies on post-harvest handling of groundnut vis-à-vis *A. flavus* infection and aflatoxin contamination at various stages of delivery chain

On the basis of studies on the modes of post-harvest handling of groundnuts in five different processing industries, the following general trend was revealed:

- In-shell groundnuts (pods) are procured by the processors either directly from Markets or directly from the farmers.
- The pods are stored temporarily in factory go-downs
- The stored pods are 'conditioned' by sprinkling water over the heaps and then left as such 20 to 24 hours before decortication. This step is followed in all factories to facilitate easy decortication and to minimize the splitting and breakage of kernels.
- After decortication, groundnut kernels are sorted manually, by electronic camera colour sorter, or both, to produce groundnuts intended for export or manufacture of peanut butter.
- The sorted kernels are subjected to heating at 160°C for 20 minutes to facilitate blanching (removal of skin). The blanched kernels are again subjected to sorting to remove off-colour kernels and then packaged or processed for preparing peanut butter.

Samples of groundnut pods/kernels were collected from each stage of processing and the moisture content, infection of *A. flavus* and contamination of aflatoxin were determined in each sample (Table 3).

The moisture content varied from 2% (roasted kernels) to 12% (conditioned pods). The moisture content of pods before conditioning was 4% indicating that the moisture content increased rapidly from 4 to 12% during conditioning and subsequently decreased through various stages of processing to as low as 2% in the roasted kernels.

The *A. flavus* infection on groundnut samples was in the range of 10 to 60%. The seeds with the highest infection belonged to samples collected after conditioning. Thus it could be concluded that the addition of water for conditioning creates a congenial environment for growth and multiplication of *A. flavus* on the pods already infected in fields and its spread to other healthy pods. Analysis for aflatoxin indicated that the aflatoxin contamination was higher in the pods collected after conditioning (32 ppb) compared to the pods collected prior to conditioning. The afltoxin contamination was quite high (81 ppb) in the discoloured kernels, which were discarded after roasting and blanching.

Table 3 Seed infection and seed colonization of *Aspergillus flavus* and aflatoxin contamination in industrial samples

S. No.	Sample	Moisture content (%)	*A. flavus* infection (%)	Aflatoxin (ppb)
1	Bulk of pods procured	4-5	25	4
2	Bulk of pods after storing	4-5	20	5
3	Bulk of pods after conditioning	11-12	60	32
4	Bulk of kernels after decortication	6-7	15	20
5	Bulk of kernels prior to sorting	5-6	40	13
6	Bulk of kernels after manual sorting	4-5	20	3
7	Sorted out off coloured kernels	6-7	30	15
8	Kernels prior to vacuum packaging	4-5	20	7
9	Roasted kernels	2-3	15	2
10	Packaged kernels	2-3	10	1
11	Discarded roasted-kernels	2-3	25	81

The study indicated that the practice of conditioning of pods to facilitate easy decortication, increased the pod moisture content from 4 to 12% and this increased moisture content favoured growth of *A. flavus* and associated enhanced contamination of groundnut by aflatoxin.

PROJECT 13: IMPACT ASSESSMENT OF IMPROVED GROUNDNUT PROUCTION TECHNOLOGIES: SUSTAINABLE LIVELIHOOD ANALYSIS

(G. D. SATISH KUMAR*, G. GOVINDARAJ AND A. P. MISHRA)

(* till 14th September, 2010)

A survey was conducted in Kutch and Jamangar districts of Gujarat to collect information on the groundnut varieties prevalent among the farmers and the sources of supply of seed. In Kutch, three taluks viz., Mandvi, Abdasa-Nalia, and Nakhatrana, were identified on the basis of the largest area under groundnut and from each taluk one village cluster comprising 2-3 villages was selected. Likewise, in Jamnagar, four taluks viz., Jamnagar, Kalyanpur, Khambhaliya and Kalavad were identified and in each taluk, one village cluster comprising 2-3 villages was selected. In both the districts the farmers were selected randomly. The survey showed that in Kutch oilseeds, bajra, jowar, cotton, pulses, date palm and brinjal are the major crops. Among the oilseeds, the important ones were groundnut, castor, rapeseed and mustard. In Jamnagar, groundnut and bajra are the major crops.

The data was collected through personal interviews of farmers and using a pre-tested, semi-structured interview schedule.

Socio-economic status of the farmers

The results indicated that in both Jamnagar and Kutch, the average age of the farmers was 43 years with nearly 22-24 years of experience with the groundnut crop. In both districts, most farmers had education up to secondary to higher secondary level. Average size of family was of six members in Jamnagar whereas it was seven in Kutch. The average size of the farm holding was 3.35 ha in Jamnagar whereas it was 4.0 ha in Kutch.

Farm mechanization

In Jamnagar, 10% farmers owned tractors, 24% had electric/oil engines for lifting water from the wells, 2.7% possessed groundnut threshers, 46% had the equipment (sprayer etc.) required for plant protection. In Kutch district, 21% farmers owned tractors, 8% had electric/oil engines, and 11% possessed groundnut threshers. All the farmers in both the districts possessed all small tools (ploughs, hoes, harrows, multi-purpose iron tool bars, etc.) required for various agricultural operations.

Groundnut varieties

An inventory of the groundnut varieties was prepared and the farmers' response on adoption of these varieties was collected. The results indicated that in Jamnagar, a little more than one third (38%) of the farmers grew GG 20, followed by the varieties Khedutbhai (18%) and TG 37A (11%) and a small fraction of farmers grew varieties like G 2, J 11, GG 10, Samudri, etc. In Kutch district, however, during *rabi* season, a vast majority of the farmers (83%) grew G 2, followed by the varieties Western 44 (14%) and J 11(2%) (Table 1).

Table 1. Varieties of groundnut grown by farmers

Sr. No	Variety	Jamnagar (n=112)		Kutch (n=119) *	
		Number	%	Number	%
1	GG 20	43	38.4	-	-
2	TPG 41	2	1.8	-	-
3	Israil	3	2.7	-	-
4	Samudri	6	5.4	-	-
5	Jl 24	-	-	-	-
6	Khedutbhai	20	17.9	-	-
7	TG 37A	12	10.7	-	-
8	G-2	10	8.9	99	83.2
9	Western 44	-	-	17	14.3
10	J 11	9	8.0	3	2.5
11	GG 10	7	6.3	-	-
		112	100	119	100

*rabi season

Sources of seed

In Jamnagar, about half (52%) of the farmers used their own seed and about one-fourth (23%) purchased from the farmers of other villages and only a small fraction (14%) purchased from the private seed dealers. In Kutch, about three-fourths (77 %) of the farmers purchased seed from private seed dealers, while 11% purchased from the farmers of other villages, 8% from the oil mills and only 2% used their own seed (Table 2).

Table 2. Source of seed of groundnut farmers in Jamnagar and Kutch

Sr. No	Source	Jamnagar (n=112)		Kutch (n=119) *	
		Number	%	Number	%
1	Self-produced and saved (own seed)	58	51.8	3	2.4
2	Farmers in the same village	4	3.6	-	-
3	Farmers in another village	26	23.2	13	10.9
4	Oil mills	1	0.9	9	7.5
5	Market yard	1	0.9	-	0.0
6	State Seed Corporation	4	3.67	5	4.2
7	Private seed dealers	16	14.3	89	76.7
8	Local seed retailer in the village	2	1.8	-	-
	Total	112	100	119	100

*rabi season

Reason stated by sample farmers for using own seed

Around 76% farmers in Jamnagar district used their own seed due to high cost while 15% did so due to non-availability of quality seed at the time of sowing. In Kutch district, the farmers used their own seed due to a high price from the other sources.

Table 3. Reasons for using own seed.

Sr. No.	Reason	Jamnagar (n=58)		Kutch(n=3)	
		Number	%	Number	%
1	Available when required	9	15.5	0	-
2	High price from other sources	44	75.9	3	100
3	Poor quality from other sources	5	8.6	0	-
	Total	58	100	3	100

Table 4. Reasons given by the farmers for not saving their own seed

Sr. No.	Reason	Jamnagar (n=54)		Kutch(n=116)	
		Number	%	Number	%
1	Available in the market when required	2	3.7	10	8.4
2	Lack of storage space for large volume	2	3.7	-	-
3	Damage by insect pests during storage	32	59.3	61	51.3
4	Pressing need for money after harvest	18	33.3	45	38.8
	Total	54	100	116	100

Majority of the farmers in Jamnagar and Kutch districts stated that they did not save their own seed due to damage of seeds by insects during storage. In Jamnagar, 33% farmers and in Kutch 39% farmers expressed that due to pressing need for cash they sold their seed immediately after the harvest.

Seed replacement frequency

Every year, in Jamnagar 29% farmers replaced seed whereas in Kutch 77% farmers did so. The high seed replacement frequency in Kutch was mainly due to huge loss of *kharif* produce to insect pests. In Jamnagar, 24% farmers replaced seed every third year and 40% replaced seed every fourth year. In Kutch, 14% and 8% farmers replaced seed every third and fourth year, respectively.

Table 5. Seed replacement frequency in Jamnagar and Kutch

Sr. No.	Frequency of seed replacement	Jamnagar (n=112)		Kutch (n=119)	
		Number	%	Number	%
1	Every year	32	28.6	92	77.3
2	After every 3 years	27	24.1	17	14.3
3	After every 4 years	45	40.2	10	8.4
4	After every 5 years	8	7.1	0	0.0
	Total	112	100.0	119	100

Technology assessment and refinement

In two villages viz. Alidra and Vadal of Junagadh district nine on-farm trials (OFTs) were conducted during *kharif* for assessment and refinement of technologies.

Improved varieties

In order to create awareness among the farmers and motivate them to adopt improved varieties, during *kharif* 2010 on-farm trials were conducted. Three improved varieties viz. TG 37A, SG 99 and Girnar 2 were taken for comparison with the popular variety GG 20. The results indicated that on an average the improved varieties recorded a yield of 1875 kg ha^{-1} compared to 1594 kg ha^{-1} with GG 20. Compared to GG 20, there was an advantage of 17.7% in pod yield and 32.6% in haulm yield with the improved varieties and the GMR improved by 23.7% and NR by 21.7%. The incremental income realized was Rs. 4844 ha^{-1} in improved practice *vis-a-vis* farmers' practice.

Table 3. The performance and profitability of improved variety

Economic indicators	*kharif*		
	Farmers' Practice	Improved Practice*	Improvement over FP (%)
Pod yield (kg ha^{-1})	1594	1875	17.7
Haulm yield (kg ha^{-1})	2356	3125	32.6
CoC (Rs. ha^{-1})	17160	20278	19.3
GMR (Rs. ha^{-1})	39765	49250	23.7
NR (Rs. ha^{-1})	22606	27450	21.7
BCR	2.3	2.4	

* TG 37 A and Girnar 2 improved varieties; SG 99 did not perform well due to very high rainfall

Balanced use of fertilizers

Effect of balanced application of fertilizers as recommended by DGR (SSP and Ammonium Sulphate) was assessed in farmers' fields for a comparison with the farmers practice of nutrient management through DAP and Urea. The results of *kharif* trials indicated that application of NPK at recommended doses through ammonium sulfate, SSP, MOP increased pod yield of groundnut by 9.3% and haulm yield by 13.3% over the farmers' practice. The incremental income realized was Rs. 3316 ha^{-1} in improved practice vis-a-vis farmers practice Hence, further refinement is required to make fertilizer application more profitable.

Table 4. Performance and profitability of balanced use of fertilizers

Economic indicators	*kharif*		
	Farmers' Practice	Improved Practice	Improvement over FP (%)
Pod yield (kg ha^{-1})	1325	1438	9.3
Haulm yield (kg ha^{-1})	1488	1671	13.3
CoC (Rs. ha^{-1})	17539	19089	8.4
GMR (Rs. ha^{-1})	38594	43460	15.9
NR (Rs. ha^{-1})	21055	24371	36.7
Incremental Income (Rs. ha^{-1})	-	3316	-

Training programmmes organized for farmers

'Latest production technologies in groundnut', this one day training programmme on was organized on 30.11.2010 for 22 farmers from Perambalur district of Tamil Nadu. The training was sponsored by ATMA.

Farmers visits to DGR, Junagadh

A total of 19 groups of farmers/students/officers visited DGR during April 2010 to March 2011. Altogether 485 visitors from various states viz., Gujarat, Rajasthan, Madhya Pradesh and Tamil Nadu visited this directorate. These visits were sponsored by the State Department of Agriculture and State Agricultural University concerned. The visitors were taken round field-experiments, laboratories, museum, library etc. The farmers/students/officers-scientist interactions meet were also organized for the benefit of the visitors.

PROJECT 14: BREEDING FOR LARGE SEEDED AND CONFECTIONERY GROUNDNUT

(CHUNI LAL, T RADHAKRISHNAN, A. L. RATHNAKUMAR, M. C. DAGLA, S. K. BISHI AND NARENDRA KUMAR*)

* since may 2010

Hybridization

In *kharif* 2010, ten crosses were attempted to incorporate large seed size coupled with high yield. Advanced breeding lines from ICRISAT and released varieties with superior agronomic traits were used in the hybridization programme. A total of 3899 buds were pollinated and 477 probable hybrid pods were harvested with a success rate of 12% (Table 1).

Table 1. Particulars of crossing programme undertaken in *kharif* 2010

Parents	Purpose of crossing	No. of buds pollinated	F_1 pods harvested
ICGV 97079 x TPG 41	High pod yield and high HSM	275	51
ICGV 97079 x GG 20	High pod yield, high shelling outturn and high oil	375	84
ICGV 97079 x GPBD 4	High pod yield and high protein	405	54
ICGV 97079 x S 230	High pod yield and high O/L ratio	490	74
TPG 41 x GG 20	High HSM, high shelling outturn and high oil	436	42
TPG 41 x GPBD 4	High HSM and high protein	416	34
TPG 41 x Dh 3-30	High HSM and low protein	400	28
TPG 41 x MH 4	High HSM	386	31
GG 20 x S 230	High shelling out turn and high O/L ratio	405	55
GG 20 x Dh 3-30	High shelling outturn and high oil	311	24
	Total	**3899**	**477**

Raising F_1s and identification of true hybrids

Ten crosses made in *kharif* 2009 were raised along with respective parents in *kharif* 2010 and the true hybrids were identified on the basis of the vigour of plants and dominant male-characters (Table 2). Pods of the identified plants were harvested plant-wise for further advancement. In all 62 such single plants were harvested representing ten cross-combinations.

Table 2. Identification of true hybrids in *kharif* 2010

Sr. No.	Name of crosses	Purpose of crossing	True hybrid plants identified
1	ICGV 00440 x Girnar 2	Large seed size & high yield	12
2	PBS 29069 x ICGV 00440	- do -	4
3	PBS 29077 x ICGV 97079	- do -	8
4	PBS 29077 x ICGV 00440	- do -	6
5	PBS 29078 x ICGV 97079	- do -	9
6	PBS 29078 x ICGV 00440	- do -	4
7	PBS 29079A x ICGV 00440	- do -	2
8	PBS 29079B x ICGV 97079	- do -	1
9	TG 40 x ICGV 99101	- do -	5
10	TG 40 x ICGV 00440	- do -	11

Selection and generation advancement

Ten crosses in F_2 generation were sown and true F_2s (segregating) were identified, and then were bulk-harvested cross-wise for advancing to next generation. Eight crosses in F_3 were sown and progenies were harvested in bulk, after rejecting one inferior cross-combination. Six crosses in F_4 were advanced without selection. Likewise, nine crosses were advanced from F_5 to F_6 generation. In *kharif* 2010 the pod yields were poor and hence no selections were made and the F_6 and F_7 generations were advanced to the next respective generations as such. (Table 3).

Table 3. Crosses advanced and selections made in *kharif* 2010

Sr. No.	Generation	Sown	Crosses Rejected	Available
1	F_2	10	0	10
2	F_3	8	1	7
3	F_4	6	0	6
4	F_5	9	0	9
5	F_6	4	0	4
6	F_7	14	0	14

Multiplication and maintenance

Twenty-two advanced breeding lines were multiplied to obtain sufficient seeds for different station trials and 49 lines (8 Spanish, 41 Virginia) were maintained.

Station trials

Two yield evaluation trials were conducted. The performance of the crop was very poor during *kharif* 2010 season because of excessive and prolonged rainfall. In both the trials observations only on SCMR, SLA and flowering traits were recorded. As the pod yields were extremely poor other observations were not recorded. The results are discussed trial-wise hereunder.

Preliminary yield evaluation trial of advanced breeding lines

Sixteen advanced breeding lines developed for large-seed size along with four check varieties (TPG 41, GG 20, M 13 and Somnath) were evaluated in *kharif* 2010. All the twenty genotypes were grown in RBD with three replications. The plot size was of two rows of 5 m each with a a plant-to-plant distance of 10 cm with in a row and row to row distance of 60 cm. Highly significant differences due to genotypes were found for all the traits. Variety GG 20 was found to be the best check for pod yield and flowering traits, while it was TPG 41 for SCMR and M 13 for SLA. None of the test entries could surpass the respective best check variety for any of the traits, except for days to 50% flowering (F_{50}), where two test entries (PBS 19014 and PBS 29137) completed flowering in significantly smaller number of days compared to the best check variety. As the yields were extremely poor, it was decided to repeat this trial as such in *kharif* 2011 (Table 4).

Table 4. Attributes of advanced breeding lines under preliminary large-seeded yield evaluation trial (*kharif* 2010)

Sr. No	Genotype	SCMR	SLA (cm^2g^{-1})	PY ($kg\ ha^{-1}$)	FI	F_{50}
	Test enry					
1	PBS 19014	26	189	210	23	25*
2	PBS 29090	30	153	311	26	29
3	PBS 29105	28	143	287	25	29
4	PBS 29106	28	160	255	27	30
5	PBS 29137	27	163	316	23	26*
6	PBS 29138	26	130	378	26	28
7	PBS 29141	23	171	386	28	30
8	PBS 29142	26	167	396	27	30
9	PBS 29143	26	173	399	27	30
10	PBS 29146	27	164	434	27	30
11	PBS 29147	30	168	376	29	31
12	PBS 29151	24	139	357	28	31
13	PBS 29153	28	156	466	27	29
14	PBS 29155	32	154	573	26	29
15	PBS 29156	28	154	405	25	29
16	PBS 29163	32	148	468	26	29
	Check					
1	TPG 41	33	138	571	26	29
2	GG 20	30	151	610	24	27
3	M 13	30	138	471	28	29
4	BAU 13	25	165	516	25	30
	Mean	28	156	409	26	29
	Range	23-33	130 -189	210-610	23-29	25-31
	CD 5%	4	28	138	2	1

Advanced large-seeded yield evaluation trial

Sixteen lines which had qualified from the preliminary large-seeded yield evaluation trial (*kharif* 2009), were evaluated in *kharif* 2010 along with four check varieties (TPG 41, GG 20, M 13 and Somnath). All the 20 genotypes were grown in a RBD with three replications. The plot size was five rows of 5 m each. The plant-to-plant distance was 10 cm within a row and the rows were spaced 60 cm apart from each other. ANOVA revealed highly significant differences due to genotypes for all the traits studied. GG 20 was found to be the best check variety for flowering traits, and for WUE traits (SCMR and SLA). TPG 41 was adjudged to be the best check variety. For pod yield M 13 has been adjudged to be the best among the check varieties. Compared to the best check variety, the values for 50% flowering (F_{50}) were smaller for three test entries (PBS 19020, PBS 19021 and PBS 19022). For the remaining traits none of the test entries could perform better than the respective best check variety. The yields of this trial were also extremely poor due to prolonged and excessive rainfall; hence the trial will be repeated as such in *kharif* 2011 (Table 5).

Table 5. Attributes of promising advanced breeding lines observed in large-seeded yield evaluation trial

Sr. No.	Genotype	SCMR	SLA (cm^2g^{-1})	PY ($kg\ ha^{-1}$)	FI	F_{50}
	Test entries					
1	PBS 19018	26	159	248	24	28
2	PBS 19020	26	135	255	24	28
3	PBS 19021	26	138	323	24	27*
4	PBS 19022	27	142	280	24	26*
5	PBS 19023	28	132	415	24	27*
6	PBS 19024	30	136	420	26	28
7	PBS 29087	28	142	309	26	31
8	PBS 29098	31	130	272	25	30
9	PBS 29112	31	131	520	26	30
10	PBS 29113	30	133	384	26	29
11	PBS 29114	31	135	380	24	30
12	PBS 29115	30	136	342	26	29
13	PBS 29144	25	158	354	27	30
14	PBS 29148	22	165	396	27	31
15	PBS 29150	27	164	351	26	30
16	PBS 29152	25	157	416	28	30
	Checks					
17	TPG 41	33	131	383	25	29
18	GG 20	29	132	449	24	28
19	M 13	29	139	457	27	31
20	BAU 13	25	145	299	27	31
	Mean	28	142	363	25	29
	Range	22-33	130-165	248-520	24-28	26-31
	CD 5%	5	13	142	2	1

PROJECT 15 : UTILIZATION OF WILD ARACHIS GENE POOLS FOR GROUNDNUT IMPROVEMENT

(S. K. BERA, P. C. NAUTIYAL, A. L. SINGH, RADHAKRISHNAN T., CHUNILAL, P. P. THIRUMALAISAMY AND ABHAY KUMAR)

Hybridization

As the climate at Junagadh during summer is not congenial, hybridization was carried out at RRS, Virdhachalam, Tamil Nadu. The following 12 back-crosses were attempted and more than 100 probable cross-pods were harvested for each cross combination.

GG 20//GG 20/CS 19,
GG 20//GG 20/OG52-1,
GG 20//GG 20/ICGV86590,
CS 19//CS 19/OG 52-1,
ICGV 86590//ICGV 86590/CS 19,
OG 52-1//OG 52-1/ICGV 86590
CS 19// GG 20/CS 19,
OG52- 1//GG 20/OG52-1,
ICGV86590//GG 20/ICGV86590,
OG52-1//CS 19/OG 52 -1,
CS 19//ICGV 86590/CS 19,
and ICGV 86590//OG52-1/ICGV86590)

Back crosses were made again under field conditions during rainy season (*kharif*) at Junagadh. Out of 13 back crosses, 7 were with inter-specific hybrids aimed at introgression of tolerance of biotic stresses while 6 were inter-varietal crosses aimed at improving kernel size and crop duration. Approximately, 500 pollinations were attempted for each combination. Probable cross-pods collected at harvest will now be used in further back-crossing during *kharif* 2011. Among the inter-specific back crosses, largest number (220) of probable cross pods were harvested from the combinations involving interspecific hybrids of *A. appresipilla* while smallest probable cross pods were harvested from the combination involving interspecific hybrids of *A. kempfmarcadoi*. Among intervarietal back crosses, the largest number of probable cross-pods was harvested from the combination involving hybridization between Chico and CS-148 while smallest number of probable cross pods was harvested from the combination involving hybridization between CS-148 and CS-281.

Identification of hybrids

The seeds from probable cross-pods harvested during *kharif* 2009 from nine interspecific and two back crosses, were sown in the field during *rabi* 2010 for identification of true hybrids. Hybrid plants were identified and tagged at 45-50 days after emergence on the basis of runner growth habit which is a dominant character from wild male parent over bunch growth habit of cultivated female parent. Six out of nine crosses, produced hybrid plants. For three cross combinations viz., 'J11/ *A. helodes*', 'J11/ *A. rigonii*' and 'J11/ *A. correntina*' attempts to produce hybrid pods did not succeed. In six crosses, the number of hybrid plants were in the range of 2 to 7, and the largest number of hybrid plants were identified from the cross 'J11/ *A. pussilla*'. The back cross 'J11//J11/*A. pussilla*' produced 3 hybrid plants while 'GG 20//J11/*A. pussilla*' did not produce any hybrid plant.

The hybrid plants of interspecific and back crosses were maintained in the field due to their perennial growth habit, while the selfed plants were rouged out. The mature pods were harvested from the perennial hybrid plants at regular intervals for further use.

Initial varietal trial

Evaluation of Spanish bunch genotypes

During summer season, 40 Spanish bunch inter-specific advanced breeding lines along with 2 checks (TAG 24 and TG 26) were evaluated in initial yield trial in a randomized block design with three replications. Each genotype was sown in a single row of three-meter with a plant-to-plant spacing of 10 cm and row-to-row spacing of 60 cm. Recommended crop management practices were followed to raise the crop. Observations on specific leaf area and SCMR were recorded 65 days after germination while biological yield, pod yield, shelling out-turn, hundred-kernel mass and percentage of sound mature kernels were recorded after harvest. Out of 40, although eight genotypes (NRCG-CSs 351, 353, 354, 358, 362, 405, 406 and 408) produced numerically higher pod yield than the best check TAG 24, the differences were not significant. These eight genotypes also showed higher values for shelling out-turn (65 to 71%) and SCMR (34 to 42) and lower values for SLA. These genotypes may have good potential for pod yield as well as drought tolerance.

During rainy season, the initial yield evaluation trial for Spanish bunch genotypes was repeated with 37 genotypes along with four checks (TG 26, GG 7, TG 37A and TAG 23). The crop was raised by following standard crop management practices. Observations were recorded on pod yield and related traits at harvest. Due to excessive rainfall in the season there was stagnation of water in the fields and consequently the pod yield levels were too low hence the data was not statistically processed.

Evaluation of Virginia genotypes

Advanced yield evaluation trial for Spanish genotypes was conducted in RBD with 3 replications during rainy season. Forty-three genotypes along with two checks (Somnath and GG 20) were included in the trial. Each genotype was sown in a single row of three-meter with a plant-to-plant spacing of 10 cm and row-to-row spacing of 60 cm. The crop was raised by following standard crop management practices. This trial was also spoilt by the excessive rainfall in the season resulting in stagnation of water in the fields and consequent low levels of pod yield.

Advanced varietal trial

Evaluation of Spanish bunch genotypes

Advanced yield trial was conducted comprising 12 interspecific Spanish advanced breeding lines and 2 checks (TAG 24 and TG 26) during summer season. Experiment was laid out in Randomized Block Design with three replications. Each genotype was sown in five rows of three meter each with a plant-to-plant spacing of 10 cm and row-to-row spacing of 60 cm. The recommended crop management practices were adopted to raise the crop. Observations on specific leaf area and SCMR were recorded in 65 days after germination while biological yield, pod yield, shelling out-turn, hundred-kernel mass and percentage of sound matured kernel were recorded at harvest. The pod yield of genotype NRCGCS-401 was significantly higher than that of the best check TG 26 while those of six other genotypes (NRCGCSs-360, 361, 368, 369, 389 and 400) were only numerically higher than that of TG-26. The shelling out-turn (65 to 69%) and SCMR (34.7 to 44) of these six genotypes was high while the SLA was low (115-227). Moreover, the values for HKM and SCMR of NRCGCS-401 were higher than those of TG 26. Performance of these genotypes needs to be confirmed.

During the rainy season, the advanced yield evaluation trial of Spanish bunch genotypes was repeated in RBD with 3 replications. Twelve test genotypes along with four checks (TG 26, GG 7, TG 37A and TAG 23) were evaluated. Each genotype was sown in five rows of three meter each with a plant-to-plant spacing of 10 cm and row-to-row spacing of 60 cm. Crop was raised by following standard crop management practices. Observations were recorded on pod yield and the related traits at harvest. The performance of all the check varieties and test entries was poor due to prolonged stagnation of water in the experimental field because of excessive and continuous rainfall during the season. Among the four checks, GG 7 recorded highest pod yield per plot (374 g), shelling outturn (55%), sound mature kernel (21%) and hundred kernel mass (30 g). The values of pod yield per plot (475 g) and percentage of sound mature kernel (46%) of genotype NRCGCS-401 were significantly higher than those of the best check GG 7 while the values of SPAD reading and shelling out turn were at par. In summer season too, the pod yield of genotype NRCGCS-401 was higher than that of the best check (GG 7). The pod yields of NRCGCS-360 and NRCGCS-391 were only numerically higher than that of GG 7.

Evaluation of Virginia genotypes

During rainy season, the advanced yield evaluation trial for Virginia bunch genotypes was conducted in RBD with 3 replications. Three genotypes along with two checks (GG 20 and Somnath) were included in the trial. The plot size was of 5 rows of 3 meter each. The spacing between plants in a row was 10 cm while the inter row spacing was 60 cm. Crop was raised by following standard crop management practices. Observations were recorded on pod yield and the related traits at harvest. Of the two checks, GG 20 was superior in respect of pod yield per plot (493 g), shelling out turn (59%), percentage of sound mature kernel (35%) and hundred-kernel mass (45.7 g) and none of the test genotypes could outperform GG 20 in terms of pod yield. Among the three test genotypes, NRCGCS-385 was the best with a pod yield of 552.8g per plot, 22% sound mature kernel, 45.0 g hundred kernel mass and 37.2 SPAD reading i.e. a performance nearly at par with GG 20.

Genotypes identified for inclusion in AICRP-G trials

Two large-seeded Spanish groundnut genotypes (NRCGCS-268 and NRCGCS-281) developed at DGR and identified earlier for inclusion in AICRP-G trials in *rabi*-season were evaluated during *rabi*-2009 and *rabi*-2010 seasons at five AICRP-G centres. Although the pod yield of both these genotypes was not significantly higher than that of national check

(TPG 41) yet on the basis of numerically higher pod yield/ha (3650 kg), kernel yield/ha (2569 kg) and significantly higher hundred kernel weight (76 g) than the national check, NRCGCS-268 has been promoted to AVT.

Freshly developed breeding lines at DGR, two Spanish bunch (NRCGCS-264 and NRCGCS-369) and two Virgina bunch (NRCGCS-424 and NRCGCS-425) have been recommended for AICRP-G testing. The Virginia bunch genotypes recorded 15 to 34% yield advantage over the best check and also showed resistance to rust and late leaf spot.

Novel germplasm developed and registered

Although the breeding lines developed through interspecific hybridization possess high level of tolerance/resistance to abiotic and biotic stresses, they can not be promoted directly as cultivars because of tight-linkage between desirable and undesirable agronomical traits. Thus these interspecific breeding lines are used as pre-breeding material in the crop improvement programme. Eight interspecific breeding lines (NRCGCS-21, NRCGCS-77, NRCGCS-83, NRCGCS-85, NRCGCS-86, NRCGCS-124, NRCGCS-180, NRCGCS-22) developed at DGR were characterized over locations and years and were found to possess multiple disease resistance (late leaf spot, rust, stem rot, PBND and Alternaria blight). These interspecific multiple disease resistant breeding lines were submitted to the NBPGR for registration. The Plant Germplasm Registration Committee approved eight multiple disease resistant groundnut germplasm for registration. These multiple disease resistant genotypes would help in broadening the genetic base of cultivated groundnut.

Screening of interspecific derivatives at Raichur, Karnataka

Over the years, several interspecific genotypes have been developed at DGR using various wild *Arachis* species. Most of these interspecific genotypes possess resistance to one or more biotic stresses. Interspecific genotypes available (437 lines) with DGR were evaluated at RRS, Raichur (a hot spot) for identification of genotypes resistant to LLS, rust, PBND and stem rot. Each interspecific genotype was sown in one row of five-meter each. Single row of susceptible check (KRG 1) was sown in every four lines of interspecific genotypes for increasing disease pressure. The genotypes were scored for occurrence of PBND 60 days after germination as well as at harvest and the incidence was expressed as per cent. Scoring for LLS and rust was done at harvest on standard 1-9 scale. The scoring for stem rot was done at harvest and was expressed as per cent. For stem rot and PBND, 77 and 111 genotypes, respectively scored less than 5% incidence. For LLS and rust, in 26 and 25 genotypes, respectively the disease score was below 3. Besides, as many as 55 genotypes showed multiple diseases resistance (stem rot, PBND, rust and LLS). The resistance in these genotypes needs further confirmation in the ensuing rabi season.

Molecular diversity analysis of *A. glabrata* accessions

Wild species of *Arachis glabrata* is grouped into section rhizomatosae under tertiary gene pool of genus *Arachis*. *A. glabrata* propagates through rhizome and not cross compatible with cultivated groundnut. Most of *A. glabrata* accessions have been reported to possess high degree of resistance to various biotic and abiotic stresses.

Somehow, these accessions have so far not been used effectively in the groundnut improvement programme because of cross incompatibility.

Of late, due to availability of molecular tools, the chances of incorporation of genes present in *A. glabrata* into cultivated background have gone up. More than 50 accessions of *A. glabrata* have so far been reported which need to be systematically evaluated for tapping the potential of genetic variability. Hence, RAPD and SSR markers were used to study the genetic diversity of 34 accessions of *A. glabrata* available at DGR. Amplification of genomic DNA of these 34 accessions using RAPD primers comprising 4 of D series, 3 of OPT series, and 3 of OPI series yielded 242 fragments. Out of 242 bands, 178 were polymorphic, with an average of 17.8 polymorphic fragments per primer. Primers D5, D6, D7, D9, OPT5, OPI5 and OPI6 produced more than 70% polymorphism. The PIC value for 10 RAPD primers varied from 0.966 (D5) to 0.969 (D6, D9, OPI5, and OPI7), with a mean of 0.968. The marker index (MI) value for 10 RAPD primers varied from 44 (OPT7) to 93.3 (D6), with a mean of 70.96. Amplification of genomic DNA of 34 *A. glabrata* accessions using 15 SSR primer pairs yielded 148 fragments. Out of which 148 bands 133 were polymorphic, with an average of 8.86 polymorphic fragments per primer. All the SSRs used in the study produced more than 70% polymorphism except PM15 and PM402 primers which produced 62.5% and 53.8% polymorphism, respectively. The polymorphic information content (PIC) value for 15 primers varied from 0.933 (TC1A02) to 0.968 (PM32), with a mean of 0.958. The marker index (MI) value for 15 SSRs varied from 52 (PM402) to 96.7 (PM188), with a mean value of 87.23. The SSRs used in this study were highly polymorphic and efficient in revealing the extent of genetic diversity present in the populations studied. High levels of genetic diversity in *A. glabrata* accessions indicated that these populations are not experiencing genetic drift.

The dendrogram constructed on the basis of band pattern generated by using RAPD and SSR primers were close representation of the values of similarity matrix. Seven polymorphic RAPD primers discriminated 30 *A. glabrata* genotypes and divided them into two major clusters where first major cluster contained 13 *A. glabrata* accessions (code Nos. R, AF, Y, AE, AD, AA, AB, AC, X, Z, T, V and U; denoted as cluster-I) and second major cluster contained 17 *A. glabrata* accessions (code No. A, G, H, F, B, C, D, E, L, N, K, M, O, Q, I, J and P; denoted as cluster-II) (Fig.-1). These two major clusters shared 50% similarity. In cluster-I, the minimum similarity (68%) was observed between accessions U and R, while the maximum (83%) was observed between accessions Y and AE. Likewise in cluster-II, the minimum similarity (60%) was observed between accessions P and A while the maximum (82%) was observed between accessions A and G. Among 30 *A. glabrata* accessions subjected to diversity analysis using RAPD, the accessions U and P were most diverse and can be used for tapping the maximum genetic diversity for improvement of groundnut. Thirteen polymorphic SSRs discriminated 30 *A. glabrata* accessions and divided them into two major clusters in which the first cluster contained 13 accessions (code Nos. R, T, U, S, V, W, X, Z, Y, AA, AD, AB and AC; denoted as cluster-I) and the second cluster contained 17 accessions (code No. A, K, F, G, B, L, C, N, D, I, E, H, J, O, M, Q and P; denoted as cluster-II) (Fig.-2). These two clusters exhibited 37% similarity between them. In cluster-I, the minimum similarity (42%) was observed between accessions AC and R while the maximum similarity (78%) was observed between accessions R and T. Similarly, in cluster-II, the minimum similarity (52%) was observed between accessions P and A while the maximum similarity (82%) was observed between accessions F and G. Accessions AC and P were most diverse among 30 *A. glabrata* accessions subjected to diversity analysis using SSR primers and both of these could be used for tapping maximum diversity for groundnut improvement.

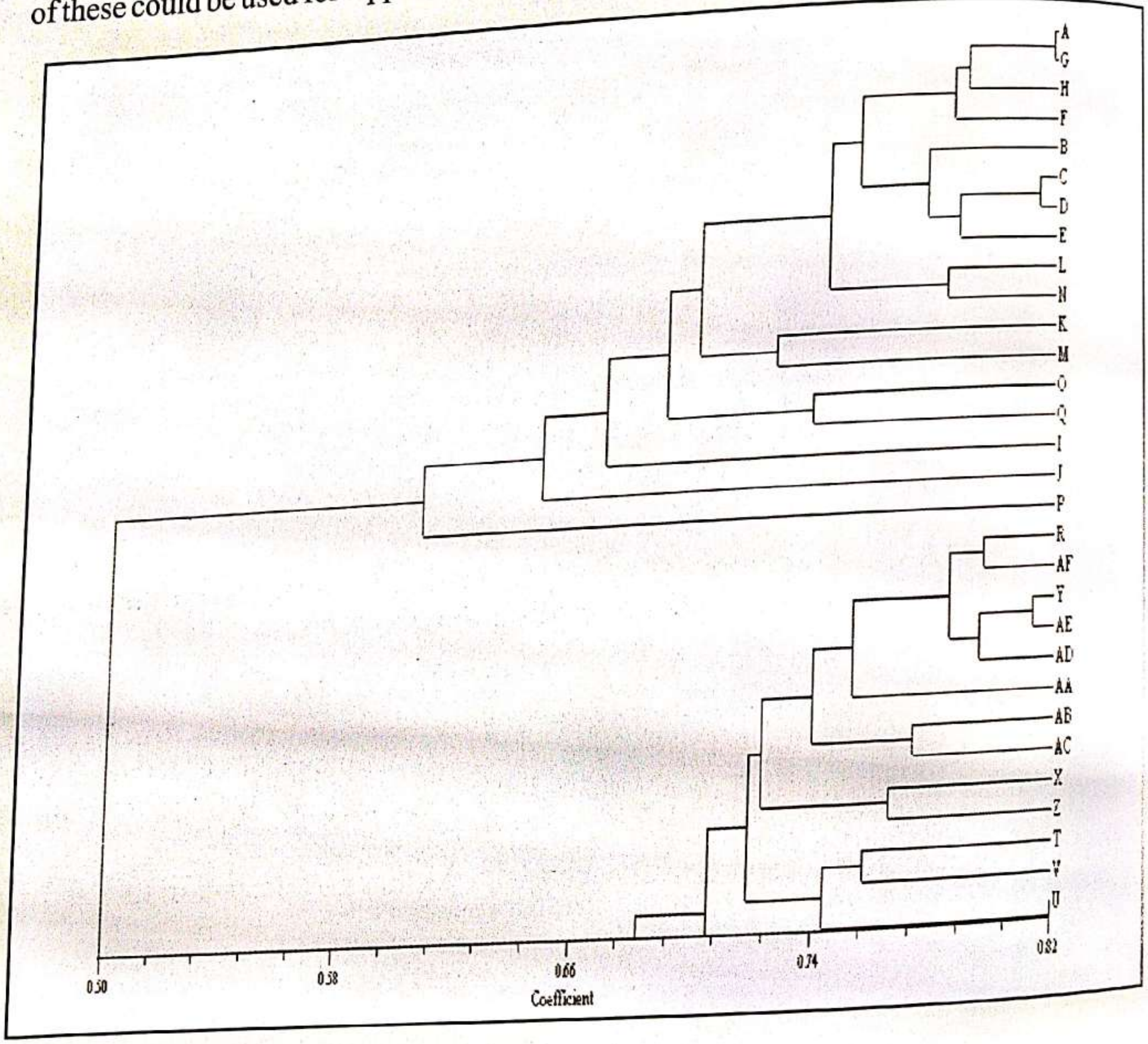

Figure 1. UPGMA cluster analysis showing the relationship and diversity among 30 accessions of *A. glabrata* as revealed by data using RAPD markers.

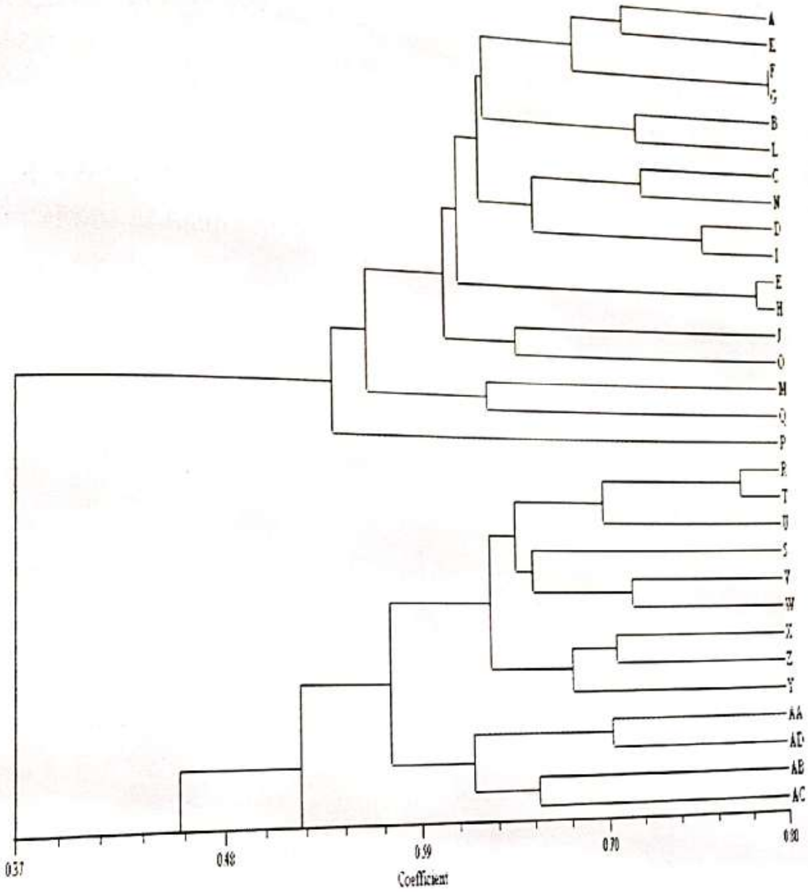

Figure 2. UPGMA cluster analysis showing the relationship and diversity among 30 accessions of *A. glabrata* as revealed by data using SSR markers.

Molecular characterization of J11, *A. diogoi* and their F_1 hybrids

A set of 31 SSR primers was screened using cultivar J11, wild species, *Arachis diogoi* and their hybrids to identify markers for use in screening of F_2 populations. As many as 21 SSRs produced polymorphism among the parents and their F_1 hybrids. Out of 21 polymorphic primers only two SSRs (PM32 and PM188) produced co-dominant alleles in the hybrids which could be useful in marker assisted selection for tolerance of LLS and rust in J 11x *A. diogoi*.

Identification of useful salinity stress responsive transcripts from *A. glabrata* accession (tolerant to NaCl induced stress)

Transcriptional analysis through DDRT-PCR was continued to understand tolerance to NaCl induced salinity stress in *Arachis glabrata* accession NRCG-11832. Some of the bands (transcripsts) were either suppressed or induced due to NaCl-induced stress for 7 and 14 days. These differentially expressed bands were eluted from agarose gel and sequenced. The differentially expressed transcripts were named 'groundnut transcript responsive to salt stress' (GTRS). Upon BLAST search for GTRS sequences (Table-1), similarity with the following important salt tolerance cds, mRNAs, nucleotide sequences and related proteins were found.

Table 1. Particulars of 20 differentially displayed bands eluted for sequencing

Primer used	Accession No.	Sample identity	Approx. size	Assigned code
OPT 13	NRCG 11832	1S (induced)	800bp	GTRS-6
OPT 18	NRCG 11832	1S (induced)	300bp	GTRS-7
OPT 18	NRCG 11832	1S (induced)	400bp	GTRS-8
OPT 20	NRCG 11832	1C(suppressed)	300bp	GTRS-9
OPT-7	NRCG 11832	1S(induced)	500bp	GTRS-10
OPT-7	NRCG 11832	1S(induced)	300bp	GTRS-11
OPT-6	NRCG 11832	1C(suppressed)	500bp	GTRS-12
OPT-6	NRCG 11832	1C(suppressed)	700bp	GTRS-13
D-8	NRCG 11832	2C(suppressed)	200bp	GTRS-14
D-8	NRCG 11832	2C(suppressed)	300bp	GTRS-15
OPT-18	NRCG 11832	2C(suppressed)	700bp	GTRS-16
OPT-19	NRCG 11832	2S(induced)	200bp	GTRS-17
OPT-19	NRCG 11832	2S(induced)	300bp	GTRS-18
OPT-8	NRCG 11832	2S(induced)	400bp	GTRS-19
OPT-8	NRCG 11832	2S(induced)	500bp	GTRS-20
OPT-7	NRCG 11832	2C(suppressed)	400bp	GTRS-21
OPT-7	NRCG 11832	2C(suppressed)	500bp	GTRS-22
OPT-10	NRCG 11832	2C(suppressed)	500bp	GTRS-23
OPT-12	NRCG 11832	2S(induced)	500bp	GTRS-24
OPT-11	NRCG 11832	2C(suppressed)	400bp	GTRS-25

GTRS-10:

1ZCD_A Chain A, Crystal Structure of the Na+H+ ANTIPORTE NHAA>pdb|1ZCD|B Chain B, Crystal Structure of the Na+H+ ANTIPORTER NHAA.

100% similarity with DQ071264.1 *Pennisetum glaucum* Na/H vacuolar antipor (NHXI) mRNA, complete cds. This plays important role during salt stress condition.

100% similarity with DQ228817.1 *Pennisetum glaucum* Na/H antiporter ge complete cds.

GTRS-12:

Up to 75% similarity with Q9SY59.1 RecName:Full=NF-X1-type zinc fing protein NFXL1;Short=AtNFXL1. It mediates E2-dependent ubiquitination (by similarit It confers resistance to osmotic stress such as high salinity and promotes H_2O_2 productio Negative regulator of some defense-related genes via a salicylic acid (SA)-depende signaling pathway.

Up to 50% similarity is found with EF576564.1 *Oryza sativa* (indica cultivar-group) clone OSS-385-480-H11 alpha-glucan phosphorylase, h isozyme mRNA, partial cds. It is given in a comparative transcriptome map of early and late salinity stress response.

80% similarity is shown with NM_122333.4 *Arabidopsis thaliana* SOS3 (SALT OVERLY SENSITIVE 3); calcium ion binding/calcium-dependent protein serine/threonine phosphatase (SOS3) mRNA, complete cds.

Up to 60% similarity is found with GR405355.1 ICCV2_CAAF_Z71TFICCV2 Salinity-stressed chickpea root cDNA library *Cicer arientium* cDNA clone ICCV2_CAAF_Z71TF 5', mRNA sequence.

Up to 55% similarity is found with GR405029.1 ICCV2 Salinity-stressed chickpea root cDNA library *Cicer arientium* cDNA clone ICCV2_CAAF_W06TF 5', mRNA sequence.

Up to 52% similarity is found with GR404643.1 ICCV2_CAAF_R54TFICCV2 Salinity-stressed chickpea root cDNA library *Cicer arientium* cDNA clone ICCV2_CAAF_R54TF 5', mRNA sequence.

Up to 52% GR404282.1 ICCV2_CAAF_N36TFICCV2 Salinity Salinity-stressed chickpea root cDNA library *Cicer arientium* cDNA clone ICCV2_CAAF_N36TF 5' , mRNA sequence.

Up to 68% GR393446.1 CAABS71TFICC1882 field drought stressed root cDNA library *Cicer arientium* cDNA clone CAABS71TF 5' , mRNA sequence.

Up to 91% similarity with NC_003070.9 *Arabidopsis thaliana* chromosome 1, complete sequence 426 bp at 5' side: WRKY10 (WRKY DNA-BINDING PROTEIN 10); transcription factor. This protein is tolerant to abiotic stress condition.

GTRS-13:

Up to 90% similarity with NM_119745.3 *Arabidopsis thaliana* ATPLDDELTA; phospholipase D (ATPLDDELTA) mRNA, complete cds. It is involved in response to water deprivation, phosphatidic acid metabolic process, hyperosmotic salinity response, response to cold, programmed cell death.

GTRS-14:

Up to 64% similarity with Q9FFK8.2 RecName: Full=NF-X1-type zinc finger protein NFXL2; Short=AtNFXL2. It mediates E2 –dependent ubiquitination (By similarity), confers sensitivity to osmotic stress such as high salinity.

Up to 56% similarity with P17202.1 RecName: Full=Betaine aldehyde dehydrogenase, chloroplastic; Short=BADH.

Up to 89% similarity with GU252706.1 *Ageratina adenophora* high-affinity potassium transporter 1 (HAK1) mRNA, complete cds.

GTRS-18:

Up to 80% similarity with NM_104167.5 *Arabidopsis thaliana* ANAC019 (*Arabidopsis* NAC domain containing protein 19): transcription factor (ANAC019) mRNA, complete cds.

Up to 93% similarity with NM_201896.2 *Arabidopsis thaliana* SLT1 (Sodium-and lithium-tolerant 1) (SLT1) mRNA, complete cds.

GTRS 19:

Up to 68% similarity with P17202.1 RecName: Full=Betaine aldehyde dehydrogenase, chloroplastic; Short=BADH; Flags: precursor.

Up to 70% similarity with NM_201896.2 *Arabidopsis thaliana* SLT1 (sodium- and lithium-tolerant 1) (SLT1) mRNA, complete cds.

Up to 100% similarity with GR403408.1 ICCV2_CAAF_D12TF ICCV2 Salinity-stressed chickpea root cDNA library *Cicer arientinum* cDNA clone ICCV2_CAAF_D12TF 5', mRNA sequence.

GTRS 20:

Up to 73% similarity with 1ZCD_A Chain A, Crystal Structure Of The Na+H+ ANTIPORTER NHAA >pdb|1ZCD|B Chain B, Crystal Structure Of The Na+H+ ANTIPORTER NHAA.

Up to 68% similarity with NM_119212.4 *Arabidopsis thaliana* hydrophobic protein, putative / low temperature and salt responsive protein, putative (AT4G30660) mRNA, complete cds.

Up to 89% similarity with GR405344.1 ICCV2_CAAF_Z60TF ICCV2 Salinity-stressed chickpea root cDNA library *Cicer arietinum* cDNA clone ICCV2_CAAF_Z60TF 5', mRNA sequence.

Up to 58% similarity is found with A8CVF3.1 RecName: Full=Dehydrin DHN1; Short=AmDHN1.

Up to 70% similarity with NM_201896.2 *Arabidopsis thaliana* SLT1 (sodium- and lithium-tolerant 1) (SLT1) *Arabidopsis thaliana* SLT1 mRNA, complete cds.

GTRS 22:

Up to 70% similarity with GR403408.1 ICCV2_CAAF_D12TF ICCV2 Salinity-stressed chickpea root cDNA library *Cicer arietinum* cDNA clone ICCV2_CAAF_D12TF 5', mRNA sequence

Up to 100% similarity with EB710040.1 S7SLT_C62 *Lolium temulentum* salt stressed subtraction library *Lolium temulentum* cDNA, mRNA sequence.

GTRS sequences coding full length Cds, proteins or functional gene related to salinity stress could be useful further for cloning and use in improvement of salinity stress in groundnut.

Nucleotide sequence submitted to the GenBank:

i) bankit1384528HQ191219: Bera S K, N P Ved and Abhay Kumar (2010) Genomic DNA sequence obtained from RAPD analysis of a drought resistant *Arachis hypogaea* cultivar, TMVNLM-2.

ii) bankit1384538HQ191220: Bera S K, N P Ved and Abhay Kumar (2010) Genomic DNA sequence obtained from RAPD analysis of a drought resistant *Arachis glabrata* accession (ICG 8902).

PROJECT 16: ECONOMIC ANALYSIS OF PRODUCTION, PROCESSING AND UTILIZATION OF GROUNDNUT IN MAJOR GROUNDNUT GROWING STATES OF INDIA

(G. GOVINDARAJ)

To study the status of groundnut crop in major groundnut growing states of India

There is a concern among the researchers and the policy makers on the declining area under groundnut crop in India. To ascertain the status of groundnut crop exponential function was used. The data for the period 1991-92 to 2008-09 was collected from authentic sources and used for analyzing the growth rates in India and in the major groundnut growing states. The results are presented in Table 1. The results revealed that there is perceptible deceleration in area under groundnut in almost all the major groundnut growing states though the rate of deceleration varied from state to state. The highest per annum rate of deceleration was observed in Tamil Nadu (5.4%) which was followed by Maharashtra (3.4%), Karnataka (2.9%) and Andhra Pradesh (2.7%). In all the major groundnut growing states except Gujarat, the annual growth rates of area were negative and higher than the national average of (2.3%). The major reason attributed to decline in area was the change in the pattern of rainfall The growth of groundnut area in Rajasthan was, however, positive. The decline in area in Gujarat was, however, very small compared to other states.

The productivity growth was positive in Tamil Nadu and Gujarat whereas it was negative in Andhra Pradesh, Karnataka and Maharashtra. To ascertain the absolute fall, the areas in two quinquennial periods (1991-95 and 2004-08) were compared. In India, during the period 1991-95, the area under groundnut crop was 81 lakh hectares which declined to 63 lakh during 2004-08. The absolute decline in groundnut area was 17 lakh ha during 19-year period. Among the major states, the largest decline was in Andhra Pradesh (5.98 lakh ha) followed by Tamil Nadu (5.14 lakh ha), Karnataka (3.48 lakh ha), Maharashtra (2.22 lakh ha) and Gujarat (0.40 lakh ha). In Rajasthan, the area increased from 2.48 lakh ha (1991-95) to 3.02 lakh ha (2004-08).

Table 1. Area and Productivity growth across major groundnut growing states (1991-92 to 2008-09)

States	Growth rates (%)		Area (lakh ha)		
	Area	Productivity	1991-95	2004-08	Absolute change
1. Andhra Pradesh	-2.7***	-1.5**	23.20	17.22	-5.98 (25.7)
2. Karnataka	-2.9***	-2.0***	12.48	9.00	-3.48 (27.8)
3. Tamil Nadu	-5.4***	1.1***	10.91	5.78	-5.14 (47.0)
4. Gujarat	-0.1 NS	4.3***	19.39	18.98	-0.40 (2.1)
5. Maharashtra	-3.4***	-0.5*	6.34	4.12	-2.22 (35.0)
6. Rajasthan	0.69 NS	4.4***	2.48	3.02	+0.54 (+21.7)
7. All India	-2.3***	0.8	81.05	63.11	-17.94 (22.1)

Note: *** 1%, ** 5% and * 10% level of significance; data in parentheses represents per cent to base year

To assess the decline in groundnut area during different seasons, the data on area in *kharif* and *rabi* summer seasons were collected for the period 1991-92 to 2008-09. The growth rates calculated using exponential function confirmed that during *kharif* season, the growth was negative in all the major groundnut growing states though the rate of deceleration varied across the states. The highest per annum growth rate of -5.9% was observed in Tamil Nadu followed by Maharashtra (-3.3% per annum), Karnataka (-2.8%) and Andhra Pradesh (-2.4%). In all the major groundnut growing states except Rajasthan and Gujarat, the annual growth rates were negative and more than the national average annual growth rate of -2.3% (Table 2). In absolute terms, during *kharif* season the highest decline was in Andhra Pradesh (4.5 lakh ha) followed by Tamil Nadu (4.4 lakh ha), Karnataka (2.8 lakh ha), Maharashtra (1.9 lakh ha) and Gujarat (0.60 lakh ha). In India, during the period 1991-95, the area under *kharif* groundnut was 68 lakh ha which declined to 54 lakh ha during 2004-08. Thus the absolute decline in *kharif* area in India was 15 lakh ha during the above period.

Though the all India area-growth has been negative, the productivity-growth has been positive in Rajasthan, Gujarat and Tamil Nadu. In Rajasthan, annual growth in productivity was 4.4% which was the highest among the major groundnut growing states.

Table 2. Area growth in different seasons in major groundnut growing states (1991-92 to 2008-09)

		Area growth rates (%)		Area (lakh ha)		
	States	***kharif***	***Rabi*/ Summer**	**1991-95**	**2004-08**	**Absolute change**
1.	Andhra Pradesh	-2.4***	-3.8***	K (19.1) R (4.1)	K (14.6) R (2.6)	K (-4.5) R (-1.5)
2.	Karnataka	-2.8***	-3.2***	K (10.2) R (2.3)	K (7.4) R (1.6)	K (-2.8) R (-0.7)
3.	Tamil Nadu	-5.9***	-4.0***	K (8.0) R (2.8)	K (3.6) R (2.0)	K (-4.4) R (-0.8)
4.	Gujarat	-0.1NS	-0.9 NS	K (18.4) R (1.1)	K (17.8) R (1.1)	K (-0.6) Small change
5.	Maharashtra	-3.3***	-3.2***	K (5.1) R (1.2)	K (3.2) R (0.9)	K (-1.9) R(-0.3)
6.	All India	-2.0***	-2.9***	K (68.58) R (12.42)	K (53.7) R (9.3)	K (-14.88) R (-3.12)

Note: *** 1% level of significance; K = *kharif*, and R= *rabi*-summer

The growth rates for area under *rabi* summer were negative in India as a whole and also in all the major groundnut growing states (Table 2). The maximum per annum rate of decline was observed in Tamil Nadu (-4.0%) followed by Andhra Pradesh (-3.8%) and Karnataka and Maharashtra (-3.2% for both). On the basis of quinquennial averages for the periods 1991-95 and 2004-08, the largest absolute fall in area in *rabi* summer season was in Andhra Pradesh (1.7 lakh ha) followed by Tamil Nadu (0.8 lakh ha), Karnataka (0.7 lakh ha) and Maharashtra (0.3 lakh ha).

On the basis of area under groundnut crop, the important districts in all the major states were also identified. For this purpose, the mean ± 0.5 SD methodology was followed. Accordingly, the names of the districts identified in the major groundnut growing states are given in Table 3.

Table 3. Important groundnut growing districts in major states

	State	Districts
1	Andhra Pradesh	Anantapur, Chittoor, Cuddapah and Kurnool
2.	Gujarat	Amreli, Bhavnagar, Jamnagar, Junagadh and Rajkot
3.	Karnataka	Tumkur, Chitradurga, Belgaum, Bellary, Gadag, Gulbarga and Kolar
4.	Maharashtra	Kolhapur, Satara, Dhule, Nasik, Sangli and Pune
5.	Tamil Nadu	Dharmapuri, Erode, Namakkal, Salem, Thiruvannamalai, Vellore, and Villupuram
6.	Rajasthan	Chittorgarh, Bikaner, Dausa, Jaipur, Jodhpur, Sikar and Tonk

To ascertain the growth of area in the important groundnut growing districts, the annual growth rates were worked out by using exponential function. The data from 1999-00 to 2008-09 were considered for this purpose.

The Important groundnut growing districts identified in Andhra Pradesh were Anantapur, Chittoor, Cuddapah and Kurnool. Among these, the maximum per annum negative growth in area was observed in Chitoor district (-2.5%) followed by Cuddapah (-1.7%). In Anantapur and Kurnool districts, however, the growth rates were positive reflecting an increase in groundnut area since 1999-00. The reason for decline in some of the districts and the economic rationale for shift to other crops from the farmers point of view needs to be investigated.

In Gujarat, five districts viz, Amreli, Bhavnagar, Jamnagar, Junagadh and Rajkot were identified and in all these districts the growth rates were negative. The largest per annum deceleration (-7.7%) was observed in Bhavnagar and the least in Jamnagar and Rajkot (-0.1%).

Table 4. Area and Productivity growth in important groundnut growing districts in major status (1999-00 to 2008-09)

S.No	States	Important districts	Growth (%) Area	Productivity
1.	Andhra Pradesh	Anantapur	1.5	-9.5
		Chittoor	-2.5	1.7
		Cuddapah	-1.7	2.4
		Kurnool	1.0	1.3
2.	Gujarat	Amreli	-1.0	14.5
		Bhavnagar	-7.7*	24.3
		Jamnagar	-0.1	79.1
		Junagadh	-1.1	14.0
		Rajkot	-0.1	57.8
3.	Karnataka	Belgaum	-4.3*	-4.7
		Bellary	-0.6	-7.1
		Chitradurga	-2.4	-7.7
		Gadag	-4.0	5.4
		Gulbarga	-9.4***	-3.7
		Kolar	-18.0***	-0.2
		Tumkur	-2.1	-4.5
4.	Maharashtra	Kolhapur	-1.8**	-1.9
		Pune	-3.5**	-3.5**
		Satara	-2.4**	-0.9
		Dhule	-3.4	4.8
		Nasik	-2.3	3.4
		Sangli	-4.3	-3.0
5.	Tamil Nadu	Dharmapuri	-23.0***	2.8
		Erode	-5.0	-1.9
		Namakkal	-9.3***	-4.3
		Salem	-12.4***	-4.5
		Thiruvannamalai	4.2	-0.3
		Vellore	-0.0	-2.9
		Villupuram	-5.1	-4.6***
6.	Rajasthan	Chittorgarh	-3.2	0.3
		Bikaner	16.5***	5.4
		Dausa	-2.2	3.8
		Jaipur	-0.8	12.5***
		Jodhpur	43.9***	8.9***
		Sikar	13.7***	6.7**
		Tonk	-8.3**	9.9

Note: *** 1%,** 5% and * 10% level of significance

In Karnataka, the districts identified were Belgaum, Bellary, Chitradurga, Gadag, Gulbarga, Kolar and Tumkur. In all these districts the growth rates were negative confirming reduction in groundnut area in these districts since 1999-00. The maximum per annum deceleration was observed in Kolar (-18 %) followed by Gulbarga (-9.4%). The reasons for deceleration need be investigated.

Kolhapur, Satara, Dhule, Nasik, Sangli and Pune districts were identified as the important districts in Maharashtra. In all these districts there was a decline in area. The maximum per annum deceleration was observed in Pune (-3.5%) followed by Satara (-2.4%) and Kolhapur (-1.8%).

In Tamil Nadu, the major districts identified were Dharmapuri, Erode, Namakkal, Salem, Thiruvannamalai, Vellore and Villupuram. Except for Tiruvannamalai, in all other districts there was a deceleration in area since 1999-00. The per annum deceleration in Dharmapuri was -23 % and in Salem -12.4%.

In Rajasthan, seven districts viz., Chittorgarh, Bikaner, Dausa, Jaipur, Jodhpur, Sikar and Tonk were identified. In Bikaner, Jodhpur and Sikar districts the growth in area was positive and significant even at 1% level. The maximum rate of growth was observed in Jodhpur (43.9%) followed by Bikaner (16.5%) and Sikar (13.7%). In some of the districts like Jaipur, Jodhpur and Sikar the productivity growth was also positive and statistically significant.

Long-term survival of groundnut production technologies in farmers situations- a post-project evaluation of implementation of TAR-IVLP

An NATP sponsored project 'Technology Assessment and Refinement through Institute Village Linkage Programme' (TAR-IVLP) was operated by DGR. The project was operated from 1999-2004 in four villages of Junagadh district viz., Vadhavi, Zanjarda, Nandarkhi and Umatwada. Nineteen technologies were assessed and validated in 605 farmers' fields. Six years later, the following technologies emerged as useful ones for the farmers:

- Groundnut + pigeon pea intercropping
- IPM technologies comprising seed treatment with carbendazim (@ 2gm kg^{-1} of seed), castor cake (soil application of castor cake@500 kg ha^{-1}), crude neem oil spray(@2%), pheromone trap (@10 ha^{-1}), pigeon pea trap crop,
- Optimum seed rate (@120kg ha^{-1} for bunch and 100 kg ha^{-1} for spreading PGPR (@500kg ha^{-1}
- Recommended doses of fertilizers (NPK 12.5:25:0 kg ha^{-1})
- Inter cropping of groundnut in cotton
- Deep tillage
- Management of yellowing in rainfed groundnut.

The technologies of 'optimum seed-rate' and 'application of PGPR' and 'recommended doses of fertilizer' were not adopted by any of the farmers, whereas deep tillage practice was adopted by all. Hence, these four technologies were not included in the survival-assessment. In the present study, information was collected from the farmers seven years after the conclusion of TAR-IVLP and the data obtained was analyzed for long-term sustainability of the technologies concerned.

Methodology

Out of four villages adopted under TAR-IVLP, only three were selected at random. During *kharif* 2010, only 40 farmers, selected randomly from these three villages, were surveyed. The information collected was subjected to non-parametric Kaplan-Meier analysis to assess the long-term survival probability S(t) using the following equation:

$$\hat{S}(t) = \prod_{t_i<t} \frac{n_i - d_i}{n_i}.$$

Where, n_i is the number of farmers at time i and d_i is the number of farmers who discontinued adoption at time i

Results of Kaplan-Meier analysis

The study revealed that different technologies introduced under TAR-IVLP had different survival probabilities under real farm situations (Table 5). During the period of project, many farmers who were willingly adopting the introduced technologies, disowned the same due to various reasons, soon after conclusion of the project. During the first year after the conclusion of TAR-IVLP, the highest probability of survival was 0.89 for 'seed treatment' followed by 0.81 for 'cotton + groundnut intercropping'. The probability of survival of 0.60 was for 'trap-crop', 0.55 for 'application of castor cake', 0.45 for 'groundnut + pigeon pea' 0.38 for 'neem oil spray' and 0.28 for 'pheromone trap'. The 'seed treatment' and 'groundnut + cotton' had the highest probability of survival essentially due to their low cost. The 'groundnut + cotton' had the associated advantage of realising groundnut fodder for cattle. The lowest probability of survival was for 'pheromone-trap' (0.28) and 'neem-oil spray' (0.38) as the benefits of these technologies were not visible to the farmers.

Seed-treatment

Since 'seed-treatment' was not only a low-cost technology but also did not require much skill for adoption, the survival rate was very high compared to all other technologies. Even after conclusion of the project, the rate of adoption dropped only marginally, as could be discerned from its high-value of probability (0.89). Even five years after the conclusion of the project, the probability value stood at 0.78.

Pheromone trap

Within one year of conclusion of TAR-IVLP, the survival-probability of this technology was only 0.28 revealing quite a low retention. After five years of conclusion of the project, the survival-probability dropped further to as low as of 0.05 indicating a very low rate success. The reasons perceived for discontinuing the adoption of this technology are:

- High cost
- Feeling of some farmers that it was not much effective
- Traps were not readily available in the market
- Traps are damaged by dogs and other animals

Groundnut + pigeon pea

After the conclusion of the project, the probability of survival of this technology decreased as the first year progressed. The probability of survival of 'groundnut + pigeon pea' was 0.45 at the end of the second year and it declined further to 0.35, 0.19 and 0.09 during the third, the fourth and the fifth year, respectively. The reasons perceived for discontinuing the adoption were:

- If pigeon pea is intercropped with groundnut, *rabi* crops like wheat, cumin etc. can not be taken
- Production of groundnut *per se* is low in intercropping
- Inter-cultural operations become tedious
- Uptake of nutrients is high in intercropping system
- High rainfall in recent years does not favour intercropping with pigeon pea

Application of castor cake

The results revealed that within one year of conclusion of TAR-IVLP, the survival probability was only 0.55 which dropped further to 0.41 during the second year. At the end of the fifth year, it was only 0.12, indicating a much lower rate of survival. The main reasons perceived for discontinuance were:

- High cost of castor cake (main reason)
- Admixtures in preparations
- Castor crop is grown and hence castor cake is not required
- Non availability of castor cake in time and in required quantity

Neem oil spray

One year after conclusion of the project, the survival probability of this technology was only 0.38 which dropped further to 0.29 after the second year. But after third year the probability stabilised at 0.17 indicating a survival rate of 17%. The reasons for discontinuing the adoption were:

- Neem oil available in market was of poor quality
- Pest damage was low and hence spray was not needed
- No immediate benefit was visible

Table 5. Cumulative survival probability of production technologies introduced through TAR-IVLP for groundnut based cropping systems

Years	Technology					
	Groundnut + Pigeon pea	Seed treatment (carbendazim)	Application of castor cake	Spray of neem oil emulsion	Use of pheromone trap	Groundnut + cotton
0-3 (during the project)	1.00	1.00	1.00	1.00	1.00	1.00
< 4 (one year after conclusion of the project)	0.45	0.89	0.55	0.38	0.28	0.81
< 5 (IInd year)	0.45	0.89	0.41	0.29	0.25	0.52
< 6 (IIIrd year)	0.35	0.89	0.28	0.17	0.14	0.45
< 7 (IVth year)	0.19	0.89	0.16	0.17	0.11	
< 8 (Vth year)	0.09	0.78	0.12	0.17	0.11	
>9					0.05	
Number of years of survival at median cumulative probability of (0.5)	3 years	> 8 years	4 years	3 years	3 years	5 years

Intercropping of groundnut with cotton

Most of the cotton growers in the adopted villages followed wider spacing (180 cm between the rows) and to utilise this inter-row space effectively this technology was introduced. The probability of survival was 0.81 one year after conclusion of the project which declined to 0.45 after three years. The probability of survival stabilised at 0.45 indicating 45% survival rate even after five years of conclusion of the project. Besides some incremental profits with intercrops, the success of this technology was due mainly to the fact that with groundnut as one of the intercrops, fodder for cattle also became available which was otherwise not available with sole crop of cotton was taken. The main reasons behind non-adoption of this technology are:

- Increased cost of labour
- The farmers who did not own cattle no longer needed fodder
- Productivity of cotton is high in sole cropping system

The technologies like 'optimum seed rate' and 'application of PGPR' were not at all practiced by the farmers and hence the survival of these technologies was not assessed. Most of the farmers opined that PGPR preparations were not available in the market and hence they could not adopt this technology.

PROJECT 17 : BREEDING FOR IMPROVED FODDER QUALITY TRAITS IN GROUNDNUT

(A. L. RATHNAKUMAR, CHUNI LAL AND R. S. JAT)

Genetic analysis of pod and fodder yields and seven fodder quality traits

The important indicators of fodder quality are nitrogen content (N), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), total sugars (TS), metabolizable energy (ME) and *in vitro* digestibility of organic matter (IVOMD).

To understand the genetics of seven fodder quality traits, the data on 36 crosses made earlier in a 6x6 diallel fashion were analyzed. The ANOVA for the seven fodder quality traits and the estimates of mean squares obtained for general combining ability (GCA), specific combining ability (SCA) and reciprocal effects are given in Table 1. The analysis indicated that there were significant differences amongst the parents, the crosses and parents vs. crosses for all the traits studied.

Table 1. ANOVA for combining ability and reciprocal effects for seven fodder quality traits in groundnut

Source of variation	d.f.	N	NDF	ADF	ADG	TS	ME	IVOMD
Replication	1	0.45	15.6	25.5	0.39	1.43	0.09	4.50
Treatments	35	0.60**	38.9**	45.2*	1.69*	3.95*	0.06*	4.25*
Parents vs Crosses	1	1.04*	387.56***	494.4***	17.1***	31.62***	0.59***	49.54***
GCA	5	2.35*	9.4*	15.4**	0.20	1.60*	0.03	2.37*
SCA	15	0.18	33.6***	38.7***	1.43***	3.30**	0.03	3.09*
Reciprocal	15	0.39	8.7	0.4	0.47	0.77	0.02	1.07
Error	35	0.12	7.2	10.2	0.30	1.08	0.02	1.29

The analysis of variance also indicated that:

1. GCA variance was significant only for nitrogen content indicating the role of additive gene action in the inheritance of this trait. Hence, it should be possible to isolate superior recombinants with high nitrogen content in the early generation itself.
2. Both GCA and SCA variances were significant for the rest of the traits, except for ME thereby indicating the role of both additive and non-additive gene action in governing these traits. Hence, proper choice of parents and postponing the selection to later generations for the traits will yield desirable results.

Combining ability effect

GCA effects: The **gca** effects were positive and significant in case of CS 19 (for nitrogen content); GG 20 (for total sugars) and PBS 24030 (for *in vitro* organic matter digestibility) indicating usefulness of these genotypes as donors in hybridization programme. Significant and negative gca effects were observed for ICGV 86590 (for total sugars) and PBS 24030 (metabolizable energy).

SCA effects of crosses: For nitrogen content, the cross 'CS 19 x GPBD 4' exhibited significant and positive SCA effects while for all the three fibre fractions (neutral detergent fibre, acid detergent fibre and acid detergent lignin) it recorded significant negative effects. The parents involved in this cross exhibited high (CS 19) and low (GPBD 4) **gca** effects respectively, for nitrogen content.

While the cross 'GPBD 4 x TG 37A' exhibited significant but negative SCA effects for nitrogen content but it recorded significant and positive SCA effects for sugar content and all the three fibre fractions. The parents involved in this cross recorded high and low **gca** effects respectively for these characters. Such deviations indicated the role of epistasis and interaction between favourable genes present in the parents.

For two traits viz., metabolizable energy and *in vitro* organic matter digestibility, none of the cross showed significant SCA effects, which could be due to poor general combining ability of the parents in the involved cross or complex nature of inheritance of the traits.

SCA effects of reciprocal crosses: In general, reciprocal effects were low in most of the crosses for seven traits. Four crosses, 'TG 37A X ICGV 86590' (0.96), 'ICGV 86590 X CS 19' (0.77), 'TG 37A X PBS 24030' (0.64) and 'TG 37A X GPBD 4' (0.52), in order of merit, however, exhibited significant and positive reciprocal effects for sugar content.

One cross each, for neutral detergent fibre (PBS 24030 x GG 20) and *in vitro* organic matter digestibility (TG 37A x ICGV 86590) exhibited positive and significant reciprocal effects.

Reciprocal effects were absent for nitrogen content, acid detergent fibre, acid detergent lignin, and metabolizable energy.

The mean values of the parents for the seven fodder quality traits (Table 2) indicated that for nitrogen content, an important trait which decides the quality of the fodders, was high in TG 37A (3.86%), PBS 24030 (3.65%) and GG 20 (3.39%) while it was low in CS 19 (1.36%) and GPBD 4 (1.46%).

The correlation between the parental means and the **gca** effects indicated significant and positive 'r' values for ADF (0.84), total sugars (0.88) and IVOMD (0.89). While the 'r' values were positive but non-significant for nitrogen content (0.58), neutral detergent fibre (0.21), acid detergent lignin (0.49) and negative and non-significant for metabolizable energy (-0.16) indicating that the parental means are not indicative of **gca** effects and the complexity of the traits concerned.

Table 2. Mean values for groundnut fodder quality traits of the best parents

Parents	N (%)	NDF (%)	ADF (%)	ADL (%)	TS (%)	ME (MJ kg^{-1})	IVOMD (%)
CS 19	1.36	80.17	65.71	13.16	3.27	6.83	45.54
GG 20	3.39	75.31	57.84	12.61	3.82	6.92	46.90
GPBD 4	1.46	76.68	60.76	13.04	3.52	7.17	47.89
ICGV 86590	2.12	76.98	64.48	13.37	2.67	6.89	45.96
PBS 24030	3.65	68.86	50.11	11.39	3.21	7.40	50.49
TG 37A	3.86	64.21	51.33	10.67	2.02	7.28	49.78
CD (p=0.05)	0.15	1.43	1.70	0.29	0.19	0.07	0.60
Heritability in narrow sense	0.37	0.54	0.48	0.45	0.42	0.30	0.37

Genetics of pod, kernel and fodder quality traits: Genetic analysis was carried out for pod, kernel and fodder yields of the cross TG 37A x ALR 2 using the mean values and their variances of the six generations viz. P1, P2, F1, F2, B1 and B2. Adequacy of the simple additive dominance model was tested by scaling and joint scaling tests. The results of scaling tests indicated that additive dominance model was inadequate for all the three traits studied and hence a perfect fit estimate of six parameters viz., m (Mean of F_2), d (additive mean component), h (dominant mean component), i (additive x additive mean component), j (additive x dominant mean component), and l (dominant x dominant mean component) were made on the assumption of digenic interaction.

Estimates of various genetic effects for this cross obtained through the analysis of the six generations means indicated the presence of non-allelic interaction for all the three yield traits. The inheritance of all the yield traits for this cross appeared to be controlled by both additive and dominant genetic effects but the magnitude of dominance effects were larger than additive component. Among the interaction effects, additive x additive and dominant x dominant type of digenic interaction were highly significant for all the three traits studied. Interestingly, additive x dominant gene effects were significant only for pod yield while it was not significant for kernel and fodder yields. More over, the 'h' and 'l' effects took opposite signs in all the three traits indicating the role of duplicate epistasis in governing these traits. These results indicated that all the three important yield traits are predominantly under the control of dominance gene sction together with duplicate epistasis. However, the magnitude of 'h' is lesser than 'l'. Postponing the selection to later generations with high selection pressure is suggested to isolate superior progenies with high pod, kernel and fodder yields.

For the seven fodder quality traits, results of scaling tests indicated the absence of epistasis and hence simple additive-dominance model was adequate to explain the gene effects of these traits. Additive genetic effects were significant and greater in magnitude than the dominance effects in case of nitrogen content. While both additive and dominance effects were significant for the fibre fractions, total sugars, metabolizable energy and IVOMD.

These results indicated that all the three important yield traits are predominantly under the control of dominance effects together with duplicate epistasis. However, the magnitude of 'h' is lesser than 'l'. Postponing the selection to later generations with high selection pressure is suggested to isolate superior progenies with high pod, kernel and fodder yields. While the fodder quality traits are non-interacting but mainly under the control of non-additive gene effects except for nitrogen content. Hence, early generation selection for nitrogen content would yield desirable results. However, in view of the strong dominance effects in case of fibre fractions, total sugars and metabolizable enegy, postponing the selection at later stages is recommended.

PROJECT 18 : DEVELOPMENT OF STATISTICAL MODELS FOR EVALUATION OF FIELD TRIALS ON GROUNDNUT CROP AND DETERMINATION OF SCENARIOS IN AREA, PRODUCTION AND YIELD

(A. P. MISHRA AND G. GOVINDARAJ)

In the last two decades, the groundnut crop has lost a considerable area to other crops in *kharif* season in almost all the major groundnut growing states. Moreover, misgivings are being expressed at many a quarters that there has not been any improvement in groundnut productivity over the decades in spite of a large investment from the exchequer for improving the productivity through scientific research. It was therefore considered necessary to study the impact, if any, of scientific research on national basis on trends of productivity of groundnut in India.

Time series data from 1949-50 to 2009-10 for all India area, production and productivity of groundnut crop has been collected for authentic sources for this study. Moreover, information on the milestones representing the level of investments made for improving productivity through scientific research were also considered. These milestones are:

- 1967: Establishment of All India Coordinated Research Project on Oilseeds (AICORPO) with its headquarters at Hyderabad
- 1972: Mid-term appraisal of AICORPO and creation of a position of Associate Coordinator for groundnut crop at PKV, Akola
- 1977: Elevation of AICORPO to Directorate of Oilseeds Research and up-gradation of Associate Coordinator for groundnut to Project Coordinator.
- 1979: Esablishment of NRC for Groundnut at Junagadh in Gujarat
- 1992: Shifting of headquarters of AICRP-Groundnut from PKV, Akola to NRCG, Junagadh (now DGR, Junagadh)

Considering 1967-68 as the base, the year in which AICOPO came into being, the indices were calculated using the formula, $I = (Pi/Q\,j)*100$, where $Pi = 1, 2, 3, \ldots n$ years and $Q\,j$ = base year. By using the calculated indices, line graphs with trend lines were plotted for area, production and productivity to study the impact of research on these descriptors of groundnut crop. It was revealed that 1967-68 onwards the area was in decreasing trend while both production and productivity were in increasing trends (Figure 1). As the increase in the productivity over the years could be there due to release of new high-yielding varieties and improved packages of cultivation, it can be concluded that the initiation of scientific research on groundnut crop and its further strengthening from time to time did bring about a commensurate improvement in the productivity of the crop which would continue to be so in the years to come.

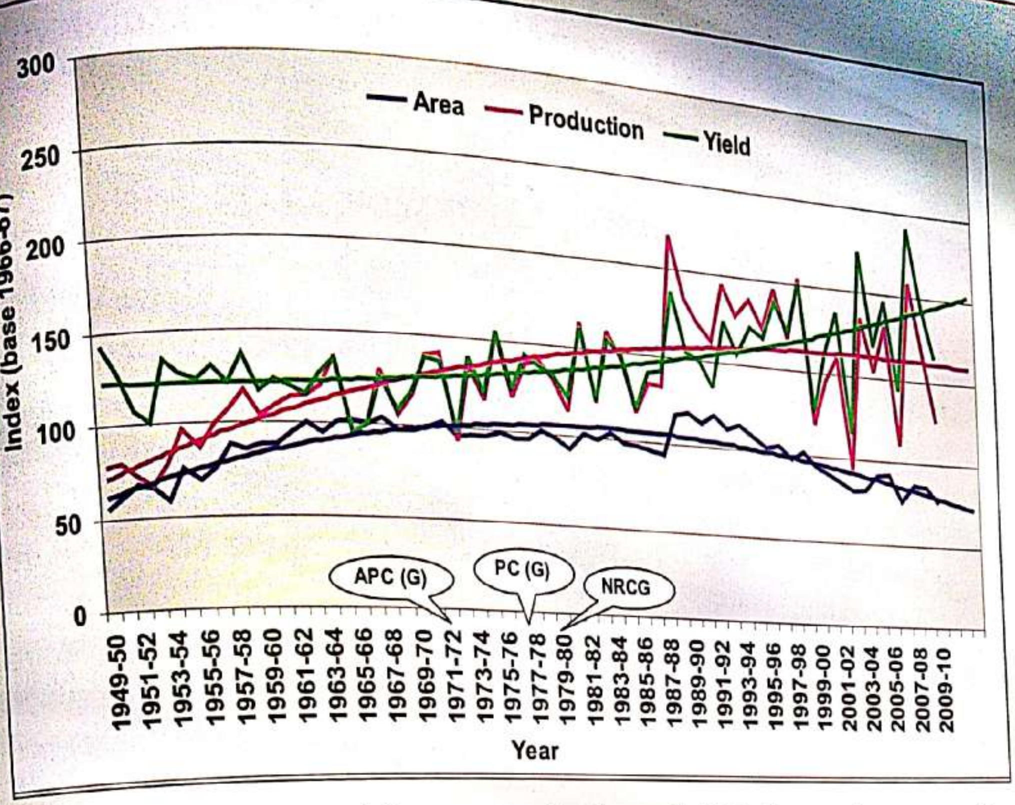

Figure 1: Index based trend for area, production and yield of groundnut crop of India

To verify the above results i.e. area in decreasing trend but production and productivity in increasing trends in the national scenarios, the forecasting model technique was adopted. Column charts were drawn and trends in area, production and yield based on linear, logarithmic, polynomial, exponential and moving average methods were drawn. Viewing the R^2 of each trend regression equation, it was revealed that polynomial regression equation was the best-suited equation for forecasting future trends. Regression forecasting model starting from 4th order to 2nd order polynomial were developed and forecast statistics of area, production and yield based on different forecasting models were calculated from 1949-50 to 2009-10 and $\Sigma\ (A-Y)^2$ was computed, where Y= actual recorded data and A= forecasted data on the basis of developed statistical model. The best model was selected for describing the trends, i.e. where $\Sigma\ (A-Y)^2$ = smallest. It was revealed that 2nd order regression polynomial model was the best suited model for the study. The regression forecas ting moded, 2nd order for area, production and yield has also been developed, using data from 1979 - 80 to 2008-09. The analysis confirmed that area was in fact in decreasing trend but both production and productivity were in increasing trends (Figure 2). It was also observed from the study that the efficiency of statistical forecasting models increases with the increase in the number of years for which data is used for analysis (Table 1).

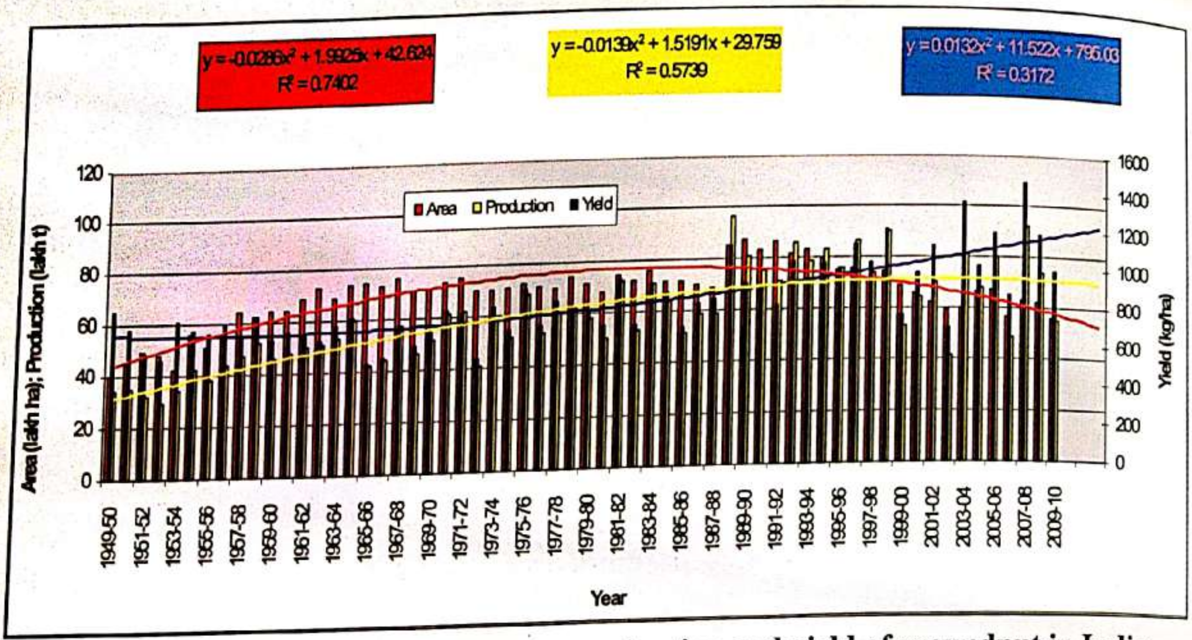

Figure-2: polynomial trends for area, production and yield of groundnut in India

Table 1. : Forecasting model with R^2 for all India area, production and yield of groundnut

	Period	Element	Statistical forecasting model	R^2
1	1979-80	Area	$y = -6.8205x^2 + 158.75x + 6848.10$	0.54
2	to	Production	$y = -5.55x^2 + 217.32x + 5446.00$	0.16
3	2008-09	Yield	$y = 0.0132x^2 + 11.522x + 795.03$	0.32
4	1949-50	Area	$y = -0.0286x^2 + 1.9925x + 42.62$	0.74
5	to	Production	$y = -0.0139x^2 + 1.5191x + 29.76$	0.57
6	2009-10	Yield	$y = 0.0132x^2 + 11.522x + 795.03$	0.32

ALL INDIA COORDINATED RESEARCH PROJECT ON GROUNDNUT

CROP IMPROVEMENT

Maintenance and evaluation of germplasm

During *kharif* 2010, at 15 centres located in Rajasthan, Uttar Pradesh, Gujarat, Maharashtra, Madhya Pradesh, Karnataka, Andhra Pradesh, and Tamil Nadu, 48 wild accessions, 88 interspecific hybrid-derivatives, and 5464 groundnut germplasm/advanced breeding lines belonging to four different habit groups were maintained. Several germplasm accessions possessing specific yield traits and tolerance of biotic and abiotic stresses were identified.

In the *rabi*-summer 2009-10, a total of 1377 genotypes comprising land races, different accessions, wild relatives, inter-specific hybrid derivatives, advanced breeding lines and germplasm accessions were multiplied at three centres. In addition, 72 inter-specific hybrid derivatives were multiplied at Vriddhachalam centre.

Hybridisation and selection

Altogether, 171 crosses in *rabi*-summer 2009-10 and 314 crosses in *kharif* 2010 were made by using different cultivars/advanced breeding lines and germplasm accessions.

In *rabi*-summer 2009-10, progenies of 550 crosses were advanced to next filial generations and at ten AICRP-G centres as many as 3021 selections were made. The selections comprised a large number (2822) of single plants and relatively a small number (199) number of progeny bulks. From amongst the total crosses advanced to different filial generations, 69% were in early generations (F2- F4) and the rest (31%) in the advanced generations (F5 onwards).

During *kharif* 2010, progenies of 1119 crosses made earlier, were advanced to their respective next filial generations. From these, a total of 14013 selections were made. These selections comprised a large number (9655) of single plants and also progeny bulks (4358). Of the total crosses advanced to different filial generations, 47% were in early generations (F1- F3) and the 53% in advanced generations (F4 onwards). Three-fourths (74%) of single plant selections (7133) made during the last season, were in early generations and the remaining (31%) were in advanced generations (2522).

For introgressing genes for resistance to foliar diseases and insect-pests from wild *Arachis* species into the cultivated types, 16 inter-specific crosses involving three wild species (*Arachis duranensis, A. cardenasii and A. batizocoi*) of the section *Arachis* and one wild species (*A. paraguariensis*) of the section *Procumbentes*, were effected at RRS, Vridhachalam. These novel sources of resistance will in turn be used in breeding programmes aimed at developing varieties with durable resistance to key pests and diseases.

In F_5 generation, 88 selections were made from eight inter-specific crosses involving amphidiploid between different wild species and the cultivated varieties. Under optimum disease pressure, at Virddhachalam and Aliyarnagar, at least seven genotypes could be identified as resistant or tolerant of rust and LLS.

Selections from breeding materials supplied by DGR and ICRISAT

Segregating and advanced generation breeding materials of objective specific crosses were supplied to AICRP-G centres for location specific selections and further advancement by DGR and ICRISAT. From amongst the progenies supplied earlier, 434 promising location-specific selections were made for advancement to the next filial generations in the ensuing *kharif* season. A total of 17 promising selections were evaluated in-station in preliminary stages and one at multi-location in Karnataka state.

From the breeding materials supplied by ICRISAT, three promising large-seeded genotypes, 76 promising high-yield genotypes in both Spanish and Virginia were selected for further evaluation.

Varietal evaluation

Seventy-eight elite breeding lines were evaluated in *rabi*-summer and 68 in *kharif*.

Of the fourteen entries tested for the second year in *rabi*-summer 2009-10, the pod (2902 kg ha^{-1}) and kernel (2049 kg ha^{-1}) yields of one entry viz., ALG 06-320 was significantly higher than those of the best check R 8808 and hence the entry ALG 06-320 was promoted to AVT in zone IIIb. In addition, the entries ICGV 95386, CTMG 6, Dh 216 and RHRGS 06021 were also promoted to AVT in the same zone on the basis of their superior yield and ancillary traits.

Of the 33 genotypes evaluated in Initial Varietal Trial (stage-I) in *kharif* season, 28 were in Initial Varietal Trial (stage-II); 4 in Advanced Varietal Trial and 1 in Advanced Large-Seeded Varietal Trial. Two genotypes in Spanish bunch (TCGS 901 and AK 1333) and three in Virginia group (RG 578, JSP 49 and RG 530) were promoted to Advanced Varietal Trial in zone IV. The genotype RG 510, which was consistent in giving high pod (2558 kg ha^{-1}) and kernel (1750 kg ha^{-1}) yields across different stages of testing, was proposed for identification.

Breeder seed production

On the basis of the availability of nucleus/breeder seed, a target of production of 16422 q breeder seed comprising 47 varieties was assigned to 20 producing centres/agencies for the year 2009-10. In *kharif* 2009, a total quantity of 3707.10 q breeder was produced and in *rabi*-summer 2009-10, another 12699 q breeder seed was produced. Thus a total of 16406 q groundnut breeder seed was produced during the year 2009-10.

For the year 2010-11, an indent for a total of 19679 q breeder seed of 54 varieties was received from DAC. Considering the availability of nucleus/breeder seed stage-I, targets for production of 11423 q seed comprising 46 groundnut varieties was assigned to 20 centres. Against this allocation, during *kharif* 2010 only 5,224 q breeder seed could be produced. To mitigate the short fall, a compensatory programme was undertaken during *rabi*-summer 2010-11 and an additional production of 9,900 q is anticipated. Thus the total production during 2010-11 would be around 15,000 q.

CROP PRODUCTION

Evaluation of groundnut cultivars for late sown conditions

At many centres, the delayed sowing by one to three weeks (normal sowing: immediately after first monsoon rains during *kharif* season) resulted in lowering of pod yield for most cultivars. However, cv. Chintamani 1, Chintamani 2 and GPBD 4 in Karnataka (at Chintamani); K 5, K 9 and Kadiri Harithandra in Andhra Pradesh (at Kadiri) and VRI-7 in Tamil Nadu (at Vriddhachalam) performed much better than other entries under delayed sown situations.

Micronutrient management in groundnut

In sandy loam soils of Mainpuri centre, soil application of zinc sulphate or boron and seed dressings of zinc sulphate or boric acid did not have any influence on the pod yield. In lateritic soils of Ratnagiri centre, however, soil application of zinc sulphate and boric acid, enhanced the pod yield.

Evaluation of post-emergence herbicides

Pre-emergence application of 'pendimethalin 30 EC (0.75 to 1.00 kg a.i./ha) + one hand weeding (between 40 to 45 DAS)' was found to be very effective in controlling weeds in groundnut during *kharif*. Post-emergence application of either 'quizalofop ethyl 5 EC (50 g a.i./ha) or imazethapyr (50 to 75 g a.i.,/ha) at 20 DAS' was found to reduce weed density. Pre-emergence application of 'pendimehalin 30 EC (0.75 to 1.00 kg a.i./ha) + one hand weeding between 40 to 45 DAS' followed by a 'post-emergence application of either Quizalofop ethyl 5 EC (50 g a.i./ha) or Imazethapyr (50 to 75 g a.i./ha) at 20 DAS' effectively reduced the weed intensity.

In *rabi*-summer, it was observed, that 'pre-emergence application of pendimethalin @ 1.0 kg a.i./ha coupled with one hand weeding at 45 DAS' was most effective in controlling the annual weeds (both mono- and di-cots). Post-emergence application of quizalofop ethyl @ 50 to 100 g a.i./ha at 20 DAS was most effective in controlling annual grassy weeds. Post-emergence application of imazethapyr @ 75 g a.i./ha (750 ml/ha) at 20 DAS was effective in controlling both monocot and dicot weeds

Development of packages for organic groundnut

Application of FYM (pretreated with beneficial micro-organisms, 7.5 t ha^{-1}); seed treatment with bio-fertilizers and bio-pesticides; either foliar spray of *Pseudomonas* (1%) or NSKE (5%) or panchagavya (3%) between 40 to 45 DAS was found effective for obtaining high pod yield.

Optimization of doses of potassium and calcium fertilizers for groundnut

Application of potassium and calcium fertilizers in doses higher than the recommended ones increased the pod yield of groundnut in sandy and sandy loam soils but did not have any influence on pod yield in medium black soils. Application of these fertilizers in split doses did not show any improvement in pod yield over the basal application of the entire quantity.

Use of gypsum for management of sulphur and calcium nutrition in groundnut

In sandy soils and sandy loam soils, application of gypsum (400 to 600 kg ha^{-1}) increased the pod yield. However, the crop did not respond to the application of gypsum in medium black soils. Basal application of entire quantity of gypsum was found to be a better mode of application than split-application at most of the centres.

Studies on the effect of row proportion and land configuration on the growth and yield of component crops in 'groundnut and sesame' intercropping system

At Jalgaon centre, groundnut + sesame in 3:1 and 4:1 row ratios produced higher groundnut equivalent yield (1833 and 1883 kg ha^{-1}, respectively) and higher net monetary returns (Rs.16,548 and Rs.16,835 ha^{-1}, respectively) than that produced by either sole groundnut (1744 kg ha^{-1} and Rs. 12,368 ha^{-1}) or sole sesame (1187 kg ha^{-1} and Rs. 13,165 ha^{-1}, respectively). Land configuration in groundnut + sesame intercropping system with various crop-row ratios of component crops did not bring any substantial improvement in the yield.

Maximization of groundnut production through nutrient management practices in *rabi*-summer

On the basis of mean of pooled-data of the 13 locations, it was revealed that groundnut responds well to application of higher than recommended doses of nitrogen, phosphorus and potassium fertilizers.

Groundnut responded well to split application of 100% RDF and also of 150% RDF. In addition to FYM @ 7.5 t ha^{-1}, the application of 100% RDF at the time of sowing and application of additional 50% (30 DAS) resulted in higher pod (2766 kg ha^{-1}) and kernel (1872 kg ha^{-1}) yields compared to application of 100% RDF alone at the time of sowing (2083 and 1391 kg ha^{-1}, respectively) and application of FYM @ 7.5 t ha^{-1} + 100% RDF at the time of sowing (2374 and 1587 kg ha^{-1}, respectively).

Split application of fertilizers (100% or 150% RDF) to groundnut was found more advantageous in light soils (red sand/lateritic soils) than in the heavy soils (medium/deep black soils).

CROP PROTECTION

Plant Pathology

Disease Resistance

The entries in IVT-I, AVT-I and AVT-II were screened for stem rot at Dharwad, Junagadh, Jalgaon, Kadiri, and Latur. The highest incidence of stem rot was recorded at Latur (96.9%), which was followed by Dharwad (35.6%), Junagadh (33.7%), Jalgaon (33.0%) and Kadiri (16.2%). Likewise, entries in IVT-I, AVT-I and AVT-II were screened for collar rot at Hanumangarh, Junagadh, Jalgaon, and Kadiri. The highest incidence of collar rot was observed at Junagadh (37.5%), which was followed by Hanumangarh (28.5%), Jalgaon (10.2%) and Kadiri (3.0%) (Table 1).

Table 1. Genotypes identified for resistance to stem rot and collar rot at AICRPG centres

Entry	Centre	
	Stem rot	Collar rot
IVK-I-10-3	Dharwad, Jalgaon, Junagadh, and Kadiri	Hanumangarh, Jalgaon, Junagadh and Kadiri
IVK-I-10-2	Dharwad, Junagadh, and Kadiri	Jalgaon, Junagadh, and Kadiri
IVK-I-10-1	Dharwad, Kadiri, and Latur	Junagadh, Jalgaon, and Kadiri
RG 510	Dharwad, Kadiri, and Latur	Jalgaon, and Kadiri
SGL 4233	Jalgaon, Junagadh, Kadiri, and Latur	Jalgaon, Junagadh, and Kadiri
IVK-I-09-9	Junagadh and Kadiri	Jalgaon, Junagadh, Kadiri, and Hanumangarh
IVK-I-09-4	Jalgaon, Junagadh, and Kadiri,	Jalgaon, Junagadh, and Kadiri,
ISK-I-09-5	Jalgaon, Junagadh, and Kadiri	Jalgaon, Junagadh, Kadiri, and Hanumangarh

Management of diseases

Collar rot

The pooled data of three locations (Junagadh, Hanumangarh and Jalgaon) for three years indicated that out of nine fungicides used as seed treatment, tebuconazole (1.5 g kg^{-1} seed) was the most efficient in controlling incidence of collar rot, and was followed by propiconazole (2 ml kg^{-1} seed) and vitavax (2 g kg^{-1} seed). The CBR too followed the same trend i.e. 3.82 with tebuconazole, 3.63 with propiconazole, and 3.58 with vitavax.

Stem rot

The data of six locations (Junagadh, Jalgaon, Raichur, Dharwad, Latur, and Vridhachalam) indicated that seed treatment with tebuconazole (1.5 g kg^{-1} seed) was quite effective in controlling the incidence of stem rot. Seed treatment with Vitavax (2 g kg^{-1} seed) was found to be second best.

Integrated management of major diseases of groundnut

Collar rot

The three-year data of Jalgaon, Junagadh, Hanumangarh, and Kadiri indicated that all the treatments were significantly superior to the control in reducing collar rot. However, seed treatment with tebuconazole (1.5 g kg^{-1} seed) and two sprays of tebuconazole (1 ml l^{-1}) at 45 and 60 DAS, was the most effective.

Stem rot

The average incidence of stem rot at six locations (Junagadh, Jalgaon, Raichur, Kadiri, Dharwad, and Latur) indicated that a combination of 'seed treatment with Trichoderma (10 g kg^{-1}) + application of neem cake (250 kg ha^{-1}) + two sprays of Hexaconazole (1.0 ml l^{-1})' was the best for controlling stem rot and this was followed by the combination 'seed treatment with tebuconazole (1.5 g kg^{-1} seed) + two sprays of tebuconazole (1 ml l^{-1}) at 45 and 60 DAS'.

Late Leaf Spot (LLS)

The average incidence of LLS at six locations (Junagadh, Hanumangarh, Raichur, Kadiri, Dharwad, and Latur) revealed that two combinations viz., 'seed treatment with mancozeb (3 g kg^{-1} seed) + two sprays of hexaconazole (1 ml l^{-1}) at 45 and 60 DAS' and 'seed treatment with *T. viride* (10 g kg^{-1}) + application of neem cake (250 kg ha^{-1}) + two sprays of Hexaconazole (1.0 ml l^{-1})' gave the effective control.

Therefore, considering the CBR and the efficacy of fungicides in controlling diseases, it could be concluded that a combination of 'seed treatment with *Trichoderma* (10 g kg^{-1} seed) + soil application of castor cake (200 kg ha^{-1}) enriched with *T. viride* (4 kg ha^{-1}) + two sprays of hexaconazole (1 ml l^{-1}) at 45 and 60 DAS' was highly economical as well as effective in managing a host of diseases like collar rot, stem rot, LLS, and rust. This was followed by combinations 'seed treatment with tebuconazole (1.5 g kg^{-1}) + two sprays of tebuconazole (1 ml l^{-1}) at 45 and 60 DAS' and 'seed treatment with mancozeb (3 g kg^{-1}) + two sprays of hexaconazole (1 ml l^{-1}) at 45 and 60 DAS'.

Management of late leaf spot and rust of groundnut

This trial was conducted by seven centres. The data obtained from six centres (Aliyarnagar, Bhubaneswar, Dharwad, Jalgaon, Raichur, and Vridhachalam) on LLS and rust revealed that a combination of 'seed treatment with mancozeb (2.0 g kg^{-1}) + three sprays of hexaconazole (1 ml l^{-1}) at 45, 60 and 75 DAS' was the best in reducing LLS and rust diseases. This was followed by the combination of seed treatment with tebuconazole (1.5 g kg^{-1}) + three sprays of tebuconazole (1ml l^{-1}) at 45, 60 and 75 DAS'. While the data obtained from Kadiri centre indicated that the combination 'seed treatment with tebuconazole (1.5 g kg^{-1}) + three sprays of tebuconazole (1ml l^{-1}) at 45, 60 and 75 DAS' significantly reduced ELS and this was followed by seed treatment with mancozeb (2g kg^{-1}) + three sprays of hexaconazole (1ml l^{-1}) at 45, 60 and 75 DAS'.

ENTOMOLOGY

Insect pest situation

At all the ten centres, sucking pests such as thrips, aphids and jassids were observed generally during early vegetative stage and were followed by defoliators (*Spodoptera* and *Helicoverpa*). Heavy incidence of *Spodoptera* was observed in most of the centres but leafminer was observed only in Raichur, Vridhachalam, Kadiri, Jalgoan and Mohanpur. At Kadiri, red hairy caterpillar was observed only here and there. Predators such as Coccinellid beetles, green lacewing bugs, ground beetles, and syrphids and parasitoids such as *Apantales* spp., *Xanthopimpala* spp. and *Compoletis chloridae* were also recorded.

Reaction of groundnut entries and genotypes to major pests of groundnut

The entries given in table below were found promising as they harboured relatively a low incidence of pests under field conditions.

Cetnre	Pest	Entry
Dharwad	*S. litura*	ASK-2010-8; IVK-2010-1; IVK-2010-1; IVK-1-2009-2, IVK-I-2009-4, and IVK-I-2009-13
	Thrips	ISK-2010-3, ISK-2010-7 and ISK-2010-9; ALSVT-2010-2; ASK-2010-1 and ASK-2010-4; IVK-2010-1 and IVK-2010-2; IVK-2010-1; AVK-2010-1, AVK-2010-2, AVK-2010-1 and AVK-2010-6; ADVRT-2010-3, ADVRT-2010-4, ADVRT-2010-5, ADVRT -7, and ADVRT-8
	Leafhopper	ISK-2010-1, ISK-2010-3, ISK-2010-7, ISK-2010-9 and ISK-2010-10; ASK-2010-8; and IVK-2010-1
Jalgaoan	*S. litura*	ISK-I-2010-5, IVK-I-2010-18, IVK-II-2009-12, ASK-I -2010-2, AVK- II-2009-4, ALSVT- I-2010-2, ADRVT-I-2010-6, ICGV-86365, JL-832, JL-776, and JL-848
	Thrips	ISK-1-2009, IVK-I-2009-2, ISK-II-2009-17, IVK-II-2009-22, ASK-1-2010-3, AVK-11-2009-3, ADRVT-II-2008-5, JL-501, JL-777, and JL-833
Jagtial	Thrips and *S. litura*	ISK-I-2010-3, ISK-I-2010-6, ISK-I-2010-12 and ISK-I-2010-31; ISK-2009-4, ISK-2009-7 and ISK-2009-30; IVK-2009-5, and IVK-2009-24
Junagadh	Jassids	ISK-I-2010-7, ADRVT-2010-2, ISK-I-2010-4, ISK-I-2010-15 and AVK-2010-1; IVK-I-2009-1, IVK-I-2009-8 and IVK-I-2009-2; ISK-I-2009-11, ISK-I-2009-3, and ISK-I-2009-16
	Thrips	AVK-2010-10; IVK-I-2010-15; ADRVT-2010-3 and ADRVT-2010-8; ISK-I-2010-6 and ISK-I-2010-14; ASK-2010-1; IVK-I-2009-9, ISK-I-2009-19, ISK-I-2009-25, ISK-I-2009-17, ISK-I-2009-7, ISK-I-2009-15, ISK-I-2009-20 and ISK-I-2009-24
Kadiri	Thrips	None
	Defoliators	None
Latur	Sucking pests and defoliators	The pest incidences were too low
Ludhiana	Sucking pests and defoliators	The pest incidences were too low
Mohanpur	Sucking pests and defoliators	The pest incidences were very high and uniform and hence the genotypic differences could not be ascertained
Raichur	Leafminer	GG-13, Kadri-3, CSMG-88-4, M-522, ALR-1, Dh-8, CSMG-84-1, ICGV-2271
Tirupathi	Leafhopper	ISK-01-10-15; ISK-II-09-1; TCGS 1092, TCGS 1114
Vridhachalam	Leafminer	ASK-2010-3, ASK-2010-6, VG-411, AVK-1, 11 and IVK-6, IVK-9, VG 437, 507, 519, 521, 715, IVK 9, ALSVT-5, IVK1-2009, IVK-12

Monitoring Sporoptera and leafminer using pheromone traps

The occurrence of *S. litura* and leafminer were monitored at Dharwad, Jalgaon, Junagadh, Kadiri, Raichur, and Vriddhachalam. The incidence of *S. litura* was observed between 30th and 38th standard week while that of leafminer between 27th and 42nd standard week.

Centre	Peak period of occurrence	
	Spodoptera litura	Leafminer
Dharwad	32nd to 36th standard week	
Jalgaon	30th to 33rd standard week	27th to 31st standard week
Jagtial	33rd standard week	
Junagadh	38th standard week	
Kadiri	35th standard week	40th to 42nd standard week
Latur	36th to 37th standard week	33rd standard week
Raichur	37th, 51st and 52nd standard week	
Vriddhachalam	-	First fortnight of August

Front Line Demonstrations (FLDs)

Improved variety

Altogether 233 FLDs were conducted with improved varieties at various centres. The demonstrations showed that with improved varieties an average pod yield of 1926 kg ha^{-1} was obtained compared to only 1468 kg ha^{-1} with the varieties otherwise popular with the farmers. With improved varieties, the average haulm yield was 3488 kg ha^{-1} compared to 2723 kg ha^{-1} with the varieties generally sown by the farmers. On an average with use of improved variety there was an increase in pod yield and haulm yield by 32% and 28% respectively.

With improved variety, the average gross returns was Rs. 58556 ha^{-1}, whereas it was only Rs.43074 ha^{-1} with the varieties popular with the farmers. With the use of improved variety, the gross and net returns increased by 38% and 63%, respectively.

In *rabi*-summer, a total of 212 FLDs were conducted with improved varieties at 17 centres. On an average, a pod yield of 2485 kg ha^{-1} was obtained with the improved varieties compared to 2018 kg ha^{-1} of the local varieties. By use of improved varieties, tThere was an enhancement in pod yield by 23% and in gross monitory returns by 27% at Rs. 69101 ha^{-1} and net returns by 39% at Rs. 42375 ha^{-1}.

Integrated Nutrient Management (INM)

A total of 34 FLDs were conducted. The INM included application of the recommended doses of NPK, micro-nutrients and gypsum. An average pod yield of 2300 kg ha^{-1} was realised with INM compared to 1724 kg ha^{-1} with farmers practice. With INM, there was an improvement in pod yield and haulm yield by 33% and 27%, respectively. The gross returns and net returns also increased by 34% and 46%, respectively.

Inter-cropping (IC)

A total of 10 FLDs were conducted. The IC technology included groundnut + pigeonpea in fixed ratios. In demonstrations, the average groundnut equivalent yield was 2215 kg ha^{-1} in intercropping compared to 1311 kg ha^{-1} in sole cropping. Compared to sole groundnut crop, in intercropping the gross returns and net returns were higher by 74% and 81%, respectively.

Integrated Disease Management (IDM)

At various centres, 32 FLDs were conducted. The average pod yield under IDM was 1865 kg ha^{-1} compared to 1457 kg ha^{-1} with the prevailing practice. The corresponding figures for average haulm yield were 3396 kg ha^{-1} and 2288 kg ha^{-1}, respectively. With IDM, there was an increase in pod yield and haulm yield by 28% and 48%, respectively.

Whole package (WP)

With WP, 65 FLDs were conducted. The WP included use of improved variety, application of RDF and micronutrients, and application of need based plant protection measures. This was compared with farmers' method of crop management. In the demonstrations, the average pod yield was 1847 kg ha^{-1} compared to 1545 kg ha^{-1} with the farmers' practice. Over the farmers' practice, with WP, the gross returns increased by 20% and net returns increased by 30%.

In *rabi*-summer, for whole package, 92 FLDs were conducted. The whole package included use of improved variety, use of balanced fertilizers including micro nutrients and need-based plant protection measures. With adoption of whole package, an average pod yield of 2552 kg ha^{-1} was obtained compared to 2079 kg ha^{-1} with the practices traditionally adopted by the farmers. The gross returns increased by 14% at Rs. 68527 ha^{-1} and the net returns 96% at Rs. 35852 ha^{-1} with whole package.

Externally Funded Projects

1. ALL INDIA NETWORK PROJECT ON SOIL BIODIVERSITY-BIOFERTILIZERS

(PI: K.K. PAL, CO-PI: R. DEY)

Funding agency: ICAR
Duration: 01.04.2007-31.03.2012
Fund: Rs. 23.00 lakh

Objectives:

- Development of microbial consortia for enhancing nutrient use efficiency and production of groundnut under low input system
- Microbial diversity in groundnut based cropping systems

Achievements:

- For studying the diversity of groundnut rhizobia in the Saurashtra region of Gujarat, 127 isolates were obtained and screened for presence of *nif* and *nod* functions (PCR and nodulation test under sterile conditions) and 73 were found to have both *nif* and *nod* functions.
- In *kharif* 2010, different delivery systems (through irrigation water, as seed treatment and through carriers like soil, talcum powder, kaoline, charcoal, and FYM) were evaluated for application of the consortium of beneficial bacteria (PGPR: *Pseudomonas* sp. C185; *Pseudomonas* sp. ACC3; PSM: *Pseudomonas* sp. ACC10 + *B. megaterium*; and groundnut rhizobia: TAL 1000 and NRCG 22) in a field trial using groundnut cultivar Girnar 2. Compared to pod yield of un-inoculated control, (1490 kg ha^{-1}), the application of consortium through soil brought about a significant enhancement (14.4%) in pod yield (1705 kg ha^{-1}). By using charcoal as carrier the pod yield improved by 11% (1655 kg ha^{-1}).

2. EXPLORING BACTERIAL AND ARCHAEBACTERIAL DIVERSITY IN KUTCH ECO-REGION OF GUJARAT FOR AGRICULTURAL AND INDUSTRIAL APPLICATIONS

(PI: K.K. PAL, CO-PI: R. DEY)

Funding agency: ICAR through AMAAS project
Duration: 01.04.2007-31.03.2012
Fund: Rs. 38.10 lakh

Objectives:

- Survey, isolation and characterisation of important bacteria from salt affected areas and salterns of Kutch eco-region of Gujarat
- Identification of potent salt tolerant strains of bacteria suitable for groundnut cultivation in salt affected areas of Kutch eco-region

- To study the diversity of representative groups of salt tolerant bacteria obtained from salt affected areas and salterns of Kutch eco-region
- Exploring source of novel gene(s), if any, of agricultural and industrial importance from diverse extremophiles with special emphasis on biocontrol, salt tolerance, bioactive peptides, industrial enzymes, etc.
- Mapping, cataloguing, and preservation of isolated and identified bacteria in National Repository.

Achievements:

- Plant growth promoting traits of important salt tolerant PGPR isolates were quantified. Quantification of phosphate solubilization and IAA production indicated that *Enterobacter* sp. R29 and *Pantoea dispersa* R5 were most potent in tri-calcium phosphate solubilization and solubilized 29.9 and 34.2 mg of phosphorus/mg protein, respectively after nine days of incubation and also brought down the pH of the medium to 4.99 and 4.33, respectively from the initial value of 7.2.
- To ascertain the novelty of genus and species among the 23 isolates of archaea of the tentative genera *Halorubrum, Haloferax, Haloarcula, Natrinema* and *Haloarcheon* studied so far, total intracellular proteins, polar lipids, GC content, electron microscopy and minimum requirements of NaCl for initation of growth, were studied. The minimum NaCl requirement for growth of the present pool of archaea was 10%. The intracellular anions and cations accumulated during the growth of these archaea, from 10% NaCl to 35% NaCl were determined on Ion Chromatograph. It was found that with increase in NaCl concentration, there was a gradual increase in accumulation of both Na+ and K+ with molar ratio of K:Na, from 1:1 at low osmolarity to 4:1 at the highest osmolarity.
- Sixteen isolates of archaea were identified on the basis of near complete 16S rDNA sequencing into the possible genus of *Haloferax, Natrinema, Halorubrum, Haloarcula* and unidentified *Haloarcheon* species and thus indicating a possibility of obtaining new genus and species as the similarity with the existing 16S rDNA was in the range of 95-99%.
- The new nodulating and nitrogen fixing organisms were identified to be *Enterobacter* sp. R29 and *Pantoea dispersa* R5 by homology with near complete 16S rDNAs sequence.
- Application of salt tolerant fluorescent pseudomonads and *Pantoea dispersa* was found to alleviate salt stress in plants by modulating enzymes associated with reducing the impact of reactive oxygen species in groundnut.

3. DIVERSITY ANALYSIS OF BACILLUS AND OTHER PREDOMINANT GENERA IN EXREME ENVIRONMENTS AND THEIR APPLICATION IN AGRICULTURE

(CCPI: K.K. PAL)

Funding agency: NAIP
Duration: 09.01.2009-31.03.2012
Fund: Rs. 63.89 lakhs

Objectives:

- Diversity analysis and identification of *Bacillus* and predominant genera from various extreme environments
- Study of diversity of *Bacillus* and other predominant genera in crop association under extreme environment and its validation
- To understand the mechanisms of adaptation in *Bacillus* and mining of relevant genes
- Selection of novel strains of *Bacillus thuringiensis* and other *Bacillus* species with insecticidal properties and isolation of novel cry and other insecticidal genes

Achievements:

- Forty-six isolates of bacilli, obtained from natural and man-made salt pans of Kachchh of Gujarat, were identified by near complete 16S rDNA sequencing. Among the Gram (+), endospore forming and aerobic bacteria, the genera identified were *Bacillus, Salinibacillus, Sediminibacillus, Salibacillus, Pontibacillus, Halobacillus, Piscibacillus, Virgibacillus, Thalassobacillus, Oceanobacillus* and some so far uncultured *bacillus* genus. However, similarity with the existing databases was in the range of 94-99% indicating thereby the possibility of novel genus and species or both within the present lot of the cultures.
- Nine probable genes (*kdp*FABC, Na/K antiproton pump, *glu*D, *ect*AB, *deg*S-*deg*U, *pro*BA, *abl*A, *ggp*S, and *tre*B), likely to be involved in imparting osmotolerance in extreme halophilic bacilli, were detected by PCR. In *Bacillus pumilus* SB49 and *Salinibacillus aidingensis* SB47, presence of *kdp*FABC, *ect*AB, *degS*-*deg*U, *pro*BA, *abl*A, *tre*B and *ggp*S genes were detected indicating the involvement of multiple genes in imparting tolerance to salinity in these two organisms.
- Conditions for DDRT-PCR were optimized for *Bacillus pumilus* SB49 and *Salinibacillus aidingensis* SB47 which both can grow in NaCl gradients. This technique will be employed for isolating genes imparting tolerance to salinity stress.

4. BIOPROSPECTING OF GENES AND ALLELE MINING FOR ABIOTIC STRESS TOLERANCE

(CCPIs: K.K. PAL AND R. DEY)

Funding agency: NAIP
Duration: 04.05.2009-31.03.2012
Total fund: Rs. 73.141 lakh

Objectives:

- Isolation and identification of microbes from extreme environments tolerant to salinity, high temperature and desiccation
- Understanding the mechanisms of tolerance of extreme environments in selected microbes
- Isolation and identification of gene(s) responsible for imparting tolerance to extreme environments
- Bioinformatic analysis of the identified genes and the encoded proteins and putative biochemical pathways responsible for abiotic stress tolerance

Achievements:

- From the samples collected from natural and man-made salt pans of Kachchh of Gujarat, 47 different fungal isolates were obtained and characterized and on the basis of sequencing of ITS region, 18 of these were identified as species of *Aspergillus, Penicillium, Hortaea, Alternaria, Stemophylium,* etc.
- Twenty fungal isolates were able to grow even at concentration of 23.5% NaCl, seven were able to grow at 65°C, fourteen could grow at 10% NaCl and 50°C and six isolates viz., MSPF 1, MSPF 2, MSPF 3, MSPF 4, MSPF 5 and NSPF 1 could grow at 23.5% NaCl and 50°C.
- Presence of NaCl in the medium was found to stimulate growth of seventeen fungi, as the addition of NaCl @ 5% improved the mycelial growth significantly.
- Osmolytes produced by *Aspergillus sydowii* BF5 at 0, 5%, 10%, 15%, 20%, 25%, 30% and 35% of NaCl were isolated and purified. The accumulation of trehalose with increase in osmolarity upto 10% was confirmed with TLC, but beyond 10%, accumulation of some unknown compounds was observed.
- *Aspergillus sydowii* BF5 was also screened for the presence of genes like *ost*BA, *tre*B, *ggp*S, Na+/H+ antiporter, etc. which are known to impart salinity tolerance in fungi.
- The conditions for DDRT-PCR were optimized for *Aspergillus sydowii* BF5 for isolation of novel genes imparting tolerance to salinity.

5. ICAR NETWORK PROJECT ON TRANSGENIC CROP

(PI: RADHAKRISHNAN, T. CO-PI: ABHAY KUMAR)

Funding Agency: ICAR

Objective

- Development of transgenic groundnut tolerant to drought/salinity
- Development of transgenic groundnut tolerant to insect pests

Transformation work was initiated with three gene constructs and good number of shoots has been regenerated. These shoots are now being selected in the antibiotic containing selection medium.

Achievements:

- For incorporating tolerance of abiotic stresses, especially drought and salinity, two gene constructs ZAT12 TF and AtDREB1a were used separately for developing transgenic groundnut mediated through *Agrobacterium*.
- Of the 380 putative transgenics developed using the gene construct AtDREB1a, 159 were tested for the presence of the transgene using gene specific PCR and 10 were found positive
- Of the 290 putative transgenics developed using the gene construct *ZAT*12 TF, 103 were tested for the presence of the transgene using gene specific PCR and 20 were found positive.
- Of the 275 putative transgenics developed using the gene construct *cry1Fa1*, 165 were tested for the presence of the transgene using gene specific PCR and 22 were found positive.

6. DEVELOPMENT OF TRANSGENIC RESISTANCE TO BUD AND STEM NECROSIS VIRUSES IN GROUNDNUT (a collaborative research project with IARI, New Delhi)

(PI: RADHAKRISHNAN, T. CO-PI: P.P. THIRUMALASAMY)

Funding Agency: DBT

Objectives

- To develop transgenic plants of groundnut with nucleocapsid protein genes derived from PBNV and PSNV
- To characterize the putative transformants for integration, expression, and inheritance of the introduced gene(s)
- To carry out evaluation of the transgenic plants for resistance to PBNV and PSNV under glasshouse conditions

Achievements:

- Viral gene constructs GBNV-N gene (groundnut bud necrosis virus - nucleocapsid protein gene) and TSV-CP gene (tobacco streak virus- coat protein gene) were developed in *E. coli* and *Agrobacterium* for attempting transformation in groundnut to confer resistance to stem and bud necrosis diseases.
- A dual gene construct (GBNV-N + TSV-CP gene) was developed in *E. coli* and *Agrobacterium* for conferring resistance to both stem and bud necrosis. Polyclonal antibodies against coat protein of TSV and GBNAV were produced.
- The gene constructs received from IARI were used for producing transgenics by using explants (immature leaves and de-embryonated cotyledons) of popular cultivars Kadiri 6 and Kadiri 136.
- Confirmed events 73 for CP gene of PSNV, 5 for NC gene of PBNV and 19 for dual construct were obtained.
- RT-PCR analyses of the events confirmed the transcription of the gene(s).
- The transgenic plants did not show any symptoms of the disease(s) upon artificially challenging with virus(es) concerned while the wild plants expressed the symptoms.
- The presence as well as the load of virus particles in both transgenic and control plants were confirmed by DAC-ELISA. Large-scale and detailed screening of the transgenic events, are in progress under containment.

7. GENE BASED GENETIC MAPS AND MOLECULAR MARKERS FOR BIOTIC STRESS TOLERANCE

(PI: RADHAKRISHNAN, T., CO-PI: A.L. RATHANAKUMAR, CHUNI LAL

Funding Agency: National Fund (Collaborative programme with ICRISAT, Patancheru and UAS, Dharwad)

Objectives

- Generation of microsatellite-enriched libraries and identification of ~500 microsatellite or simple sequence repeat (SSRs) loci
- Generation of groundnut unigene-derived SNP markers and development of cost effective CAPS assay
- Construction of integrated genetic maps with SSR, SNP and DArT markers
- Phenotyping of mapping populations at 3 locations (ICRISAT, NRCG, UAS) over 3 years

Achievements:

- The mapping population of the cross 'JL24 × ICGV 86590' comprising of 209 lines which segregate for rust and LLS resistance were genotyped at MPKV, Digraj (hotspot for the foliar fungal diseases).

- The disease incidence was in the range of 2 to 9 for LLS and 4 to 8 for rust.
- The parental genotypes and mapping population were phenotyped for morphological traits like flower-colour, leaf-colour, leaf-shape, leaf-tip morphology, peg- pigmentation, stem-pigmentation, stem-hairiness, and leaf-hairiness. The parental genotypes as well as the mapping population exhibited a limited variation for the stated morphological traits
- Screening of the parental lines (JL 24 and ICGV 86590) using 455 primers was completed. Of these, 62 primers showed difference between the two parents.

8. EVALUATION OF GROUNDNUT GERMPLASM FOR MORPHOLOGICAL, PHYSIOLOGICAL AND MOLECULAR CHARACTERS/TRAITS ASSOCIATED WITH DROUGHT TOLERANCE FOR ENHANCING PRODUCTIVITY IN RAIN-DEPENDENT SYSTEM

(PI: P. C. NAUTIYAL, CO PIS : RADHAKRISHNAN T.,
A. L. RATHNAKUMAR., CHUNILAL)

Funding Agency: National Fund for Basic and Strategic Research in Agriculture (NFBSFARA), Indian Council of Agricultural Research

Objectives

- Morphological characterisation of leaf, canopy, leaf angles and root architecture
- Eco-physiological interactions of water-use efficiency, leaf water relations and high temperature tolerance
- Genetic and molecular characterisation and steps towards QTL under standing

Achievements:

- From the germplasm accessions, advanced breeding lines, and core collection of NRCG and ICRISAT, 580 germplasm accessions and advanced breeding materials selected earlier were evaluated for drought tolerance and a core group of 200 lines was formulated for the physiological and molecular characterisation.
- From the core group, 92 selected lines were analyzed for traits of drought tolerance under conditions of rain-dependent, protected irrigation, and rain out shelter (ROS: T3). Thirty-three selected lines were analyzed further for chlorophyll fluorescence under normal irrigation (100% cpe) and water-deficit stress (50% cpe) conditions during summer season. Traits associated with drought tolerance were identified from the experiment conducted during summer and rainy seasons.
- Ninety-two lines were analyzed for root traits in concrete root-study-blocks. Both root and shoot traits associated with drought tolerance were identified. The molecular markers (SSRs) associated with these traits also were identified.

9. OVER EXPRESSION OF PR10 GENE CLONED FROM SALT STRESS TOLRANT CELL LINES OF *ARACHIS HYPOGAEA* IN GROUNDNUT CULTIVAR(S) FOR ABIOTIC STRESS TOLERANCE

(PI: S.K. BERA, CO-PI: PROF. NEERA BHALLA SARIN, SCHOOL OF LIFE SCIENCES, JNU, NEW DELHI)

Funding Agency: DBT

Fund: 31.99 lakhs

Objective:

- Enhancing salt tolerance of two salt sensitive groundnut (*Arachis hypogaea*) cultivars (GG 2 and TAG 24) by over expressing PR10 gene, isolated from salt tolerant cell lines of *Arachis hypogaea* L.var JL 24.

Achievements:

- Over 2500 putative transgenic plants of two varieties TAG 24 (1070) and GG 2 (1430) were regenerated.
- Using PR10 gene specific primer, 321 (203 of GG 2 and 118 of TAG 24) putative transgenics were screened.
- Altogether 55 PCR positive plants were obtained out of which 35 plants were of GG 2 and 27 of TAG 24.
- Three PCR positive plants were confirmed in southern hybridization.

10. EVALUATION OF AGRICOL® AND CHEMIEBOR® FOR THEIR SUITABILITY AS A SOURCE OF BORON IN GROUNDNUT CULTIVATION IN INDIA

(PI: A.L. SINGH, Co-PI: J.B. MISRA and R. S. JAT

Objective:

To determine the optimum dose and mode of application of Agricol and Chemiebor as boron fertilizers for groundnut crop

Achievements:

The field trials, conducted in various soils at Junagadh, Mainpuri, Jaipur, Tindivanam, Aliyarnagar, Hanumangarh, Manipur and Mizorum during 2007-2009 to find out effectiveness and feasibility of applying Agricol and Chemiebor as sources of B in groundnut along with others. The results indicated that application of B has pronounced influence on, flowering, yield and yield attributes. Soil application of 2 kg B ha^{-1} as Agricol, Chemiebor, Supercolemanite, Borosol, Solubor, Librel, Solu-B and

Maxibor increased pod yield by 8-51, 6-32, 6-39, 6-24, 6-30, 7-48, 12-46 and 8-30%, respectively over control as against 6-55% by borax and 7-15% by boric acid. The foliar application of Chemiebor, Borosol, Solubor, Librel and Solu-B increased pod yield by 13-28, 15-33, 12-21, 5-30, 6-24%, respectively, indicating more or less a similar response.

The net return and benefit:cost ratio (BCR) due to use of various sources of B (calculated year-wise at DGR, Junagadh) were mainly due to variation in pod yield, and both were more during summer (2.26-3.89) than during *kharif* (1.46-2.56). All the sources of boron enhanced the net returns significantly for all seasons except *kharif* 2009. All the sources of B, however, did not enhance the BCR. Application of only Agricol, Chemiebor, Borax and Boric acid increased the BCR significantly during both the years and seasons.

Thus, it is essential to apply 2.0 kg B ha^{-1} to improve groundnut pod filling and quality besides productivity. Any of the sources of B mentioned above may be used for this purpose.

11. IDENTIFICATION OF STEM ROT (*SCLEROTIUM ROLFSII* SAAC.) RESISTANT GENOTYPES IN GROUNDNUT (*A. HYPOGAEA*) THROUGH MUTATION BREEDING

(PI: A.L. RATHNAKUMAR; CO-PI (s): CHUNI LAL AND VINOD KUMAR)

Funding Agency: Department of Atomic Energy, Govt. of India

Objectives:

- To induce additional variability for yield and related traits through mutation
- To evaluate the usefulness of induced mutations in creating additional sources of variability for resistance/tolerance to stem rot
- To identify potential mutants having high yield with desired level of resistance or tolerance to stem rot

Achievements:

- In summer 2010, M_3 population of a Spanish bunch variety TAG 24 comprising 136 single plants (identified earlier for showing <30% incidence of stem rot under sick plot conditions in *kharif* 2009) was raised in the sick plot to confirm the resistance/tolerance of stem rot. The maximum stem rot incidence of 67.1% was observed in genotype CS 421, which was followed 64.3% in the check variety TAG 24. A total of 103 mutant genotypes of TAG 24 were identified in M_4 generation with <20% incidence of stem rot under sick plot conditions.
- In *kharif* 2010, M_1 population of GG 20 comprising 780 single plants was raised in the sick plot and screened for resistance/tolerance of stem rot. The soil population of *S. rolfsii* in sick plot was 23 cfu x 10^3. Under this disease pressure, the incidence of stem rot in the susceptible genotype TAG 24 was 63%. As many as 96 mutant genotypes of GG 20 were identified with <20% incidence of stem rot under sick plot conditions in M_2 generation.
- These populations will be further screened under sick plot conditions to identify promising high yielding mutants with resistance/tolerance of stem rot.

PUBLICATIONS

Research articles

Bera, S.K., Vinodkumar, Radhakrishnan, T., Sojitra, V.K. and Gedia, M.V. (2010). Interspecific derivatives for widening the genetic base of groundnut. *Indian J. Plant Genet. Resour*. 23(2):160-163.

Dey, R., Pal, K.K. and Tilak, K.V.B.R. (2011). Influence of soil and plant type on diversity of rhizobacteria. *Proceedings of National Academy of Sciences* (accepted).

Nautiyal, P.C., Ravindra, V., Rathnakumar, A.L. and Zala, P.V. (2011). Increasing groundnut productivity in semi-arid tropics by utilizing genetic variability in agronomical desirable traits (*Field Crop Research*, under revision).

Rathnakumar, A.L., Hariprasanna, K. and Lalwani, H.B. (2010). Genetic improvement in Spanish type groundnut. *Arachis hypogaea* L. varieties in India over the years. *Indian Journal of Oilseeds Research* 27(1).

Ravi, K., Vadez, V., Isobe, S., Mir, R.R., Guo, Y., Nigam, S.N., Gowda, M.V.C., Radhakrishnan, T., Bertioli, D. J., Knapp, S. J. and Varshney, R. K. (2011). Identification of several small main-effect QTLs and a large number of epistatic QTLs for drought tolerance related traits in groundnut (*Arachis hypogaea* L.) *Theoretical and Applied Genetics* 122:1119-1132.

Singh, A.L. Hariprasanna, K., Chaudhari, V., Gor, H.K. and Chikani, B.M. (2010). Identification of groundnut (*Arachis hypogaea* L.) cultivars tolerant of salinity. *Journal of Plant Nutrition*, 33: 1761-1776.

Sumanth Kumar, V.V., Satish Kumar, G.D., Ravisankar H., Mishra, A.P. and Rathanakumar, A.L. (2010). Linux based groundnut germplasm resource information system. *Intensive Agriculture* January-March: 15-17.

Thirumalaisamy, P. P., Jadon, K. S., Koradia, V.G. and Padvi, R.D. (2011). Biological control of soil borne and foliar fungal diseases in groundnut. *Journal of Biological Control* (accepted).

Thirumalaisamy, P. P., Padvi R.D., Koradia V.G. and Misra, J.B. (2010). Aflatoxin contamination during processing of groundnut and its value-addition in industries. *Indian Journal of Mycology and Plant Pathology* 32: 102-103.

Papers presented at symposia/seminars/conferences/other fora

Bera, S.K., Ved, Nikita P. and Rathod, P.J. (2011). Agrobacterium mediated genetic transformation of groundnut cultivars using PR10 gene for enhancing tolerance to salinity stress. Proceedings of International Conference on Plant Science in Post Genomic Era, February 17-19, 2011, School of Life Sciences, Sambalpur University, Orissa, India. Pp. 65.

Bishi, S.K., Chakraborty, K., Rathod, P.J. and Misra, J.B. (2011). Potential of groundnut as a functional food. National level seminar on "Functional food: A new concept for sustainable livelihood" , Junagadh Agricultural University, Junagadh, March 10, 2011.

Bishi, S.K., Mittal, G., Rathod, P.J., Gedia, M.V. and Misra, J.B. (2010). Potential of FTNIR spectroscopy for predicting oil content of samples of groundnut genotypes, 65th OTAI Annual convention, International Seminar and Expo, New Delhi, December 3-5, 2010.

Bishi, S.K., Tank, P.C., Kaneriya, J.P. and Nautiyal, P.C. (2011). Influence of drought stress on seed flavor quality in Spanish and Virginia groundnut cultivars. International Conference in Plant Science in post Genomic Era, February 17-19, 2011, School of Life Sciences, Sambalpur University, Sambalpur, Orissa, pp. 66.

Dey, R., Sherathia, D.N., Dalsania, T.L., Savsani, K.A. and Pal, K.K. (2010). Characterization and evaluation of DAPG-producing groundnut rhizobacteria for using them for development of suppressive soils. National Symposium on Innovations in Plant Pathology Research and Human Resource Development, November 24-26, 2010, Junagadh Agricultural University (JAU), Junagadh, Gujarat, pp. 107.

Gururaj Sunkad, Bera, S.K. and Konda, C.R. (2010). Studies on seasonal incidence, loss estimation, epidemiology and host plant resistance for peanut virus of groundnut in north eastern Karnataka. Proceedings of the 9th Australasian Plant Virology Workshop, November 16-19, 2010, Melbourne, Australia. Pp. 71.

Jat, R.S., Meena, H.N., Pal, K.K. and Singh, V. (2010). Effect of citric acid on P availability and pod yield of groundnut. XIX National Symposium on "Resource Management Approaches towards Livelihood Security", December 2-4, 2010, UAS, Bangalore.

Misra, J.B. and Bishi, S.K. (2010). Prospects of genetic engineering of groundnut (*Arachis hypogaea* L.) for improving its nutritive and culinary attributes of its kernels, 65th OTAI Annual convention, International Seminar and Expo, New Delhi, December 3-5, 2010.

Pal, K.K., Dalsania, T.L., Manesh, T., Ghorai, S. and Dey, R. (2010). Identification and characterization of plant growth- promoting pseudomonads having potential of biological control of soil-borne fungal pathogens of groundnut. National Symposium on Perspective in the Plant Health Management, Anand Agricultural University (AAU), Anand, December 14-16, 2010, pp. 17.

Pal, K.K., Dey, R., Dalsania, T.L. and Savsani, K.A. (2010). Presence of novel extreme halophilic bacilli in hypersaline environments of the Little and Greater Rann of Kachchh in India. 8th International Congress on Extremophiles, Sao Miguel, Azores, Portugal, September 12-16, 2010.

Singh, A.L. and Hariprasanna, K. (2010). *In situ* screening and identification of salinity tolerant groundnut cultivars. *In* Proc. Natl. Conf. of Plant Physiology on "Physiological and Molecular Approaches for Crop Improvement under Changing Environment" November 25-27, 2010, Banaras Hindu University, Varanasi, India. 93 pp.

Thomas, M., Pal, K.K., Dey, R., and Dave, S.R. (2010). Biodiversity of extreme haloarchaea in salterns of the Little and Greater Rann of Kachchh in India. 8th International Congress on Extremophiles, Sao Miguel, Azores, Portugal, September 12-16, 2010.

Varshney, R., Gowda, C., Radhakrishnan, T., Bhimana, G., Pandey, M., Sujay, V., Koppolu, R., Vadez, V., Nigam, S.N., Upadhyaya, H., Khedikar, Y., Isobe, S., Guohao He, Bertioli, D., Knapp, S. and Cook, D. (2011). Towards Integrating Genomics in Breeding in Groundnut (*Arachis hypogaea* L.) Plant & Animal Genomes XIX Conference, January 15-19, 2011. Town & Country, Convention Center, San Diego, CA. P

Ved Nikita P., Bera, S.K. and Radhakrishnan T. (2010). Differential expression of transcripts in *Arachis glabrata* L. under NaCl induced salinity. Proceeedings of National Conference of Plant Physiology, November 25-27, 2010, Institute of Agricultural Sciences, BHU, Baranasi, India, Pp. 287.

Manual/Books/Book chapters

- Sharma, M.P., Sharma, S.K., Prasad, R.D., Pal, K.K. and Dey, R. (2011). Application of AM fungi for improving productivity of major annual oil-seed crops. In "Mycorrhizal Fungi: Use in Sustainable Agriculture and Forestry", edited by Zakaria M. Solaiman, Lynette K. Abbott and Ajit Varma. Springer.
- Singh, A.L. (2010). Physiological basis for realizing yield potentials in groundnut.In: Advances in plant Physiology (Ed. A. Hemantranjan) Vol. 12 pp. 131-242. Scientific Publishers (India), Jodhpur, India .
- Singh, A.L., Jat, R.S., Chaudhari, V., Baria, H. and Sharma, S. (2010). Toxicities and tolerance of mineral elements boron, cobalt, molybdenum and nickel in crop plants. In: Plant Nutrition and Abiotic Stress Tolerance (Ed: Naser A. Anjum) (Invited Review article). Plant Stress 4 (Special Issue 2): 31-56 @2010 Global Science Books (Print ISSN 1749-0359).

Germplasm registered

1. Rathnakumar, A.L., Radhakrishnan, T., Bera, S.K., Lalwani, H.B., Raval, L. and Singh, S. (2011). NRCG 14326 (INGR 10032; IC 0548192), NRCG 14336 (INGR 10033; IC 0582477) NRCG 14350 (INGR 10034; IC 0582478) NRCG 14409 (INGR 10035; IC 0582479), Groundnut *Arachis hypogaea* L. germplasm. Spanish bunch germplasm accessions with fresh seed dormancy. *Indian J. Plant Genet. Resour.* 24(1): P-112

2. Rathnakumar, A.L., Radhakrishnan, T., Bera, S.K., Lalwani, H.B., Joshi, N. and Singh, S. (2011). NRCG 11846 (INGR 10041; IC 0583392), Groundnut (*Arachis hagenbeckii* Benth) germplasm with high fodder bio-mass (2.4 ton/ha/year), suitable even under wasteland conditions, perennial in nature; useful for pasture development, high crude fibre (31.2%) and ash (11.7%) contents
NRCG 11847 (INGR 10042; IC 0583393), Groundnut (*Arachis glabrata* Benth) germplasm with high fodder bio-mass (3.8 ton/ha/year), suitable under wasteland conditions, perennial in nature; useful for pasture development, high protein content (16.9%)
NRCG 17205 (INGR 10045; IC 0583396), Groundnut (*Arachis prostrata* Benth) germplasm with high fodder bio-mass (3.6 ton/ha/year), suitable even under wasteland conditions, perennial in nature; suitable for pasture development, binds soil through tough rhizomes, high protein content (14.2%) and iron content (0.7%).
NRCG 17206 (INGR 10046; IC 0583397), Groundnut (*Arachis marginata* Gardner) germplasm, with high fodder bio-mass (3.2 ton/ha/year), suitable even under wasteland conditions, perennial in nature; suitable for pasture development, binds soil through tough rhizomes, high protein content (16.8%) and iron content (0.7%). *Indian J. Plant Genet. Resour.* 24(1): PP-115-116.

3. Rathnakumar, A.L., Radhakrishnan, T., Bera, S.K., Lalwani, H.B., Joshi, N. and Singh, S. (2011). NRCG 12035 (INGR 10043; IC 0583394), Groundnut (*Arachis appressipila* Krapov. and W.C. Gregory) Germplasm, with high fodder bio-mass (1.8 ton/ha/year), suitable even under wasteland conditions, seed forming, semi-perennial; suitable for pasture development, protein content (14.8%)
NRCG 12990 (INGR 10044; IC 0583395), Groundnut (*Arachis pintoi* Krapov. and W.C. Gregory) germplasm, with high fodder bio-mass (2.7 ton/ha/year), suitable even under wasteland conditions, perennial in nature; suitable for pasture development, protein content (12.1%) and iron content (0.5%). *Indian J. Plant Genet. Resour.* 24(1): P-117.

Meetings/Trainings Attended

Dr. A. L. Singh

- National Conference of Plant Physiology on "Physiological and Molecular Approaches for Crop Improvement under Changing Environment", BHU, Varanasi, November 25-27, 2010.

Dr. N.K. Jain

- National Seminar on "Characterization and Conservation of Biodiversity for Sustainable Agriculture", MPUAT, November 12-13, 2010.
- One day western/central region workshop of Technology Mission on Oilseed and Oil palm Organization, Gandhinagar (Gujarat), December 12, 2010.
- Annual *Rabi*-Summer Groundnut Researchers Group Meeting, BCKV, Mohanpur (W.B.), November 18-19, 2010.
- NAIP Management Development Programme on " Leadership for Innovations in Agriculture", Indian Institute of Management, Lucknow, February 21-25, 2011.

Dr. H.N. Meena

- *Kharif* Groundnut Workshop, University of Agricultural Sciences, Dharwad-April 24-26, 2010.

Dr. G. Govindaraj

- *Kharif* Groundnut Workshop, University of Agricultural Sciences, Dharwad-, April 24-26, 2010.

Dr. Radhakrishnan, T.

- Training programme on Real-Time PCR at Applied Biosystems, Lab, India, Gurgaon, Haryana, August 2-4 2010.
- Meeting of stakeholder institutions/organizations under national agricultural biosecurity network NASC, New Delhi, March 22, 2011.
- Zonal meeting of ITMUs, CIRCOT, Mumbai, March 11-12, 2011.
- Review Meeting of DUS test centres & Projects, Lecture Hall, NASC, New Delhi, February 25, 2011.
- *Rabi*-summer groundnut group meeting, BCKVV, Kalyani, November18-19, 2010.
- Meeting on Information and communication Technology in ICAR, NASC complex, New Delhi, November 3-4, 2010.
- National workshop on molecular markers , ICRISAT, Patancheru, October 27-29, 2010.
- Meeting of the bioinformatics grid, NBPGR, New Delhi, August 7, 2010.
- Consultation on biotechnology research in ICAR, NASC, New Delhi, July 26-27, 2010.
- Annual review meeting of the network project on transgenic crops, NRCPB, New Delhi, May 19-20, 2010.
- Annual review meeting of the project on NFBSFARA ,UAS Dharwad, May 8, 2010.
- Annual *kharif* workshop, UAS Dharwad, April 24-26, 2010.
- Annual review meeting of the DBT funded project, TNAU, Coimbatore, April 5-6 , 2010.

Dr. A.P. Mishra

- *Kharif* Groundnut Workshop, University of Agricultural Sciences, Dharwad April 24-26, 2010.
- XVI National Conference of Agricultural Research Statisticians, December 23- 24, IASRI, New Delhi.
- 2-day Orientation / Installation training under NAIP for SAS software , MPUAT, Udaipur, June 21-22.
- Training programme on SAS software, under NAIP, MPUAT Udaipur, February 14-19, 2011.

Dr. S. K. Bera

- National Conference of Plant Physiology on "Physiological and Molecular Approaches for Crop Improvement under Changing Environment", BHU, Varanasi, November 25-27, 2010.

Dr. K. K. Pal

- Training programme on use of Real time PCR at accredited laboratory of Applied Biosystems, Gurgaon from 2-4 August 2010.
- Training programme on functional genomics under NAIP-Allele mining project at IASRI, New Delhi from 11-21 January 2011.
- National symposium on Perspective in the Plant Health Management, Anand Agricultural University, Anand, December 14-16, 2010.
- Annual workshop for NAIP sub-project "Bioprospecting of genes and allele mining for abiotic stress tolerance", February 1. 2011, CISH, Lucknow.
- Two days thematic workshop of NAIP component IV, February 7-8, 2011, IIHR, Bengaluru.

Dr. R. Dey

- National Symposium on Innovations in Plant Pathology Research and Human Resource Development, November 24-26, 2010, Junagadh Agricultural University (JAU), Junagadh, Gujarat.
- Half-yearly review meeting of AMAAS (Application of Microorganisms in Agriculture and Allied Sectors) project, NBAIM, Mau, February 21, 2011.

Mr. S.K. Bishi

- Training programme on "Commercial level application of UV, Visual and NIR Spectroscopy methods, fluorescence spectroscopy and chemometric data analysis for evaluation of foods and biomaterials", Central Institute of Post–Harvest Engineering and Technology (CIPHET), January 3-8, 2011.

Mr. M. C. Dagla

- Training programme (21 days winter school) on "Marker assisted selection for enhancement of rust resistance and quality traits in wheat", Directorate of Wheat Research, Karnal, January 5-25, 2011.
- *Kharif* Groundnut Workshop, University of Agricultural Sciences, Dharwad-, April 24-26, 2010.

Dr. P. P. Thirumalaisamy

- 21 days training on 'Harnessing the potentials of bio-pesticides against pest and diseases: Its implication in sustainable crop protection', November 9-29, 2010, TNAU, Coimbatore.
- Thematic workshop on "Strategic research for pest and disease dynamics in relation to climate change" under National Initiative on Climate Resilient Agriculture, CRIDA, Hyderabad, February 26-27, 2011.
- Workshop to review the conduct of DUS test held at NAARM, Hyderabad, August 11-12, 2010.
- Annual *kharif* groundnut workshop, University of Agricultural Sciences, Dharwad April 24-26, 2010.

Mr. Harish G.

- ICAR sponsored summer school on "Advances in agricultural acarology", October 8-28, 2010, GKVK, UAS Bangalore.
- Workshop on "Approved uses of pesticides in agriculture", New Delhi, August 30, 2010.
- *Rabi*-summer groundnut group meeting, BCKVV, Mohanpur, November 18-19, 2010.
- Training programme of 21 days on 'Biorational insect pest management', TNAU Coimbatore.

Dr. Narendra Kumar

- Training programme (21 days winter school) on "Marker assisted selection for enhancement of rust resistance and quality traits in wheat", Directorate of Wheat Research, Karnal, January 5-25, 2011.
- Annual *Rabi*-Summer Groundnut Researchers Group Meeting, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, November 18-19, 2010.

Dr. Prasanna Holajjer

- Foundation Course for Agricultural Research Service (FOCARS), NAARM, Hyderabad in 90th FOCARS, April 4 to July 17, 2010.
- *Rabi*-summer groundnut group meeting, BCKVV, Mohanpur, November 18-19, 2010.
- ICAR sponsored advanced training course on 'Biorational insect pest management', CAFT Centre, TNAU, Coimbatore , from February 17 to March 9, 2011.

Dr. K.S. Jadon

- Foundation Course for Agricultural Research Service (FOCARS), NAARM, Hyderabad, in 92nd FOCARS, September 1 - December 29, 2010.

Mr. Abhay Kumar

- Training on Viral Genomics and Transgenic Development, Centre of Advanced Faculty Training, Division of Plant Pathology, IARI, New Delhi, July 8-28, 2010.

Dr. R. S. Jat

- Short course on "Carbon stabilization, saturation and sequestration: Evolving concepts, mechanisms and approaches, IISS, Bhopal, November 23- December 2, 2010.

Dr. K. Chakraborty

- Foundation Course for Agricultural Research Service (FOCARS), NAARM, Hyderabad, in 92nd FOCARS, September 1 - December 29, 2010.

Dr. D. Bhaduri

- Foundation Course for Agricultural Research Service (FOCARS), NAARM, Hyderabad, in 92nd FOCARS, September 1 - December 29, 2010.

Awards/Recognition

Dr. N.K. Jain, Principle Scientist, elected Councilor for Gujarat state, Indian Society of Agronomy, IARI, New Delhi (2011-12).

Trainings organized

One day training programme on latest groundnut production technologies was organized on 30.11.2010 for Tamil Nadu farmers.

Human Resource as on 31.03.2011

	Name	Designation
1.	Dr. J. B. Misra	Director
2.	Dr. P. C. Nautiyal	Principal Scientist (Plant Physiology)
3.	Dr. A. L. Singh	Principal Scientist (Plant Physiology)
4.	Dr. Radhakrishnan T.	Principal Scientist (Plant Breeding)
5.	Dr. A. L. Rathnakumar	Principal Scientist (Agronomy)
6.	Dr. N. K. Jain	Principal Scientist (Plant Breeding)
7.	Dr. A. P. Mishra	Senior.Scientist (Agril. Statistics)
8.	Dr. Chuni Lal	Senior.Scientist (Plant Breeding)
9.	Dr. S. K. Bera	Senior.Scientist (Genetics and Cytogenetics)
10.	Dr. K. K. Pal	Senior Scientist (Microbiology)
11.	Dr. Rinku Dey	Senior Scientist (Microbiology)
12.	Dr. G. Govindaraj	Scientist (Agril. Economics)
13.	Dr. H. N. Meena	Scientist (Agronomy)
14.	Sh. M. C. Dagla	Scientist (Plant Breeding)
15.	Sh. Abhay Kumar	Scientist (Plant Biotechnology)
16.	Sh. Sujit Kumar Bishi	Scientist (Plant Biochemistry)
17.	Dr. Thirumalaisamy, P. P.	Scientist (Plant Pathology)
18.	Sh. Harish G.	Scientist (Entomology)
19.	Dr. Narendra Kumar	Scientist (Plant Breeding)
20.	Dr. Koushik Chakraborty	Scientist (Plant Physiology)
21.	Dr. Debarati Bhaduri	Scientist (Soil Science)
22.	Dr. K.S. Jadon	Scientist (Plant Pathology)
23.	Dr. Prasanna Holajjer	Scientist (Nematology)
24.	Dr. K. S. Kalariya	Scientist (Plant Physiology)
25.	Dr. Ajay B.C.	Scientist (Plant Breeding)
26.	Ms. S. M .Chauhan	Technical Officer, T (7-8)
27.	Sh. D. M. Bhatt	Technical Officer, T (7-8)
28.	Dr. D. L. Parmar	Technical Officer, T (7-8)
29.	Sh. N. R. Ghetia	Technical Officer, T (7-8)
30.	Sh. P. V. Zala	Technical Officer, T (7-8)
31.	Sh. V. G. Koradia	Technical Officer, T (7-8)
32.	Sh. P. K. Bhalodia	Technical Officer, T (7-8)
33.	Dr. R. S. Tomar	Farm Superintendent, T6
34.	Sh. V. K. Sojitra	Technical Officer, T6
35.	Sh. H. B. Lalwani	Technical Officer, T6
36.	Sh. H. M. Hingrajia	Technical Officer, T6
37.	Sh. Ranvir Singh	Technical Officer, T6
38.	Dr. S. D. Savaliya	Technical Officer, T6

	Name	Designation
39.	Sh. H. K. Gor	Technical Officer, T6
40.	Dr. J. R. Dobaria	Technical Officer, T6
41.	Dr. M. V. Gedia	Technical Officer, T6
42.	Sh. P. R. Naik	Technical Officer, T6
43.	Mrs. V. S. Chaudhary	Technical Officer, T6
44.	Sh. Virendra Singh	Technical Officer, T6
45.	Sh. B. M. Chikani	Technical Officer, T6
46.	Sh. D. R. Bhatt	Technical Officer, T5
47.	Sh. R. D. Padavi	Technical Officer, T5
48.	Sh. V. K. Jain	Technical Officer, T5
49.	Sh. H. V. Patel	Technical Officer, T5
50.	Sh. Prabhu Dayal	Technical Officer, T5
51.	Sh. C. B. Patel	Technical Assistant, T4
52.	Sh. J. G. Kalaria	Technical Assistant, T4
53.	Sh. K. H. Koradia	Technical Assistant, T4
54.	Sh. A. M. Vakharia	Technical Assistant, T4
55.	Sh. G. J. Solanki	Technical Assistant, T3
56.	SH. P. B. Garchar	Technical Assistant, T3
57.	Sh. Sugad Singh	Technical Assistant, T3
58.	Sh. N. M. Safi	Technical Assistant, T3
59.	Sh. B. M. Solanki	Technical Assistant, T2
60.	Sh. G. G. Bhalani	Technical Assistant, T2
61.	Sh. Pitabas Dash	Technical Assistant, T2
62.	Sh. R.N. Mallik	Administrative Officer
63.	Sh. G.C. Prasad	Finance and Accounts Officer
64.	Sh. J. B. Bhatt	Assistant Administrative Officer
65.	Sh. R.T. Thakar	Assistant
66.	Sh. M. B. Kher	Security Supervisor
67.	Ms. S. Venugopalan	Assistant
68.	Ms. M. N. Vaghasia	Assistant
69.	Sh. R. D. Nagwadia	Assistant
70.	Sh. C. G. Makwana	UDC
71.	Sh. H. S. Mistry	LDC
72.	Sh. P. N. Solanki	LDC
73.	Sh. M.H. Kava	LDC
74.	Ms. Rosamma Joseph	PS to Director
75.	Sh. L. V. Tilwani	PA
76.	Sh. Y. S. Karia	PA

	Name	Designation
77.	Sh. N. M. Pandya	SSS
78.	Sh. D. M. Sachania	SSS
79.	Sh. R. B. Chawada	SSS
80.	Sh. C. N. Jethwa	SSS
81.	Sh. R. V. Purohit	SSS
82.	Sh. M. B. Sheikh	SSS
83.	Sh. K. T. Kapadia	SSS
84.	Sh. J. G. Agrawat	SSS
85.	Sh. V. N. Kodiatar	SSS
86.	Sh. R. P. Sondarwa	SSS
87.	Sh. G. S. Mori	SSS
88.	Sh. V. M. Chawda	SSS
89.	Mrs. D. S. Sarvaiya	SSS
90.	Sh. N. G. Vadher	SSS
91.	Sh. A. D. Makwana	SSS
92.	Sh. P. M. Solanki	SSS
93.	Sh. B. J. Dabhi	SSS
94.	Sh. C.G. Moradia	SSS

Sanctioned strength, employees on position and their category-wise distribution as on 31.03.2011

Category	Sanctioned	On position	General	SC	ST	OBC
Scientific	39 + 1 RMP	25	15	04	02	04
Technical	40	36	23	04	05	04
Administrative	14+2	13 + 2	07 + 02	02	00	04
Supporting	19	18	04	04	03	07
Total	**112 + 03**	**92 + 02**	**49 + 02**	**14**	**10**	**19**

Discipline and grade wise sanctioned scientific positions

Discipline	Scientist	Sr. Scientist	Pr. Scientist	Total
Agril. Economics	1	-	-	1
Agril. Entomology	2	1	-	3
Agril. Extension	1	-	-	1
Agril. Statistics	-	1	-	1
Agronomy	1	1	1	3
Biochemistry (PS)	1	1	-	2
Biotechnology (PS)	2	1	-	3
Genetics and Cytogenetics	1	1	-	2
Microbiology	1	1	-	2
Plant Breeding	6	2	1	9
Plant Pathology	2	2	1	5
Plant Physiology	2	1	-	3
Soil Science (Pedology)	1	1	-	2
Agril. Engineering	1	-	-	1
Nematology	1	-	-	1
Total	**22**	**14**	**3**	**39**

Transfer

Sr. No.	Incumbent	Transferred from	Transferred to	With effect from
1.	Shri C.P. Singh, T (7-8)	DGR, Junagadh	IISR, Lucknow	13.08.2010
2.	Dr. G. D. Satishkumar	DGR, Junagadh	DOR, Hyderabad	17.09.2010
3.	Shri Surajpal Singh, T5	DGR, Junagadh	CIRG, Makhdoom	06.01.2011
4.	Shri R. N. Mallik, A.O	DGR, Junagadh	CIRG, Makhdoom	11.02.2011
5.	Dr. R. S. Jat, Scientist	DGR, Junagadh	DMAPR, Boriavi	28.02.2011

Resignation

Shri Manjunatha, Scientist, Plant Biotechnology resigned from ARS w.e.f. 14.12.2010

Financial upgradation

DPC held on 25.05.2010 for Administrative and Skilled Supporting Staff; benefit to 16 employees

DPC held on 23.07.2010 for Administrative and Skilled Supporting Staff; benefit to 19 employees

DPC held on 25.11.2010 – Shri L.V. Tilwani promoted to the grade of PA

DPC held on 06.09.2010 – Smt. Rosamma Joseph and Shri Y.S. Kariya promoted to the grade of Personal Secretary and Personal Assistant, respectively

Superannuation

Smt. Veena Girdhar, Technical Officer, T6, w.e.f. 31.12.2010

Death

Shri B. K. Bariya, SSS on 10.01.2011

Important Meetings

Institute Management Committee (IMC)

The meeting of the 10th Institute Management Committee of the DGR, Junagadh was held on 30th June 2010. Shri R.N. Mallik, Member Secretary presented the Action Taken Report of 9th IMC meeting. There were total 10 items on agenda in the last i.e. 9th meeting of IMC and action taken by the Institute on each item was apprised to the committee. This was followed by discussion on the items of agenda for the X th IMC meeting. The meeting discussed a number of proposals put up to the committee for consideration related to provision of laptop, portable printer (laser jet) and portable LCD projector to Scientist I/c, AICRP (G); demolition and re-construction of boundary wall of eastern side of the farm; metalling of internal road of farm; fund for construction of farmers training hall and seed storage stores; re-structuring of main electric supply line to overcome chronic problem of voltage drop; organization of scientific units at DGR for enhancing administrative efficiency; and provision of mobile phone facilities on functional necessity basis. Considering the need of DGR, the committee agreed to recommend most of the proposals to Council. The meeting was chaired by Dr. J. B. Misra, Director, DGR, Junagadh. Dr. D.B. Kuchchadia, Principal, Institute of Agri. Business Management, JAU, Junagadh; Dr. A.H. Menon, Dean, College of Agril. Engineering & Technology, JAU, Junagadh; Dr. C. Chattopadhyay, Principal Scientist, IIPR, Kanpur; Shri Thiru K. Mohan, Deputy Director of Agriculture (Pulse and Oilseeds), Commissioner of Agriculture, Chennai; Dr. T. Radhakrishnan, Principal Scientist, DGR, Junagadh; Shri Haridasbhai Bikhabhai Zala, Progressive Farmer, Vadhavi, participated in the meeting as Members and Shri R.N. Mallik, Administrative Officer, as the Member Secretary.

Institute Research Committee (IRC)

The 55th and 56th meetings of Institute Research Committee were held from 11-13 May 2010 and 27 January-3 February 2011, respectively. Both the meetings were chaired by the Director, DGR. During the meetings, a project-wise progress of research work was reviewed and the technical programme for ensuing seasons were finalized. The PIs of different projects presented the highlights of their respective projects and then proposed future plans of work. The plans of work proposed by the scientists were discussed thoroughly in the meeting and subsequently the plans were approved keeping in view the priorities and available resources.

GENERAL INFORMATION

Institute Management Committee

Chairman

Dr. J. B. Misra, Director, DGR, Junagadh

Members

Dr. R.A. Sherasiya, Director of Agriculture (Gujarat), Krishi Bhavan, Sector 10-A, Gandhinagar

Shri S. Kosalaraman, IAS, Commissioner of Agriculture, Chepauk, Chennai – 600 005

Dr. A.H. Memon, Principal and Dean, College of Agriculture Engg. & Tech., JAU, Junagadh-362 001, Gujarat

Shri Madhubhai K. Mankad, Progressive Farmer, Krishi Vigyan Kendra, Gundala Road, At. Sadau, Tal. Mundra (Kutch) 370 421

Shri Haridasbhai Bikhabhai Zala, Progressive Farmer, Post at: Vadhavi, Dist. Junagadh

Om Prakash Nagar, Finance & Accounts Officer, Central Arid Zone Research Institute (CAZRI), Light Industrial Area, Jodhpur 342 003

Dr. V. S. Bhatia, Principal Scientist, National Research Centre for Soybean, Khandwa Road, Indore 452 001

Dr. D. Kumar, Principal Scientist & Project Coordinator (Arid Legumes), Central Arid zone Research Institute, Jodhpur 342 003

Dr. C. Chattopadhyay, Head, Division of Crop Protection, Indian Institute of Pulses Research, Kanpur 208 024

Dr. D.B. Kuchchadia, Director of Research, Junagadh Agril. University, Junagadh

Dr. T. Radhakrishnan, Principal Scientist, DGR, Junagadh

Member Secretary

Administrative Officer, DGR, Junagadh

Research Advisory Committee

Chairman

Dr. J. H. Kulkarni, Ex-Vice Chancellor, UAS, Dharwad, 'Suggi', Alur Compound, 3rd Cross, Sadhankeri, Dharwad–580 008, Karnataka

Members

1. Dr. S.N. Nigam, Principal Scientist (groundnut), ICRISAT, Patancheru P.O., Hyderabad – 502 324
2. Dr. V. Muralidharan, Professor (Oilseeds), Department of Oilseeds, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore-641003.

3. Dr. G. S. Jadhav, Ex-Director Instruction, MAU, Parbani, 'Prasad', 243, N-3, CIDCO, Aurangabad-431 003, Maharashtra
4. Prof. R. L. Savaliya, Director of Ext. Education, Junagadh Agricultural University, Junagadh 362 001, Gujarat
5. Dr. G. V. Subbaratnam, Retd. Professor of Entomology, Agri. Biotech Foundation, A. P. Netherlands Biotechnology Programme, ATIC Building, ARI Campus, ANGRAU, Rajendranagar, Hyderabad- 500 030
6. Director, Directorate of Groundnut Research, Junagadh-362 001
7. Assistant Director General (O & P), Indian Council of Agricultural Research (ICAR), Krishi Bhavan, New Delhi – 110 114
8. Shri Madhubhai K. Mankad, Progressive Farmer, Krishi Vigyan Kendra, Gundala Road, At. Sadau, Tal. Mundra (Kutch) 370 421
9. Shri Haridasbhai Bikhabhai Zala, Progressive Farmer, Post at: Vadhavi, Dist. Junagadh

Member Secretary
Dr. P.C. Nautiyal, Principal Scientist, DGR, Junagadh-362 001

Institute Research Committee

Chairman:	Director, DGR
Members:	All scientists of DGR, Junagadh
Member Secretary:	Dr. Rinku Dey, Senior Scientist

Institute Joint Staff Council

Chairman- Director, DGR

Members: Staff side
1. Shri D. R. Bhatt, Secretary-IJSC and Member-CJSC
2. Shri V. K. Jain, Member
3. Shri Y. S. Karia, Member
4. Mrs. M. N. Vaghasia, Member
5. Shri C. N. Jethawa, Member
6. Shri B. J. Dabhi, Member

Members: Office side
1. Dr. P. C. Nautiyal, Principal Scientist
2. Dr. Chuni Lal, Senior Scientist
3. Dr. R. Dey, Senior Scientist
4. Shri C. P. Singh, Technical Officer (T-7/8).
5. Administrative Officer
6. Finance & Accounts Officer

FINANCE AND ACCOUNTS

EXPENDITURE STATEMENT FOR THE YEAR 2010-11

DGR-Main Unit

Rupees in lakhs

Sr. No.	Budget Head	Non-Plan			Plan		
		BE	RE	Expenditure	BE	RE	Expenditure
1	Estt. Charges	385.00	460.00	454.53	0.00	0.00	0.00
2	OTA	0.00	0.00	0.00	0.00	0.00	0.00
3	Wages	40.00	42.00	34.45	0.00	0.00	0.00
4	T.A.	5.00	6.00	5.99	8.00	8.93	8.93
5	HRD	0.50	0.50	0.51	4.00	5.00	4.99
6	Other Charges including Equipment	55.80	93.50	92.82	238.00	253.41	253.32
7	Works	10.00	4.00	3.97	50.00	32.66	32.66
	Total	**496.30**	**606.00**	**592.27**	**300.00**	**300.00**	**299.90**

AICRP-G

Rupees in lakhs

Sr. No.	Budget Head	Allocation	Expenditure
1	Pay and Allowances	316.27	316.27
2	TA	6.90	6.90
3	Contingency	58.08	57.75
4	HRD	0.00	0.00
5	Non-recurring contingency	44.75	44.75
	Total	**426.00**	**425.67**

Directorate of Groundnut Research
Post Box No. 5, Ivnagar Road
Junagadh - 362 001, Gujarat, India

Phones

Director	: 0285-2673382 (direct) 0285-2672550 (telefax) 0285-2675831 (residence)
EPABX	: 0285-2672461/2673041
Administrative Officer	: 0285-2672843
Guest House	: 0285-2673629
FAX	: 0285-2672550
Telegram	: GNUTSEARCH
E-mail	: director@nrcg.res.in
URL	: http://www.nrcg.res.in