International *Arachis* Newsletter

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Co-publishers

Peanut CRSP
Peanut Collaborative Research Support Program
(http://www.grilTin.pcachnct.edu/pnulcrsp.html)

ICRISAT
International Crops Research Institute for the Semi-Arid Tropics
(http://www.icrisat.org)

About Peanut CRSP

The Peanut Collaborative Research Support Program is an international program supported by USA1D Grant LAG-G-00-96-00013-00 to The University of Georgia. The research supported seeks environmentally sound, sustainable agriculture production and food delivery systems for peanut. The program has five thrusts addressing priority constraints to the global peanut industry (aflatoxin, production efficiency, socioeconomic forces, postharvest processing, and utilization). Peanut CRSP also works to foster human resource development and the communication of research results.

The Peanut CRSP provides support for collaborative research, training, and exchange of information through grants to 12 universities in USA linked to 15 host countries in the developing world. Both host countries and USA are expected to benefit from the activities of Peanut CRSP. Peanut CRSP actively collaborates with other organizations with interest in advancing development through the application of science and technology.

About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, chickpea, pigeonpea, and groundnut - five crops vital to life for the ever-increasing populations of the SAT. ICRISAT's mission is to conduct research that can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services; and publishing.

ICRISAT was established in 1972. It is supported by the Consultative Group on International Agricultural Research (CGIAR), an informal association of approximately 50 public and private sector donors. It is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP) and the World Bank. ICRISAT is one of 16 nonprofit CG1AR-supported Future Harvest Centers.

IAN Scientific Editor

S N Nigam

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From the Editor

Let me first thank all the subscribers of IAN who responded to our questionnaire on the utility of IAN. We have reproduced some of the responses in this issue. It is heartening to note from the responses that IAN continues to serve its purpose of providing a worldwide communication link for all those who are interested in the research and development of groundnut. We shall continue our efforts to keep the world groundnut community's interest alive in this publication. I welcome your suggestions to improve this publication further without diminishing the focus of its original objectives. The co-publisher of IAN, Peanut CRSP, has suggested to place the 'News and Views' section on a web site (see write-up below). This is a welcome development and I am sure it will certainly enthuse the IAN readership. We seek cooperation from our contributors in following the guidelines given for publication in IAN and responding to reviewers' queries promptly.

I would like to acknowledge YS Chauhan, M Ferguson, V Mahalakshmi, N Mallikarjuna, B Ntare, S Pande, P Parthasarathy Rao, GV Ranga Rao, KPC Rao, TJ Rego, OP Rupela, R Serraj, HC Sharma, RP Thakur, HD Upadhyaya, and F Waliyar (ICRISAT), and Nageswara Rao Rachaputi (QDPI, Australia) who reviewed IAN manuscripts.

By the time this issue is in your hand, it would be the festive season again. The IAN group at ICRISAT and Peanut CRSP wish IAN readers merry Christmas and a very happy new year.

SN Nigam

Dear Subscriber,

We hope that you enjoy this copy of the International *Arachis* Newsletter. We are proposing that we improve the service of communicating to you news items and announcements by exploiting the power of the Internet.

We propose to establish a web site that will allow you to submit news items, letters to the editor, and announcements at any time. These contributions will be both distributed electronically and ALSO accumulated for publication in the printed version of the newsletter. However, these items will be distributed to all electronic subscribers as soon as they are accepted by the Editorial Panel, and thus will be released on a more timely basis.

We are working on creating the web page that will manage this additional system and you are invited to subscribe to the 'messenger service' at the following browser address:

http://168.29.148.65/ArachisInternationalNews.htm

If you know of colleagues who may like to subscribe please share this address with them.

If there is sufficient interest in this means of communication among the international *Arachis* research and development community we will explore adding more services that exploit our expanding connections and modern technologies.

JH 'Tim' Williams
Peanut CRSP

Summer Groundnut Work Recognized

SK Srivastava, Assistant Professor, Directorate of Research, Chandra Sekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India was awarded for his work conducted at the Groundnut Research Station, Mainpuri, on evaluation and dissemination of short-duration groundnut varieties for summer cultivation. The award, consisting of a citation and cash prize, was given at the 2nd National Innovation Day function, 15 October 2001

(Birthday of Bharat Ratna Dr APJ Abdul Kalam) organized by the National Innovation Day Celebration Committee and Council of Science and Technology, Uttar Pradesh Government, Lucknow, India.

Vietnam Honors Nigam

SN Nigam has won a prestigious honor from the government of Vietnam - the Medal for Agriculture and Rural Development. It was given for his contributions to groundnut R&D in Vietnam, where he has developed and sustained research and training partnerships for many years. Nigam received the medal at a special function in Hanoi in July 2002.

Make a Ten-dollar Peanut Sheller from Concrete

The Peanut Collaborative Research Support Program (CRSP) would like to draw the attention of extension, research, small industries, and non-governmental organizations (NGOs) to the development of a low cost groundnut sheller by Jock Brandis in North Carolina, USA.

The Malian Peanut/Groundnut Sheller is a simple machine, requiring materials costing less than US$ 10. It is hand operated and is capable of shelling 50 kg of raw, sun-dried pods per hour. It is made of concrete, poured into two simple fiberglass molds, some primitive metal parts, one wrench, and any piece of rock or wood that might serve as a hammer. It accepts a wide range of pod sizes without adjustment. If necessary, adjustment is easily done in seconds. In Mali, it is estimated that one machine will serve the needs of a village of 2000 people. The life expectancy of the machine is around 25 years. Its design is in public domain and we expect that local experimenters will improve the design in due course. We offer every possible technical assistance to non-profit groups planning to use this design in their programs. Commercial groups are welcome to use any information provided on the web site, free of charge.

The plans are available from the web at: <http: / / www.peanutsheller.org>

People who do not have access to the Internet and would like further information can write to either: Jock Brandis, 1317 Princess Street, Wilmington, NC 28401, USA, or Peanut CRSP, 1109 Experiment Street, Griffin, GA 30223, USA.

Jock Brandis developed this sheller after a visit to Mali where he saw that the large labor cost of hand shelling was a constraint to the use of groundnut as a cash crop for women. After an initial prototype was developed and tested in USA, Jock fabricated a machine and tested the design in Mali using local materials.

Contributed by JH 'Tim' Williams, Peanut CRSP, 1109 Experiment Street, Griffin, GA 30223, USA Phone: 770-228-7312; Fax: 770-229-3337; Website: http://www.griffin.peachnet.edu/ pnutcrsp.html

Groundnut Germplasm Project Workshop in Mali

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), as Project Executing Agency (PEA) of the Groundnut Germplam Project (GGP), organized an end of project final workshop from 22 to 25 April 2002 at the International Conference Center, Bamako, Mali. The objectives were to present the achievements of the project to a wide range of stakeholders and identify follow-up action for a sustainable seed production and delivery scheme in West Africa. Forty-two participants from 13 countries representing partners in research (23), regional organizations (3), development (9), private sector (3), and producers (4) attended the workshop. The meeting was opened by Dr Adama Traore, President of the West African Council for Agricultural Research and Development on behalf of the Hon. Minister of Rural Development of Mali.

Participants of the Groundnut Germplasm Project Workshop, 22-25 April 2002, Mali.

The workshop was organized in four sessions:

1. The history and objectives of the project
   - Objectives of the project
   - Genetic resources management and utilization
   - Breeder and foundation seed production
   - Training and information dissemination
2. Characterization of the groundnut sector
   - Global and regional market prospects: competitiveness of African producers
   - Seed supply systems in West Africa: assessment of prospects for improvement
3. Examples of groundnut seed supply schemes in Mali, Niger, Nigeria, and Senegal
   - Regional strategy for seed multiplication and distribution
4. Parallel group discussions
   - Genetic resources conservation and utilization
   - Strengthening of seed multiplication and distribution
   - The role of the public and private sector in the groundnut sector

Conclusions of the working groups were presented in a plenary session entitled "Strategies for groundnut seed sector improvement".

In closing, the Common Fund for Commodities (CFC) representative, Dr Mohamed Ramouch, expressed satisfaction at the attainment of the project objectives and reiterated the interest of CFC to support a follow-up program. He stated: "This workshop is the first step to the closure of the project and the final evaluation will take place towards the end of 2002. The results, no doubt, will have a positive impact on the groundnut seed sector in this part of the world. 1 take this opportunity to congratulate the partners of the Common Fund for Commodities and all those associated with the execution of GGP for a remarkable job."

Mr Peter Thoenes, representing the Food and Agriculture Organization of the United Nations (FAO), the Supervisory Body, thanked CFC and ICRISAT for gathering a wide range of stakeholders. Excerpts from his presentation are given below:

"Interesting presentations and discussions have been made and in particular, the market prospects for groundnuts. GGP achievements clearly show that the main goals and objectives have been attained through remarkable participation of all partners in the project. There is a forward-looking approach for future action focusing on downstream activities. These activities should build on GGP but with new dimensions involving a much wider range of stakeholders requiring a new strategy.

The main elements of this strategy are:

- No longer research driven program but market demand driven. New partnerships to build and work closely guided by private sector, NGOs, policy makers, etc.
- Integrating seed production and distribution system - informal and formal seed sector with involvement of private sector with commercial interest leading to new partnership arrangements.
- Choose a demand driven approach targeting clear-cut markets at national, regional, and international levels. This will require a further in-depth analysis of aspects presented on market prospects.

Thus the implications are:

- The new project will be of an experimental nature with pilot activities in limited number of locations representative of the region, shared experiences in the region, and up-scaling of most successful models.
- Effort is required to include all potential actors in the region working on groundnuts.
- Innovative ways to stimulate/support private sector involvement.

The outputs of this workshop will help in achieving the follow-up activities."

Steering Committee Meeting

On the last day of the workshop, 25 April 2002, a special meeting of the Steering Committee was convened to discuss the outcome of the workshop and arrangements for the closure of the project. The project activities ended on 30 June 2002 and the closing date is 31 December 2002. The PEA presented a proposed plan of action from June to December 2002. This was endorsed by the Steering Committee and was sent to CFC through FAO for final approval.

Training Program

The University of Georgia in collaboration with the International Consortium for Agricultural Systems Applications (ICASA) is organizing a Training Program on DSSAT Version 4, Assessing Crop Production, Nutrient Management, Climatic Risk and Environmental Sustainability with Simulation Models. The overall goal of this workshop is to familiarize the participants with a comprehensive computer model for the simulation of crop growth and yield, soil and plant water, nutrient and carbon dynamics and their application to real world problems. The workshop will make extensive use of the new Windows-based DSSAT V4 and a new Cropping System Model that includes CERES, CROPCRO, CENTURY, and other modules. The workshop will be held from December 9 through December 18, 2002 at the University of Georgia in Griffin, Georgia, USA. The cost of the workshop is US$ 1,500. For further information contact Gerrit Hoogenboom at gerrit@griffin.peachnet.edu or visit website www.ICASAnet.org.

Wild *Arachis* on the Web

The importance of the wild relatives of cultivated groundnut (*Arachis hypogaea*) to the improvement of the crop has long been recognized. Wild species of groundnut, endemic to South America, have been collected and conserved since the times of the first plant collectors. Today, there are numerous records of the existence of populations, herbarium samples, and genebank accessions housed at a number of institutes around the world, all having different identification coding systems. To bring clarity to past conservation, research, and plant breeding efforts as well as to enhance the future efficiency of both conservation and utilization of wild *Arachis* germplasm, a comprehensive and extensive database of 3514 records, comprising and cross-referencing wild *Arachis* accessions held in the major genebanks, specimens held in herbaria, and citations made in publications, has been compiled by HT Stalker, ME Ferguson, JFM Valls, RN Pittman, CE Simpson, and PJ Bramel. The database has been web-enabled and is available for querying at http://www.icrisat.org/text/research/grep/homepage/groundnut/arachis/start.htm. This database of cross-reference accessions is based on collector name and number in the databases of EMBRAPA, United States Department of Agriculture (USDA), Centro Internacional de Agricultura Tropical (CIAT), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Texas A&M University, and North Carolina State University as well as in herbaria and publications. A hard copy of this database shall be made available in the future. If you have comments regarding the database content or design, or website please contact Morag Ferguson (M.Ferguson@cgiar.org). The authors of the database also request all future *Arachis* collectors to help keep the database updated by providing information regarding new collections.

Contributed by ***ME Ferguson,*** *ICRISAT, PO Box 39063, Nairobi, Kenya*

Current ICRISAT Groundnut Research and Integrated Projects

Investor	Project title	Project coordinator	Grant amount (In US$)	Duration
Asian Development Bank	Rapid crop improvement for poor farmers in the semi-arid tropics of Asia	JH Crouch	1 200 000	Jan 2001–Dec 2003
Australia/ACIAR	Selection for peanut varieties with low aflatoxin risk	SN Nigam	204 000	Jul 2001–Jun 2004
Australia/ACIAR	Seeds of life – East Timor	SN Nigam	58 000	Nov 2000–Jun 2003
Australia/ACIAR	Improving yield and economic viability of peanut production in Papua New Guinea and Australia using integrated management and modeling approaches	HD Upadhyaya	12 193	1 Jul 2002–30 Jun 2005
Belgium/DGIC	Towards sustainability of groundnut and cereal production in West Africa: management of peanut clump virus	F Waliyar	784 000	2000–04
CFC/FAO IGG-OOF	Conservation, evaluation and dissemination of groundnut germplasm, and foundation seed production and distribution for the West African region	F Waliyar	2 221 000	1996–02
CGIAR/ICARDA/CAC	Research activities on groundnut and on management of drought in chickpea, targeted to the Central Asia and the Caucasus (CAC) region	SN Nigam	34 000	2000–02
Germany/BMZ/GTZ	Promotion of legume cultivation in Malawi, Mozambique, Zimbabwe and Zambia – Phase V	Allan Chiyembekeza	521 000	Oct 2000–Sep 2003
IFAD	Farmer-participatory improvement of grain legumes in rainfed Asia	SN Nigam	1,300,000	1 Sep 2001–20 Sep 2005
India/ICAR/NATP	Aflatoxin contamination in groundnut: mapping and management in Gujarat and Andhra Pradesh	SN Nigam	39 900	2000–03
India/ICAR/NATP	An integrated approach to control stem necrosis disease of groundnut	SN Nigam	40 700	2001–04

continued

Investor	Project title	Project coordinator	Grant amount (in US$)	Duration
India/MAHYCO Research Foundation	Management of tospoviruses in selected crops and strategies for management of tobacco streak virus	F Waliyar	10 500	2001–03
India/UK – APRLP/DFID	Convergence of agricultural, livestock improvement initiatives in watersheds – support to APRLP	SP Wani	464 000	Jun 2002–Jul 2004
OPEC Fund for International Development	Technological empowerment of poor groundnut farmers in Asia: a step towards better rural economy	SN Nigam	100 000	2001–02
PLAN International-Malawi	Groundnut Project in Malawi	Allan Chiyembekeza	182 000	Nov 1998–Dec 2002
Plan International–Zambia	Groundnut Project in Zambia	Allan Chiyembekeza	12 109	Nov 2001–Oct 2002
UK – DFID/CPP	Strategies for reducing aflatoxin levels in groundnut-based foods and feeds in India: A step towards improving health of humans and livestock	F Waliyar	212 000	Jul 2000–Dec 2002
USA/University of Georgia/ Peanut CRSP	Support for: International *Arachis* Newsletter; International Peanut Congress 2004; groundnut rosette in South East Africa; aflatoxin model	F Waliyar	20 000	2002–03
USAID/TARGET	More bang for the research buck: Raising farmers' incomes through use of profitable grain legume technologies and better linkages to markets	SN Silim RB Jones	600 000	2002–04
USAID/US University Linkages	Quantifying yield gaps and abiotic stresses in soybean- and groundnut-based production systems	P Pathak	90 000	2001–03

Feedback from Readers on International *Arachis* Newsletter

A questionnaire slip was sent to all readers of the International *Arachis* Newsletter (IAN) along with issue no. 21. Responses on the usefulness of IAN were received from 122 persons in 28 countries. Highlights of some comments are reproduced below.

Country	Response	Some comments
Argentina	3	IAN serves our finality.
Bangladesh	4	All the teachers and students of the department will be benefited from IAN. This is a unique opportunity for us.
Belgium	1	Many researchers are interested in the work published.
Brazil	1	IAN covers different research areas of *Arachis. Arachis* is an important crop for the third world, and the IAN gives importance and needed information to this region. The papers do not follow a rigid pattern. This enables faster publishing of the information.
Burundi	1	IAN gives information on germplasm, results on trials and pests, etc.
Costa Rica	1	IAN keeps researchers updated on developments in the groundnut world globally and this is important to all of us.
Chile	1	Nuestra biblioteca es unade la masimportantes en el area agricola, ademas es el centro nacional agri.
China	5	This newsletter helps us keep abreast of new advances in peanut science, and serves as an international forum for peanut scientists worldwide to publish their research communications. IAN is really indispensable.
Ethiopia	2	I am a researcher on oil crops, so this newsletter is useful.
France	1	ICRISAT publications are useful for students and their professors.
Ghana	1	Faculty members, researchers, and students of the faculty of agriculture find the articles in IAN very useful.
India	65	Concise information on groundnut crop from the whole world is available in this newsletter.
Indonesia	3	Since my research is on peanut, this newsletter is useful, especially information on agronomy of peanut.
Japan	2	IAN gives useful information and perspectives for research in peanut.
Malawi	1	IAN provides updated information on groundnut production which helps me boost groundnut production as I work with farmers.
Malaysia	2	IAN is a useful reference for research officers.

continued

Country	Response	Some comments
Mexico	2	I use IAN as reference to support my research proposals and to be updated on research reports.
Myanmar	2	IAN provides up-to-date information for researchers at CARI and YAU.
Niger	1	IAN provides global and useful information on groundnut which are not published elsewhere.
Nigeria	2	This newsletter gives valuable reports on current research work on groundnut.
Pakistan	2	IAN is playing an important role among the national and international scientific community to update the information regarding research, improvement, and development in different parts of the world. We became aware of the current activities on peanut research. This improves the scientific knowledge and establishes linkages among different scientists.
Papua New Gunea	1	Our food crops and grains section consult it for research purposes and the pathology staff consult it for information on diseases.
Philippines	2	Results applicable to our conditions are adopted from the IAN and taught in science classes.
Sri Lanka	4	Latest research information on groundnut appropriate to Sri Lanka is available. Also, there are avenues to contact scientists on groundnut research.
Sudan	1	IAN is the only standard source of information for groundnut research and literature.
Thailand	1	IAN is the only publication which informs me about R&D of groundnut in the world.
USA	5	IAN allows communication of research among scientists working on groundnut, especially those in developing countries. Without IAN, many would not know what was occurring in the research world, and people like myself (in USA) would not know what was occurring in much of Asia and Africa.
Zambia	5	IAN is the only link to the groundnut world of science and proves useful in all respects - informative and educative with current information. With Internet out of reach of many third world research centers, this publication is very important and should continue.
Total	122	

Genetic Resources and Enhancement

Pod and Seed Storage: Cost-Benefit Study for Groundnut Germplasm Conservation

N Kameswara Rao[1], Bonwoo Koo[2], and DVSSR Sastry' (1. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India; 2. International Food Policy Research Institute (IFPRI), 2033 K Street, N.W., Washington D.C. 20036, USA)

The Genebank at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India conserves about 15,342 accessions of groundnut germplasm assembled from 93 countries. The germplasm is stored in the form of pods under medium-term storage conditions (4°C and 30% relative humidity). Pod storage, however, requires far greater storage space compared to seed storage; hence it is likely to be more expensive, especially when the storage temperature and relative humidity are controlled by mechanical means. Recently, Rao et al. (in press) found only marginal advantage in terms of seed longevity with pod storage compared to seed storage. Hence they recommended that active collections of groundnut germplasm could be conserved in the form of seeds to reduce the conservation costs. We compared the actual costs of conservation of pods and seeds in two groundnut cultivars JL 24 and ICGS 76 under medium-term conditions.

The groundnut germplasm accessions conserved as pods in ICRISAT Genebank, occupy two large storage rooms (each of 260 m^3) and this requires about 100,000 kWh yr^{-1} of electricity. Pods occupy more than three times the volume required for storage of seeds (Rao et al., in press). Hence when pods of groundnut accessions are shelled and stored in the form of seeds, they could be accommodated in one small modular room of about 130 m^3, requiring only 30,000 kWh yr^{-1} of electricity to maintain similar storage conditions. The overall annual storage costs of pods and seeds were estimated at US$ 0.97 and 0.38 per accession, respectively (Table 1). The costs included electricity, quasi-fixed labor, and equipment maintenance charges (but excluded capital items such as storage module). Thus, the cost saving per accession is US$ 0.59 or about US$ 9,050 per year for conserving the entire collection of groundnut by changing to storage of seeds instead of pods. However, the slightly longer survival due to pod storage results in less frequent regeneration. Therefore, when evaluating

Table 1. Annual cost (US$) for conservation of groundnut germplasm under different protocols at ICRISAT Genebank, Patancheru, India.

Item	Pods	Seeds
Quasi-fixed labor (e.g., senior manager, scientist, etc.)	1 500	1 500
Equipment maintenance		
Labor (e.g., technicians, daily labor, etc.)	900	450
Non-labor (e.g., supplies)	500	250
Electricity	12 000	3 600
Total cost of conservation of 15342 accessions	14 900	5 800
Conservation cost per accession	0.97	0.38

the cost-efficiency in the context of long-term maintenance of germplasm, the regeneration cost under different methods of storage also needs to be included. The cost of regenerating one accession of groundnut is estimated at US$ 13.06 for pod storage, and it increases to US$ 13.26 for seed storage due to the extra labor cost incurred for shelling (Koo et al. 2001).

At ICRISAT, groundnut germplasm accessions are regenerated when seed germination falls below 75%. Based on the estimates of seed longevity derived by probit analysis, Rao et al. (in press) predicted that germination of seeds of ICGS 76 from pods stored under medium-term conditions could decrease from 100% to 75% in about 4266 days compared to 4179 days in shelled seeds. Similarly in JL 24, the germination of seeds from stored pods is expected to decrease from 100% to 75% in 4732 days compared to 4652 days in seeds. Assuming an 11-year regeneration interval under both storage methods, the cost of storing and regenerating an accession forever would be US$ 62.49 for pod storage and US$ 47.72 for seed storage when the real rate of interest is 4% (Table 2). Thus the total cost of conserving 15,342 groundnut accessions in perpetuity would be US$ 958,716 for pod storage and US$ 732,126 for seed storage. The net cost saving by switching to storage of seeds, therefore, would be US$ 226,590, without significantly compromising storage longevity. However, it should be noted that in the present ICRISAT scenario, the labor cost for shelling that contributes to regeneration cost is very low compared to electricity cost that affects storage cost. If the structure of costs is reversed, the size of the savings due to the change of protocol may be different.

Table 2. In-perpetuity cost (US$) of storing and regenerating groundnut germplasm under different protocols at ICRISAT Genebank, Patancheru, India.

Item	Pods	Seeds
Storage cost[1]	25.22	9.88
Regeneration cost at 11 years interval[2]	37.27	37.84
Total regeneration cost per accession	62.49	47.72
Total regeneration cost of all 15,342 accessions	958 716.00	732 126.00

1. The in-perpetuity cost of an operation that is performed annually with a cost of X from time zero is given by

$$C_{\infty}^{1} = X + \frac{X}{(1+r)} + \frac{X}{(1+r)^2} + \cdots = X\left[1 + \frac{1}{(1+r)} + \frac{1}{(1+r)^2} + \cdots\right] = \frac{X}{1-a}$$

whereas $a = \frac{1}{(1+r)} < 1$ and r is the real rate of interest.

For example, if it costs US$ 2.07 to store one accession of groundnut germplasm pods per year, the present value of the cost of storing that accession in perpetuity is US$ 53.82 with 4% interest rate.

2. The in-perpetuity cost of an operation that is performed every n^{th} year from time zero with a cost of X is given by

$$C_{\infty}^{n} = X + \frac{X}{(1+r)^n} + \frac{X}{(1+r)^{2n}} + \cdots = X\left[1 + \frac{1}{(1+r)^n} + \frac{1}{(1+r)^{2n}} + \cdots\right] = \frac{X}{1-a^n}$$

For example, if the regeneration cost of groundnut is US$ 13.06 and it is done every 11 years, then the present value of the cost of regenerating an accession in perpetuity is US$ 37.22 with 4% interest rate.

References

Koo B, Pardey PG, Rao NK, Bramel PJ, and Wright BD. 2001. Cost of conserving genetic resources at 1CRISAT. Review Paper. Washington D.C., USA: International Food Policy Research Institute.

Rao NK, Sastry DVSSR, and Bramel PJ. (In press.) Effects of shell and low-moisture content storage on groundnut seed longevity. Peanut Science.

Aneuploids in Groundnut

SK Bera, P Paria, and T Radhakrisnan (National Research Centre for Groundnut (NRCG), PB no. 5, Junagadh 362 001, Gujarat, India)

Interspecific hybridization was attempted between cultivated tetraploid groundnut *(Arachis hypogaea)* cultivar J 11 under section *Arachis* as female parent and wild perennial diploid species, *Arachis paraguariensis* under section *Erectoides* as pollen parent under field conditions during rainy season. A total of ninety-two probable cross pods from the above cross were collected and seeds were grown in the field for identification of hybrid plants. But none of the plants were found to be hybrids. However, one plant was morphologically like the female parent but poor in vigor. Meiotic chromosome analysis in pollen mother cell (PMC) confirmed that the plant with poor vigor and 19 bivalents was a nullisomic, the 2n chromosome number of groundnut being 40. The nullisomic plant had narrow leaflets and blooming was delayed by nearly two hours; about 95-98% fertile (stainable) pollen was produced which germinated normally in aqueous medium standardized for groundnut.

Meiotic analysis revealed that pairing behavior at Metaphase I in the nullisomic plant was normal. The PMC having 19 bivalents constituted the modal class. Univalents and trivalents in the PMCs were rare. The mean chromosome configuration per PMC at Metaphase I was 0.63 univalents and 18.54 bivalents. Similar pairing of chromosomes in nullisomic was reported earlier by Singh et al. (1981) in groundnut. Equal distribution of chromosome 19/19 in Anaphase I was observed in about 50% PMCs. Rest of the PMCs showed unequal separation of 20/18 or 21/17. The occurrence of nullisomy and univalents in PMC suggest that groundnut is amenable for producing an aneuploid series.

Table 1. Phenotypic comparison between groundnut cultivar J 11 (female parent) and the nullisomic plant.

Plant characters	111	Nullisomic plant
Leaflet area (cm^2)	9.22	4.30
Leaflet length (cm)	4.65	3.99
Leaflet width (cm)	2.52	1.68
Petiole length (cm)	3.24	2.30
Stipule length (cm)	2.40	2.03
Sepal length (joined) (cm)	8.00	8.46
Sepal length (single) (cm)	10.00	10.13
Hypanthium length (cm)	27.33	15.54
Stomatal length (mm)	0.02	0.02
Stomatal width (mm)	0.02	0.01
Petal length (mm)	13.60	11.26
Standard length (mm)	8.00	7.73
Wing length (mm)	8.80	8.00
Pollen size (mm)	0.06	0.07
Anther length (mm)	13.02	11.26

The mode of origin of nullisomy in interspecific crosses is not understood fully. The species used as pollen parent had a different genome (E1) which is cross incompatible with other species. At maturity, the nullisomic plant produced a total of eleven mature pods of which only four progeny plants were raised successfully. Of the four plants, two were confirmed as nullisomic having 2n chromosome number of 38. Some phenotypic differences were observed between J 11 and the nullisomic plant (Table 1).

Reference

Singh D, and Joshi BC. 1981. Aneuploids in groundnut. Indian Journal of Genetics 41:161-163.

High Yields with Ideal Ideotypes of Groundnut Varieties TAG 24 and TG 26

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Superior groundnut *(Arachis hypogaea)* varieties from Trombay, Mumbai, Maharashtra, India have been released. The Trombay groundnut (TG) variety, TAG 24 (pedigree: TGS 2 x TGE 1) was released in 1991 for rabi (postrainy season) or summer cultivation in the Vidharba region of Maharashtra (Patil et al. 1995). Subsequently, it was also released in the states of Karnataka, Rajasthan, and West Bengal and became popular in Andhra Pradesh, Orissa, Madhya Pradesh, Punjab, and Tamil Nadu. Another variety, TG 26 (pedigree: BARCG 1 x TG 23) was released in 1996 in Gujarat, Maharashtra, and Madhya Pradesh (Kale et al. 1997). The superiority of TAG 24 was noticed in the All India Coordinated Research Project on Oilseeds rabi/summer varietal trials between 1987 and 1997, where it surpassed 11 check varieties and gave yield advantage up to 25% (Kale et al. 1999).

Concerted efforts to disseminate these varieties in different groundnut-growing states facilitated TAG 24 and TG 26 to become popular among the farming community. Farmers have been obtaining high yields of TG varieties in many parts of the country. Mr JB Gunde harvested high yields of 10,175 kg ha^{-1} and 10,542 kg ha^{-1} dry pods from TAG 24 and TG 26, respectively (Table 1). Another farmer, Mr MN Ghuge also obtained dry pod yields of 9,280 kg ha^{-1} and 9,487 kg ha^{-1} from TAG 24 and TG 26, respectively. Mr Gunde had sown the crop on broad-bed and furrow system [developed by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)], either with or without polythene mulch; a plant population of 600,000 ha^{-1} at 3 seeds $hill^{1}$ (200,000 hills ha^{-1}) was maintained. On the other hand, Mr Ghuge used flat field, with a plant population of 400,000 ha"[1] (25 cm x 10 cm spacing). Seed treatment included 6 g of thiram, 6 g of bavistin, 25 g of phosphate solubilizing bacteria, and 25 g of *Rhizobium* kg^{-1} seed. Ten tons of farmyard manure, 25 kg nitrogen, 130 kg phosphorus, *75* kg potassium, 5 kg borax, 10 kg zinc sulfate, and 2.5 kg ferrous sulfate ha^{-1} were applied at the time of sowing. A mixture of 3 g borax and 15 g of ferrous sulfate L^{-1} of water was sprayed 30 days after emergence (DAE). The crop was protected from pests and diseases by applying 5 ml of monocrotophos, 3 g of bavistin, and 6 g of mancozeb (at 10 DAE), and 5 ml of monocrotophos (at 30 DAE) L^{-1} of water. The crop was irrigated with sprinklers at 3-4 days intervals. Mr Gunde also used pre-emergence herbicide (Basalin® at 2 L ha^{1}). Both the farmers harvested these varieties in less than 115 days after sowing during summer (February to May).

Groundnut is considered photosynthetically a very efficient crop with need for strong sunlight (Sun Yanhao et al. 1996). The theoretical yield

Table 1. Pod yield of TAG 24 and TG 26 on farmers' fields in Maharashtra, India.

Farmer	District	Year	Yield (kg ha^{-1})
TAG 24			
HM Khan	Yawatmal	1995	4 000
A Kalyani	Solapur	1999	4 875
JB Gunde	Kolhapur[1.2]	1997	5 399
		1998	6 484
		2001	10 175
MN Ghuge	Parbhani[2]	2001	9 280
TG 26			
A Kalyani	Solapur	1999	4 500
JB Gunde	Kolhapur[12]	1997	9 458
		1999	8 780
		2000	10 542
Y Bobade	Baramati	2000	6 000
MN Ghuge	Parbhani[2]	2001	9 487

1. Yields were recorded by the Statistical Wing of Department of Agriculture, Government of Maharashtra based on crop cutting surveys.
2. Grown with polythene mulch.

potential for Spanish cultivars with short duration and medium bold pods based on maximum leaf area index and net assimilation rate was 11.91 ha^{-1} in Guangdong province, China; for medium-duration cultivars, based on radiation use efficiency of 5.4% over 80 days, it was 17.3 t ha^{-1} at Shandong province, China (Sun Yanhao 1982). In China, Sun Yanhao and Wang Caibin (1990) reported dry pod yield of 11.2 t ha*[1] in a 0.1-ha plot and 9.6 t ha^{-1} in 14-ha plot. In Zimbabwe, Hilderbrand (1980) also reported pod yield of 9.6 t ha^{-1} . At ICRISAT, Patancheru, India, yields up to 7 t ha^{-1} have been obtained in small plots and up to 5 t ha^{-1} on large plots (ICRISAT 1991).

A suitable plant type with an ideal environment is the basis for high yield in groundnut. Saxena and Johansen (1990) proposed the concept of functional ideotype by including morphological, phenological, physiological, and biochemical traits that could improve yield and quality in a specified target environment. Both TAG 24 and TG 26 have most of the morphological and physiological traits defined by Johansen and Nageswara Rao (1996) and Sun Yanhao et al. (1996) in their ideotypes. These traits are:

- Semi-dwarf growth habit which helps to increase plant population per unit area, prevents lodging, and permits pegs to enter the soil early.
- Small, thick, dark green leaves which enhance the radiation use efficiency (Johansen and Nageswara Rao 1996) and water use efficiency (ACIAR 1995).
- Determinate flowering which synchronizes pod maturity and helps in enhanced diversion of photo-assimilates to pod development (unpublished data).
- Early maturity which helps to escape end-season drought.
- Enhanced dry matter partitioning, pod and seed growth rates, and harvest index (unpublished data).

Nigam and Gowda (1996) reported 26% higher pod yield over local variety due to improved variety; the yield further increased to 61% by cultivating the same improved variety under improved cultural practices (better growing environment). We observed that the high-yielding ability of TAG 24 **and** TG 26 is exploited by farmers by growing them under suitable agro-ecology such as summer environment, balanced nutrition, and uninterrupted but controlled irrigation to achieve high yields. Also, foliar diseases incidence is low in the summer season.

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Evaluation of Short-duration Groundnut Genotypes for the Arid Zone of Northwestern Rajasthan, India

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The hot arid ecosystem of northwestern Rajasthan, India is characterized by low and erratic rainfall, frequent droughts, high temperatures, and high wind velocity leading to high rate of evapotranspiration and drought (Rao and Singh 1998). The introduction of Indira Gandhi Nahar (an irrigation canal) in the region has increased the availability of irrigation water. Therefore, groundnut *(Arachis hypogaea)* crop has become an important component of the cropping systems of the northwestern arid zone for both fodder as well as grain production. Traditionally, farmers of this region tend to sow groundnut varieties of 8-9 months duration. These varieties experience peak summer months when lot of irrigation is required to raise a successful crop. Moreover, if the crop is sown more than three consecutive years in the same field, farmers reported a steady decline in groundnut yield. This seems to be due to the imbalance of soil nutrients created by traditional long-duration varieties. Recently, shortage of water in irrigation canals has been experienced and the crop has additionally begun to suffer from intermittent droughts. Hence, there is an urgent need to introduce short-duration groundnut varieties that have intermittent drought tolerance for this region. A preliminary experiment was, therefore, conducted to evaluate short-duration groundnut genotypes for intermittent drought tolerance.

A field experiment was conducted at the research farm of the Regional Research Station, Central Arid Zone Research Institute (CAZRI), Bikaner in Rajasthan. The field was disc plowed and a basal dose of single superphosphate at 40 kg P_2O_5 ha^{-1} was incorporated into the soil at the time of land preparation. The experiment was laid out in a split plot design with sowing beds [flat bed (FB); and broad-bed and furrow (BBF)] as main plots and genotypes as sub-plots. The broad beds were of 1.2 m width with 0.3 m wide furrows. The seeds of 10 groundnut genotypes (ICGS 11, ICGS 44, ICGVs 86015, 87846, 89104, 91117, 92109, 92113, 92116, and 92206) procured from ICRISAT were used in the study. Before sowing, seeds were treated with thiram and captan (at 3 g kg"[1] seed) to prevent seedling diseases. Sowing was done on February 14,2001. The plot size for each entry was 2.0 m x 1.2 m, with planting space of 30 cm between rows and 10 cm within a row. The crop received adequate sprinkler irrigation throughout the growing period, except during mid-season drought. Mid-season drought was imposed from 52 to 75 days after sowing (DAS) by withholding irrigation. The total rainfall during the crop-growing season was 130.5 mm, out of which only 5 mm was received during the drought period. The treatments were replicated three times. Plants were sampled from an area of 0.2 m x 4 rows at the onset of intermittent drought (52 DAS), end of drought (72 DAS), and at final harvest (FH). Total dry matter [vegetative (i.e., aboveground parts) mass + pod mass], pod mass, crop growth rate, and partitioning coefficient were estimated as described by Nageswara Rao et al. (1988). Crop growth, pod growth, and partitioning during mid-season drought and recovery phase following the alleviation of mid-season drought were quantified as follows:

Crop growth rate (CGR) = $(Dm\ t_3 - Dm\ t_2)/(t_3 - t_2)$

Pod growth rate (PGR) = $(Pd\ t, - Pd\ t_2)/(t_3 - t_2)$

Partitioning factor (P_f) = PGR/CGR

where t_2 = 72 DAS, t_3 = at FH, Dm = Total dry matter, and Pd = Pod dry mass.

The results showed that the recovery in growth rates following the release of drought was higher in most of the genotypes when grown on the BBF system as compared to FB (Table 1). Four genotypes, ICGVs 92113, 86015, and 87846, and ICGS 11, achieved a significantly higher CGR during the recovery phase when grown on BBF than on FB. PGR during the recovery phase was significantly higher in three genotypes (ICGVs 92113, 92116, and 86015) when grown on BBF than on FB, unlike ICGV 92206 and ICGS 11. About half of the genotypes studied maintained higher partitioning when grown on BBF than when grown on FB. The sowing bed x genotype interaction was significant for PGR and P_f but was not significant for CGR. Significant variations for CGR, PGR, and P, were noticed among genotypes sown either on BBF or FB. The bi-plotting of CGR and P_f during the recovery phase following the termination of drought showed that chances of combination of higher CGR with higher P_f are greater when genotypes are grown on BBF rather than on FB (Fig. 1). Three genotypes (ICGVs 92113, 92116, and 86015) achieved above average CGR and P_t when grown on BBF, while only one genotype achieved this when grown on FB. The total dry matter and pod yield were higher in most genotypes (7 out of 10) when grown on BBF as compared with FB. ICGV 92113 produced the highest pod yield and total dry matter under both BBF and FB. But there is a marked improvement in both the parameters in all test genotypes when grown on BBF than on FB (Table 1). The sowing bed x genotype interaction was not significant for total dry matter but was significant for pod yield.

These results indicate that the BBF system of raising the crop is promising for short-duration groundnut genotypes in the arid zone of north-western Rajasthan. Thus some superior short-duration genotypes could help boost yields in this region. More experiments are needed to validate this observation and develop as a production practice for the farmers of this region.

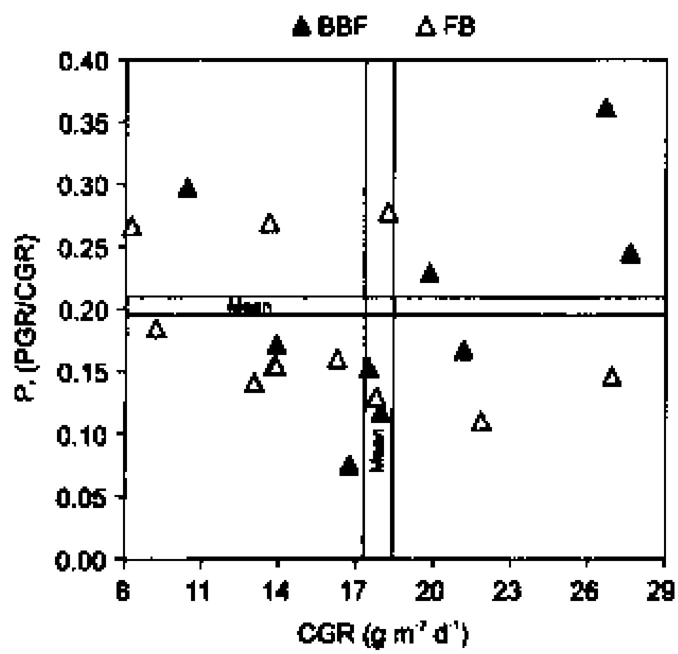

Figure 1. Bi-plot between crop growth rate (CGR) and partitioning (P_f) during recovery phase following the termination of drought in 10 selected groundnut genotypes grown on broad-bed and furrow (BBF) or flat bed (FB) (PGR = Pod growth rate).

Table 1. Variation in crop growth rate (CGR), pod growth rate (PGR), and partitioning factor (P_f) during the recovery phase following the termination of drought and in total dry matter and pod yield at maturity in groundnut genotypes during summer 2001 at Regional Research Station, CAZRI, Bikaner, Rajasthan, India.

Genotype	CGR ($g\ m^{-2} d^{-1}$) FB[1]	CGR ($g\ m^{-2} d^{-1}$) BBF[1]	PGR ($g\ m^{-2} d^{-1}$) FB	PGR ($g\ m^{-2} d^{-1}$) BBF	P_f FB	P_f BBF	Total dry matter ($g\ m^{-2}$) FB	Total dry matter ($g\ m^{-2}$) BBF	Pod yield ($g\ m^{-2}$) FB	Pod yield ($g\ m^{-2}$) BBF
ICGS 11	8.3	16.7	1.9	1.2	0.27	0.08	907.5	1629.4	165.0	103.1
ICGS 44	13.9	13.8	2.2	2.2	0.15	0.15	1381.9	1340.6	185.6	185.6
ICGV 86015	13.0	19.8	1.9	4.6	0.14	0.23	1237.5	1815.0	165.0	391.9
ICGV 87846	9.2	17.5	1.7	2.7	0.18	0.15	907.5	1691.3	144.4	226.9
ICGV 89104	21.9	21.2	2.2	3.4	0.11	0.17	2062.5	1959.4	185.6	288.8
ICGV 91117	16.2	10.4	2.1	3.1	0.16	0.30	1568.1	1093.1	185.6	266.1
ICGV 92109	17.8	18.0	2.2	2.7	0.13	0.12	1711.9	1753.1	185.6	226.9
ICGV 92113	18.2	26.7	5.3	9.2	0.28	0.36	1744.9	2516.3	453.8	783.8
ICGV 92116	26.9	27.6	3.9	6.8	0.15	0.24	2563.4	2619.4	330.3	577.5
ICGV 92206	13.6	13.9	3.5	2.1	0.26	0.17	948.8	1381.9	309.4	185.6
Mean	15.9	18.6	2.7	3.8	0.18	0.20	1502.7	1779.9	231.0	323.8
CV (%)	16.2		19.2		18.0		15.2		16.3	
LSD (0.05)										
Sowing Bed (SB)	2.00		1.32		0.088		306.7		72.8	
Genotype (G)	1.78		0.29		0.023		147.9		18.4	
SB × G	NS[2]		2.37		0.075		NS		97.0	

1. FB = Flat bed; BBF = Broad-bed and furrow.
2. NS = Not significant.

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Performance of Groundnut Germplasm at High Temperature During the Reproductive Phase in Rajasthan, India

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The availability of irrigation has increased cultivation of rabi (October-March) and summer (February-June) groundnut *(Arachis hypogaea)* in several areas in Rajasthan, India; however, crop sown in January in Nachana, Bikaner, Hanumangarh, and Durgapura areas encounter low (8 to 18°C) temperatures during germination phase. Under such a situation, the crop takes about 20-25 days to emerge, and uniform crop stand is generally not achieved. If the crop is sown in the last week of February or first week of March, it germinates well but encounters high temperatures at the time of pollination and pod-filling (May and June), when maximum ambient temperatures vary from 30 to 45°C. A high temperature adversely affects performance of groundnut. Therefore, cultivars that can tolerate high temperatures are required for late sowing conditions. The objective of this study was to screen groundnut germplasm accessions for their tolerance to high temperature during the reproductive phase.

Seventy-two germplasm accessions belonging to different botanical groups (Spanish, Valencia, and Virginia) were screened for tolerance to high temperature at Hanumangarh and Durgapura. These were sown on 27 February and 16 March 1996 at Hanumangarh, and on 3 and 24 February 1996 at Durgapura. The experiment was conducted in a randomized block design with three replications. Each genotype was sown in 5 rows, each of 4 m length, with a spacing of 10 cm (between seed) and 45 cm (between rows). The crop sown on the first date was harvested after 140 days, and that sown on the second date was harvested after 120 days at the two locations.

The early-sown crop (first date) experienced minimum temperature between 5 and 10°C, and maximum temperature between 20 and 25°C during germination and early seedling stage at both the locations. During the reproductive phase, temperatures ranged between 30 and 40°C at Hanumangarh, and between 30 and 38°C at Durgapura (Fig. 1). Thus the crop experienced sub-optimal temperatures during germination and early seedling stage, and supra-optimal temperatures during the reproductive phase at both the locations. At the final harvest, an area of 0.30 m^2 from each plot was sampled; from each sample observations such as number of pegs, immature pods, and mature pods $plant^{-1}$ were recorded on 6-7 plants. The vegetative plant parts from each sample were dried in an oven at 80°C until a constant weight was achieved. Harvest index (HI) was calculated as a ratio of dry mass of pods to dry mass of total biomass. The data of two sowing dates at each location were pooled and analyzed. Significant genotypic variation was found in number of pegs and pods, dry mass, and HI. The interactions between the date of sowing and genotype were also significant for all the traits (Table 1). The crop sown early took 7-10 days longer for seedling emergence, and for flower initiation, probably due to low soil and ambient temperatures (soil data not given), than the second date of sowing.

Table 1. Pod yield and yield attributes of high temperature tolerant and susceptible germplasm accessions of groundnut grown during summer 1996 at two locations in Rajasthan, India.

Genotype	Days to 50% flowering	Pegs (hanging) (no. plant⁻¹)	Immature pods (no. plant⁻¹)	Mature pods (no. plant⁻¹)	Vegetative mass (g m⁻²)	Total dry matter (g m⁻²)	Pod yield (g m⁻²)	Harvest index
Hanumangarh								
Tolerant (1st sowing)								
TKG 19A	40	8	16	12	1040	1460	420	0.28
ICGS 76	38	8	14	11	2073	2433	360	0.14
Kadiri 3	38	5	14	7	880	1206	326	0.27
ICG 3793	40	3	11	5	560	833	273	0.32
Tolerant (2nd sowing)								
ICGV 86031	22	10	11	13	1226	1592	366	0.22
TG 22	24	21	15	6	646	946	300	0.31
ICG 3704	23	7	15	6	2500	2800	300	0.10
ICGV 86754	23	1	10	11	833	1120	286	0.25
Susceptible (1st sowing)								
NCAc 343	39	6	2	10	966	1006	40	0.04
ICG 5263	41	7	6	2	1440	1480	40	0.03
Susceptible (2nd sowing)								
RG 141	24	4	9	9	1086	1119	33	0.02
ICG 2730	23	5	5	1	506	552	46	0.08
SE ±	–	2.69	2.83	2.52	13.91	15.28	6.61	0.005
CV (%)		68.44	59.89	97.85	2.13	2.11	9.51	10.05
Durgapura								
Tolerant (1st sowing)								
RG 335	58	80	50	16	1830	2249	419	0.18
ICG 86644	71	15	8	5	1886	2166	280	0.12
ICGV 86031	64	19	17	7	1500	1840	340	0.18
ICGV 86754	65	8	20	9	486	820	333	0.40
Tolerant (2nd sowing)								
TG 17	51	27	13	10	813	1440	626	0.43
DRG 101	52	20	9	8	1113	1686	573	0.34
RS 1	47	31	15	11	3620	4226	606	0.14
ICG 3096	49	19	9	8	1280	1713	433	0.25
Susceptible (1st sowing)								
ICG 221	74	11	2	1	1090	1183	93	0.07
ICG 3141	65	24	19	1	360	480	120	0.25
Susceptible (2nd sowing)								
NCAc 343	55	12	7	2	1113	1180	67	0.05
ICG 221	47	12	7	3	813	886	73	0.08
SE ±	–	0.93	3.08	1.25	13.06	14.04	4.11	0.005
CV (%)		56.78	78.17	74.59	2.77	2.54	4.99	6.29

In general, crop performance in terms of number of mature pods was better in the second date of sowing and ICGV 86031 and NCAc 343 were identified as tolerant and susceptible to high temperature stress, respectively (Table 1). The HI declined drastically in all the culrivars, irrespective of date of sowing and locations; for example, HI was only 0.28 in TKG 19A in first date of sowing at Hanumangarh. Such a low HI was mainly due to greater reduction in number and size of the reproductive sink than the vegetative mass. Several advanced breeding lines developed at Hanumangarh and Durgapura such as RS 1, RGs 332, 335, 337, 340, and 280, and DRGs 101, 102, and 103 were included as local checks. In general, these lines performed better than other lines and RG 335 gave highest pod yield (419 g m^{-2}) in first date of sowing at Durgapura. DRG 101 and RS 1 were also among the high pod yielding lines at Durgapura in the second date of sowing (Table 1). Thus the genotypes with less number of pegs may be considered susceptible for high temperatures during the pollination phase, whereas the genotypes with higher number of mature pods and mass may be considered as tolerant to high temperature both during pollination and pod development phase.

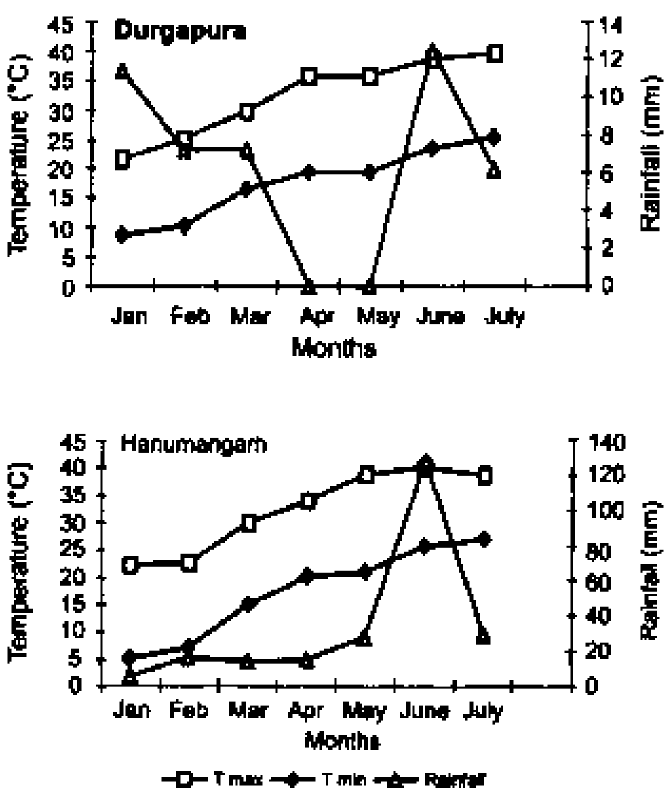

Figure 1. Weather parameters during groundnut crop growth period at Durgapura and Hanumangarh in Rajasthan, India, 1996 summer season (February-July).

Pod yield, in general, was high in some genotypes irrespective of locations and dates of sowing [specific leaf area (SLA) (cm g^{-1}) is given in parentheses for each genotype]: TKG 19A (170), CSMG 84-1 (185), Kadiri 3 (205), ICGV 86031 (140), ICGS 76 (145), and TG 22 (150). The SLA of some of these genotypes, when compared with others like ICG 476 (210) and ICG 4747 (201) showed that except Kadiri 3 all the genotypes fall in the medium and low SLA group, i.e., thicker leaves. Also, ICGS 76 was found to be tolerant to high temperature on the basis of studies conducted on leaf membrane thermostability at the National Research Centre for Groundnut (NRCG), lunagadh, Gujarat, India. We feel there is a need to study the relationship between SLA and high temperature tolerance and if such relationship is discovered then it would be easier to identify heat tolerant genotypes. The genotypic variations may also be exploited to enhance genetic resources for high temperature tolerance.

More Efficient Breeding of Drought Resistant Groundnut in India and Australia

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The yield of groundnut *(Arachis hypogaea)* in India and Australia is usually severely constrained by drought during crop growth, arising from unpredictable rainfall combined with high evaporative demands and production on low water-holding capacity soils where they are grown. The breeding of more drought resistant genotypes has been a long-term goal of groundnut improvement research in the Indian Council of Agricultural Research (ICAR), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India, and Queensland Department of Primary Industries (QDPI), Australia.

New opportunities to develop higher yielding drought tolerant groundnut genotypes emerged in the Australian Centre for International Agricultural Research (ACIAR)-funded project on "Selection for water-use efficiency (VVUE) in Food Legumes" (PN 9216) implemented in India during 1993-98, which developed a detailed understanding of the physiological factors determining yield in water-limited environments (Wright and Nageswara Rao 1994, Wright et al. 1996). A simple crop analytical model has been used to analyze pod yield variation under water limited conditions into three functional components following the framework proposed by Passioura (1977):

Pod yield = Water transpired (T) x Water-use efficiency (TE) x Harvest index (HI)

A major outcome of this project was the development of economical, rapid, and easily measured surrogate measurable for each of these traits, thus allowing their potential quantification in large numbers of germplasm and breeding populations.

Plant breeders and crop physiologists now believe more rapid progress can be aided by *a priori* knowledge of the physiological basis of crop performance under drought conditions. This strategy involves the breeding of better adapted and higher yielding cultivars by identifying reliable traits of drought tolerance to complement conventional breeding programs. This knowledge, the germplasm sources, and enthusiastic team spirit as well as continued support from ACIAR, ICAR, and ICRISAT provided an excellent opportunity for development and implementation of another follow-up ACIAR-funded project (CS 97/114) "More Efficient Breeding of Drought Resistant Peanuts in India and Australia" during 1997-2000 in India and Australia. This project involved collaboration between research centers of the All India Coordinated Research Project (AICRP), agricultural universities in India, ICRISAT, and QDPI (Table 1).

The project CS 97/114 was aimed to implement and apply the physiological knowledge generated in the previous project to test whether indirect selection using the trait approach can improve the efficiency of selection for drought resistance in large-scale groundnut breeding programs, involving breeders, physiologists, and modelers in a truly collaborative research program.

Specific Objectives of the Project

1. To develop more efficient screens and selection methods for yield component traits through better physiological understanding, and giving special attention to the soil-plant analyses development (SPAD) chlorophyll meter readings (SCMR).
2. To make crosses involving parents identified for high TE, T, and HI as well as combining them in the background of locally adapted varieties, then evaluate and validate the use of physiological selection traits to achieve superior yield performance in appropriate target environments in both Australia and India.
3. To make a quantitative assessment of the cost-benefit of using indirect selection methods compared to conventional yield selection approaches for the identification of drought resistant groundnut cultivars.

Project Implementation and Progress

The breeding and selection program was implemented at four centers in India [ICRISAT, Patancheru; National Research Centre for Groundnut (NRCG), Junagadh; Oilseeds Research Station, Jalgaon; and Regional Agricultural Research Station, Tirupati] and at one center in

Table 1. Partners involved in the ACIAR-funded groundnut project.

Institution	Personnel
Australia	
Queensland Department of Primary Industries Farming Systems Institute PO Box 102 Toowoomba Qld 4680	Dr GC Wright Dr Rao CN Rachaputi (RCN) Mr AL Cruickshank Mr R Strahan Mr J Page Mr D Fresser
India	
International Crops Research Institute for the Semi-Arid Tropics Patancheru 502 324 Andhra Pradesh	Dr SN Nigam Dr S Chandra Dr HS Talwar Mr B Manohar Ms K Sridevi Rupa
All India Coordinated Research Program (AICRP) on Groundnut National Research Centre for Groundnut (NRCG) PB no. 5 Junagadh 362 001 Gujarat	Dr MS Basu Dr A Bandyopadhyay Dr RK Mathur Dr Manivel
Regional Agricultural Research Station Acharaya NG Ranga Agricultural University Tirupati 517 502 Andhra Pradesh	Dr PV Reddy Dr RP Vasanthi
Agricultural Research Station Acharaya NG Ranga Agricultural University Anantapur 515 001 Andhra Pradesh	Dr T Yellamanda Reddy Dr S Vasundhara
Oilseeds Research Station Mahatma Phule Krishi Vidyapeet Jalgaon 425 001 Maharashtra	Dr MP Deshmukh Dr RB Patil
Regional Research Station Tamil Nadu Agricultural University Vriddhachalam 606 001 Tamil Nadu	Dr SE Naina Mohammed Dr Vindhiya Varman
Agricultural Research Station AICRP on Groundnut Durgapura Jaipur 302 018 Rajasthan	Dr SN Sharma Dr KN Sharma
Maharana Pratap University of Agriculture and Technology Udaipur 313 001 Rajasthan	Dr AK Nagda
University of Agricultural Sciences GKVK Campus Bangalore 560 065 Karnataka	Prof M Udayakumar Dr MS Sheshshayee Dr H Bindu Madhava

Australia (QDPI, Kingaroy) during 1997-99. The selected progenies were evaluated during 2000-2001 seasons at 8 locations in India and 6 locations in Australia.

The project has made significant progress in several areas, and highlights of outputs to date are summarized below:

More efficient screens and selection methods for yield component traits:

The current project assessed the possible application of a hand-operated portable SPAD-chlorophyll meter in assessing specific leaf area (SLA), specific leaf nitrogen (SLN), and TE in pot culture and field experiments. The results have shown that when protocols for leaf sampling and SLA measurements were followed, SCMR can be a very effective surrogate measure of SLA and hence TE in groundnut genotypes (Nageswara Rao et al. 2001). Further studies at the University of Agricultural Sciences, Bangalore, India have reconfirmed these findings by establishing strong relationship between SCMR, TE, and carbon isotope discrimination (Sheshshayee et al., in press).

Evaluation and validation of the use of physiological selection traits to achieve superior yield performance in appropriate target environments in both Australia and India:

- Parents identified in the previous Project (PN 9216) have been used to make bi-parental crosses; crosses of these with locally adapted varieties were made in the four breeding centers in India and in the breeding program in Australia.
- The trait-based selection method used "Selection Index" as a criterion to identify progenies with high levels of desired traits (T, TE, and HI) as well as seed yield (Chandra et al., unpublished), whereas in the empirical method conventional selection methods were used.
- Overall, there was no difference between empirical and physiological trait-based selection in development of higher yielding genotypes in either India or Australia. However, trait-based selection retained high-yielding progeny that also had higher transpiration efficiency; i.e., trait-based selection retained useful genotypes that would have been discarded with conventional empirical selection.
- In India, progenies have been developed that are significantly higher yielding than locally adapted varieties in each of the main groundnut growing regions of India in both rainy (rainfed) and postrainy (irrigated) seasons.
- In Australia, some short-season progenies with very low aflatoxin levels in drought environments and a few other progenies with high blanchability (a desirable quality attribute) have been identified.

Cost-benefit analysis of using indirect selection methods compared to conventional yield selection approaches:

An economic scenario analysis of the benefits of the ACIAR research project in developing elite groundnut genotypes showed that the adoption (25% after 10 years) of a variety with an average yield advantage of 137 kg ha^{-1} seed over the best local check variety, would yield economic benefits equivalent to a net present value of Rs 7197 million (Australian $ 287 million) in 10 years after release of the variety in India.

A similar analysis with elite groundnut genotypes with the yield advantage of those identified in the Indian research component (e.g., 20% yield benefit over local checks) in Australia showed that the adoption (25% after 10 years) would yield economic benefits equivalent to a net present value of Australian $ 4.8 million in 10 years after release of the variety in country.

Review Report

The project has concluded with the final review meeting held during 25-27 February 2002, at ICRISAT, India. The review team members were Dr Ray Shorter, CSIRO Plant Industry, Brisbane, Australia, and Prof. Arumugakannu Narayanan, Emeritus Scientist (ICAR), Sugarcane Breeding Institute (SBI), Coimbatore, India.

A few excerpts from the Review Report follow:

"The Project Leaders have developed a very strong cooperative and collaborative culture among research managers from the participating institutions and scientists in both countries engaged in Project activities. Project management has been effective in ensuring that financial and human resources were available to undertake the agreed research activities in ICAR, ICRISAT, and collaborating universities in India, and in QDPI in Australia."

"There have already been significant capacity building and scientific impacts from the Project: skills of Indian scientists have been enhanced through numerous training activities, additional infrastructure has been made available particularly in India, and scientific knowledge of the physiology and breeding of peanut for adaptation to drought has been advanced. There are significant potential community impacts that will be realised when genotypes developed in the Project with, on average, 20% higher yields than local checks in India are released and adopted by Indian farmers."

"Overall the Project has competently addressed the three objectives as specified in the Project proposal. However some additional data analysis is required to fully extract valuable information from the Project results and so enhance the benefits of the Project for continuing peanut breeding and research activities in both countries."

The outputs from the project and the proceedings of the final review meeting are soon to be published as an ACIAR Technical Report.

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Performance of Introduced Medium-duration Groundnut Genotypes in Eastern Sri Lanka

Kumuthini D Harris and V Arulnandhy (Faculty of Agriculture, Eastern University, Chenkalady, Sri Lanka)

Although groundnut *{Arachis hypogaea)* is a minor crop in Sri Lanka, there is good scope to increase its cultivation in the country. Currently, it is grown on 9896 ha with a production of 5912 t. The average national productivity is 597 kg ha^{1} (FAO 1996). Because of its low yield, farmers do not embark on its large-scale cultivation. The primary reason for low yield in Sri Lanka is the non-availability of suitable varieties for cultivation. Therefore, the Eastern University located at Chenkalady in eastern Sri Lanka has been testing groundnut varieties through a collaborative program with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India. We compared the performance of 14 groundnut varieties of ICRISAT origin with Red Spanish, a local check variety.

This investigation was carried out at the Eastern University farm, Chenkalady during June-September 1996 (Experiment 1) and February-May 1997 (Experiment 2). The region falls within the dry zone of Sri Lanka and under the DL_2 agro-ecological zone. The mean annual rainfall ranges from 1600 to 2130 mm and the mean temperature during experimentation was 30-32°C. The texture of the soil is sandy (<20% silt and clay with structure-less single grain).

The 14 test varieties (ICGVs 86885, 86928, 88311, 88329, 88330, 88332, 88335, 88336, 88338, 88342, 88345, 88347, 88348, and 89318) and the local check (Red Spanish) were planted in a randomized complete block design (RCBD) with three replications. The cultivation practices were in accordance with the recommendations of the Department of Agriculture, Sri Lanka. All the varieties were harvested at 115-120 days after sowing for yield estimation. The yield and yield components such as number of pods $plant^{-1}$, shelling percentage, and 100-seed mass were recorded at harvest.

Experiment 1

The pod yield varied from 4592.8 kg ha"[1] in ICGV 89318 to 2067.6 kg ha[1] in Red Spanish (Table 1). ICGV 89318 produced 122% more yield than Red Spanish which was significantly greater at 5% level. The top yielder ICGV 89318 differed significantly in yield from the rest of the varieties included in the experiment, except ICGV 88345. Number of pods plant[1] was significantly higher in ICGV 88336 than in ICGVs 88329,88311, 88332, and 88338 and Red Spanish. Shelling percentage was highest (69.5) in ICGV 88338 and was significantly higher than that of ICGVs 86928, 88336, 88342, 88347, 89318, and 88332 and Red Spanish. The 100-seed mass was highest (73 g) in ICGV 88345 followed by ICGV 88338, and it significantly differred from ICGVs 86928, 88330, 88332, 89318, 86885, 88329, 88336, 88342, 88347, and 88348 and Red Spanish. It was low in ICGV 88328 and Red Spanish. In this experiment, ICGVs 89318, 88338, and 86885 performed remarkably well compared to the local check Red Spanish,

Table 1. Performance of ICRISAT groundnut varieties at Chenkalady, Sri Lanka, June-September 1996[1].

Variety	Pod yield (kg ha^{-1})	Number of pods $plant^{-1}$	Shelling (%)	100-seed mass (g)
ICGV 86885	3532.9 bc	10.3 ab	61.7 bcd	46.4 d
ICGV 86928	3199.6 bc	8.2 abed	68.1 ab	52.4 cd
ICGV 88311	3104.1 bc	6.5 cd	59.9 cd	62.7 abc
ICGV 88329	2193.1 de	7.2 bcd	63.5 abc	43.7 de
ICGV 88330	3116.8 be	10.2 ab	65.3 abc	50.7 cd
ICGV 88332	2984.2 bed	5.8 d	52.9 e	52.0 cd
ICGV 88335	3482.0 be	8.4 abed	67.4 ab	53.4 bcd
ICGV 88336	3370.7 bc	11.1a	62.7 bcd	49.4 d
ICGV 88338	3577.4 be	6.5 cd	69.5 a	65.0 ab
ICGV 88342	2799.7 cde	8.0 abed	61.9 bcd	48.4 d
ICGV 88345	3755.1 ab	9.2 abc	67.8 ab	73.0 a
ICGV 88347	3450.7 be	9.0 abcd	59.3 cde	47.7 d
ICGV 88348	3339.6 be	10.4 ab	64.6 abc	45.7 d
ICGV 89318	4592.8 a	10.3 ab	59.4 cde	51.4 cd
Red Spanish (check)	2067.6 e	6.3 cd	56.4 ed	32.7 e

1. Figures followed by the same letter in each column do not differ significantly at $P < 0.05$ based on Duncan's New Multiple Range Test.

Table 2. Performance of eight selected ICRISAT groundnut varieties in Chenkalady, Sri Lanka, February-May 1997[1].

Variety	Pod yield (kg ha^{-1})	Number of pods $plant^{-1}$	Shelling (%)	100-seed mass (g)
ICGV 86885	2328.8 ab	10.0 bc	73.7 a	60.0 bc
ICGV 88335	2415.5 ab	11.0 abc	70.8 a	63.4 bc
ICGV 88336	2624.2 ab	14.0 a	65.3 cd	55.4 cd
ICGV 88338	3162.0 ab	11.0 abc	73.4 a	73.4 a
ICGV 88345	3205.0 a	10.0 abc	64.9 ed	64.7 b
ICGV 88347	2355.5 ab	8.0 c	65.6 bed	50.0 e
ICGV 88348	2539.9 ab	13.0 ab	70.6 abc	57.1 bed
ICGV 89318	2286.6 ab	10.0 bc	59.6 e	56.7 bcd
Red Spanish (check)	2248.8 b	9.0 bc	63.5 ed	40.0 e

1. Figures followed by the same letter in each column do not differ significantly at P <0.05 based on Duncan's New Multiple Range Test.

Experiment 2

Eight varieties that performed well in Experiment 1 were selected for further evaluation. In this experiment, two varieties, ICGV 88345 and ICGV 88338, performed remarkably well compared with the check variety Red Spanish (Table 2). ICGV 88345 ranked first in pod yield (3204 kg ha^1) followed by ICGV 88338 (3162 kg ha^1). It was significantly better than Red Spanish with 42% superiority in pod yield. This variety also gave significantly higher yield than Red Spanish in Experiment 1. ICGV 88345 was comparable to Red Spanish in number of pods $plant^{-1}$ and shelling percentage but its 100-seed mass (64.7 g) was significantly superior to the latter.

Both studies (Experiments 1 and 2) revealed that the ICRISAT variety ICGV 88345 is a potential candidate for introduction into the farming systems of eastern Sri Lanka. However, this variety should be further evaluated in farmers' fields before it is recommended for release.

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On-farm and Participatory Evaluation of Groundnut Varieties for Summer Cultivation in Uttar Pradesh, India

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Uttar Pradesh stands ninth in both area and production of groundnut *(Arachis hypogaea)* in India. An analysis of rainy season groundnut cultivation in Uttar Pradesh has exhibited a definite declining trend during the past two decades due to damage caused by white grub and bud necrosis disease in normal sown and early sown crop, respectively (Singh and Srivastava 1995). There has been a long felt need of early-maturing groundnut cultivars (90-95 days maturity period) that can be used for late planting in the rainy season and also for spring (summer) planting (Sindhu and Pathak 1989). Therefore, 33 short-duration groundnut varieties were evaluated at the Groundnut Research Station (GRS), Mainpuri, Uttar Pradesh during summer and rainy season in 1997-2000 to test

Table 1. Performance of selected short-duration groundnut varieties during summer and rainy season, 1997–2000 (pooled), Groundnut Research Station, Mainpuri, Uttar Pradesh, India.

Variety	Dry pod yield (t ha^{-1})		Insect/disease incidence[1] (%)											
			Anarsia		*Dorylus*		Termite		Early leaf spot		Late leaf spot		Bud necrosis	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
D_4D_8-6	1.51	1.27	1.7	2.6	19.7	8.3	3.9	4.9	7.0	30.0	0.0	4.0	0.0	7.6
D_4D_8-10	1.93	1.22	1.7	3.0	9.1	7.9	1.4	3.4	7.0	28.6	0.0	7.0	0.0	9.5
D_4D_8-14	1.77	1.32	1.7	4.0	15.4	6.7	0.6	2.6	7.3	33.0	0.0	8.7	0.0	6.8
ICGV 93468	1.76	1.50	1.3	2.3	9.8	5.6	0.2	4.8	5.0	32.0	0.0	5.7	0.0	6.1
Kaushal (control)	1.12	1.35	1.4	3.4	12.6	7.6	0.3	6.7	6.0	37.8	0.0	6.8	0.0	12.8
SE ±	0.14	0.10	0.2	0.3	2.8	1.9	0.9	0.6	0.9	2.2	0.0	1.1	0.0	1.9

1. *Anarsia* (pod borer) – Number of shoots bored in 10 plants in a plot.
Dorylus (pod borer) and termite – Percentage of pods bored.
Early/Late leaf spot – Disease score (1 = No disease, 0%; 2 = Lesions present largely on lower leaves, no defoliation, 1–5%; 3 = Lesions present largely on lower leaves, very few on middle leaves, defoliation of some leaflets of lower leaves, 6–10%; 4 = Lesions on lower and middle leaves but severe on lower leaves, defoliation of some leaflets of lower leaves, 11–20%; 5 = Lesions present on all lower and middle leaves, more defoliation of lower leaves, 21–30%; and 6 = severe lesions on lower and middle leaves, lesions present but less severe on top leaves, extensive defoliation of lower leaves, defoliation of some leaflets of middle leaves, 31–40%.)
Bud necrosis – Percentage of affected plants at 60 days after emergence.

their feasibility to improve the socioeconomic status of farmers. These varieties were received from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (29 ICGV and 4 UAS Dharwad varieties) and included ICGVs 96337, 96412, 96395, 96433, 96443, 96342, 96332, 96399, 96395, 96329, 95290, 95271, 94357, 94299, 95299, 95296, 95319, 95311, 94313, 96357, 96356, 96360, 96349, 96359, 95337, 93468, 96453, 93460, 86158, DG-40, D_4D_8-6, D_4D_8-10, and D_4D_8-14. All the test varieties gave higher yield in summer as compared to rainy season due to less incidence of insect pests and diseases. But the incidence of pod borer {*Dorylus* sp) was higher in summer than in the rainy season. Varieties D_4D_8-10, D_4D_8-14, ICGV 93468, and D_4D_8-6 were found most suitable during summer and they produced 1.93, 1.77, 1.76, and 1.51 t ha^{-1} dry pod yield, respectively (Table 1) in groundnut-wheat *(Triticum* aestivum)-groundnut cropping system at GRS, Mainpuri.

Due to the high yield potential and low incidence of insect pests and diseases during summer, the above varieties were considered quite safe for farmers as well as the environment, because there was least requirement of pesticides. A participatory evaluation with 10 farmers in Rajpura village of district Mainpuri was conducted in summer season of 2001. Groundnut pod yield

Table 2. Pod yield of groundnut varieties on farmers' fields during summer season 2001, village Rajpura, Mainpuri district, Uttar Pradesh, India.

Name of farmer	Variety	Area sown (ha)	Yield (t ha^{-1})
Ram Das	D_4D_8-10	0.16	3.00
Nand Ram	D_4D_8-10	0.16	3.00
Balak Ram	D_4D_8-10	0.16	2.75
Rajpal	D_4D_8-10	0.12	2.00
Raghuvir Singh	D_4D_8-10	0.12	2.10
Ram Swaroop	D_4D_8-10	0.08	3.00
Ram Swaroop s/o Misrila	D_4D_8-10	0.16	2.75
Ram Prakash	D_4D_8-6	0.16	2.50
Bishun Dayal	D_4D_8-6	0.12	2.35
Jog Raj	ICGV 93468	0.08	2.00
Mean		0.13	2.55

varied from 2.0-3.0 t ha^{-1} in maize *(Zea mays)*-potato (*Solanum tuberosum*)-*groundnut* cropping system (Table 2). The crop was sown at 30 x 10 cm spacing around 15 March in sandy loam soil with a seed rate of 80 kg ha^{-1} and with 10 kg nitrogen (N) ha^{-1} 30 kg $P_2O_5 ha^{-1}$ 45 kg K_2O ha^{-1}, and 200 kg gypsum ha^{1} at the time of last harrowing. The crop required four irrigations and was harvested in 90 days. It was further observed that produce of rainy season soon after harvest could be utilized for summer sowing and vice-versa. Farmers in Rajpura village have now started to multiply seed of these varieties in both the seasons and are selling it to needy farmers. This is the first success of summer groundnut cultivation with farmers' participation in Uttar Pradesh. Farmers have covered about 25 ha as per the availability of the seed and have adopted summer groundnut cultivation because they are getting remunerative returns in comparison to other summer crops such as mung bean *(Vigna radiata),* black gram *(Vigna mungo),* and sunflower *(Helianthus annuus)* (Table 3). A farmer fair and field visit was organized in June 2001. This event promoted the adoption of summer groundnut cultivation by participating and non-participating farmers.

Table 3. Comparative output of different crops during summer season 2001, Uttar Pradesh, India.

Crop	Average yield (t ha^{-1})	Average price (Rs t^{-1})	Total returns (Rs ha^{-1})
Sunflower	1.5	8 000	12 000
Mung bean	1.0	15 000	15 000
Black gram	0.8	15 000	12 000
Groundnut	3.0	20 000	60 000

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Groundnut Releases/Pre-releases

New Groundnut Variety GG 7 Released in Gujarat and Rajasthan, India

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Gujarat is the largest groundnut *(Arachis hypogaea)* growing state of India with an area of 0.2 million ha and production of 0.25 million t of pods.

Figure 1. Groundnut variety GG 7 released in Gujarat and Rajasthan, India.

Table 1. Quality characteristics of groundnut variety GG 7 and check varieties.

Quality	GG7	JL 24	SB XI	GG 2
Shelling outturn (%)	69.3	70.7	71.3	75.0
Oil (%)	49.0	47.9	48.5	48.8
Sound mature seed (%)	91.0	90.0	89.0	94.0
100-seed mass (g)	47.7	45.3	38.3	34.5

At present, Spanish bunch groundnut varieties occupy about 30% of the total groundnut area grown in the state. The remaining 70% area is covered by Virginia bunch and Virginia runner groundnuts. The Spanish bunch varieties such as SB XI (J 11) and GG 2 currently grown in the state have medium size pods and seeds. The seeds of these varieties are exported with trade name "Java" and are used for making peanut butter. The newly released Spanish bunch variety GG 7 has large pods and seeds (Fig. 1). The seeds are uniform in size and have attractive seed coat color.

GG 7 is bred and developed from the cross S 206 x FESR 8-1-9-B-B. It was released and notified in 2001 for rainy season (kharif) cultivation in Gujarat and southern part of Rajasthan state. It is erect in growth habit and early in maturity (100 days). Its leaves are elliptical in shape and green in color. Pods are two-seeded and large with moderate reticulation, constriction, and beak. Seeds are large, spheroidal, and pink in color. The seed has 69.3% shelling outturn and 49.0% oil content (Table 1). GG 7 produced 18.8%, 21.3%, and 44.8% higher seed yield than check varieties JL 24, SB XI, and GG 2, respectively (Table 2).

GPBD 4: A Spanish Bunch Groundnut Genotype Resistant to Rust and Late Leaf Spot

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GPBD 4 is a high-yielding, improved Spanish bunch groundnut *(Arachis hypogaea* subsp *fastigiata* var *vulgaris)* cross derivative developed at the Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad, Karnataka, India. It is resistant to late leaf spot *(Phaeoisariopsis personata)* and rust *(Puccinia arachidis).* GPBD 4 is early maturing with high pod growth rate, partitioning coefficient, and shelling outturn. It has high oil content and oleic acid/linoleic acid (O/L) ratio than susceptible ruling cultivars besides having desirable pod and seed features (Motagi 2001). It is in pre-release phase in Zone VIII (Northern Transitional Tract) of Karnataka.

Origin and Development

GPBD 4 is derived from a cross between KRG 1 and ICGV 86855. KRG 1 (Selection from Argentine) is an early maturing, Spanish bunch local cultivar susceptible to foliar diseases developed at the Regional Research Station, Raichur, Karnataka. ICGV 86855 (A *hypogaea* x *A. carderiasii)* is a Virginia *(A. hypogaea* subsp *hypogaea* var *hypogaea)* bunch interspecific derivative, resistant to rust and late

Table 2. Average pod and seed yield (kg ha^{-1}) of GG 7 during the rainy season at four locations in India[1].

	GG7		JL 24		SB XI		GG 2	
Year of testing	Pod	Seed	Pod	Seed	Pod	Seed	Pod	Seed
1997	2024	1393	1584	1115	1612	1170	1620	924
1998	1897	1312	1602	1158	1588	1134	1133	843
1999	2791	1836	2464	1578	2263	1402		
Mean	2149	1465	1786	1233	1742	1209	1425	891
% increase over GG 7			20.3	18.8	23.3	21.3	30.9	44.8

1. Trials were conducted al Junagadh, Amreli, and Navsari in Gujarat, and at Udaipur in Rajasthan.

Table 1. Pod yield (t ha^{-1}) of GPBD 4 in different trials during rainy season at Dharwad, Karnataka, India.

	Station trials			Multilocation trials[1]				Farm trials		
Variety	1997	1998	Mean	Dharwad	Sankeshwar	Nippani	Mean	2000	2001	Mean
GPBD 4	3.77	3.97	3.87	4.02	4.06	3.16	3.75	1.72	1.21	1.46
JL 24 (control)	2.27	2.39	2.39	3.58	2.97	3.02	3.19	1.62	1.02	1.32
% yield increase over control	66.1	66.2	66.2	12.5	37.0	4.8	17.7	5.8	19.0	10.9

1. During 1999, 2000, and 2001.

leaf spot. It was developed at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India. GPBD 4 was developed through pedigree selection in F_2 generation for rust and late leaf spot resistance using infector row technique and for other agronomically desirable characters. The selected F_2 plant was advanced until F_6 generation. The full pedigree of GPBD 4 is D 39d (KRG 1 x ICGV 86855 F_2-B_1-B_1-B_1-B_1). It has been registered with the National Bureau of Plant Genetic Resources (NBPGR), New Delhi, India (registration number INGR 01031) (Gowda et al., in press).

Performance

In station trials conducted over two years under disease epidemics, GPBD 4 produced a mean pod yield of 3.87 t ha^1, 66.2% more than control cultivar JL 24 (Table 1). The oil (109.9%) and haulm (50.3%) yields of GPBD 4 were also significantly higher than those of JL 24 (Table 2). The average pod yield of GPBD 4 across three locations (Dharwad, Nippani, and Sankeshwar) and three rainy seasons (1999, 2000, and 2001) was 3.75 t ha"[1] compared to 3.19 t ha^{-1} for check variety JL 24, accounting for 17.7% advantage (Table 1). In farm trials conducted during rainy season in 2000 (at 12 sites) and 2001 (at 8 sites), GPBD 4 out-yielded JL 24 by 10.9% (Table 1). In Zone **II,** across two locations (Raichur and Bheemarayangudi) during 2000 **and** 2001 rainy season, **GPBD 4** recorded 30.9% **and** 89.6% **higher pod** yield **than** check cultivars **R 8008 and JL 24,** respectively. **In All India Coordinated Research Project (AICRP) trials in Zone V (across** nine locations) during 2000 rainy season, GPBD 4 had 24.9% higher pod yield than JL 24. Reduction in yield of pod (13%), oil (14.9%), and haulm (15.8%) due to foliar diseases was markedly less in GPBD 4 as compared to 40.3%, 42.6%, and 48.6%, respectively in JL 24 (Motagi et al. 2000a, 2000c, Motagi 2001).

Plant and Seed Characters

GPBD 4 has an erect growth habit with sequential branching pattern. It has medium-size wide-elliptic, dark green leaves (IBPGR and ICRISAT 1992). It has four primary and two secondary branches. It matures in 105-110 days after sowing in the rainy season at Dharwad. It has medium-size pods (22.3 mm average length and 8.9 mm average width) with slight reticulation, slight beak, and moderate constriction. The majority of pods are two seeded with an average shelling outturn of 76%. The seeds are tan and contain 48% oil with 1.76 O/L ratio; the 100-seed mass is 42 g (Motagi et al. 2000c).

Reaction to Diseases and Insect Pests

GPBD 4 was evaluated for rust and late leaf spot over three seasons and locations **and rated** a mean score of 3 and **4** for rust **and late leaf spot** compared **to** 8 **and** 9 respectively, **for JL 24 on a 1-9 disease rating** scale, **where** 1 = **no disease and** 9 = **80-100%** disease **(Table** 2). **It** is **less susceptible to bud necrosis disease and the defoliating insect** ***Spodoptera*** *litura* **compared to JL 24 (AICRP 2001). It is moderately efficient in iron absorption in calcareous soils (Motagi et al. 2000b).**

Table 2. Performance of GPBD 4 under foliar diseases epidemic during 1998 rainy season at Dharwad, Karnataka, India.

Variety	Pod yield ($t\ ha^{-1}$)	Oil yield ($t\ ha^{-1}$)	Haulm yield ($t\ ha^{-1}$)	Shelling outturn (%)	Oil content (%)	100-seed mass (g)	O/L ratio[1]	Pod growth rate	Partitioning coefficient	Days to maturity	Score[2] LLS	Score[2] Rust
GPBD 4	3.97	1.49	1.40	78.7	48.0	37.6	1.78	24.2	63.1	105–110	4	3
ICGV 86590 (resistant)	3.06	0.71	1.03	57.0	39.9	37.4	0.93	21.3	59.8	115–120	8	3
ICGV 87165 (resistant)	4.12	1.07	2.43	59.4	43.5	49.6	1.56	19.0	42.5	120–125	4	3
JL 24 (susceptible)	2.39	0.70	0.85	67.6	43.7	41.6	0.96	19.9	62.8	100–105	9	8
CD (5%)	0.52	0.21	0.14	3.6	2.0	3.2	0.1	0.3	3.3	–	–	–
CV (%)	6.3	10.9	6.9	3.2	2.4	4.5	4.3	0.9	3.0	–	–	–

1. O/L = Oleic acid/linoleic acid.
2. Mean score rated on 1–9 disease rating scale, where 1 = no disease and 9 = 80–100% disease incidence.

Seed Availability

The Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad maintains the breeder seed of GPBD 4. Large quantities of basic seed are also produced for sale. Seeds of GPBD 4 are deposited with NBPGR genebank. Limited quantities of seed, without limitation on the use, is available on request with Dr MVC Gowda, Professor, Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad 580 005, Karnataka, India (email: mvcgowda@satyam.net.in; fax: 0836-448349).

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Mutant 28-2: A Bold-seeded Disease and Pest Resistant Groundnut Genotype for Karnataka, India

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Groundnut *(Arachis hypogaea)* is mainly crushed for oil in India. Decorticators supply seed to oil millers but bold seed, hand picked selections (HPS) from the same seed lots are used for confectionery purpose. HPS fetch a higher premium of Rs 4000-5000 t^{-1} and among the popular local Spanish bunch cultivars, JL 24 is preferred because of its bold seed. Mutant 28-2 is superior to JL 24 due to higher pod yield, bolder seeds, and resistance to late leaf spot and pests *(Spodoptera* and thrips). It is in pre-release phase in Zone VIII (Northern Transitional Tract) of Karnataka, India.

Origin and Development

Mutant 28-2 is a high-yielding improved Spanish groundnut *(A. hypogaea* subsp *fastigiata* var *vulgaris)* variety developed at the University of Agricultural Sciences, Dharwad, Karnataka. It is an ethyl methane sulfonate (EMS) (0.5%) induced mutant derivative of Valencia line VL 1. VL 1 is **a** mutant derivative of a taxonomically important variant, Dharwad Early Runner (DER) (Gowda et al. 1989). DER is a derivative of cross Dh 3-20 x CGC 1. Dh 3-20 is a Spanish bunch genotype while CGC 1 is a Virginia *(A. hypogaea* subsp *hypogaea* var *hypogaea)* runner. Mutant 28-2 is resistant to late leaf spot because of elimination of suppressor element present in DER by mutation (Motagi et al. 2000a). Mutant 28-2 was selected from a group of secondary mutants of VL 1 because of its resistance to late leaf spot and desirable agronomic features. It has been registered with the National Bureau of Plant Genetic Resources (NBPGR), New Delhi, India (registration number INGR 98003) as leaf spot, army worm, and thrips resistant germplasm (Gowda et al. 1998).

Performance

In station trials at Dharwad during 1996 and 1997 rainy season, Mutant 28-2 out-yielded the check variety JL 24 by 31.9% (Table 1). Under disease epidemic at Dharwad, it has recorded significantly less reduction in yields of pod (11.2%), seed (11.8%), and haulm (9.2%), and in 100-seed mass (11.4%) as compared to 40.4%, 42.3%, 51.5%, and 20.3%, respectively in check variety JL 24 (Table 2). Mutant 28-2 gave 9.6% higher pod yield than JL 24 in advanced trials at three locations over two years. In large-scale farm trials at 16 sites during 1999-2000, it gave 14.5% more pod yield than JL 24 (Table 1). Mutant 28-2 has bolder seed with 100-seed mass of 54.07 g as against 41.63 g in JL 24 (Table 2). It has high oil content (47%) and oleic acid/linoleic acid (O/L) ratio (0.99) as compared to JL 24 (44% and 0.96 respectively) (Motagi et al. 2000b).

Table 1. Pod yield (t ha^{-1}) of Mutant 28-2 in different trials during rainy season at Dharwad, Karnataka, India.

	Station trials			Multilocation trials			Farm trials		
Variety	1996	1997	Mean	1997	1998	Mean	1999	2000	Mean
Mutant 28-2	3.92	3.80	3.86	3.75	2.17	2.96	1.36	1.70	1.54
JL 24 (control)	2.57	3.28	2.93	3.53	1.87	2.70	1.07	1.62	1.35
% yield increase over control	52.6	15.8	31.9	6.2	16.0	9.6	26.7	5.0	14.5

Table 2. Performance of Mutant 28-2 under disease epidemic during 1998 rainy season at Dharwad, Karnataka, India.

	Pod yield			Seed yield			Haulm yield			100-seed mass		
Variety	Unprotected ($t\ ha^{-1}$)	Protected ($t\ ha^{-1}$)	Reduction (%)	Unprotected ($t\ ha^{-1}$)	Protected ($t\ ha^{-1}$)	Reduction (%)	Unprotected ($t\ ha^{-1}$)	Protected ($t\ ha^{-1}$)	Reduction (%)	Unprotected (g)	Protected (g)	Reduction (%)
Mutant 28-2	3.83	4.31	11.2	2.65	3.00	11.8	1.18	1.30	9.2	54.07	60.93	11.4
JL 24 (control)	2.39	3.99	40.4	16.11	2.79	42.3	0.85	1.75	51.5	41.63	52.30	20.3
CD (5%)	5.17	4.64	-	4.96	4.99	-	1.39	1.26	-	3.24	4.69	-
CV (%)	6.32	6.29	-	11.64	9.62	-	6.88	4.63	_	4.51	5.32	-

Plant and Seed Characters

Mutant 28-2 is a Spanish bunch variety having decumbent-3 growth habit, and sequential branching with stem pigmentation. It has narrow elliptic green leaves with acute leaflet tip and hairy leaf margin (IBPGR and ICRISAT 1992). Mutant 28-2 has four primary and 4-5 secondary branches. It has clustered pod bearing with moderately constricted pods. It is characterized by the absence of reticulation and pod beak. Most of the pods are two-seeded with an average shelling outturn of 70%. Seed is dark tan in color. Mutant 28-2 matures in 100-105 days during rainy season.

Reaction to Diseases and Insect Pests

At Dharwad, late leaf spot score was 5 in Mutant 28-2 and 8 in JL 24 on a 1-9 disease rating scale (Motagi et al. 1996). Mutant 28-2 had only 10% of the leaf area damaged due to armyworm *(Spodoptera litura)* as against 38.7% in check variety JL 24 (Rajendraprasad et al. 2000). It had least damage (19.2%) due to thrips as against 46.7% in JL 24. It had colonization severity of 3.0 for *Aspergillus flavus* as compared to 3.7 in JL 24 on a 1-4 scale (Varma et al. 2001).

Seed Availability

The University of Agricultural Sciences, Dharwad maintains **the** breeder seed **of Mutant** 28-2. Seed **of** Mutant 28-2 is also deposited with **NBPGR** genebank. A small quantity **of** seed is available on request for research purpose with Dr MVC Gowda, Professor, Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad 580 005, Karnataka, India (email: mvcgowda@satyam.net.in; fax: 0836-448349).

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Biotechnology

Molecular Diversity among Groundnut Varieties Differing in Drought Tolerance Traits

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India ranks first in groundnut *(Arachis hypogaea)* area and second in production after China. Groundnut is grown annually on about 8 million ha, and 80% of this is cultivated under rainfed conditions. The remaining 20% is grown under protected irrigation conditions during postrainy (rabi)/summer seasons. The average yield of groundnut under rainfed conditions is 1.0 t ha"[1] compared to 1.6 t ha^{-1} in postrainy irrigated conditions. Drought is the major abiotic constraint to groundnut productivity under rainfed conditions in India. The three patterns of drought that affect groundnut crop are early drought, mid-season drought, and end-of-season drought. Early drought for 15-20 days soon after emergence is beneficial for the groundnut crop; the latter two forms of drought cause substantial reduction in groundnut yield (Rao et al. 1989). Several sources of tolerance to mid- and/or end-of-season drought have been identified in groundnut (Rao et al. 1989). Harvest index (HI), specific leaf area (SLA), total transpiration, transpiration efficiency, and water-use efficiency (WUE) are associated with drought tolerance in groundnut (Rao et al. 1993).

Knowledge of genetic diversity in a crop species is fundamental to its improvement. Recent studies revealed polymorphism in cultivated groundnut using DNA amplification finger printing (DAF) and amplified fragment length polymorphism (AFLP) (He and Prakash 1997); random amplified polymorphic DNA (RAPD) (Bhagwat et al. 1997, Subramanian et al. 2000, Dwivedi et al. 2001); and simple sequence repeats (SSRs) (Hopkins et al. 1999). The objective of this study was to assess diversity among 37 groundnut genotypes differing in drought tolerance traits. This will be used to assess the heterotic potential of crosses and their ability to release transgressive segregation in later generations. Diversity estimates will also be used to select diverse lines for mapping and genetic enhancement.

Young leaves from 2-week-old plants, grown under glasshouse conditions, were bulk harvested for each line and immediately placed in liquid nitrogen for DNA extraction using cetyltri-methylammonium-bromide (CTAB) method (Saghai-Maroof et al. 1984). Four SSR assays (primer sequence identity pPGP seq 2F05; pPGP seq 2B10; pPGP seq 3D09; and pPGP seq 1B09) (ME Ferguson, ICRISAT, personal communication) were performed on 37 genotypes differing in drought tolerance traits. The polymerase chain reaction (PCR) mixture (20 ul) consisted of 1.0 ul (5 ng) of genomic DNA, 2.0 µl of 10x PCR buffer, 4.0 µl of 10 mM magnesium chloride, 1.5 ul of 2 mM dNTPs, 2.5 ul of 4 p moles SSR primer (both forward and reverse), 8.2 ul of double distilled water, and 0.8 units Taq DNA polymerase. Amplification was performed in 0.2 ml thin-walled tubes placed in a Thermal Cycler (DYAD Engine Peltier Thermal cycler, MJ02451, USA). The samples were initially incubated at 94°C for 2 min, and then subjected to 35 repeats of the following cycle: 94°C for 45 sec, 60°C for 1 min, 72°C for 1.5 min followed by a final extension of 10 min at 72°C. PCR products were separated using polyacrylamide gel electrophoresis and visualized using silver staining. The amplified fragments were scored as T for the presence and '0' for the

Table 1. Genotype pairs suggested for diversification and mapping quantitative trait loci (QTL) associated with transpiration (T), transpiration efficiency (TE), and harvest index (HI) in groundnut.

Trait	Genotype pair	Dissimilarity (D_{ij}) range
For diversification of HI	ICGV 94100 with ICGVs 94106, 94113, 97068, 97093, 99247, 99231, 99235, and 99236; Chico	0.50 to 0.78
	ICGV 94106 with ICGVs 94113, 96294, 97068, 97093, 98381, 98382, 99237, 99238, 99249, 99241, and 99243	0.50 to 0.56
	ICGV 97068 with ICGVs 97093, 98381, 98382, 99237, 99238, 99249, 99241, 99243, 99247, 99231, 99233, 99235, 99236, and 99249	0.50 to 0.75
For combining T, TE, and HI	ICGV 97068 with CSMG 84-1	0.78
For developing recombinant inbred lines (RILs) for mapping QTL for HI	TMV 2 Narrow Leaf Mutant with ICGVs 94106, 97068, and 99247; Chico	0.50 to 0.56
	CSMG 84-1 with ICGVs 94100, 94113, 97068, and 99235	0.56 to 0.78

absence of a band from higher to lower molecular weight. Similarity coefficients (Nei and Li 1979) were used to determine pair-wise genetic similarity between lines and were subtracted from unity to derive genetic dissimilarity (D..).

Differences in DNA profiles were observed in 537 of the 666 pair-wise comparisons analyzed among 37 drought tolerant genotypes. The D_{ij} values ranged from 0.11 to 0.78. Forty-two or these comparisons showed D_{ij} values of over 0.50 (Table 1). ICGV 94100 with ICGV 94106, ICGV 97068, ICGV 99247, and Chico; and ICGV 97068 with CSMG 84-1, ICGV 99231, ICGV 99247, and ICGV 99236 showed large differences (D_{ij} values of 0.75 to 0.78) in their DNA profiles. ICGV 99247 and CSMG 84-1 belong to subsp *hypogaea* and the remaining genotypes to subsp *fastigiata.* CSMG 84-1 has been released in India and ICG 1471 (55-437) in Senegal. The former possesses high transpiration (T) and transpiration efficiency (TE), and low harvest index (HI). The latter is early maturing, drought tolerant, and resistant to *Aspergillus flavus.* Chico is a source of early maturity and possesses high HI but has very small seed size. The above-mentioned genotype pairs may be crossed to select drought tolerant populations with high HI. The populations derived from genetically diverse parents are expected to release transgressive segregants with high HI and such progenies should perform better under drought environments. CSMG 84-1 should be crossed with ICGV 97068 to select progenies with high T, TE, and HI. This cross may also be used to develop recombinant inbred lines (RILs) for mapping quantitative trait loci (QTL) associated with T, TE, and HI. Other crosses for mapping QTL for HI are TMV 2 Narrow Leaf Mutant (TMV2NLM) with ICGV 94106, ICGV 97068, ICGV 99247, and Chico; and CSMG84-1 with ICGV 94100, ICGV 94113, ICGV 97068, and ICGV 99235. TMV2NLM is an alternately branched mutant selected from TMV 2.

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Molecular Diversity among Accessions Possessing Varying Levels of Resistance to Early Leaf Spot in Groundnut

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Early leaf spot (ELS) *(Cercospora arachidicola)* and late leaf spot (LLS) (*Phaeoisariopsis personata)* are the most important foliar diseases of groundnut *(Arachis hypogaea)* causing yield losses of >50% in the semi-arid tropics. Early leaf spot is also the predominant disease of groundnut in Southern Africa. Several sources of resistance to ELS are reported in the literature (Singh et al. 1997); however, these show only low to moderate resistance. There is a need to identify diverse germplasm that differ in resistance to ELS; these germplasm lines should be intercrossed to select for high level of resistance to ELS. The ELS resistant accessions have not been studied for genetic diversity. Variation in DNA profiles in lieu of phenotypic diversity may be used to identify diverse germplasm. This study was therefore carried out to determine genetic diversity among selected groundnut germplasm with varying levels of resistance to ELS to identify those with distinct DNA profiles for mapping and genetic enhancement in groundnut.

Eighteen random amplified polymorphic DNA (RAPD) assays (Williams et al. 1990), using random oligonucleotide primers (F20, G12, GN13, 115, 118, J17, J18, K2, K12, L6, 03, 07, 09, O10, V12, V15, V16, and V17), were performed on 16 accessions (ICGs 405, 6232, 6709, 6886, 6973, 7501,8521,8529,9987,9989,9991,9995,9998,10000, 10478, and 10914) possessing varying levels of resistance to ELS. These accessions are land races (except ICGs 405, 6232, 6886, and 10478, which are breeding lines) and have originated in South America; these belong to subsp *fastigiata* var *fastigiata.* Young leaves from 2-week old plants, grown under glasshouse conditions, were bulk harvested for each line and immediately placed in liquid nitrogen for DNA extraction following cetyltriniethylammonium-brornide (CTAB) method (Saghai-Maroof et al. 1984). The polymerase chain reaction (PCR) was performed following Dwivedi et al. (2001). The amplified fragments were scored as '1' for the presence and '0' for absence of a band from higher to lower molecular weight. Polymorphism (%) specific to any single primer for a given set of genotypes was estimated as:

$$P = (N_p/N_A)100$$

where N_A is the total number of amplified fragments and N_p is the number of polymorphic fragments. Similarity coefficients (S_{ij}) (Nei and Li 1979) were used to determine pair-wise genetic similarity between lines, and the S_{ij} values were later deducted from unity to derive genetic dissimilarity (D..).

Eighteen primers produced polymorphic differences of 11.7% to 55.0%, with an average of 27.4% per primer. The primers F20, J17, V15, and V16 produced greater polymorphic differences than other primers. This report further confirms the RAPD variation earlier reported in cultivated groundnut germplasm (Bhagwat et al. 1997, Subramanian et al. 2000, Dwivedi et al. 2001). The differences in D_{ij} values among 120 pair-wise comparisons of 16 accessions ranged from 0.041 to 0.305 with an average of 0.1298. These accessions based on foliage damage could be grouped into three classes: resistant to ELS (20 to 40% foliage damaged) (ICGs 405, 9987, 9989, 9991, and 10000); tolerant to ELS (41 to 80% foliage damaged) (ICGs 6232, 6886, 6973, 8529,9995, and 9998); and susceptible to ELS (>80% foliage damaged) (ICGs 6709,7501,8521,10478, and 10914). ICG 405 with ICG 9987 (D.. value 0.1258) and ICG 10000 with ICG 405 (D_{ij} value 0.131), ICG 9989 (D_{ij} value 0.124), ICG 9987 (D_{ij} value 0.181), and ICG 9991 (D.. value 0.154) were relatively distantly related yet resistant to ELS and may therefore be crossed to select progenies with enhanced resistance to ELS. ICG 10914 is highly susceptible to ELS and therefore may be crossed with ICGs 9987, 9991, 405, 10000, and 9989 (D_{ij} value between 0.240 and 0.305) for development of recombinant inbred lines for identification of DNA markers linked with resistance to ELS. Once DNA markers linked with ELS resistance are located, they may be used in marker-assisted breeding for resistance to ELS in groundnut.

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Wide Hybridization in *Arachis hypogaea:* Genetic Improvement and Species Relationship

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The chromosomal configurations in Metaphase I of F_1 interspecific hybrids are usually taken as the criterion in judging the genome relationships between two species (Roy 1959) though it has been stated that deduction from pairing must have an erroneous margin of error (Darlington 1937). However, this cytological tool is efficient to throw some light towards the species relationship and different cytogenetical problems (Stebbins 1971). The present investigation was carried out to understand the genomic homology between *Arachis hypogaea* (groundnut) and *A. cardenasii* (ICG 11558). Hybridization was attempted using J 11, a Spanish bunch groundnut cultivar as female parent and wild perennial runner diploid 'A' genome species, *A. cardenasii* as male parent under field condition during rainy season. Pods from cross pollinations were harvested and sown in the field directly in the following rabi (postrainy) season. Hybridity of the F_1s was initially detected by wild runner trait of the diploid species. Later, the hybridity was confirmed by chromosomal (2n=30) count in pollen mother cell (PMC). Hexaploids were induced by colchicine treatment of confirmed triploid hybrids. Flower buds were fixed in carnoy's solution (6:3:1) and squashed in 2% propino carmine solution for meiotic analysis.

Though triploid hybrids of J 11 x ICG 11558 flowered profusely, they were sterile and failed to produce pegs. Induced hexaploids were more akin to cv J 11 except for leaf area and leaflet thickness. Induced hexaploids were fertile and produced considerable number of pegs and pods. Meiotic analysis of triploid F_1 plants revealed 2n=30 chromosomes, with varying degree of chromosomal association ranging from complete 15 II to 2 I + 9 II + 3 III + 1 IV. The mean chromosomal association (Table 1) of triploid hybrids at Metaphase I was 3.451 + 10.42 II +1.14 III + 0.26 IV + 0.04 V. Our observations confirmed earlier reports (Stalker 1980, Singh and Moss 1982, 1984) on the number of bivalents and multivalents observed in triploid hybrids. It revealed that the set of chromosomes contributed by the diploid species usually paired with one and occasionally with both sets of chromosomes of *A. hypogaea* to form more than 10 bivalents and some multivalents in the PMCs. The configuration of trivalents (Table 2) observed were in the form of chain (46%), Y (25%), ring (1.7%), and Z or undescribed figure 2.5%. The observed configuration of trivalents and tetravalents in this study were unusual and difficult to draw any conclusion. The ring trivalents observed in triploid hybrid indicated that at least one iso-chromosome may be present in the *Arachis* genome. Frequent chromosomal rearrangements as observed in B genome of *A. batizocoi* (Stalker 1980) may have provided in the past the mechanism for development of iso-chromosome as detected in this study. The observed Y and undescribed tetravalents are possible only when four doses of homologous chromosomes are present in PMCs. The triploid hybrid in this study is supposed to be AAB genomically. Assuming certain degree of homology between A and B genome chromosomes one can expect autosyndetic trivalents suppressor system due to their hybridity. The autosyndetic tetravalents as observed in the presently studied triploid hybrid is possible only when one assumes selective duplication of at least one chromosome in either of the two genomes.

Based on similar observations, Swaminathan (1953) concluded that selective duplications of chromosomes are common in potato *(Solanum tuberosum).* If such duplications happened in the genomes of *Arachis* in course of its evolution, it will be difficult to propose the basic number of *Arachis* as x=10. Penaloza et al. (1996) have reported n=9 in *A. decora* and Lavia (1996, 1998) has reported the same number in *A. palustris* and *A. praecox.* Lavia (1998) proposed that *A. palustris* and *A. praecox* might have originated by loss of one chromosome from the other species having

Table 1. Mean chromosomal association of triploid F_1 hybrids and induced hexaploids.

	Mean chromosomal association				
No. of cells observed	I	II	III	IV	V
150 (Triploid)	3.45	10.42	1.14	0.26	0.04
100 (Hexaploid)	26.29	14.49	0.02	0.06	-

Table 2. Multivalent configuration in Metaphase I of pollen mother cells of triploid hybrid.

Trivalents		Tetravalents	
Configuration	No. observed	Configuration	No. observed
Chain	55	Y	12
Y	30	Spoon	6
Ring	2	U	2
Z	3	Chain	2
Undescribed	3	Unidentified	3
Unidentified	27		

n=10 based on the karyotype analysis. But karyotype analysis alone may be insufficient to conclude the origin of a species. On the contrary, the autosyndetic tetravalents observed in this study strongly indicate that reverse may be true, i.e., the basic number of the genus *Arachis* is x=9 and the species having n=10 might have originated by selective duplication of chromosome(s). The variable chromosomal associations ranging from univalents to pentavalents in triploid hybrids resulted in mostly unequal separation of chromosome in Anaphase I (Table 3) and segregated in two to four poles. Some cells, however, showed bipolar and equal chromosomal separation. It may be pointed out that numerically equal and bipolar separation in Anaphase I may not end up with balanced and fertile gametes. All these anomalous segregation of chromosomes were responsible for high degree of pollen sterility in triploid hybrids. However, colchicine induced hexaploids were fertile and produced progeny. A total of 76 progenies from hexaploids were analyzed and found that 71 plants had 2n=60 chromosomes, 2 plants had some extra chromosomal fragments along with 60 chromosomes, and 3 plants had either less than or more than 60 chromosomes. Chromosomal association in Metaphase I (Table 1) of these hexaploid plants showed mostly univalents and rod bivalents though few trivalents and tetravalents were also observed. Mostly bipolar random chromosomal separation was observed in Anaphase I in PMCs of these hexaploids. Occurrence of univalents and a lower number of tetravalents than expected ones in such amphidiploids and even in autopolyploids is not an unusual feature and have been assumed to be due to various reasons such as preferential pairing (Riley and Law 1965), and mechanical adaptation (Manton 1950). Stebbins (1971) suggested that this tendency is more likely in plants with smaller chromosomes and lower chiasma frequency like groundnut.

Table 3. Chromosomal segregation in Anaphase I of triploid hybrids.

Segregation pattern	No. of cells observed
14/16	20
13/17	40
15/15	7
12/18	7
11/19	3
10/20	3
Tetra polar segregation	10

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Pathology

Bacterial Pod Rot: A New Threat to Groundnut under Rice-based Cropping System in Orissa, India

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Groundnut (*Arachis hypogaea*) is one of the most important cash crops of the state of Orissa in India with highest yield among the oilseed crops. It has wide adaptability as kharif (rainy season), pre-rabi, rabi (postrainy season), and summer crop. However, groundnut cultivation as pre-rabi and rabi crop in river belt and rice (*Oryza* sativo)-fallow land, respectively, provide maximum returns with productivity (pod yield) of 2-3 $t ha^{-1}$. Efforts are now being made for its extensive cultivation in rice-based receding moisture situation to increase land and water-use efficiency in the state.

A new disease, bacterial pod rot caused by *Erwinia carotovora* and reported by Dhal et al. (2000), is spreading gradually in the new areas with greater intensity causing severe reduction in pod yield and marketability of the seed. The disease was observed in a severe form in groundnut crop grown in sandy clay loam soil especially, when the crop was grown during summer with irrigation after the harvest of paddy. The symptoms of the disease mostly confined to the shell of the groundnut pods (Samalo et al. 1991, Panda 1996, Meher 1997, Dhal et al. 2000, March et al. 2001). However, in this case, symptoms were also observed on the tip of the gynophores and young developing pods.

Twenty-five genotypes were screened for bacterial pod rot under normal field condition of a rice-fallow system. The experiment was conducted at the farm of the Central Rice Research Institute, Cuttack, Orissa during the first week of January 2001 in a randomized block design with three replications. Plot size was 4 m x 3 m with row to row and plant to plant spacings of 45 cm and 10 cm, respectively. Recommended crop management practices were adopted for the experiment. Ten randomly selected plants were collected from each plot at 10-day intervals starting from 30 days after emergence until

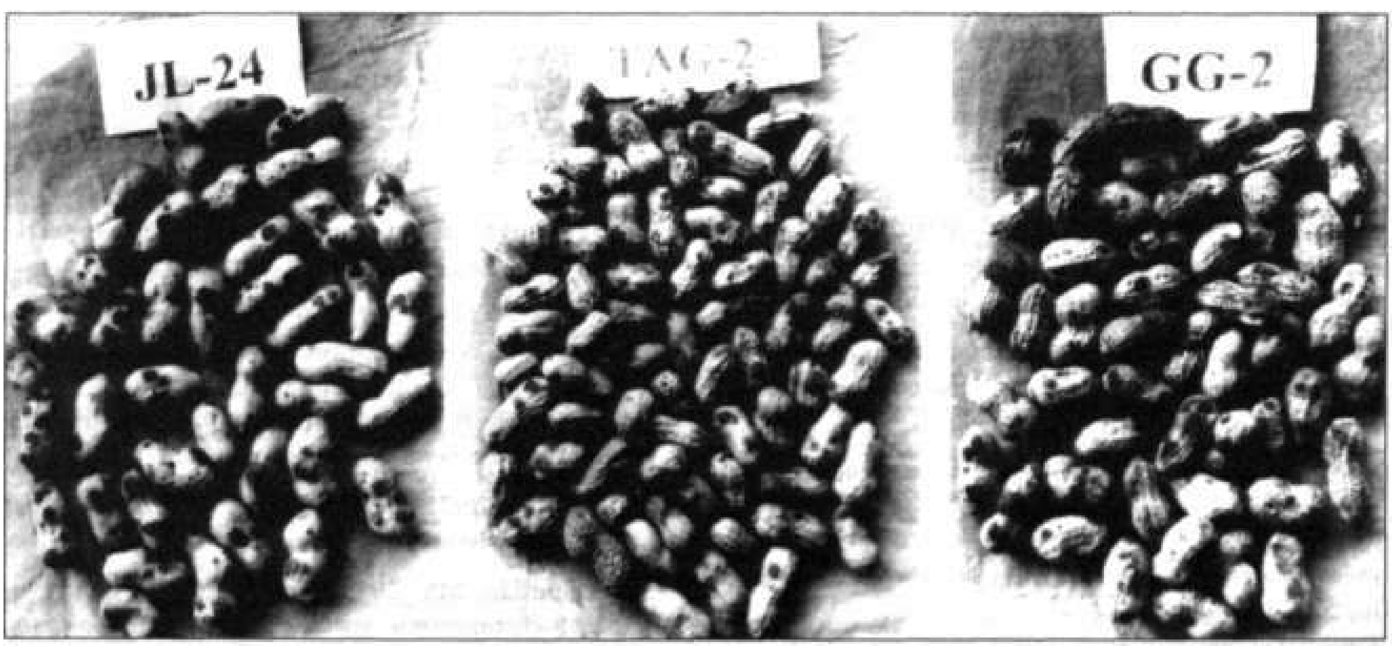

Figure 1. Groundnut pods of three genotypes infected with bacterial pod rot.

Table 1. Field screening of groundnut genotypes against bacterial pod rot during rabi 2001, Cuttack, Orissa, India.

Genotype	Total pods[1] (number plant^{-1})	Infected pods[1] (number plant[1])	Infected pods (%)
AK 12-24	20	17	85
Co 1	15	12	80
GG2	19	17	89
Girnar 1	20	16	80
JL 24	20	18	90
K 134	18	15	83
RG 141	10	8	80
TAG 24	18	16	89
TKG 19A	13	9	69
Gangapuri	15	10	67
MH 4	14	12	86
BG 2	14	10	71
ICGV 86325	15	11	73
Kadri 3	20	16	80
Kaushal	16	14	88
RS 138	10	9	90
HNG 10	15	13	87
RB 46	16	12	75
NFP 101	11	7	64
NFP 104	10	7	70
5S	15	10	67
FE(ESG) 8	15	13	87
FE(ESG) 10	16	12	75
PBS 8	15	11	73
OG 52-1	18	14	78
Mean	16	12	74
SE±	3	3	8
CV (%)	12	12	32

1. Mean of 30 plants, 10 plants plot^{-1}.

harvesting of the crop. Observations were recorded on the date of disease appearance and number of infected pods per plant.

The disease first appeared in all genotypes between 30 and 40 days after emergence as pimple-like minute spots either on the tip of the gynophore or young developing pod surface which enlarged to raised, circular, brownish spots and later turned dark due to rotting of tissue. In severe cases, holes were formed on the pod and the infection extended below the pod wall resulting in seed rot. Several necrotic spots coalesced causing deformation of pods; severely affected pods had no seed.

Disease score of 25 groundnut genotypes recorded on pods after harvesting revealed that all the test genotypes were susceptible to bacterial pod rot (Table 1). However, GG 2, JL 24, AK 12-24, Girnar 1, and K 134 were highly susceptible. The disease incidence ranged from 70 to 80% with pods showing necrotic spots (Fig. 1). The pods that remain in the soil could provide a large reservoir for fresh infection.

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Evaluation of an Integrated Management Package to Reduce Preharvest Seed Infection by *Aspergillus flavus* in Groundnut

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Aflatoxin contamination in groundnut (*Arachis hypogaea*) is one of the major problems that can occur at preharvest and postharvest stages affecting the quality of the produce and thus trade. Aflatoxins are produced by *Aspergillus flavus* and *A. parasiticus,* which can invade the pods during crop growth, when the conditions are congenial for the pathogen (Hill et al. 1983). An integrated approach through combining chemical, cultural, and biological management options could be a viable option for reducing preharvest contamination of seed in groundnut production systems. The efforts to subdue preharvest aflatoxin problem should be based on the principles of greater ecological sustainability in the long run keeping in view minimal use of pesticides. Through a collaborative project, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the Indian Council of Agricultural Research (ICAR) evaluated an integrated package at ICRISAT, Patancheru, Andhra Pradesh, India during the rainy season in 2001 to demonstrate the effectiveness of improved package vis-a-vis farmers' practice.

Methodology

Two treatments, integrated aflatoxin management package (IAMP) and farmers' practice were compared in Alfisol fields at ICRISAT, Patancheru. Each treatment was conducted on a 0.1-ha plot. The IAMP comprised: summer plowing of the field; seed treatment with carbendazim (Bavistin 50 WP) at 4 g kg^{-1} seed; furrow application of *Trichoderma harzianum* at 50 g culture mixed in 50 kg farmyard manure before sowing [to make a final population of 1 x 10^6 colony forming units (cfu) g^{-1} soil]; spray of Nimbucidin (250 ml in 50 L water) for controlling foliar diseases and insects; and a second spray of carbendazim (50 g) + Dithane M-45 (250 g) in 50 L of water, if required; harvesting plants at 75% pod maturity; drying the harvested plants by inverted windrows method for 3 days to avoid contact between the pods and wet soil; and removing insect-damaged and diseased pods. In both practices, hand weeding was done twice, at 20 and 45 days after sowing.

The farmers' practice (as a control) included summer plowing, harvesting pods at full maturity, drying pods by leaving them in the field, and removing damaged pods, but did not include any chemical and biological treatments.

Application of *A. flavus* inoculum. To ensure infection, a highly toxigenic strain of *A. flavus* (Af 11-4) was multiplied on pearl millet *(Pennisetum glaucum)* seeds, mixed with farmyard manure and applied in both the practices when the crop was at 50% flowering stage (the most susceptible stage of the crop).

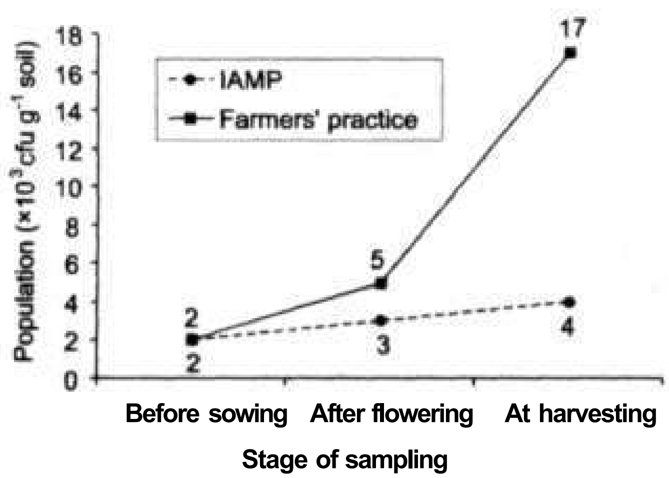

Figure 1. Soil population of *Aspergillus flavus* (Af 11-4) at different crop growth stages in plots with IAMP (integrated aflatoxin management practice) and farmers' practice during the rainy season, 2001 at ICRISAT, Patancheru, India.

Soil and pod sampling. Soil was sampled at three stages to monitor the levels of *A. flavus* population. Initial sampling was done just before sowing; the second sampling was done prior to application of the pathogen inoculum (at 50% flowering stage), and the final sampling at harvest in both experimental plots. Pods from the improved package plot were harvested at 75% maturity level and dried by inverted windrows method for three days. On the other hand, pods in the control plot (farmers' practice) were harvested at full maturity and dried by leaving them in the field.

Seed infection, aflatoxin content, and *A. flavus* population in soil. Pods were shelled and seeds were surface sterilized before plating them on Czapek Dox agar (CDA) fortified with rose bengal (25 mg L^{-1}) and incubated at 25°C for four days in dark. From each plot, 100 apparently healthy seeds were selected. Number of seeds colonized by typical *A. flavus* was counted and expressed as percent seed infection. Seed samples (50 g) were soaked in sterile distilled water for 4 h, later dried and incubated at 25°C overnight prior to aflatoxin estimation by using enzyme-linked immunosorbent assay (ELISA), a simple and quick immunoassay protocol for estimation of aflatoxins (Devi et al. 1999).

Soil samples (200 g from a composite bulk of 1000 g soil from 5 random spots in a field) were sieved. The fine powder was serially diluted with sterile distilled water to 10^{-3} and 10^{-4} concentrations and plated on AFPA *(Aspergillus flavus* and *parasiticus* agar) medium (Pitt et al. 1983). The plates were then incubated for 2-3 days at 28°C in dark and typical *A. flavus* colonies were counted and population density was expressed as cfu g^{-1} soil.

Other diseases. The crop was given supplemental irrigation to avoid moisture stress throughout the growing season. In both the plots, other important diseases were recorded by selecting ten blocks, each comprising 100 plants row^{-1}. Disease incidence was scored as percentage of infected plants for stem rot (*Sclerotium rolfsii*) and on a 1-9 scale for late leaf spot. Bud necrosis was scored for the presence (+) or absence (-) of infected plants.

Results and Discussion

The indicators for the effectiveness of integrated management of aflatoxin contamination were fungal infection and aflatoxin content in the seed and *A. flavus* population in the soil. Despite the similar initial population levels in both the plots, cumulative gain in the cfu was observed in the plot where farmers' practice was followed indicating unremitting growth in *A. flavus* due to absence of any control measures. On the other hand, the beneficial effects of soil treatment with the antagonistic fungus *Trichoderma* sp was apparent in the plot with improved package, despite the addition of *A. flavus* inoculum during flowering stage, which produced spores at 1.82×10^7 m^{-1} row (Fig. 1). *Trichoderma* sp being a potential antagonist might have prevented the proliferation of *A. flavus* in the soil. *Trichoderma* sp has the ability to inhibit the growth of *A. flavus* in vitro by production of non-volatile antibiotics (Desai et al. 2000).

Seed infection studies revealed predominance of *A. flavus* infection in plot with farmers' practice (10%) over improved package (2%) (Table 1).

Table 1. Evaluation of an integrated aflatoxin management package and farmers' practice in groundnut (cv ICGS 11) during the rainy season, 2001 at ICRISAT, Patancheru, India.

Parameter	Integrated package	Farmers' practice
Seed infection by *Aspergillus flavus* (%)	2	10
Pod yield (kg ha^{-1})	555	544
Late leaf spot damage[1]	6.9 (±0.23)	7.7 (±0.15)
Stem rot incidence (%)	2.5 (±0.62)	31.0 (±4.70)
Bud necrosis incidence[2]	+	+

1. Mean of 10 replications; 1-9 disease rating scale where 9 = susceptible.
2. + = Disease noticed.

This could be because of inhibition of initial rhizosphere soil population build up of *A. flavus* by seed treatment with systemic fungicide and application of biocontrol agent in the improved package. Although no aflatoxin contamination was recorded in seed samples in both practices, with 10% seed infection levels in farmers' practice it is likely that aflatoxin levels would be higher under farmers' storage conditions than under dry conditions.

The improved package recorded only a marginal increase in pod yield than farmers' practice, reflecting the fact that aflatoxin contamination is more of a qualitative problem in groundnut than quantitative. The concomitant effects of the improved package were evident in scanty incidence of late leaf spot and stem rot diseases over farmers' practice. Further, application of such a package in the long run would improve soil health and might result in improved yields as well.

These results need further confirmation, and relative economics of the two cultivation practices could be compared from on-farm evaluation trials at village level in aflatoxin risk sensitive areas in the target districts of Andhra Pradesh and Karnataka during the rainy season in 2002.

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Bio-efficacy of Fungicides for Control of Leaf Spots of Groundnut in Northeastern Dry Zone of Karnataka, India

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Groundnut *(Arachis hypogaea)* is an important oilseed crop of Karnataka in India. It is cultivated in an area of 1.3 million ha, the production being 1.0 million t and productivity 0.8 t ha^{-1} (Directorate of Agriculture 1997). In recent years, irregularity in supply of water from Tungabhadra and Upper Krishna Project canals and unpredictable rainfall as well as disease problems have made groundnut cultivation risky, particularly in northeastern dry zone of Karnataka. Early leaf spot caused by *Cercospora arachidicola* and late leaf spot caused by *Phaeoisariopsis personata* are endemic diseases in the rainy season causing 90% defoliation. Besides causing quantitative losses, these diseases are responsible for reduction in protein content and oil recovery (Gupta et al. 1987). So far no variety has been identified as resistant or tolerant to these diseases and adapted to the agroclimatic conditions of the region. Therefore, use of fungicides is the only alternative for effective

Table 1. Effect of different fungicides on the severity of early and late leaf spots of groundnut at the Regional Research Station, Raichur, Karnataka, India.

Treatment	Concentration (%)	Percent disease index[1] 1995	1996	Pooled mean	Disease control (%)	Yield ($t\ ha^{-1}$) 1995	1996	Pooled mean	Yield increase over control (%)
Difenconazole	0.1	12.29 (20.47)	12.52 (20.68)	12.41 (20.61)	75.19	1.29	1.30	1.29	27.72
Hexaconazole	0.1	20.55 (26.94)	21.03 (27.28)	20.79 (27.13)	58.44	1.24	1.27	1.26	24.75
Chlorothalonil	0.2	26.34 (30.87)	25.06 (30.03)	25.70 (30.45)	48.63	1.23	1.26	1.25	23.76
Calixin	0.05	34.37 (35.82)	31.83 (34.33)	33.10 (35.08)	33.83	1.06	1.11	1.09	8.08
Carbendazim granules	0.05	29.13 (32.64)	28.17 (32.04)	28.65 (32.35)	42.73	1.18	1.18	1.18	16.83
Carbendazim WP	0.05	26.87 (31.20)	26.15 (30.75)	26.52 (30.99)	46.99	1.17	1.20	1.19	17.82
Mancozeb	0.2	31.54 (34.15)	30.40 (33.46)	30.97 (33.73)	38.10	1.20	1.23	1.22	20.79
Control (untreated)	-	52.14 (46.22)	47.93 (43.78)	50.03 (45.03)	-	1.00	1.02	1.01	-
CD (P = 0.05)		3.57	1.98	2.42		0.084	0.12	0.17	
CV (%)		6.32	3.57	4.32		4.09	5.47	5.49	

1. Figures in parantheses are angular transformed values.

management of the disease. Though some fungicides such as mancozeb (0.2%) and carbendazim WP (0.05%) are already recommended by different workers in the region, it is necessary to test the efficacy of new fungicides against leaf spots.

Experimental trials were conducted at the Regional Research Station, Raichur, Karnataka for two years during the rainy season in 1995 and 1996. The popular but highly susceptible cultivar JL 24 was sown on 3 x 5 m^2 plots in a randomized block design with three replications. All standard and recommended package of practices such as tillage, spacing, manuring, irrigation, and insect control were followed for cultivation of the crop. The test fungicides were applied as foliar spray with a high volume sprayer. The first spray was given at 30 days after emergence when the initial symptoms of the disease appeared on plants. This was followed by two more sprays at fortnightly intervals. Observations on disease intensity (both early and late leaf spots) were recorded 15 days after the third spray. Ten plants were selected randomly from each plot and plants were graded on a 1-9 scale (Subrahmanyam et al.). Percent disease index (PDI) was worked out using the following formula:

$$\text{PDI} = \frac{\text{Sum of all numerical ratings}}{\text{Total plants observed x Maximum rating}} \quad 100$$

The PDI values were transformed by angular transformation and analyzed statistically. Dry pod and haulm yields were also recorded. The percentage disease control was calculated using the formula:

$$\frac{\text{Disease severity (\%) in control} - \text{Disease severity (\%) in treatment}}{\text{Disease severity (\%) in control}} \times 100$$

The percentage pod yield increase over control was also calculated and data were analyzed statistically. The benefit-cost ratio was calculated by taking into account the actual cost of fungicide and actual market price of the produce.

The comparison of pooled means indicate that all fungicides significantly reduced the severity of leaf spots and increased the pod yield as compared with untreated control. However, they showed differential effects in controlling the disease under field conditions (Table 1). The fungicides difenconazole (0.1%) was the most effective followed by hexaconazole (0.1%) and chlorothalonil (0.2%). Plants in these treatments also showed better performance; pod yield was high and a similar trend was observed as for disease control.

Jadeja et al. (1999) reported 67% disease control and 68% increase in yield of groundnut with difenconazole. Dubey (1997) reported that three sprays of chlorothalonil was found to be economical for the management of leaf spots of groundnut.

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Field Evaluation of Plant Extracts for Control of Late Leaf Spot in Groundnut

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Late leaf spot (LLS), caused by *Phaeoisariopsis personata* is an important disease of groundnut *(Arachis hypogaea)* throughout the world and causes substantial loss of both haulm and pod yields (Subrahmanyam et al. 1995). The disease has been effectively controlled by chemical fungicides, which cause environmental pollution. The need to find eco-friendly disease control measures is desirable. The secondary metabolites produced by plants possess antifungal activity against a wide range of plant pathogenic fungi. These metabolites can be used either alone or in combination with other disease management strategies to reduce the use of chemical fungicides. In an earlier study, aqueous leaf extracts of *Datura metel* and *Lawsonia inermis* were found to inhibit the in vitro conidial germination of P. *personata* and control LLS in greenhouse environment (Kishore et al. 2001). We report further evaluation of these two leaf extracts for control of LLS under field conditions.

Field experiments were conducted at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India during 1999 and 2000 rainy season. The experiments were conducted in a completely randomized block design with three replications. Four rows, each 9 m long, were maintained in each plot. Groundnut cultivar TMV 2, susceptible to LLS was used in these experiments. To obtain uniform disease pressure, an infector row of TMV 2 was maintained on either side of each plot. Infected crop debris of the previous season was evenly spread on infector rows at 35 days after sowing (DAS). Infector rows were also spray inoculated with conidial suspension (20,000 corudia ml^{-1}) of

P. perosnata in the evening on a cloudy day. Subsequently, sprinkler irrigation was provided in the evening for about 30 min up to 10 days after inoculation to maintain leaf wetness at night. Freshly prepared aqueous leaf extracts of D. *metel* (2% w/v) and L. *inermis* (5% w/v) (Kishore et al. 2001) and Kavach (chlorothalonil, 0.2% w/v) were tested for control of LLS. The leaf extracts and kavach were applied as a foliar spray at 500 L ha^{-1} at 45,60,75,90, and 105 DAS. Plots sprayed with water were maintained as control. The disease severity was recorded on a 1-9 rating scale (Subrahmanyam et al. 1995) at an interval of 10 days starting from 45 DAS. At harvest, pods from each plot were hand picked, sun dried, weighed, and yield was calculated. Disease development was similar in both the seasons; hence the data was pooled and analyzed.

In control plots complete defoliation occurred at 95 DAS and the LLS severity was rated 9.0. The extract of D. *metel* continuously reduced the disease progress up to 115 DAS and severity of LLS at harvest (115 DAS) was significantly less than in the control. In comparison to control, L. *inermis* extract could contain the disease progress up to 95 DAS (7.3 severity) and the disease severity at harvest was at par with control. Severity of LLS was significantly less in plots sprayed with Kavach than in plots sprayed with extracts of D. *metel* and L. *inermis* (Fig. 1).

Table 1. Pod yields of groundnut cultivar TMV 2 after control of late leaf spot with antifungal compounds[1].

Treatment	Pod yield (t ha^{-1})	Increase in pod yield over control (%)
Datura metel leaf extract (2% w/v)	0.89	48.3
Lamsonia inermis leaf extract (5% w/v)	0.72	20.0
Kavach (0.2% w/v)	1.23	105.0
Control	0.60	-
LSD (P = 0.01)	0.18	

1. Values are means of six replications from two sets of experiments.

Pod yields in plots sprayed with *L. inermis* and D. *metel* leaf extracts were respectively 20.0% and 48.3% higher than in the control plots (Table 1). With an increase of 48.3% in pod yields, D. *metel* extract offers an economical and eco-friendly alternative for fungicidal application to control LLS. Also, the antifungal activity of *D. metel* extract against P. *personata* was heat stable and unaltered even after an incubation of 180 days at 28°C (Kishore et al. 2001). *Datura metel* extract has been reported as inhibitory to other pathogenic fungi such as *Colletotrichum capsici* and increases the activities of defense related enzymes, peroxidase, and polyphenol oxidase in *Capsicum annuum* (Asha and Kannabiran 2001). The increase in pod yield by application of *L. inermis* extract was due to less disease severity till seed maturation stage. This supports the earlier observation that leaf extract of *L. inermis* reduces the severity of both LLS and rust and increases pod yields by 15-40% (Ghewande 1989). Though Kavach has increased the pod yield by 105% it has to be sprayed five times to double the pod yield. Further, integration of D. *metel* extract with the existing disease management

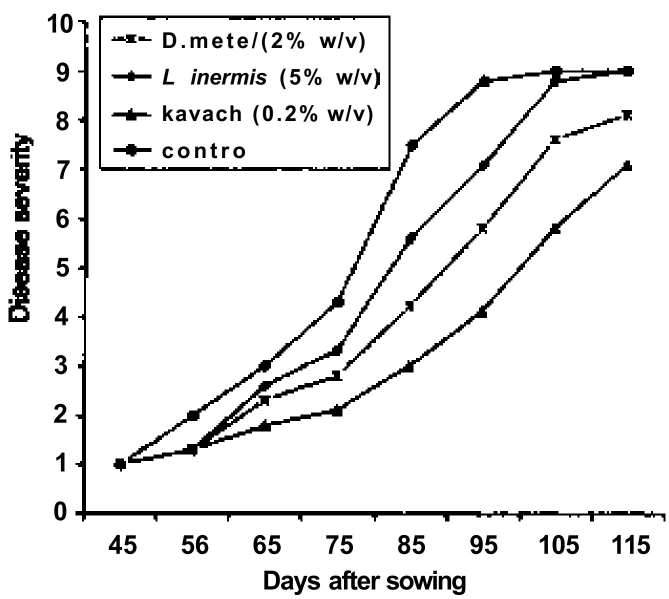

Figure 1. Effect of leaf extracts *(Datura metel, Lawsonia inermis)* and Kavach on severity of late leaf spot groundnut cultivar TMV 2 (Note: Each point is the mean of six replications from two sets of experiments).

strategies may drastically reduce the dependency on fungicides for control of LLS.

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Entomology

Groundnut Leaf Miner *Aproaerema modicella* in Southern Africa

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The groundnut leaf miner (GLM) {*Aproaerema modicella* Deventer) (Lepidoptera: Gelechiidae) was recorded on groundnut {*Arachis hypogaea)* in South Africa during 2000. An outbreak of the pest was first noticed on the Vaalharts Irrigation Scheme (27°50' S and 24°50' E). During 2001, GLM was observed over the entire groundnut production area in the Free State, Northern Cape, North West and Mpumalanga provinces, causing severe damage to groundnut crops. It was also recorded on soybean *(Glycine max)* and lucerne (*Medicago sativa*).

Aproaerema modicella has only been reported from countries in south and southeast Asia, namely Pakistan, India, Sri Lanka, Bangladesh, Myanmar, Thailand, Laos, Kampuchea, Vietnam, China, the Philippines, Indonesia, and Malaysia (Mohammad 1981). It is an important pest of groundnut in India (Shanower et al. 1993). The first report of *A. modicella* in Africa was on groundnut in Uganda during 1998 (Page et al. 2000), in Mozambique in 1999 (NF Madogolele, personal communication), and in Malawi in 2000 (Subrahmanyam et al. 2000).

Adults of *A. modicella* are grayish moths that lay eggs singly on the underside of leaves and on petioles. Yellowish green larvae hatch, tunnel into the leaves, and feed between the upper and lower epidermis of leaves. Damaged leaves become brown, rolled, and desiccated, resulting in premature loss of leaves. Later instars appear on the leaf surface to roll and web it, or to web two or more leaves together. Pupation takes place inside the webbed leaflets. Loss of leaves results in poor groundnut haulm production and causes a reduction in yield under heavy GLM infestations.

Page et al. (2000) speculated that GLM was confined to a particular area in Uganda while Subrahmanyam et al. (2000) suggested that it may be a poor migratory pest. However, within two years after it was first noticed in Uganda, it was also noticed as a pest in Malawi (Subrahmanyam et al. 2000) and Mozambique (NF Madogolele, personal communication). Due to the widespread occurrence and devastating damage inflicted by GLM to groundnuts in Africa, research is currently being conducted by the Agricultural Research Council - Grain Crops Institute, South Africa to develop an integrated pest management program for GLM on groundnuts.

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Screening Wild *Arachis* for Resistance to Groundnut Plant Hopper *Hilda patruelis* in Malawi

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The groundnut plant hopper *(Hilda patruelis* Stal) is a destructive but sporadic pest of groundnut *(Arachis hypogaea)* and other crops in Southern Africa (NRI 1996). A number of non-crop host plants have recently been documented as alternative hosts of groundnut hopper in Malawi and Zimbabwe (Minja et al. 1999). *Hilda* infests 2-5% groundnut plants in most countries of southern Africa during the normal growing seasons, but extensive damage (up to 80%) has been observed in some groundnut fields during prolonged dry spells or in off-season crops (Weaving 1980, Minja et al. 1999). Research on the groundnut plant hopper has been undertaken in Zimbabwe (PPRI1982) and South Africa (Van Eeden 1993). The research efforts in South Africa resulted in the identification of some wild *Arachis* and cultivated groundnut genotypes with resistance to *H. patruelis* (PS Van Wyk, Agriculture Research Council, Portchefstroom, South Africa, personal communication). Some of those lines were sent to Malawi for field screening (Table 1).

The genotypes were first planted in single row plots of 6 m, during the long rainy season (December-March) in 1999 to increase the seed and preliminary assessment for *Hilda,* termites, and groundnut rosette incidence. Seed germination was poor, particularly in *A. arasterio,* where only one seed per row germinated and survived to harvest (Table 1). All the lines were compared to JL 24 as a local check, which matured almost at the same time as the test genotypes. In the results, only the means are shown because the variations were too large due to mortality and poor germination. These preliminary observations indicated that *Hilda* infested all the test genotypes (Table 1). Termites and rosette incidence were also observed in all the test genotypes except on *A. arasterio.* Due to heavy rainfall, most of the plants remained green till harvest, but due to poor plant stand, no comparisons were made.

In the winter crop (off-season) planted in June 2000, seed germination was >95% and there was no termite or rosette incidence. But *Hilda* infestation was observed on all plants at the late podding stage (Table 2). JL 24, ICG 8740, ICGV 90082, and ICGV 93437 were included in the trial as local checks. There were two rows per plot of 6 m. All *A. arasterio* plants were green and healthy at the time of assessment, whereas ICG 8740 had the highest number of dead and wilted plants. The 6 wild species as well as PC 205 DB and

Table 1. Insect pest and disease incidence (% plants attacked) in wild *Arachis* and cultivated groundnut genotypes at crop maturity during 1999 cropping season at Chitedze Research Station, Malawi.

Genotype	Registration no.	Origin	Collection (year)	*Hilda*	Termites	Rosette
Wild *Arachis*						
A. villosulicarpa	RG 296	USA	1971	50	56	22
A. erecta	RC 294	Tanganyika	1971	28	6	61
A. arasterio[1]	RG 293	Zimbabwe	1971	100	0	0
A. monticola	RG 373	USA	1971	44	8	40
A. sp 1	RG 591	USA	1987	30	9	9
A. sp 2	RG 593	USA	1987	18	15	9
Cultivated checks						
Sellie	(= Natal Common × Namark)	South Africa	1999	33	13	47
PC 205 DB	(= Harts × (Sellie × (Guat × Atete)))	South Africa	1999	26	9	49
PC 186 K2	(= Swallow (Sellie × (Guat × Atete)))	South Africa	1999	54	44	26
JL 24		India		36	18	48
ICGV 93437	(= ICGV 86063 × ICGV 86065)	ICRISAT				
ICGV 90082	(= NCAc 343 × (OG 69 × NCAc 17090))	ICRISAT				
Mean (with *A. arasterio*) ± SE				41.9 ± 17.4	17.8 ± 13.6	31.1 ± 21.7
Mean (without *A. arasterio*) ± SE				35.4 ± 11.6	19.8 ± 14.0	34.6 ± 22.3

1. Only 1 plant survived in a 6-m row.

Table 2. Reaction of wild *Arachis* and cultivated groundnut genotypes to natural *Hilda patruelis* infestation in winter-sown (off-season) field trial at late podding stage at Chitedze, Malawi during mid-October 2000.

Genotype	Green and healthy plants (%)	Wilted plants (%)	Dead plants (%)
Wild *Arachis*			
A. villosulicarpa	93	7	0
A. erecta	87	13	0
A. arasterio	100	0	0
A. monticola	95	5	0
A. sp 1	89	4	7
A. sp 2	86	10	4
Cultivated checks			
Sellie	41	29	30
PC 205 DB	92	8	0
PC 186 K2	57	23	20
JL 24	44	33	23
ICG 8740	12	20	68
ICGV 93437	90	10	0
ICGV 90082	51	15	34
Mean	72.1	13.6	14.3
SE±	12.7	10.2	13.8

ICGV 93437 were quite healthy at the late podding stage despite *Hilda* infestation. The number of dead plants in these entries ranged from 0 to 7%, compared to a mean of 14.3% dead plants at podding. ICGV 93437 has been released in Zimbabwe under the name Nyanda (van der Merwe et al. 2001). This variety is tolerant to drought and resistant to aphids; perhaps its resistance to *Hilda* has contributed to its release in Zimbabwe, where this pest is sporadic but one of the most serious sucking pests on the crop (Weaving 1980, PPRI 1982). These genotypes could be considered for further screening and use in groundnut improvement in southern Africa.

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Correlation Studies on the Attraction of Groundnut Leaf Miner *Aproaerema modicella* Moths and Weather Factors

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The groundnut leaf miner *Aproaerema modicella* is one of the most important and widely distributed foliage feeders of groundnut *(Arachis hypogaea)* crop in Asia (Wightman et al. 1990). It affects the growth and yield of the plants, especially in rainfed groundnut. Logiswaran and Mohanasundaram (1985) reported pod yield losses of >50% due to leaf miner. Groundnut leaf miner populations fluctuate widely between seasons. Abiotic factors, principally rainfall, humidity, and temperature are frequently suggested as causes of population fluctuations. An early detection of the pest is often the key to its effective management. The trapping technique may be a more effective method of detection of the pest than the visual method to determine the intensity of incidence. Adult populations of *A. modicella* have been monitored so far through light trap. The identification of female sex pheromone of *A. modicella* has made it possible to use traps baited with synthetic pheromone for monitoring this pest. We worked out the relationship between moths caught in the light trap as well as pheromone trap and weather factors to assess the influence of these weather factors on the field incidence and moth catches.

The study was conducted at the Oilseeds Research Station, Tindivanam, Tamil Nadu, India during 1996 rainy season (kharif) at 30 days after sowing. The pheromone traps (Delta trap) were placed in the groundnut field and the number of moths caught was recorded daily for 50 days. The moths caught in the light trap were also recorded daily for the same period. Multiple regression equations were fitted with weather factors to define their relationship with the number of moths caught in the light trap and pheromone trap.

The results of the multiple regression analyses are presented in Tables 1 and 2. While considering pheromone trap catches for a period of 50 days, relative humidity alone exerted a significant positive influence whereas the maximum and minimum temperature and rainfall exerted a negative influence on adult emergence and was not significant (Table 1). The multiple regression equation fitted with the weather factors (X) for pheromone trap catches (Y) of leaf miner moths is:

$$Y = -11.55 -0.39^{NS}X_1 -0.65^{NS}\ X +1.63^{*}\ X_3 -0.28^{NS}X_4$$

where X_1 is maximum temperature, X_2 is minimum temperature, X_3 is relative humidity, and X_4 is rainfall constant.

While considering light trap catches of leaf miner moths for the same period of 50 days, the relative humidity alone exerted a significant positive influence whereas the maximum and minimum temperature and rainfall exerted a negative influence on adult emergence which was not significant (Table 2). The multiple regression equation fitted with the weather factors for light trap catches of leaf miner is:

$$Y = -19.85 - 0.17^{NS} X_1 - 0.02^{NS} X_2 + 0.54^{*} X_3 - 0.12^{NS} X_4$$

Logiswaran and Mohanasundaram (1985) reported that the light trap catches of leaf miner moths exerted a positive correlation with the field incidence. Khan and Raodeo (1987) reported that rainfall was the key factor for regulating leaf miner populations in groundnut. Amin (1987) reported that heavy rainfall reduced the leaf miner population. Ghule et al. (1989) also reported that heavy precipitation followed by break in the monsoon and increase in sunshine hours favored multiplication of the pest. Our study also confirms the findings of Logiswaran et al. (1982a) who reported a significant negative correlation between infestation and temperature. Logiswaran and Mohanasundaram (1987) also reported that the number of moths caught in the light trap exerted a negative association with maximum temperature, minimum temperature, and wind velocity. However, in our study the total rainfall alone exerted a negative association with the moths caught in the light trap and pheromone trap. The high rainfall may have a more subtle influence on leaf miner population dynamics by increasing the humidity and favoring fungal pathogens. More gravid females were trapped in the light trap indicating that the method can also be used for the management of the pest besides monitoring purposes (Logiswaran 1984). Our study indicated that apart from

Table 1. Correlation between pheromone trap catches (Y) of leaf miner moths and weather factors (X) (n = 50)[1].

Variable	Correlation coefficient	Partial regression coefficient	Standard error	't' value	r^2
X_1 (Maximum temperature)	-0.098^{NS}	-0.390	0.430	-0.907^{NS}	0.3680*
X_2 (Minimum temperature)	-0.157^{NS}	-0.646	1.378	-0.469^{NS}	
X_3 (Relative humidity)	0.328*	1.633	0.746	2.189*	
X_4 (Rainfall)	-0.077	-0.282	0.480	-0.587^{NS}	
Constant		-11.55			

1. NS = Not significant.
 * Significant at P = 0.05; CD (P = 0.05) = 2.01.

Table 2. Correlation between light trap catches (Y) of leaf miner moths and weather factors (X) (n = 50)[1].

Variable	Correlation coefficient	Partial regression coefficient	Standard error	't' value	r^2
X_1 (Maximum temperature)	-0.126^{NS}	-0.174	0.145	-1.196^{NS}	0.413^{NS}
X_2 (Minimum temperature)	-0.234*	-0.170	0.466	-0.036^{NS}	
X_3 (Relative humidity)	0.368**	0.541	0.252	2.146*	
X_4 (Rainfall)	-0.094	-0.116	0.162	-0.716^{NS}	
Constant		19.85			

1. NS = Not significant.
 * Significant at *P* = 0.05; CD (*P* = 0.05) = 2.01.
 **Highly significant at *P* = 0.01; CD (*P* = 0.01) = 2.68.

monitoring, mass trapping is possible in pheromone traps to reduce the pest population. The attraction of leaf miner moths were more in the pheromone trap compared to the light trap.

Besides abiotic factors, there are several other crop factors such as sowing time, age of the crop, initial leaf miner larval population, presence of natural enemies, and other agronomic practices that influence the leaf miner moth catch in the light trap and pheromone trap. Lewin et al. (1979) reported that early sowing led to higher infestation of leaf miner whereas Logiswaran et al. (1982a) concluded that later plantings were more heavily attacked. Sowing taken up in the second fortnight of July (rainfed) and January (irrigated) was ideal for avoiding the infestations and for obtaining increased yield (Logiswaran et al. 1982a). Leaf miner incidence was lowest at 20 days after sowing while it was highest at 80 days after sowing (Logiswaran et al. 1982b). Logiswaran and Mohanasundaram (1985) observed that leaf miner incidence was lower when groundnut was intercropped with sorghum *(Sorghum bicolor),* pearl millet (*Pennisetum glaucum),* or cowpea *(Vigna unguiculata*) than in monoculture. Muthiah et al. (1991) reported that the damage on groundnut 50 days after sowing was lesser in groundnut intercropped with castor *(Ricinus communis),* pearl millet, and black gram *(Vigna radiata*) than in pure crop of groundnut. Natural control by diseases, predators, and parasitoids is important in suppressing leaf miner population and can also influence moth catch in the light trap and pheromone trap. From our study it is evident that both the pheromone and light traps were positively influenced by relative humidity and negatively influenced by all other weather factors. Both these traps can be used effectively for monitoring the adults of groundnut leaf miner.

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The Changes of Photosynthetic Properties During Groundnut Leaf Senescence

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The appearance of leaf senescence in groundnut *(Arachis hypogaea)* is well known. The main characteristics of leaf senescence are that the leaves turn yellow and then fall off. The study of leaf senescence in groundnut is still incomplete (Narayanan and Chand 1986, Sahrawat et al. 1987). At present, the key measure for increasing production in high-yielding groundnut fields is to protect leaves from senescing early and falling off at the late phase, especially after applying growth regulators (such as PP_{333} and B_9) to control overgrowth and prevent lodging. In groundnuts that showed early leaf senescence, pod filling and yield were affected (Li Xiangdong et al. 1998, 2000). Research about the changes of photosynthetic properties in groundnut leaves during leaf senescence has not been reported systematically. Therefore, in this paper, the changes of photosynthetic properties in groundnut leaves during leaf senescence were studied with two high-yielding groundnut cultivars to identify the mechanism of leaf senescence and provide theoretical basis for preventing groundnut from senescing, and thus increasing yield.

Materials and Methods

Two identical treatment experiments with cultivars Luhua 11 and Fu 8707 were conducted in four replicates in a randomized block design on the experimental farm of Shandong Agricultural University, China. From the blooming date, the leaves of main stem were tagged on the day of leaf unfolding, then the net photosynthesis rate (Pn), intercellular CO_2 concentration (Ci), stomatal conductance (Cs), stomatal resistance (Rs), and transpiration rate (Tr) of tagged leaves were measured every 10 days, by the portable photosynthesis system of LI 6200 (LICOR, USA) at 10-14 h on sunny and calm days. At the same time of measuring Pn, the chlorophyll content of tagged leaves on main stems was measured according to Arnon method (Arnon 1949).

Results and Discussion

Content of chlorophyll. During the process of leaf growth and senescence, the changes in chlorophyll contents, Ch1 (a+b), Ch1 a, and Ch1 b, in groundnut leaves may be simulated with the equation $Y_{chl} = A + B x + Cx^2$, where x refers to the days after leaf unfolding. The changes in Ch1 (a+b), Ch1 a, and Ch1 b contents increased gradually after leaf unfolding, reaching the maximum, and finally decreasing slowly (Fig. 1 and Table 1). According to the equation, it was possible to calculate the number of days necessary for chlorophyll content rising to the maximum ($Ch1_{max}$) and the number of days necessary for dropping to half of maximum ($Ch1_{\Delta 50(-)}$).

Table 1. Changes in chlorophyll (Chi) content (mg dm^{-2}) in groundnut leaves during leaf senescence[1].

Cultivar	Ch1	Equation	P(t)	Days of $Ch1_{max}$	Days of $Ch1_{\Delta 50(-)}$
Luhua 11	Ch1 a	$y=1.4267+0.05521x-0.001088x^2$	$1.128x10^{-2}$	25.4	56.6
	Ch1 b	$y=0.4529+0.02032x-0.0003679x^2$	$7.742X10^{-3}$	27.6	59.2
	Ch1 (a+b)	$y=2.0581+0.07196x-0.001456x^2$	$9.197X10^{-3}$	24.7	56.5
Fu 8707	Ch1a	$y=1.6167+0.02911x-0.0007560x^2$	$2.110X10^{-3}$	19.3	54.7
	Ch1 b	$y=0.518+0.01021x-0.0002333x^2$	$5.219X10^{-3}$	21.9	58.6
	Ch1 (a+b)	$y=2.135+0.03932x-0.0009892x^2$	$2.604X10^{-3}$	19.9	55.6

1. Days of $Ch1_{mak}$ = -B/(2C); Days of $Chl_{\Delta 50(-)} = [-B-\sqrt{(B^2-4AC)/2}]/(2A)$.

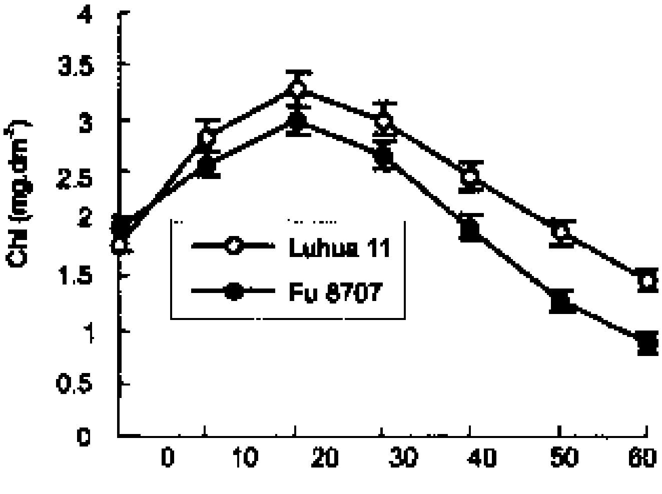

Figure 1. Changes in Chl (a+b) content in groundnut leaves during leaf senescence.

Chl_{max} shows that the content of chlorophyll starts decreasing when the leaves begin to senesce; while $Chl_{A50(-)}$ shows that it begins to degrade rapidly, when the leaves senesce rapidly. According to the equation analysis in Table 1, it is clear that the Chl (a+b) content of Luhua 11 started to decrease at 24.7 days, and then decreased quickly at 56.5 days after leaf unfolding; but in Fu 8707 it decreased at 19.9 days and 55.6 days respectively. This showed that the decrease in chlorophyll content was obviously different between the two cultivars during leaf senescence. The days of Chl_{max} and

Table 2. Changes in Chl a/b ratio in groundnut leaves during leaf senescence at 0-60 days after leaf unfolding.

Cultivar	0	10	20	30	40	50	60
Luhua 11	3.11	3.02	2.99	2.96	2.66	2.57	2.54
Fu 8707	3.13	3.08	3.01	2.90	2.83	2.70	2.24

$Chl_{\Delta 50(1)}$ of Fu 8707 were earlier than that of Luhua 11; so Fu 8707 senesced earlier than Luhua 11. The change in Chl a content was basically the same as that of Chl (a+b), but the days of Chl_{max} and $Chl_{\Delta 50(-)}$ of Chl b were a little later than that of Chl (a+b). In addition, the ratio of Chl a/Chi b of the two cultivars decreased gradually from leaf unfolding to falling off (Table 2). These results indicated that Chl a decomposed more rapidly than Chl b during leaf senescence. The increase and decrease in chlorophyll content in groundnut leaves mainly depended on Chl a, while Chl b was relatively stable during the synthesis and decomposition of chlorophyll.

Net photosynthesis rate. During the process of leaf growth and senescence, the change in net photosynthesis rate (Pn) in groundnut leaves may also be simulated with the equation $Y_{pn}= A + Bx + Cx^2$, where x refers to the days after leaf unfolding (Table 3). According to the equation, it was possible to calculate the number of days necessary for Pn rising to the maximum (Pn_{max})

Table 3. Changes of net photosynthesis rate (Pn), stomatal conductance (Cs), intercellular CO_2 concentration (Ci), transpiration rate (Tr), and limiting value of stomata (Ls) in groundnut leaves during leaf senescence[1].

Cultivar		Equation	P(t)	Days of Chl_{max}	Days of $Chl_{\Delta 50(-)}$
Luhua 11	Pn	$y = 18.3836+1.1428x-0.02295x^2$	8.341×10^{-5}	24.9	51.6
	Cs	$y = 3.9023+0.1710x-0.003584x^2$	1.170×10^{-4}	23.9	52.6
	Ci	$y = 289.3221+0.3238x$	5.607×10^{-6}		
	Tr	$y = 42.3273+0.7822x-0.01498x^2$	2.289×10^{-7}	26.1	68.0
	Ls	$y = 0.2503-0.002607x$	1.995×10^{-4}		
Fu 8707	Pn	$y = 19.0513+0.7335x-0.01692x^2$	3.853×10^{-5}	21.7	49.9
	Cs	$y = 2.2290+0.1416x-0.002972x^2$	3.221×10^{-3}	23.8	49.5
	Ci	$y = 283.8373+0.5065x$	1.893×10^{-7}		
	Tr	$y = 35.3403+1.4383x-0.03038x^2$	9.750×10^{-5}	23.7	53.0
	Ls	$y = 0.2895-0.003353x$	2.501×10^{-8}		

1. Pn: μ mol CO_2 m^{-2} s^{-1}; Cs: cm s^{-1}; Ci: µ1 L^{-1}; Tr: mmol H_2O m^{-2} s^{-1}; Ls = 1-Ci/Ca.

and the number of days necessary for dropping to half of maximum ($Pn_{\Delta 50(-)}$). Pn_{max} shows that Pn starts to decrease, while $Pn_{\Delta 50(-)}$ shows that Pn begins to degrade rapidly. According to the equation analysis in Table 3, the days of Pn_{max} and $Pn_{\Delta 50(-)}$ were significantly different in the two cultivars and were 24.9 days and 51.6 days after leaf unfolding for Luhua 11; and 21.7 days and 49.9 days for Fu 8707 respectively. This indicated that the decrease in Pn in Fu 8707 started earlier than in Luhua 11 during leaf senescence. In comparison with the changes of chlorophyll content, it was clear that the days of Pn_{max} were in accord with Chl $(a+b)_{max}$, but the days of $Pn_{\Delta 50(-)}$ were earlier than that of Chl $(a+b)_{\Delta 50(-)}$ during leaf senescence. Therefore, it could be concluded that before leaf senescing, chlorophyll was the main factor affecting Pn. The high and low values of chlorophyll content basically reflected the rate of Pn but after leaf senescing, the decrease of chlorophyll content and Pn was not concordant; Pn decreased more rapidly than chlorophyll content. This indicated that during leaf senescence, besides chlorophyll other factors (such as chloroplast structure destroying, membrane lipide superoxidation enhancement, and O_2 accumulation) could also affect Pn.

Intercellular CO_2 concentration, stomatal conductance, transpiration rate, and limiting value of stomata. During the process of leaf growth and senescence, the changes of Cs and Tr were basically similar to that of Pn (Table 3). This showed that Pn reduction was due to decrease in Cs and Tr. During the process of leaf growth and senescence, Ci went linearly up and could be simulated with the equation $y = A + Bx$, where x refers to the days after leaf unfolding; the slope for Fu 8707 (0.5065) was higher than for Luhua 11 (0.3238). According to the CO_2 concentration of the air (Ca) and Ci, the limiting value of stomata (Ls) for photosynthesis could be modeled as $Ls = 1-Ci/Ca$. The stomatal factor and non-stomatal factor to cause decrease in photosynthesis could be distinguished by the change of Ls during leaf senescence. Ls decreased linearly after leaf unfolding, the decrease rate of Fu 8707 (0.003353) being faster than that of Luhua 11 (0.002607) (Table 3). This indicated that during leaf senescence, the limiting value of stomata for photosynthesis decreased gradually, but that of non-stomata increased constantly. Non-stomatal factors reduced Pn in late phase. Compared with Luhua 11, the photosynthetic properties of Fu 8707 decreased earlier and faster during leaf senescence.

Conclusions

The decline of photosynthetic properties is one of the main characteristics of plant senescence. The decrease of leaf photosynthetic capacity begins after the leaf is fully unfolding. During protein hydrolysis, chloroplast breaks up, chlorophyll content decreases, leaves turn yellow, and the photosynthetic properties decrease rapidly. This study showed that Pn increased gradually after leaf unfolding and reached the maximum during 20-25 days after leaf unfolding; it then decreased slowly and later decreased rapidly at about 50 days after leaf unfolding. During the lag phase of Pn, the decrease in Pn was mainly caused by the reduction of Cs and Tr (Li Xiangdong 2000). After getting into lag phase of Pn, the Ls was very low. This indicated that non-stomatal factors (such as chloroplast structure destroying, membrane lipide superoxidation enhancement, and O_2 accumulation) were the main reasons for reduction in Pn at lag phase. The obvious characteristic of leaf senescence is that leaves turn yellow. The decrease in chlorophyll content is the main indication of leaf senescence. But the exact reason of chlorophyll content decrease is still not clear. One hypothesis considered that the number of chloroplasts was maintained constant. But it was gradual reduction of chlorophyll in the chloroplast that caused decrease in chlorophyll content (Martinoia et al. 1983, Mae et al. 1984). The other possibility considered that it was the reduction in number of chloroplasts that led to decrease in chlorophyll content (Wittenbach et al. 1982, Araus and Labrana 1991). This study showed that disintegration of chloroplast, and reduction in chloroplast number caused decrease in chlorophyll content during groundnut leaf senescence. The decrease in Chl a content did not synchronize with Chl b; Chl a broke up faster than Chl b, and the rate of Chl a/Chl b decreased gradually. Hence Chl a/Chl b was regarded as a much better index of photosynthetic properties. Chlorophyll is the basis of photosynthesis and its content is immediately related to Pn. From this study, we concluded that increase in chlorophyll content caused increase in Pn after leaf unfolding. But it was not decrease in chlorophyll content alone that led to reduction in Pn. Before chlorophyll content decreased rapidly, Pn had reduced quickly. Besides chlorophyll content, other physiological factors (such as chloroplast structure, membrane lipide superoxidation enhancement, and O_2^- accumulation) caused decrease in Pn at the late phase of leaf senescence. In the productive practice, it was feasible to use chlorophyll content to estimate the value of Pn for young and middle-aged leaves, but it was unreliable for senescing leaves. The fact that the quick-drop in Pn was faster than decrease in chlorophyll content showed that it was possible to increase Pn or delay its reducing rate, and delay leaf senescing by taking regulative measures based on chlorophyll content during the late phase of leaf senescence.

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Effect of Sulfur Application on the Distribution of S, Ca, and Fe in Chlorotic Groundnut on Alfisol in Java

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Groundnut *(Arachis hypogaea)* is planted mainly on Alfisol in Java Island. Chlorosis on young leaves of groundnut is a common problem occurring on the crop planted in Alfisol with soil pH more than 7.4 and annual rainfall of 2009 mm. Pod yield is reduced by 20-70%, depending on the intensity of chlorosis. Field observations clearly indicate that interveinal chlorosis on young leaves resemble symptoms of iron (Fe) deficiency. Also, soil and leaf analysis indicate high Fe content. Recent researches in the chlorotic problem areas indicated that the symptoms could be due to Fe, zinc, and potassium deficiencies, high soil pH, and high soil calcium carbonate ($CaCO_3$) content.

High soil pH and high soil $CaC0_3$ content not only induce low Fe solubility in the soil (Barber 1995), but also result in Fe inactivation and translocation inhibition in the plant (Gunton 1989). Considering some research results, Mengel (1994) concluded that Fe-chlorotic symptom is a physiological process that occurs in roots and leaves. Split application of 400 to 600 kg S ha^{-1} reduce soil pH and chlorosis, and therefore increase pod yield by more than 20% (Taufiq and Sudaryono 1998). Application of Fe-EDTA or $FeSO_4$ (Goos and Johnson 2000), K,SO_4 (Barak and Chen 1984) could reduce chlorosis.

Planting a tolerant groundnut genotype to overcome chlorosis due to nutrient deficiency is recommended as it is practical and economical. Until recently, there was no groundnut genotype that was consistently tolerant to chlorosis. Thus, nutritional management to overcome chlorosis is important.

The earlier research work indicated that chlorosis is caused by complex factors, which are related to each other. One way to identify the cause is by comparing distribution of nutrients within the plant that presumably correlate with chlorotic phenomenon. It is expected that this method will help in identifying the cause of chlorosis, which will guide nutritional management practices to overcome this problem.

A pot experiment to determine the effect of elemental sulfur (S) application on groundnut growth, incidence of chlorosis, and distribution of S, calcium (Ca), and Fe in the plant was carried out in the greenhouse at the Research Institute for Legumes and Tuber Crops (RILET) in East Java, Indonesia from November 2000 to January 2001 using alkaline Alfisol. The top 40-cm depth soil was collected from farmers' fields at Brondong,

Table 1. Effect of elemental sulfur (S) application on S, calcium (Ca), and iron (Fe) content chlorotic intensity, chlorophyll content index, and shoot dry mass of groundnut grown on alkaline Alfisol in Java[1].

S application	Nutrient content (%)			Chlorotic	Chlorophyll	Shoot dry
(g kg^{-1} soil)	S	Ca	Fe	score	content index	mass (g $plant^{-1}$)
In YFEL[2]						
0.0	0.45 a	3.31 a	0.022 a	4.0	22.5	2.06 a
0.5	0.80 c	2.87 ab	0.029 a	2.0	29.7	3.06 b
1.0	0.74 b	2.53 bc	0.025 a	2.4	30.5	3.25 bc
1.5	0.79 b	2.22 cd	0.022 a	1.7	41.5	3.65 cd
2.0	0.68 b	2.00 d	0.027 a	1.0	40.4	3.75 d
In shoot + older leaves						
0.0	0.23 a	2.64 a	0.049 a			
0.5	0.43 b	2.53 ab	0.041 a			
1.0	0.49 b	2.53 ab	0.042 a			
1.5	0.49 b	2.25 bc	0.034 a			
2.0	0.51 b	2.08 c	0.040 a			
In roots						
0.0	0.46 a	1.31 a	0.185 a			
0.5	1.44 b	2.07 b	0.211 a			
1.0	1.73 b	2.50 b	0.150 a			
1.5	1.79 b	2.50 b	0.139 a			
2.0	1.86 b	2.45 b	0.135 a			

1. Data recorded at 42 days after sowing.
Values in the same column with the same letter for each plant part are not significantly different at LSD 5%.
2. YFEL = Youngest fully expanded leaves.

Lamongan District (East Java Province). The soil has pH 7.6,22.8% $CaCO_3$, 7.56 ug SO_4 g^{-1},and 3.7 ug Fe g^{-1} (DTPA-Fe). Sulfur fertilizer (85% S) was applied 30 days before sowing at 0, 0.5, 1.0, 1.5, and 2.0 g S kg^{-1} soil. The treatments were laid out in a randomized complete design with three replications.

Soil moisture content was maintained at 50% of field capacity during S incubation (30 days), and later at field capacity during the crop growing period. A recent Indonesian groundnut variety Singa was used. Parameters were S, Ca, and Fe content, chlorophyll content index on youngest fully expanded leaves (YFEL) (using a chlorophyll meter SPAD-502), chlorotic intensity score, and shoot dry mass. These parameters were observed when the plants showed chlorotic symptoms and there was no indication to recover. This occurred at 38 days after sowing (DAS) and the plants were harvested at 42 DAS (pegging stage). The chlorotic score was recorded on 1-6 rating scale, where 1 = normal (no chlorosis); 2 = very low (pale green leaflet with green vein); 3 = low (yellowish green leaflet with green vein); 4 = moderate (yellowish leaflet with green vein); 5 = high (yellow leaflet and vein); 6 = very high (yellowish white leaflet and vein).

The results indicated that S application increased S content in YFEL, shoot + older leaves, and roots in the following order: YFEL>shoot + older leaves>roots. In the chlorotic groundnut crop, S content in these plant parts was lower than in normal plants (Table 1). Without S application, the plants showed moderate chlorosis with score of 4 and lower chlorophyll content index; shoot dry mass reduced by 57% and S content in YFEL, shoot + older leaves, and roots was 0.45%, 0.23%, and 0.46% respectively. Application of 0.5 g S kg^{-1} soil increased S content in these plant parts by about 50% (Table 1). The optimum S content in groundnut leaves at 50% flowering was 0.67% (Tandon 1989). Duke and Reisenauer (1986) showed that S content of >0.5% in leaves is poisonous. It means that concentration of 0.45% S in the YFEL or 0.23% S in the shoot + older leaves was at the deficiency level. Visual observation indicated no toxicity symptom in the groundnut leaves, even though S content in YFEL of normal plant was >0.5%.

Calcium content in YFEL, shoot + older leaves, and roots of chlorotic groundnut was 3.31%, 2.64%, and 1.31% respectively, while in normal groundnut it was 2.0%, 2.08%, and 2.45% respectively (Table 1). High Ca-uptake might be due to high soil $CaCO_3$ content (22.81%). These data showed that S application reduced Ca content both in the YFEL and in shoot + older leaves, but increased Ca content in the roots. It means that S application inhibited Ca translocation into the YFEL and shoot + older leaves.

Sulfur application did not affect Fe content in all plant parts analyzed. The content of Fe was in the order of YFEL<shoot + older leaves<roots. The Fe content ranged from 0.022% to 0.029% Fe (220-290 µg Fe g^{-1}) in YFEL and 0.034% to 0.049% Fe (340-490 µg Fe g^{-1}) in shoot + older leaves. It indicated that there was no difference in Fe content between the chlorotic groundnuts and the normal plants. An adequate level of Fe in the shoots at flowering stage was 50-75 µg Fe g^{-1} (Jones et al. 1991).

Chlorotic score positively correlated with Ca content in YFEL (r = 0.91), and negatively correlated with S content in YFEL (r = -0.96). Chlorophyll content index in YFEL negatively correlated with chlorotics score (r = -0.86). As both chlorotic score and chlorophyll content index did not correlate with Fe content in YFEL, chlorotic symptoms in groundnut grown on alkaline Alfisol therefore might be due to high Ca and low S contents in the plants. This implied that elemental S application could be used as an alternative to overcome chlorosis in groundnut grown on alkaline Alfisol.

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Enhanced Growth of Groundnut by Plant Growth Promoting Rhizobacteria

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Rhizobacteria are the group of bacteria that colonize the rhizosphere naturally. These are soil bacteria that stimulate plant growth after inoculation of seeds or roots and beneficial interactions can be enhanced if these are effectively managed. The beneficial bacteria termed as plant growth promoting rhizobacteria (PGPR) stimulate growth of plants. The PGPR have been studied in various crop plants (Burr and Caesar 1983). Fluorescent *Pseudomonas* spp have been studied as the most potential and promising group of PGPR. This study was undertaken to isolate predominant rhizobacteria from groundnut (*Arachis hypogaea*) rhizosphere and rhizoplane for appraising their plant growth promoting activity. Effect of these PGPR in relation with *Rhizobium* in establishment of association with groundnut was also studied.

The rhizosphere microflora was isolated by serial dilutions (10^{7} dilution) following the method used by Nielsen et al. (1998). Four selective media [Eosin-methylene blue agar for enterobacteria, King's B medium, *Pseudomonas* isolation agar (Himedia), and *Pseudomonas fluorescens* agar (Himedia)] and four non-selective media (nutrient agar, peptone dextrose agar, potato dextrose agar, and soil-extract agar) were used. All the media were supplemented with cycloheximide (1 mg L^{-1}) to inhibit fungal growth.

The isolation of rhizoplane bacteria was done by serial dilution (10^{-7} dilution) on selective and non-selective media as described earlier. The plants were sampled from three different locations of fields of Nanded, Maharashtra, India. Three replications were kept for each location. Characterization of the cultures was done and characters were recorded following Collins and Lyne (1976). Identification was done up to generic level as per Bergey's Manual of Systematic Bacteriology (Holt and Krieg 1984, Holt et al. 1986). Bacteria were grown to log phase in nutrient broth and optical density was adjusted to 10^{8} cells ml^{-1} using barium chloride ($BaCl_2$) standards. One ml of each isolate was added over the sown seeds and covered with soil-sand mixture. *Rhizobium* inoculation was also included in the studies. *Rhizobium* culture used in the study was isolated from a commercial *Rhizobium* inoculant available locally. *Rhizobium* was characterized by their ability to nodulate and produce acid in mineral salt mannitol medium (Vincent 1970). *Rhizobium* was grown to log phase on nitrogen free mannitol broth and optical density was adjusted to 10^{3} cells ml^{1}.

Table 1. Effect of inoculation with rhizobacteria on growth parameters and yield of groundnut cv TAG 24 in pot trials in Nanded, Maharashtra, India.

Description	Treatment[1]	30 DAS[2]	60 DAS	90 DAS	Harvest[3]
Plant height (cm)	T_1	3.17	7.54	14.63	15.55
	T_2	3.46	8.46	15.17	16.06
	T_3	3.77	8.93	15.90	16.63
		3.11	6.91	13.50	14.33
	SE±	0.110	0.083	0.151	0.134
	CV (%)	3	5	6	7
No. of branches		1.97	4.53	6.63	6.18
	T_2	2.02	4.88	6.87	6.23
	T_3	2.05	4.97	6.94	6.50
	T_4	1.83	4.33	6.40	5.93
	SE±	0.071	0.080	0.073	0.136
	CV (%)	4	5	5	6
Leaf area (cm^2 $plant^{-1}$)	T_1	151.84	699.96	1267.16	705.22
	T_2	153.20	754.52	1445.64	812.43
	T_3	154.32	926.76	1791.56	1117.63
	T_4	151.32	599.56	978.77	498.17
	SE±	3.407	4.284	8.433	11.006
	CV (%)	4	5	7	7
Total dry matter (g $plant^{-1}$)		2.53	9.70	18.25	15.77
	T_2	2.55	10.35	20.10	17.93
	T_3	2.58	11.77	23.16	20.86
	T_4	2.51	8.17	15.93	13.25
	SE±	0.044	0.435	0.757	0.644
	CV %	4	6	6	7
Pod mass (g $plant^{-1}$)	T_1	–	2.70	5.93	7.35
	T_2	-	3.84	7.63	9.27
	T_3	-	4.69	10.17	11.93
	T_4	-	1.94	4.36	5.50
	SE±	-	0.241	0.487	0.309
	cv %	-	5	4	7

1. T_1 = *Rhizobium* treated; T_2 = Plant growth promoting rhizobacteria (PGPR) treated; T_3 = *Rhizobium* + PGPR treated; T_4 = Control. CV (%) indicates rounded off values.
2. DAS = Days after sowing.
3. At 117 DAS.

Rhizobacterial isolates were tested on groundnut under greenhouse conditions where the mean temperature was 28°C with a photoperiod of 14 h light and 40-70% relative humidity. The experiments were conducted in randomized block design with the cultivar TAG 24 during 2000-01. Groundnut seeds were surface sterilized with sodium hypochlorite (NaOCl) solution (1%) for 5 min and rinsed in sterile distilled water. Five seeds were sown in sterilized plastic pots filled with 2 kg of sterile soil-sand mixture (4:1). Sixteen pots were allocated for each treatment. Seedlings were thinned to two per pot after emergence. The uninoculated control and treatments were replicated four times and regularly watered with sterilized water. Two plants from each treatment were selected randomly for analysis of growth parameters.

In field trials, the plot size was of 5.4 m x 4.5 m containing 10 rows with a row spacing of 0.45 m. Five plants were selected randomly from each treatment plot for recording the growth

Table 2. Effect of inoculation with rhizobacteria on growth parameters and yield of groundnut cv TAG 24 in field trials in Nanded, Maharashtra, India.

Description	Treatment[1]	30 DAS[2]	60 DAS	90 DAS	Harvest[3]
Plant height (cm)	T_1	2.55	7.18	12.11	13.20
	T_2	3.11	8.23	15.58	16.89
	T_3	3.52	9.75	17.35	18.25
	SE±	0.263	0.155	0.36	0.461
	CV (%)	4	5	7	7
No. of branches	T,	1.60	4.25	6.11	5.80
	T_2	2.08	4.81	6.72	6.38
	T,	2.23	5.35	7.18	6.77
	SE±	0.179	0.163	0.077	0.085
	CV (%)	5	5	8	10
Leaf area (cm^2 $plant^{-1}$)	T_1	152.96	692.52	1023.76	573.16
	T_2	160.12	717.68	1255.28	754.52
	T_3	167.88	763.20	1807.56	1108.50
	SE±	4.844	4.907	8.173	11.006
	CV (%)	5	8	7	9
Total dry matter (g $plant^{-1}$)	T_1	2.29	7.94	13.21	14.47
	T_2	3.69	10.43	17.25	16.25
	T_3	2.70	11.17	20.88	19.71
	SE±	0.055	0.464	0.608	0.865
	CV (%)	5	9	10	11
Pod mass (g $plant^{-1}$)	T_1	-	2.58	4.27	5.83
	T_2	-	2.96	5.63	7.19
	T,	-	4.09	6.92	9.10
	SE±	-	0.233	0.259	0.295
	CV (%)	-	7	10	13

1. T_1 = Uninoculated; T_2 = Plant growth promoting rhizobacteria (PGPR) treated; T_3 = *Rhizobium* + PGPR treated. CV (%) indicates rounded off values.
2. DAS = Days after sowing.
3. At 117 DAS.

parameters. Recommended agronomic practices for this region were followed.

For pot as well as field trials, plants were uprooted at regular intervals after sowing. Height of plants, number of branches, leaf area, dry pod mass, and total dry matter were recorded. The total dry matter was recorded after drying the haulms at 60°C till constant weight was obtained. The crop was harvested at 117 days after sowing and data was statistically analyzed and differences were assessed for their significance.

A total of 105 bacteria were isolated. Of these, 67% were from the rhizosphere and 33% from the rhizoplane of groundnut. Gram-negative bacteria accounted for about 65% whereas gram-positive bacteria accounted for only 35% of the total bacteria. *Pseudomonas* was most predominant (42%) followed by *Bacillus* (28%) and *Enterobacter* (21%); the remaining bacteria (9%) belonged to different genera of microorganisms such as *Micrococcus, Proteus,* and *Klebsiella.* Among the *Pseudomonas* group, 30% were fluorescent.

Effect of the 105 isolates on plant growth varied; plants showed stunted growth, root and shoot elongation, or neutral response. Three isolates increased the root length while 14 isolates increased shoot length over the uninoculated control. An increase in fresh and dry mass was recorded by

16 strains. Three were classified as *Pseudomoms* spp, nine as *Bacillus* spp, and four as *Enterobacter* spp. Studies on PGPR involved mainly *Pseudomonas* because of their siderophore complexes and production of antibiotic compounds (de Weger et al. 1986).

In preliminary experiments, the responses of the bacterization of groundnut seeds by rhizobacteria varied during greenhouse trials. Sixteen isolates were classified as plant growth promoters during the course of the study. Two isolates identified as *Enterobacter* spp promoted highest plant growth followed by one isolate each of *Pseudomonas fluorescens* and *Bacillus* sp. In the greenhouse pot trial and field trial, a mixture of these three strains was used for inoculation of seeds.

All the five parameters studied were significantly higher in *Rhizobium* + PGPR followed by PGPR treatment alone than *Rhizobium* alone and uninoculated control both in field as well as in pot trials (Table 1). The treatment of PGPR in combination with *Rhizobium* was the best treatment than PGPR or *Rhizobium* alone (Table 2). The decrease in total dry matter is attributed to the senescence of leaves.

The results presented in this study indicate the presence of diverse microflora in the rhizosphere of groundnut. This study also indicates that selective bacterization with PGPR can improve growth of groundnut.

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Socioeconomics

An Economic Evaluation of Agricultural Production in Senegal: Evidence from the Diourbel and Thies Regions

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Agriculture is one of the most important sectors of the Senegalese economy. More than 60% of the total active population relies on agriculture, and this sector represents 17.4% of the gross domestic product (GDP). Senegalese agriculture is largely monocultural, characterized by the predominance of groundnut (*Arachis hypogaea*). This crop accounts for more than 50% of the total area 3,728,000 ha available for cropping and for 40 to 50% of export earnings (Jammeh 1987, Diop 1995).

Data from 1998 and 1999 were used to select six representative farms in Thies and Diourbel, two regions in the center of the Senegalese Peanut Basin. The representative farms were selected based on acreage, equipment, output level, and labor availability. Three farms were chosen from a total of 38 in Diourbel and another three from a total of 106 in Thies. These six representative farms presented different resource levels. Farms in Diourbel are on average larger and better equipped than farms in Thies.

Enterprise budgeting and linear programming (LP) techniques were used in order to determine the profitability of individual crops and optimal cropping patterns for the typical farms located in both regions. A mathematical statement of LP model is shown in Table 1.

An intensification analysis through the introduction of La Fleur 11, which is a relatively new groundnut variety; and the availability of capital, a major constraint for farm investments, are also included in the models (Subrahmanyam et al. 1999). All scenarios are described in Table 2.

High groundnut seeding densities seem to be the most significant productivity factor in the study area. The three farms for which output yield is >1 t ha^{-1} reported seeding rates above 90 kg ha^{-1}. In contrast, farm 006, with seeding rate of 29 kg ha^{1} has the lowest yield (0.515 tha^{-1}).

Equipment level is another important factor accounting for farm productivity. For example, farms 003 and 005, the best-equipped farms, have the highest groundnut results, while farm 004, the least equipped farm, does not cultivate groundnut, and farm 001 with a low level of equipment, cultivated only 0.8 ha of groundnut. The availability of a seeder, in particular, is a critical determinant of the level of groundnut farmed since seeding operation must be done in a short period.

As already indicated, a whole farm analysis is conducted using LP techniques. A base scenario reflecting the observed cropping patterns as well as other conditions of the representative farms are defined.

The LP model shows that groundnut and sorghum (*Sorghum bicolor*) production are the most profitable options to use agricultural land in Diourbel and Thies, respectively. Farms devote almost all their land to groundnut in Diourbel when food security, land rotation, and capital constraints are excluded. In Thies, farms devote most of their land to sorghum production. Moreover, capital is a major constraint for groundnut expansion because of the high cost of purchased seeds. (Additional details can be found in Cisse 2000.)

The first conclusion that can be drawn from this study is that farms in Thies and Diourbel are less profitable than farms located elsewhere in the Senegal Peanut Basin (Martin 1988). However, as would be expected, the analysis shows considerable variability in profitability across farms. Another relevant finding is that farms tend to be quite specialized. Groundnut and millet are the only common crops present in all farms. These two crops combined represent more than 90% of the cultivated land (Cisse 2000).

The absence of policies encouraging the intensification of agricultural production (seed quality, equipment replacement, and fertilizer and pesticide use) along with rainfall instability and soil degradation are the major reasons for low profitability. Thus, in order to improve agricultural productivity and increase farm income in Diourbel and Thies, several measures should be taken. First, improvement in credit access to

Table 1. Linear programming model[1].

Subject to: $\sum (A_{ij} * X_j) \leq B_i$

Maximize $Z = \sum_{j=1}^{n} (R_j * X_j) - \sum_{k=1}^{n} (C_k * X_k) - \sum_{a=1}^{n} (C_a * Xa) - \sum_{l=1}^{n} (C_l * X_l) - FC$

1. Z = Net profit; R_i = Returns over purchased inputs for growing crop j; X_i = The level grown of the j-th crop; C_k = Variable cost per day for the k-th machinery activity; X_k - The level of k-th machinery activity in days; C_a = Variable cost of draft animal; X_a = The level of animal days; C_i = Cost of hired labor per day; X_j= Hired labor at a specific time period in days; FC = Total annual fixed costs; A_{ij} = Amount of resource *i* consumed by each unit of the /-th activity; B_i = Amount of resource *i* available.

Table 2. Description of scenarios and results obtained from linear programming model for six farms in Senegal[1].

Description of scenarios	Profit indicators	001	002	003	004	005	006
Observed	Net profit (FCFA)	367 127	55 145	722 151	248 660	819 196	291 148
	Change in profit (FCFA)	0	0	0	0	0	0
	Land use (ha)	3.00	2.00	4.00	3.00	5.00	3.00
Base							
Restriction on cowpea and okra land:							
- Okra[2]: ≤0.5 ha	Net profit (FCFA)	585 596	97 326	6135 776	468 975	2377 098	2341 829
- Cowpea[4]: ≤20% of available land	Change in profit (FCFA)	0	0	0	0	0	0
- No restriction on crop rotation and capital availability.	Land use (ha)	4.00	9.94	21.09	5.00	7.35	20.20
I							
Rotation requirement:	Net profit (FCFA)	494 151	68 223	3863 699	NA	1641 703	2341 829
- Groundnut should not exceed 50% of the cultivated area.	Change in profit (FCFA)	−91 445	−29 103	−2272 077	NA	−735 395	0
	Land use (ha)	4.00	6.97	21.09	NA	7.35	19.95
- The restriction on cowpea and okra is maintained.							
II							
Food self-sufficiency requirement:	Net profit (FCFA)	471 290	NA[5]	5382 185	462 080	1823 486	2187 182
- Millet and/or sorghum land is set to meet the requirement.	Change in profit (FCFA)	−114 306	NA	−753 591	−6 895	−553 612	−154 647
	Land use (ha)	4.00	NA	21.09	5.00	7.35	20.20
- The restriction on cowpea and okra is maintained but the groundnut rotation requirement is released.							
III							
Operating capital constraint:	Net profit (FCFA)	412 345	25 238	118 502	468 975	1063 953	2341 829
- Availability of operating capital: ≤FCFA 30,000	Change in profit (FCFA)	−173 251	−72 088	−4947 274	0	−1313 145	0
- Release of rotation requirement and food self-sufficiency but maintain okra and cowpea area restrictions.	Land use (ha)	4.00	NA	21.09	5.00	7.35	20.20
IV							
Inclusion of La Fleur 11 in the cropping system:	Net profit (FCFA)	813 724	1939 266	6151 174	1053 230	NA	4230 831
- All other restrictions except those on okra and cowpea areas are removed.	Change in profit (FCFA)	228 128	1841 940	15.398	584.255	NA	1889 002
	Land use (ha)	4.00	9.94	21.09	5.00	NA	20.20

1. Farms 001 to 003 = in Diourbel; 004 to 006 = in Thiès; FCFA = Franc de la Communauté Financière de l'Afrique; NA = Not applicable.
2. Only applicable for farm 003.
3. Applicable for all farms with cowpea in their cropping systems.

small farmers would allow for increased fertilizer, pesticide, and higher seed quality use.

Second, production and marketing costs could be reduced by greater liberalization of the input and output markets and investments in rural infrastructure. The disengagement of the state from agricultural input supply and a larger role for the private sector in the implementation of small businesses should be stimulated.

Third, animal traction, which played a major role in Senegalese agriculture before the adjustment policies of the 1980s, should also be developed.

Fourth, and consistent with related works (Bravo-Ureta et al. 1997), La Fleur 11 shows higher profitability, compared to traditional groundnut varieties, and should be made more available in regions with limited rainfall, such as Diourbel and Thies.

Finally, the diversification of income sources could contribute to reduced risk in farming; thus, non-cropping activities in rural areas should be promoted. Non-farm income could be an important stimulus to farm productivity by providing capital that could be used to acquire purchased inputs as well as machinery and equipment (Cisse 2000).

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The main theme of the meeting was the "Aflatoxin Research in WCA" and its objectives were to take stock of achievements in groundnut research and development in the region, enable participants to discuss constraints to groundnut production and the means to overcome them, identify future needs and facilitate collaboration between national, regional, and international partners. One of the sessions of the workshop also served as the third official meeting of the Aflatoxin Working Group that was created in 1994. The recommendations of this working group and those of the meeting as well as 27 papers that were presented are included in these proceedings.

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Information for IAN contributors

Publishing objectives

The International *Arachis* Newsletter is published annually by the International Crops Research Institute for the Semi-Arid Tropics (ICR1SAT) and the Peanut Collaborative Research Support P rogram, USA. It is intended as a worldwide communication link for all those who are interested in the research and development of groundnut or peanut *(Amchis hypogaea* I ..) and its wild relatives. Though the contributions that appear in IAN are peer-reviewed and edited, it is expected that the work reported will be developed further and formally published later in refereed journals. It is assumed that contributions in IAN will not be cited unless no alternative reference is available.

IAN welcomes short contributions (not exceeding 1000 words) about matters of interest to its readers

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Send us the kind of information you would like to see in IAN.

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- Results of recently concluded experiments, newly released varieties, recent additions to germplasm collections, etc.
- Genome maps and information on probe-availability and sequences, and populations synthesized for specific traits being mapped. Glossy black and white prints of maps should be included, if possible. Partial maps can also be submitted.
- Short reports of workshops, conferences, symposia, field days, meetings, tours, surveys, network activities, and recently launched or concluded projects.
- Details of recent publications, with full bibliographic information and 'mini reviews' whenever possible.
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- Keep the items brief remember, IAN is a newsletter and not a primary journal. About 1000 words is the upper limit (no more than three double-spaced pages).
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Information for IAN contributors

Publishing objectives

The International *Arachis* Newsletter is published annually by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the Peanut Collaborative Research Support Program, USA. It is intended as a worldwide communication link for all those who are interested in the research and development of groundnut or peanut *(Arachis hypogaea* I „) and its wild relatives. Though the contributions that appear in IAN are peer-reviewed and edited, it is expected that the work reported will be developed further and formally published later in refereed journals. It is assumed that contributions in IAN will not be cited unless no alternative reference is available.

IAN welcomes short contributions (not exceeding 1000 words) about matters of interest to its readers.

What to contribute?

Send us the kind of information you would like to see in JAN.

- Contributions should be current, scholarly, and their inclusion well-justified on the grounds of new information.
- Results of recently concluded experiments, newly released varieties, recent additions to germplasm collections, etc.
- Genome maps and information on probe-availability and sequences, and populations synthesized for specific traits being mapped. Glossy black and white prints of maps should be included, if possible. Partial maps can also be submitted.
- Short reports of workshops, conferences, symposia, field days, meetings, tours, surveys, network activities, and recently launched or concluded projects.
- Details of recent publications, with full bibliographic information and 'mini reviews' whenever possible.
- Personal news (new appointments, awards, promotions, change of address, etc.)

How to format contributions?

- Keep the items brief- remember, IAN is a newsletter and not a primary journal. About 1000 words is the upper limit (no more than three double-spaced pages).
- If necessary, include one or two small tables (and no more). Supply only the essential information; round off the data-values to just one place of decimal whenever appropriate; choose suitable units to keep the values small (e.g., use tons instead of kg). Every table should fit within the normal type-written area of a standard upright page (not a 'landscape' page). Do not use the table-making feature of the word processing package; use simple tab set to prepare tables.
- Black-and-white photographs and drawings (prepared in dense black ink on a white card or a heavy-duty tracing paper) are welcome - photocopies, color photographs, and 35-mm slides are not. Please send disk-files (with all the data) whenever you submit computer-generated illustrations.
- Keep the list of references short - not more than five references, all of which should have been seen in the original by the author. Provide all the details including author/s, year, title of the article, full title of the journal, volume, issue, and page numbers (for journal articles), and place of publication and publishers (for books and conference proceedings) for every reference. Cite references as in this issue.
- Express all the quantities only in SI units.
- Spell out in full every acronym you use.
- Give the correct Latin name of every crop, pest, or pathogen at the first mention.
- Type the entire text in double spacing. Please send a file, which should match the printout, on a double-sided/high density IBM-compatible disk using **Microsoft Applications.**
- Contact the Editors for detailed guidelines on how to format text and diskettes.
- **Include the full address with telephone, fax, and e-mail numbers of all authors.**

The Editors will carefully consider all submitted contributions and will include in the Newsletter those that are of acceptable scientific standard and conform to requirements. The language of the Newsletter is English, but where possible, articles submitted in other languages will be translated. Authors should closely follow the style of the reports in this issue. Contributions that deviate markedly from this style will be returned for revision, and could miss the publication date. Communications will be edited to preserve a uniform style throughout the Newsletter. This may shorten some contributions, but particular care will be taken to ensure that the editing will not change the meaning and scientific content of the article. Wherever substantial editing is required, a draft copy of the edited version will be sent to the contributor for approval before printing.

Contributions should be sent before 30 June to:

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