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Peanut CRSP
Peanut Collaborative Research Support Program
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ICRISAT
International Crops Research Institute for the Semi-Arid Tropics
(http://www.cgiar.org/icrisat)

About Peanut CRSP

The Peanut Collaborative Research Support Program is an international program supported by USAID 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, socio-economic forces, post-harvest 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 10 universities in the USA linked to 14 host countries in the developing world. Both host countries and the 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, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT's mission is to conduct research which 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 one of 18 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is 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 World Bank, and the United Nations Development Programme (UNDP).

IAN Scientific Editor

S N Nigam

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News and Views

From the Editor

This issue of the Newsletter contains several contributions from Africa. The Editor would like to thank the scientists who responded to his request made in the last issue of the Newsletter. The Editor pleads with other scientists in Africa to share their research results and experiences with others through the medium of this Newsletter. It is important to maintain this momentum.

New scientific developments are taking place in almost all fields of knowledge. Agriculture is no exception to this. Developments in biotechnology have opened up new vistas in crop improvement research. However, in many developing countries scientists are not fully aware of these possibilities because of lack of access to the appropriate literature. The Newsletter community will benefit greatly from learning above these developments in groundnut. The Editor would like to invite scientists involved in biotechnology research in groundnut to contribute popular/semi-popular articles to the Newsletter to create general awareness in the Newsletter community of the possibilities and limitations of biotechnology in groundnut.

Another area which remains under-represented in the Newsletter is the section on News and Views. Readers of the Newsletter are encouraged to contribute to this section freely.

The Editor would like to acknowledge the contribution of the following reviewers to this issue of IAN:

Y S Chauhan, S L Dwivedi, C L L Gowda, C Johansen, P K Joshi, V K Mehan, R C Nageswara Rao, Piara Singh, R D V J Prasada Rao, A Ramakrishna, G V Ranga Rao, D V R Reddy, L J Reddy, T J Rego, D C Sastri, H C Sharma, K K Sharma, S B Sharma, S D Singh, V Subramanian, and H D Upadhyaya.

By the time this issue of the Newsletter is in your hands, we shall all be in a festive mood. The Editor would like to extend the Seasons' Greetings to all the readers of the Newsletter.

S N Nigam

Second International Crop Science Congress

More than 1300 delegates (of whom over 500 were from 70 countries worldwide) gathered to reflect on "Crop Productivity and Sustainability — Shaping the Future" at the Second International Crop Science Congress (ICSC), held at Vigyan Bhawan, New Delhi, India, 17–24 Nov 1996. It was organized by the National Academy of Agricultural Sciences, and the Indian Council of Agricultural Research (ICAR), New Delhi, India, and co-sponsored by the Consultative Group on International Agricultural Research (CGIAR), Washington, and Pioneer Hi-breed International, Iowa, both from USA, and Maharashtra Hybrid Seed Company Limited (MAHYCO) Research Foundation, Mumbai, Association of Seed Industry, Mumbai, National Seed Corporation, New Delhi, all from India.

The Congress was inaugurated by the then President of India, Dr Shankar Dayal Sharma. He released a coin, a stamp, and a book entitled "Fifty years of Crop Science Research in India". Besides the President, other chairs were Mr Chaturanan Mishra (Minister of Agriculture), Mr Beni Prasad Verma (Minister of Communication), Dr Y K Alag (Minister of State for Planning and Science and Technology), Dr R S Paroda (Director General, ICAR, and Secretary, Department of Agricultural Research and Education [DARE]), Dr K J Frey (First President of ICSC), Dr Ismail Serageldin (Chairman, CGIAR, and Vice President, World Bank), Dr C J Nelsen, Dr M S Swaminathan (President, National Academy of Agricultural Sciences [NAAS]), and Prof R B Singh (Director, Indian Agricultural Research Institute [IARI], New Delhi).

Plenary Lectures, Symposia Lectures, and Working Group Base Papers were presented. The Symposium papers were presented in the following 11 sessions: Emerging trends in improvement of food and fibre crops; Emerging trends in the management of biotic stresses; Ecological foundations for sustainable productivity; Emerging trends in improvement of fruit, vegetable, and ornamental crops; Emerging trends in management of abiotic stresses; Crop and cropping systems; Emerging trends in improvement of plantation and medicinal crops; Emerging trends in improvement of forest trees and perennials; Methods of analysis of quantitative data in crop research; Technology assessment and transfer; and Meeting the emerging concerns.

This Congress gave a strong impetus to agricultural research and development, both nationally and internationally. Since eco-technology is the path to an evergreen revolution, there is a need to develop varieties which use less water, soil, and pesticide. More stress should be laid on biofertilizers, rather than on chemical fertilizers. Biotechnology is a new field in developing countries; it should be popularized. Participants at the Congress were agreed on the need to launch a strong global movement to protect the rich biodiversity of the planet. Other conclusions of the Congress were the following:

- A second green revolution is possible only if yield ceilings in crops are raised. Hybrid technology will push yields up further in the major food crops
- Crops need to be introduced into new ecological niches, e.g., soybean in fallow lands, and others
- Cost-effectiveness and efficiency of input use, integrated nutrient management, and integrated water management need to be improved
- Genetic potential of crop species needs to be consolidated by insulating them against diseases and pests for which no resistance is available, possibly using molecular marker techniques
- Value addition in agricultural commodities is required
- Postharvest technologies need to be updated
- Avenues for by-product utilization need to be explored

About Scientists

Dr P S Bharodia, Research Scientist (Groundnut), Gujarat Agricultural University, Junagadh, Gujarat, India, received the Sardar Patel Agricultural Research Award 1995/96 for his outstanding research work in the field of plant breeding and genetics, especially in pulse crops. The Award, sponsored by the Government of Gujarat, Department of Agriculture and Cooperation, Gandhinagar, was given by the Chief Minister Mr Shankarsingh Vaghela at Town Hall, Gandhinagar, on 30 Dec 1996. Dr Bharodia has also received the Hari Om Ashram Award, and has been commended by the Nobel laureate Dr Norman E Borlaug for his outstanding research work on wheat in 1985/86.

Dr H R Pappu has joined the Department of Plant Pathology, University of Georgia, Coastal Plain Experiment Station, Tifton, Georgia, USA, as an Assistant Professor. He obtained his PhD from the University of Alberta, Edmonton, Canada, and did postdoctoral work at the University of Florida, Gainesville, Florida, USA. At the University of Georgia, he has research and extension responsibilities in the area of plant virology. His current research projects include molecular characterization, epidemiology, and control of tomato spotted wilt tospovirus infection of groundnut in Georgia; development of rapid and sensitive, polymerase chain reaction (PCR)-based detection and differentiation of peanut stripe potyvirus strains; and production and use of virus-specific antisera in virus diagnosis. He can be contacted on +1 912 386 3371 (phone); +1 912 386 7285 (fax); hrp@tifton.cpes.peach.net.edu (e-mail).

In-country Training Course on Groundnut Production Technologies in Swaziland

The Groundnut Production Technology Training Course was held at Malkerns Research Station, Swaziland, from 17 to 21 Mar 1997. The course was inaugurated by Mr N M Nkambule, Principal Secretary, Ministry of Agriculture and Cooperatives, and the participants were welcomed by Mr D Gama, Acting Chief Research Officer. Twenty extension workers including six women from different regions of the country attended the training course.

The major objective of the course was to develop and upgrade the skills of extension workers, and to encourage the exchange of ideas and experiences between them for effective transfer of groundnut production technologies to farmers in the country.

The participants were trained in identification of varieties suitable to various production systems in the country, groundnut plant and its reproductive biology, cultural practices, cropping systems, management of diseases and pests, and seed production. The course was largely field oriented. The participants were also shown a video "This is ICRISAT".

The training course was sponsored by the Southern African Development Community (SADC)/ICRISAT Groundnut Project. Two ICRISAT scientists based in Malawi (P Subrahmanyam and P J A van der Merwe) served as resource persons.

Groundnut project flowers

The importance of groundnut is growing in southern Africa – and so is the size of ICRISAT's research team. Since 1995, the Institute had only two groundnut scientists in the region, a breeder on deputation from ICRISAT-Patancheru, and a pathologist (P Subrahmanyam, ICRISAT Country Representative in Malawi, and Team Leader of the Southern African Development Community [SADC]/ICRISAT Groundnut Project). Four scientists have been recruited during the past year. They are all based in Malawi, and split their time between the SADC/ICRISAT Project and core-funded project activities throughout southern and eastern Africa.

John Russell, Scientist (Technology Transfer – Farming Systems), is the new coordinator for the SADC/ICRISAT Groundnut Project. He has spent much of the past 20 years in Africa. An agronomist by training (Universities of Maryland and Florida), he has worked in a range of areas related to adaptive research and farming systems research and training. He was an independent consulting agronomist and trainer based in Gainesville, Florida; worked on an International Fund for Agricultural Development (IFAD)-funded project as an Adaptive Research Specialist and adviser to the Ministry of Agriculture in Zanzibar; headed the International Institute of Tropical Agriculture's (IITA) farming systems unit in northern Cameroon; and was a training director with the US Peace Corps in Morocco and Zaire. He joined ICRISAT in Jan 1997, and will focus on two areas – design, implementation, and analysis of on-farm trials, and on-farm research to facilitate adoption of new varieties and management practices for groundnut.

Piet van der Merwe, Principal Scientist (Breeding), who joined the project in Sep 1996, was formerly Head of the Breeding Section at the Oil and Protein Seed Centre in Potchefstroom, South Africa. He was at Potchefstroom for 23 years, working on sunflower hybrids and (mainly) short-duration spanish confectionery groundnut for export. He helped develop a range of cultivars including Sellie – the most widely grown groundnut variety in southern Africa – and cultivars with resistance to black pod rot, which was then the most serious groundnut disease in South Africa. At ICRISAT, he is focusing on breeding for resistance to rosette and leaf spots, and particularly on developing high-yielding, resistant, short-duration breeding lines.

Duncan Boughton, Senior Scientist (Socioeconomics), joined ICRISAT in Aug 1996 from Michigan State University, USA, where he was a Visiting Assistant Professor in the Department of Agricultural Economics. His areas of specialization are agricultural economics and natural resources management in tropical agriculture (University of Reading, UK, and Michigan State University). He also worked in the Gambia for 5 years as a farming systems economist. His time at ICRISAT is divided between two regional projects (groundnut and pigeonpea). In both projects, he works with NARS staff to evaluate the appropriateness of improved varieties and management practices; diagnose constraints to adoption in seed delivery, farm-level production, marketing, and processing; and monitor adoption and impact.

Sieglinde Snapp, Scientist (Agronomy and Soil Fertility), joined the project in Jul 1996 after 3 years as a Rockefeller Postdoctoral Fellow with the Malawi Ministry of Agriculture and the University of Malawi. She has her roots in plant physiology and crop nutrition (degrees from Washington State University, University of Minnesota, University of California, Davis); and later branched out into studies on the use of fertilizer and organic amendments to improve soil quality and nutrient efficiency. Dr Snapp will coordinate ICRISAT's soil fertility work in the SEA region, working through a network of collaborators, using fertility modeling and farmer-participatory methods to develop inexpensive ways to manage soil fertility in different agroecologies.

Yield gains through polythene mulch technology

Scientists at the National Groundnut Research Centre (NRCG), Junagadh, Gujarat, India, are excited by their initial success in using polythene mulch technology to achieve groundnut yields as high as 9.5 t ha^{-1}. A news report in the daily *Business Line* (22 Oct) reports that on-farm trials of summer groundnut under irrigation over two seasons have given an extraordinary 5.4–9.5 t ha^{-1} compared to the average 2.6 t ha^{-1}. This technology has already had spectacular success in China (see the special supplement to the International *Arachis* Newsletter no. 15, which describes the technologies currently used for groundnut cultivation in China).

A significant step in the testing of this technology has been the development of low-density polythene films (10–12 μm) by the plasticulture group of Indian Petrochemical Corporation Limited (IPCL). With the polythene file that IPCL provides, NRCG plans to test this technology in many strategic locations: under riverbed and rice-fallow residual moisture conditions in the eastern States of India; low temperature areas in the northern and northwestern States after the harvest of rice, *toria*, and potato; and in the coastal saline soils under high temperatures in Gujarat and Rajasthan.

News from Cereals and Legumes Asia Network (CLAN)

Workshops and Meetings

Workshop on Managing Legumes Nitrogen Fixation in the Cropping Systems of Asia, 20–24 Aug 1996, ICRISAT-Patancheru, India

This workshop was also the second meeting of the Working Group on Nitrogen Fixing Legumes of Asia (NiFLA), formerly known as the Asia Working Group on Biological Nitrogen Fixation in Legumes (AWGBNFL), and was co-sponsored by the Australian Centre for International Agricultural Research (ACIAR), and ICRISAT. The meeting's focus was on the use of rhizobial inoculants in farmers' fields and quantification of nitrogen (N_2) fixed by legumes. Discussions were also held on soil biology/soil fertility, and host-plant selection for N_2 fixation. The meeting also served as a platform to review a project funded by ACIAR (no. 9210) on nitrogen fixation in Pakistan, Nepal, Bangladesh, and Australia. Forty-eight participants from 12 countries were joined by 20 scientists from ICRISAT-Patancheru for the deliberations during the workshop, and a workplan for future research was developed. The workshop also brought together public sector, private sector, and nongovernmental organizations involved in the research and production of bio-inoculants.

Workshop on Residual Effects of Legumes in Rice and Wheat Cropping Systems of the Indo-Gangetic Plains, 26–28 Aug 1996, ICRISAT-Patancheru, India

Forty participants representing Rice-Wheat Consortium member countries (Bangladesh, India, Nepal, and Pakistan), Cornell University, USA, Vietnam, and ICRISAT met in the workshop to collate and interpret the existing information and knowledge on legumes' residual benefits on subsequent crops in the region and to formulate future research plans. The presentations covered topics on biological nitrogen fixation and residual effects of legumes (including winter, summer, and rainy season), forage and green manure legumes, their management, and prospects of legumes in rice-wheat cropping systems. The group discussed the research needs of grain legumes, green manures and forage legumes, and constraints to adoption of technologies in the target regions. The participants desired good linkages with the Rice-Wheat Consortium to implement the proposed research agenda. The proceedings of the meeting will be published.

CLAN Country Coordinators' Steering Committee Meeting, 13–14 Nov 1996, Bangkok, Thailand

The meeting was co-sponsored by the Field Crops Research Institute, Thailand, Asian Development Bank (ADB), and ICRISAT. Country Coordinators from Bangladesh, China, India, Indonesia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, and Thailand, and representatives from ADB, Iran, International Board for Soil Research and Management (IBSRAM), and Asian Institute of Technology (AIT), participated in the meeting. The Country Coordinators (including Iran) presented the status and plans for collaborative research in CLAN, and suggestions for improving networks' usefulness to members. Representatives from ADB, AIT, and IBSRAM also made presentations. Participants felt that more research activities aimed at natural resource management are needed, as are research issues related to sustainability of agricultural systems.

The participants reviewed research activities in each member country, and the region; explored ways to improve effective exchange of genetic material, technology and information; and increased opportunities for human resource development. Discussions were held to find ways to improve communication and information exchange between member countries and the CLAN Coordination Unit (CLAN CU) for effective networking. Guidelines were formulated for future network activities to increase close cooperation between the members and within the region. The Steering Committee agreed to include Iran as a new member of CLAN.

The "Terms of Reference for CLAN Steering Committee" were approved with minor modifications (see Special Report below). To ensure continuity and smooth coordination of in-country activities, the group resolved to recommend the nomination of a Deputy Country Coordinator to assist and act on behalf of the Country Coordinator from each member country. CLAN CU will arrange to get nominations from the member countries.

Workshop on Joint Impact Assessment of NARS-ICRISAT Technologies in the Semi-Arid Tropics, 2–4 Dec 1996, ICRISAT-Patancheru, India

A workshop on joint NARS-ICRISAT impact assessment was conducted at ICRISAT-Patancheru to present results and progress of impact studies jointly undertaken by ICRISAT and Asian and African NARS; to provide a forum for peer review among scientists; and to discuss the research agenda for research evaluation and impact assessment, and set priorities for 1997. The papers presented in the workshop covered studies on assessment of adoption and impact evaluation of genetic enhancement research, natural resource management research, networking, and utilization and value of intermediate products such as improved germplasm and screening techniques. Twenty-three scientists from Bangladesh, India, Indonesia, Mali, Nepal, and Sri Lanka, and 46 scientists from ICRISAT participated in the workshop.

A workshop on "Harmonization of databases for GIS Analysis of Cropping Systems in the Asia Region" co-sponsored by Cornell University, Rice-Wheat Consortium and ICRISAT was held during 18–19 Aug 1997 at ICRISAT-Patancheru. Six Geographic Information Systems (GIS) specialists from Centro Internacional de Mejoramiento del Maïz y del Trigo (CIMMYT, Mexico), International Rice Research Institute (IRRI, Philippines) Centro Internacional de Agricultura Tropical (CIAT, Colombia), International Centre for Integrated Mountain Development (ICIMOD, Nepal), and 25 ICRISAT staff were joined by seven scientists from Bangladesh, India, Nepal, Pakistan, and Sri Lanka. The participants discussed GIS software options and protocols for interchangeability of GIS formats, database requirements, availability, storage, and exchange procedures; and provided recommendations for optimizing regional interaction in use of GIS for cropping system analysis in the Indo-Gangetic Plains.

Human Resource Development

Training Workshop on the Ureide Method for Measuring N_2 Fixation by Field Grown Legumes, 13–19 Aug 1996, ICRISAT-Patancheru, India

Twelve participants from Bangladesh, India, Myanmar, Vietnam, Nigeria, and ICRISAT attended the training workshop consisting of lectures on legume nitrogen fixation, the relevance of nitrogen fixation of agricultural production systems, and hands-on practical sessions on measuring N_2 fixation by the xylem ureide method including sampling and analysis, and data interpretation.

Training Workshop on Modeling Management Effects on Resource Conservation and Use in Semi-Arid Tropics, 25–29 Nov 1996, ICRISAT-Patancheru, India

A hands-on training workshop was conducted by ICRISAT jointly with the Central Research Institute for Dryland Agriculture (CRIDA), India, and the Australian Centre for International Agricultural Research (ACIAR) to introduce a systems approach using simulation modeling; provide practical experience with simulation models; and develop skills in the presentation of models and their value to system analysis. Twenty-two participants from Colombia (1), India (15), Thailand (2), Venezuela (1), and ICRISAT-Patancheru (3) attended the workshop.

A training program on "Use of GIS in Analysis of Cropping Systems" was cosponsored by Cornell University, USA, Rice-Wheat Consortium, and ICRISAT, and was organized at ICRISAT-Patancheru, 18–29 Aug 1997. Seven scientists from Bangladesh, India, Nepal, and Sri Lanka participated for an update on potential use of GIS, remote sensing, and crop modeling in analysis of cropping systems. The participants had hands-on experience in assembling databases and analysis of such data to characterize production systems and identify constraints to adoption of GIS and related technologies in cropping system analysis with specific reference to Indo-Gangetic plains.

Training Courses on Quality Control in Insect Nuclear Polyhedrosis Virus Production, 10–13 Oct 1996, and 28–31 Jan 1997, ICRISAT-Patancheru, India

The training courses were cosponsored by the Natural Resources Institute, UK, and ICRISAT-Patancheru. Thirteen researchers from private sector Indian agrochemical companies, five from public sector companies, one from Vietnam, and two ICRISAT-Patancheru staff attended the course. Senior scientists from UK (2), and the Tamil Nadu Agricultural University, India (1), joined ICRISAT scientists as resource persons for the courses. Participants were introduced to the biology of insect viruses; techniques for NPV production; identification of NPV and techniques for quality control of NPV formulations; diagnosis, colony maintenance and contamination; bioassay of insect viruses and DNA analysis; field application of NPV and field efficacy assessments; and use of NPV in IPM programs.

In-country Training Courses on Statistical Design and Analysis of Experiments

Courses were conducted in Vietnam (16–28 Dec 1996, Vietnam Agricultural Science Institute, Hanoi, and 30 Dec 1996 to 5 Jan 1997, Oil Plants Institute, Ho Chi Minh City), Nepal (30 Mar to 9 Apr 1997, Regional Agricultural Research Station, Parwanipur), and Sri Lanka (26 May to 7 Jun 1997, In-service Training Institute, Gannoruwa). The objectives were to impart skills for designing statistically sound and cost-effective research experiments to adopt efficient experimental techniques, statistical analysis procedures, and to provide hands-on experience on using INSTAT and MSTAT-C statistical software for analyses and interpretation of data.

Scientists working in various research stations under the National Agricultural Research Systems (NARS) attended the courses. A pre-training evaluation and a post-training evaluation clearly indicated the need and usefulness of the training course to the participants. Participants in general were of the opinion that the course was useful, and suggested that the course should be organized frequently to cover all NARS scientists.

In-country Training Course on On-farm Research Methodologies, 10–12 Mar 1997, Joydebpur, Bangladesh

The training course was co-sponsored by Bangladesh Agricultural Research Institute (BARI), and CLAN/ICRISAT. Twenty-five scientists from different disciplines belonging to various regional agricultural research stations of BARI participated in the event. On the first day, presentations were made on the need, concepts, and issues in on-farm research, identification and prioritization of constraints to production, and planning and implementation of on-farm research. The participants conducted a diagnostic survey (using rapid rural appraisal methods) on the second day in Tangail district. On the final day, the participants planned on-farm research trials to alleviate the identified production constraints. The participants found the course very useful but felt the duration was too short. It was agreed that a follow-up on this course is necessary, and that BARI would initiate the necessary steps since its future research agenda lays strong emphasis on on-farm adaptive research orientation.

In-country Training Program on Groundnut Production Technology, 26–27 Aug 1997, Malang, Indonesia

The training program was cosponsored by the Research Institute for Legumes and Tuber Crops (RILET), Malang, and CLAN/ICRISAT. Twenty-six persons, including leading farmers, extension staff, and researchers from RILET and Agricultural Technology Assessment Institutes (ATAI) from groundnut production areas of Java, Bali, and Nusa Tenggara, participated. Five scientists from RILET and one scientist from ICRISAT were resource faculty to the course. Various aspects of improved groundnut production technology were presented and discussed.

Training Workshop on the Detection and Estimation of Aflatoxins Using Immunochemical Methods, 24 Nov to 6 Dec 1997, ICRISAT-Patancheru, India

Sixteen participants from 12 countries attended the Workshop which was funded by the Peanut Collaborative Research Support Program (Peanut CRSP), the Asia Pacific Association of Agricultural Research Institutions (APAARI), and the Asian Development Bank (ADB) through CLAN. Participants received hands-on training on estimation of aflatoxins by utilizing an indirect enzyme-linked immunosorbent assay (ELISA) procedure and a simple thin-layer chromatography (TLC) method. The two methods were compared and ELISA was found to be superior.

During the course several lectures were also given. The resource person was an authority on aflatoxin research, Dr David Wilson of the University of Georgia, USA. Dr Wilson gave an introductory lecture on the biology of *Aspergillus flavus*, aflatoxin contamination, and a general introduction to mycotoxins. Further lectures dealt with the factors leading to aflatoxin contamination, sampling procedures, comparison of analytical and immuno-chemical methods, the health hazards that aflatoxin poses to livestock and humans, and aflatoxin management before and after contamination.

The participants rated the course excellent.

Special Report on Terms of Reference for CLAN Steering Committee

Given below is a condensed version of the Terms of Reference for the Steering Committee approved at the CLAN Country Coordinators Steering Committee Meeting, 13–14 Nov 1996, Bangkok, Thailand.

The Cereals and Legumes Asia Network (CLAN) was established in 1992 to serve as a research and technology exchange network for Asia involving sorghum, pearl millet, chickpea, pigeonpea, and groundnut. CLAN is an agricultural research network consisting of a group of countries and institutions (national/international) who have come together to collaborate in solving and addressing common agricultural problems, and to use existing resources more effectively. The objective of CLAN is to coordinate, support, and assist in collaborative research and technology exchange involving CLAN mandate crops, and their resource management; the ultimate goal is to improve the well-being of Asian farmers by improving the production and productivity of crops in a sustainable manner.

Network structure. The network structure consists of bilateral and multilateral linkages. The bilateral element consists of the Memoranda of Understanding (MoUs) between ICRISAT and the member countries, and the subsequent development of bilateral workplans. The MoUs serve as an umbrella for the administrative protocols and procedures that facilitate joint research, and exchange of staff and materials.

The multilateral component consists of linkages and activities that involve two or more member countries. These include workshops, meetings, steering committee meetings, monitoring tours, working groups, training courses, and information exchange that link all the members.

Membership. Asian countries that grow one or more CLAN crops, and have indicated willingness to join and contribute to the network's research and technology exchange become CLAN members. Currently Bangladesh, China, India, Indonesia, Iran, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam are members of CLAN.

Other countries who have marginal interest in CLAN mandate crops, and/or have not indicated willingness to join the network as core members, are considered associate members. Regional and international organizations/institutes working in Asia can also be invited to become associate members. They can participate in network-sponsored meetings, training courses, etc., at their own cost.

Coordination Unit. The Coordination Unit (CU) is based at ICRISAT-Patancheru, and a CLAN Coordinator is in-charge of its activities. The CU provides logistic and administrative support to network activities. The CLAN Coordinator facilitates implementation of planned activities of the network.

Country Coordinator. Each country appoints a senior scientist/research administrator (with considerable decision-making authority) for the coordination, liaison, and smooth functioning of collaborative activities. An alternate or Deputy Country Coordinator will also be nominated by each country to coordinate activities in the absence of the Country Coordinator. The Country Coordinator (or Deputy) is the main administrative link between the CU, the NARS of that country, and the CLAN Cooperators.

Steering Committee. The Steering Committee (SC) will provide overall guidance to the research efforts of the network, and broad resource allocation. The Steering Committee consists of one representative (the Country Coordinator) from each member country. The CLAN Coordinator will serve as member-secretary of SC. Representatives from other countries, and regional and international institutions, can participate in SC meetings as Observers.

Specific responsibilities of SC include

- Review progress of network collaborative research and suggest future activities
- Suggest overall research agenda for the network and the working groups
- Identify institutions and allocate responsibilities for network research
- Develop ways to strengthen and promote linkages between national programs, and to ensure integration of collaborative activities with national programs
- Consider and approve requests for admission of new countries/institutions to the network
- Develop and approve a calendar of events (workshops, meetings, training programs, etc.)
- Allocate and approve budgets for the network activities.

Steering Committee member. The Country Coordinator (or Deputy Country Coordinator) nominated by the country will represent the country in the SC. The responsibilities of a SC member are to

- Represent all the institutions in the network member country
- Participate in SC meetings and other meetings as needed
- Ensure that the national program scientists get adequate institutional and infrastructural support to meet research commitments
- Facilitate linkage between scientists in local institutions (research institutes, universities, NGOs, etc.)
- Ensure that network activities planned are complementary to national research programs.

Steering Committee Chairperson. The SC will elect a Chairperson among the Country Coordinators to serve for a 2-year period, and until the next Chair is elected. The chairperson will

- Preside over the SC meetings
- Prepare, with CLAN Coordinator, the draft minutes of the meeting to be approved by SC

- Periodically monitor network research activities at selected countries along with CLAN Coordinator
- Review and assist the CLAN Coordinator in identifying opportunities and prepare proposals for donor funding.

Meetings. The SC will meet once a year, or more if needed, to review progress, approve plans/proposals, and address policy and organizational issues as they arise. Every attempt will be made to hold the meeting with other network related/sponsored events.

Inclusion of a new member. The SC can formally approve membership based on the following criteria

- The country must be located in the Asia region
- One of the CLAN mandate crops must be a priority and significant crop of the country concerned
- The country should have expressed willingness and commitment to participate in collaborative research and technology exchange with other countries
- The country's institutions should have the capacity to support network research activities in terms of capital and human resources.

Termination of membership

- A member country can cancel its membership by informing the SC Chairperson in writing at least 1 year before the proposed date of termination, giving valid reasons for such action. Such communication can be sent only by the official who is signatory to the MoU with ICRISAT.
- The SC can also consider termination of membership, if SC finds that the country is not contributing towards the objectives of the network.

Mr. Narongsak Senanarong, Director, Field Crops Research Institute, Bangkok, Thailand, was elected the Chairperson of SC for 1997 and 1998. Indonesia hosted the Steering Committee Meeting during Nov 1997.

Genetics and Plant Breeding

Selection of Groundnut Plants with Enhanced Resistance to Late Leaf Spot Through In Vitro Mutation Technique

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Leaf spot diseases caused by two species, *Phaeoisariopsis personata* (late leaf spot) and *Cercospora arachidicola* (early leaf spot), are widely distributed both in tropical and subtropical areas of the world wherever groundnut is grown. Yield losses because of these diseases can be as high as 50% (Wells et al. 1994). In the absence of suitable resistant varieties, chemical control is at best a short-term solution to this problem. However, experience in applying radiation or chemical mutagens to in vitro cultured plant material is limited, and there are few reports on successful selection of mutants after in vitro application of mutagens (Micke et al. 1990). This study aims to develop late leaf spot resistant lines using in vitro mutation techniques.

Cotyledonary nodes (0.5–1.0 cm) from VRI 2, a popular cultivar grown in Tamil Nadu and other parts of South India, were aseptically dissected out from 7-day-old seedlings and cultured on MS (Murashige and Skoog 1962) medium supplemented with $\propto$ naphthalene acetic acid (NAA) and 6-benzylaminopurine (BAP) (1.0 mg L^{-1} each). Two week old calluses with multiple shoot buds were subjected to gamma irradiation (50, 100, 150, 200, and 250 Gy). Irradiated calluses were transferred onto a medium containing various concentrations of pathotoxic culture filtrates (25, 50, 75, and 100% v/v) of late leaf spot. Calluses resistant to the pathotoxic culture filtrate were isolated and subcultured for 1–2 passages. Healthy resistant calluses (as judged by absence of browning) were then transferred onto MS regeneration medium supplemented with BAP (1.0–2.0 mg L^{-1}), NAA (0.5 mg L^{-1}), and 3% (w/v) sucrose. Regenerated shoots were rooted and transferred to field. Well-established plants flowered normally and set viable seeds. The progenies of 83 plants were screened for reaction to late leaf spot by inoculation of spore suspension of *P. personata* in the field. The percentage disease index (PDI) among the susceptible 73 R_1 progenies ranged from 65–85% as judged according to Wheeler (1969). However, ten progenies with a PDI range between 30-50% as compared to 60–100% among the control plants, were considered resistant. Among the ten R_2 progenies studied further, 71.8–85.6% of the plants exhibited enhanced resistance compared to the control. The PDI was 20–40% for the resistant R_2 plants and 55–75% for the control. The results suggest that it is possible to use in vitro mutation techniques to obtain disease-resistant plants in groundnut.

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Release of Groundnut Cultivar VRI 4 in Tamil Nadu, India

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The groundnut cultivar VG 8918 was released as variety VRI 4 for general cultivation in Tamil Nadu by the State Variety Release Committee. It is a bunch type with irregular branching and matures in 110 days. It is derived from a cross between VG 5 (MK 374 × R 33-1) and NC Ac 17090.

The variety was evaluated in different research stations during 1993 rainy season, and 1993/94 postrainy/summer seasons, and in farmers' fields during the rainy season of 1994 and postrainy/summer 1994/95 seasons in 92 locations in Tamil Nadu. It recorded a mean pod yield of 1660 kg ha^{-1} (rainfed), and 2171 kg ha^{-1} (irrigated), as against 1412 kg ha^{-1} (rainfed), and 1947 kg ha^{-1} (irrigated) by the local control, VRI 2. In the initial varietal trial of the All India Coordinated Varietal Trials conducted during the 1993 rainy season, this cultivar recorded a mean pod yield of 1927 kg ha^{-1} compared to 1625 kg ha^{-1} by the national control, JL 24, during the 1994 rainy season.

VRI 4 has 6–7 primary and 4–6 secondary branches. The leaves are dark green. The pods are medium-sized without much constriction, and with prominent reticulation and a slight beak. The medium-sized seeds (100-seed mass 40.8 g) are packed compactly inside the pod. There are 1–4 seeds per pod, the frequency of 2- and 3-seeded pods being higher. The seeds are round to flat in shape. The shelling percentage of the variety is 72.1, and oil content is 47%.

Table 1. Chemical composition of seed of groundnut cultivars VRI 4 and VRI 2.

	Variety	
Chemical composition	VRI 4	VRI 2
Total soluble sugars (%)[1]	10.9	7.8
Oleic to linoleic acid ratio	2.2	1.1
Fatty acid composition (%)		
Palmitic	12.3	14.0
Stearic	2.9	3.2
Oleic	53.3	39.5
Linoleic	24.2	35.6
Arachidic	1.4	1.3
Eicosenoic	0.94	0.89
Behenic	3.1	3.7
Lignoceric	1.7	1.7

1. Estimated in defatted samples.

Biochemical analysis (Table 1) of VRI 4 seeds shows that it is high in soluble sugar, and is hence tasty. The oleic to linoleic acid ratio of this variety (2.2) is high, hence the shelf-life of the oil is longer. The retention of the pods in the soil at harvest is very low because of thick and strong pegs. It is tolerant to rust disease. It has recorded a maximum rust score of 4.0 compared to 7.5 by VRI 2 on a 1–9 scale, where 1 = no disease, and 9 = more than 80% infected leaf area. The fodder yield of the variety is 4120 kg ha^{-1}, compared to 3270 kg ha^{-1} by VRI 2, the popular bunch variety of the State.

Acknowledgment. Thanks are due to Dr S N Nigam, Principal Scientist (Groundnut), ICRISAT-Patancheru, India, for his help in arranging for the biochemical analysis of the samples at ICRISAT.

Screening of Groundnut Germplasm for Resistance to Seed Rot and Collar Rot Diseases Caused by *Aspergillus niger*

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Seed rot and collar rot caused by *Aspergillus niger* van Teighem, are serious diseases in most of the groundnut-growing areas of the world, especially in sandy soils. Collar rot causes up to 50% loss in yield (Chahal et al. 1974). The most effective way to manage these diseases is to grow resistant varieties (Mathur and Sharma 1970). Therefore, selected germplasm lines obtained from the National Research Centre for Groundnut, Junagadh, Gujarat, and C S Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, both in India, were screened against two virulent isolates of *A. niger* (soil isolate 16 and seed isolate 24) in a sandy soil field under artificial inoculation conditions at Bidhan Chandra Krishi Viswavidyalaya farm, Mohanpur.

The isolates of *A. niger* were multiplied on sand maize meal medium for 10 days at 28±1°C in polypropylene packets (25 × 15 cm) and then mixed thoroughly with an upper 8 cm of double-sterilized sandy soil (1:3 v/v), kept

Table 1. Seed rot and collar rot incidence in various groundnut germplasm lines caused by two isolates of *Aspergillus niger*.

Isolate	Line	Growth habit[1]	Seed rot (%)		Collar rot (%)	
Soil Isolate 16	2848	VB	4.1	(11.7)[2]	4.1	(11.7)
	583 13	VR	8.3	(16.7)	12.5	(20.7)
	JH 225	SB	4.1	(11.7)	12.5	(20.7)
	EC 20998	VB	8.3	(16.7)	4.1	(11.7)
	C 421	SB	4.1	(11.7)	0.0	(0.0)
	C No 1780	SB	4.1	(11.7)	4.1	(11.7)
	2976	VB	12.5	(20.7)	4.1	(11.7)
	EC 20978	VB	33.3	(35.2)	8.5	(16.9)
	2971	VB	33.3	(35.2)	12.5	(20.7)
	EC 21004	VB	12.5	(20.7)	4.1	(11.7)
	Rajkot Local	VR	20.8	(27.1)	4.1	(11.7)
	C 176	VR	16.6	(24.0)	12.5	(20.7)
	Kaulikoro	VR	12.5	(20.1)	4.1	(11.7)
	4383-3	VR	33.3	(35.2)	8.3	(16.7)
	PI 262101	VL	12.5	(20.7)	8.3	(16.7)
	D No 686	SB	58.3	(49.8)	8.3	(16.7)
	GA 188	SB	29.1	(32.6)	4.1	(11.7)
	JH 113	SB	62.5	(52.2)	8.3	(16.7)
	EC 4110	SB	68.6	(54.7)	4.1	(11.7)
	GO Q53	SB	75.0	(60.0)	0	(0)
Control	PI 268589	VL	58.3	(49.8)	8.3	(16.7)
Seed Isolate 24	2809	VB	8.3	(16.7)	8.3	(16.7)
	2976	VB	8.3	(16.7)	12.5	(20.7)
	EC 133115	VR	8.3	(16.7)	8.3	(16.7)
	EC 20998	VB	8.3	(16.7)	4.1	(11.7)
	EC 1716	VR	16.6	(20.0)	4.1	(11.7)
	EC 6618	SB	54.1	(47.5)	8.3	(16.7)
	C 175	VR	16.6	(24.0)	8.3	(16.7)
	C 178	VR	41.6	(40.1)	12.5	(20.7)
	C No 1780	SB	8.3	(16.7)	8.3	(16.7)
	Cyprus Groundnut	VR	29.1	(32.6)	12.5	(20.7)
	Savner Local	VL	45.8	(42.6)	8.3	(16.7)
	PI 268772	SB	20.8	(27.1)	8.3	(16.7)
	PI 268612	SB	25.3	(30.2)	8.3	(16.7)
	PI 268527	VL	37.5	(37.8)	8.3	(16.7)
	Strain 11	VL	50.0	(35.0)	8.3	(16.7)
	Dekut BOUB	SB	20.8	(27.13)	8.3	(16.7)
	O-103-10	SB	37.5	(37.8)	4.2	(11.8)
Control	PI 268589	VL	54.1	(47.5)	8.3	(16.7)
CD at 5%			Seed rot		Collar rot	
Germplasm lines			14.8		12.9	
Isolates			4.7		4.1	
Germplasm lines × isolate			20.9		18.3	

1. VB = virginia bunch, SB = spanish bunch, VR = virginia runner, VL = *Vulgaris*.
2. Figures in parentheses are angular transformed values.

in plastic bags (20-cm dia). These bags were kept in a greenhouse for 3 days, and the moisture level of the bags was maintained by watering every 2 days.

Ten surface-sterilized seeds (0.1% $HgCl_2$ solution for 1 min) of each line were sown in each inoculated bag, kept randomly following a complete randomized design. Seeds were watered at 2-day intervals. Seven days after sowing (DAS), seeds were taken out carefully from the infested soil and the percentage of rotted seeds was computed. Ten-day-old seedlings were inoculated with the isolates at the collar region. Inoculum for this purpose was developed on potato dextrose agar.

The experiment was conducted in the prerainy season during 1990, 1991, and 1992. In this experiment, PI 268589 was used as a control. Since the required amount of seeds were not available, two separate sets of seeds were used against two different isolates (isolate 16 and isolate 24) in this experiment. Groundnut lines were rated as immune (0%), resistant (1–8.3%), and moderately susceptible (8.3–20%) (Chahal et al. 1974). The two-way analysis and interactions of data are shown in Table 1.

The lines 2848, EC 20998, C 421, and C No 1780 showed resistant reactions against the soil isolate 16 and 2809, and the lines EC 20998 and EC 133115 against seed isolate 24. The germplasm lines C 421 and C No 1780 are field resistant to both seed rot and collar rot diseases in the sandy soils of West Bengal. All other germplasm lines showed either susceptible or moderately susceptible reactions to both the diseases (Table 1). Lines C 421 and C No 1780 can be recommended for wide cultivation in the sandy soils of West Bengal.

Acknowledgment. The authors are indebted to the National Research Centre for Groundnut, Junagadh, Gujarat, and Directorate of Seed Research, C S Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh.

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Evaluation of Advanced Groundnut Lines for Resistance to Early and Late Leaf Spots, Andhra Pradesh, India

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Early leaf spot (ELS) (*Cercospora arachidicola*) and late leaf spot (LLS) (*Phaeoisariopsis personata*) are the two most important fungal diseases of groundnut in India. Both these leaf diseases are present in the groundnut growing belt of Rayalaseema (scarce rainfall zone) of Andhra Pradesh causing considerable yield losses, particularly when they appear early in the season. Individually or in combination, the two diseases can cause more than 50% losses in yield (McDonald et al. 1985). Though some fungicides have been reported to reduce the disease intensity, the best and safest way to manage them is by using resistant varieties. This paper reports field screening of some of the advanced breeding lines for ELS and LLS, and their yield and yield attributes.

Thirty-three advanced generation breeding lines along with two control varieties, Vemana and JL 24 were evaluated for their resistance to ELS and LLS. The experiment was conducted in a randomized block design with two replicates under natural field conditions during the 1996 rainy season at the Agricultural Research Station, Kadiri. The net plot size was 14.4 m^2. A spacing of 30 cm between rows and 10 cm between plants within a row was adopted. ELS was scored at 40 and 60 days after sowing (DAS) and LLS at 70 and 90 DAS using a 1–9 field scale (Subrahmanyam et al. 1995) and the mean scores reported. Since the season during which the experiment was conducted experienced an unusual and excessive rainfall during the entire crop growth period, there was sufficient build-up of the disease inoculum which started early in the season and progressed till harvest.

None of the entries tested were resistant to both the leaf spot diseases (Table 1). Only one genotype ICGV 86252/JL24-3 was resistant to LLS (score of 3). Nine genotypes were moderately resistant to ELS (3.5–5.0), 12 genotypes were moderately resistant to LLS (4–5), and seven genotypes were moderately resistant to both ELS and LLS. Vemana with moderate resistance to LLS (susceptible to ELS) gave the highest pod yield (2.03 t ha^{-1}), while the other control JL 24 was susceptible to

Table 1. Reaction of 33 groundnut genotypes to early and late leaf spots, and their yield and yield attributes, Agricultural Research Station, Kadiri, Andhra Pradesh, India, rainy season 1996.

Genotype	Early leaf spot[1]	Late leaf spot[1]	Pod yield (t ha^{-1})	Shelling turnover (%)	Seed yield (t ha^{-1})	100-seed mass (g)	Sound mature seed (%)
TMV 2 × C 391-1	6.5	4.5	1.52	68.0	1.04	35.5	92.0
TMV 2 × C 391-2	6.5	4.5	1.68	71.0	1.20	31.5	90.5
JL 24 × Ah 316-S-4	6.0	6.5	1.78	73.0	1.30	35.0	91.5
JL 24 × Ah 316-S-5	6.5	7.0	1.54	73.5	1.13	33.0	90.5
TMV 2 × Girnar	5.5	6.5	1.44	66.0	0.95	33.0	93.0
TMV 2 × X 14-4-B-8-B × Ec 21137-1	6.5	7.0	1.57	75.0	1.18	33.5	93.0
TPT 1 × C 391	6.0	7.5	1.30	71.5	0.93	31.5	92.5
Kadiri 3 × Egret × A2-1	6.5	7.0	1.60	70.0	1.12	31.5	90.0
ICGV 86517 × GB 66-1	6.5	7.0	1.64	73.0	1.20	30.0	91.0
ICGV 86189 × ICGV 86031	6.5	4.5	1.45	66.0	0.95	32.5	88.5
ICGV 86011 × JL 24	6.5	4.5	1.59	72.0	1.14	31.0	83.5
ICGV 86015 × JL 24	6.0	6.5	1.59	69.5	1.10	33.0	88.5
ICGV 86189 × ICGV 86005	6.0	4.0	1.12	66.0	0.74	34.0	82.0
TMV 2 × NC Ac 17090 × JL 24-3	5.5	7.5	1.80	61.5	1.10	30.5	91.5
ICG 1140 B	6.0	8.0	1.54	69.5	1.07	31.0	94.5
JL 24 × ICGV 62 × Kadiri 3	6.5	7.0	1.45	70.0	1.01	34.0	97.0
TPT 1 × NC Ac 17090	7.0	7.0	1.37	71.5	0.98	31.0	94.0
ICGV 86517 × GB 66-2	6.0	4.0	1.57	70.5	1.11	32.5	95.0
Kadiri 3 × ICG 2716	4.5	7.5	1.09	69.5	0.76	23.5	95.0
ICGV 86517 × GB 66-4	5.0	4.5	1.62	71.0	1.15	33.0	91.5
ICGV 86252 × JL 24-2	3.5	4.0	1.71	69.0	1.18	27.5	91.0
ICGV 86252 × JL 24-1	3.5	4.0	1.08	70.0	0.75	30.0	96.0
TMV 2 × NC Ac 17090 × JL 24-5	3.5	8.0	1.57	65.0	1.02	27.5	93.0
TPT 1 × NC Ac 17090-2 × ICGV 86139 × ICGV 86031	5.0	4.0	1.46	64.0	0.93	33.5	90.5
ICGV 86252 × JL 24-3	5.0	3.0	1.55	69.0	1.07	32.0	93.0
ICGV 86517 × GB 66	3.5	4.5	1.35	62.5	0.85	28.5	92.5
ICGV 86252 × JL 24-4	5.0	4.0	1.05	69.5	0.73	24.0	87.5
JL 24 × TPT 1	5.5	8.0	1.26	66.0	0.83	27.0	88.5
JL 24 × TPT 1-1	5.5	8.0	1.79	73.5	1.32	34.5	94.5
K 134 × CO 2	6.0	6.0	1.85	68.0	1.26	33.5	91.5
Controls							
Vemana	6.0	5.0	2.03	71.0	1.44	28.0	80.0
JL24	7.0	8.0	1.47	72.0	1.06	34.0	90.5
SE			±0.04	±2.3	±0.06	±1.0	±1.1
CD ($P = 0.05$)			0.08	4.8	0.13	2.4	2.3
CV (%)			6.36	8.02	9.06	10.01	9.03

1. Early and late leaf spot were scored on a 1–9 scale; where 1 = no disease, and 9 = 81–100% severity (Subrahmanyam et al. 1995).

both the leaf spots and gave a pod yield of 1.47 t ha^{-1}. ICGV 86252 × JL 24 was resistant to LLS but moderately resistant to ELS, and gave significantly superior pod yield over JL 24. The genotypes ICGV 86517 × GB 66-4 and ICGV 86252 × JL 24-2 were moderately resistant to both ELS and LLS, and gave significantly superior pod yields over JL 24. The superiority in pod yields of these genotypes was reflected in either one or more of the ancillary characters studied.

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GG 20: A More Suitable and Adaptive Semi-spreading Virginia Bunch Groundnut Variety for Gujarat, India

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Groundnut is an important crop of Gujarat and annually grown in 2–2.2 million ha of the 10.5 million ha of the total cultivated area of the State. It is mostly grown in Saurashtra and Kutch regions of Gujarat under dry farming conditions. The rainfall in these regions is insufficient and erratic. Therefore, there is no stability in total production and productivity of groundnut in the State. Short-duration groundnuts, which cover about 35% of the area under groundnut, can be successfully grown under low and short span rainfall but fail under high and long span rainfall condition. On the other hand, the virginia runner type groundnut which covers about 65% area can be successfully harvested under high and long span rainfall, but fails under low and short span rainfall because of moisture stress in the soil. There is thus a need to develop genotypes that can be grown under varying rainfall conditions. Research at the Gujarat Agricultural

Table 1. Performance (productivity ha^{-1}) of groundnut variety GG 20 across seasons, Gujarat, India.

Year of testing (rainy season)	Rainfall (mm) at Junagadh: Low and short span (days)		Rainfall (mm) at Junagadh: High and long span (days)		Productivity of GG 20 in research experiments (kg ha^{-1}): Junagadh	Productivity of GG 20 in research experiments (kg ha^{-1}): Average	Average productivity in Gujarat (kg ha^{-1})
1987	138	11	-	-	1909	1909 (1)[1]	86
1988	-	-	1390	64	3819	3272 (3)	1602
1989	-	-	806	47	1620	1351 (7)	782
1990	-	-	852	48	1019	2157 (6)	526
1991	509	41	-	-	-	917 (4)	291
1992	-	-	941	48	1712	1593 (5)	1067
1993	517	42	-	-	961	1444 (4)	251
1994	-	-	1036	65	991	1271 (9)	1168
1995	481	45	-	-	1609	1584 (10)	483
1996	630	32	-	-	2731	1705 (10)	650[2]
SSP[3]	455	34.2	-	-	1442	1512	352
LSP[4]	-	-	1005	54.4	1832	1929	1029

1. Figures in parentheses show number of test locations in Gujarat.
2. Expected productivity.
3. Average under low and short span rainfall.
4. Average under high and long span rainfall.

University, Junagadh, was initiated to develop genotypes adaptive to both the rainfall conditions. GG 20, the first semi-spreading, virginia bunch variety was developed and released in 1991 for cultivation in the State. It gives highly stable yield under both the rainfall conditions, and shows better adaptability in most soil types (Table 1).

Of the 10 years of evaluation of the variety GG 20, 5 years were characterized by low and short span, and 5 years with high and long span rainfall conditions. No considerable increase or decrease in productivity of GG 20 in research experiments at Junagadh and in multilocational experiments in Gujarat was observed under low and short span, and high and long span rainfall conditions. However, drastic differences in productivity of old varieties (J 11, GG 2, GAUG 10, GG 11), was found in these two rainfall situation. GG 20 recorded higher productivity than the state average productivity during the same period of testing. GG 20 also secured the first group of top-ranking varieties in research experiments at most of the locations and years during testing. This indicates that this variety has better stability and adaptability for pod yield under a wide range of soil and rainfall conditions.

Three New Groundnut Varieties Released in Gujarat, India

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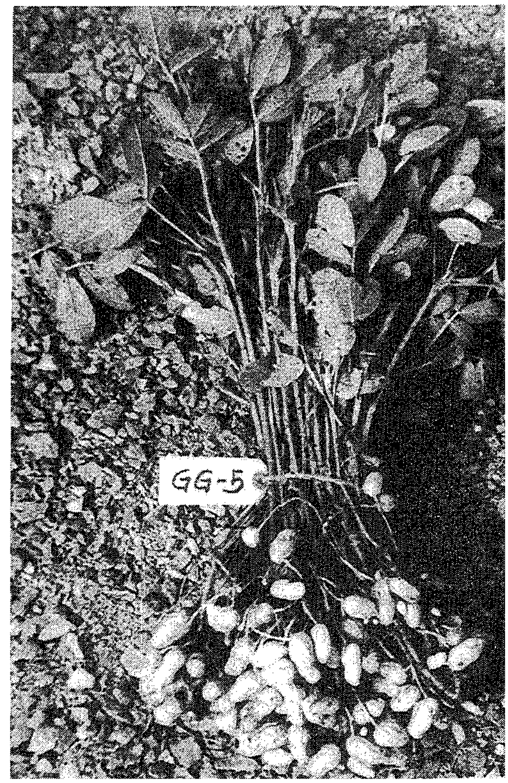
Groundnut is an important cash crop in Gujarat state and is grown on about 2 million ha in the rainy season (Jun–Nov) and on 150 000 ha in the postrainy season (Jan–May). Currently, the short-duration, erect spanish variety GG 2 is grown on about 35% of the area under the crop, and GAUG 10, and GG 11 (spreading-type varieties) are grown on the other 65%. All these three varieties were released 10 years ago, and have become susceptible to disease. Therefore it was essential to breed high-yielding and more adaptive new genotypes to increase productivity and total production of groundnut in the state. Three new genotypes, GG 5 (a spanish bunch), GG 20 (a virginia bunch), and GG 13 (a virginia runner), were developed by Gujarat Agricultural University (GAU), and released for general cultivation in the state by the State Variety Release Committee.



Variety GG 5 was developed from the cross 27-5-1 × JL 24. It is a short-duration variety (101 days) like GG 2 (102 days), and JL 24 (100 days). It is erect in growth habit with early fast growth. The leaves are obovate in shape and green in color, pods are two seeded and broad based without constriction. The seeds are spherical in shape and medium in size (100-seed mass 44.6 g) with an attractive light rose testa. Shelling percentage is 73.7, and oil content is 48.8%. It does not have fresh seed dormancy. It has given 18.2% more yield than JL 2, and 23.7% more than GG 2. This variety was released for general cultivation for rainy season for the Saurashtra region of Gujarat in 1996.

Variety GG 20 was developed from the cross GAUG 10 × R 33-1. It is of short-duration, and takes 109 days to mature, compared to 115 days taken by GAUG 10. It is semi-spreading in growth habit. The synchronous flowering habit of this variety results in more pod bearing around the main stem. The pods are uniform, and yield more sound matured seed than GAUG 10—one of the most important traits of this variety. Its leaves are elliptical, and dark green. Pods are two seeded and cylindrical with moderate constriction and reticulation. The seeds are bold in size (100-seed mass 65.2 g) and elliptical with attractive dark rose testa and having 45 count for HPS groundnut. Its shelling percent is 73.4 and oil content is 50%. It possesses fresh seed dormancy. It has given 22.1% higher yield, compared to Kadiri 3. GG 20 was released for general cultivation in the rainy season in Gujarat state in 1991. This variety has been found suitable under both dry farming and irrigated conditions. It has shown good adaptability under a wide range of agroclimatic conditions. It fits well under intercropping systems.

Variety GG 13 was developed from the cross GAUG 10 × TMV 10. It is medium in duration, taking 120 days to mature, compared to 111 days of GG 11. It is spreading in growth habit. The leaves are oblong and dark green. Pods are medium in size and cylindrical with moderate constriction and reticulation. Seeds are medium in size (100-seed mass 46.0 g) with a light rose testa. Shelling percentage is 69.2, and oil content is 49.6%. This variety has extremely good pod-bearing habit, and gave 37.4% higher pod yield than GG 1. This variety was released for general cultivation in the rainy season in Gujarat in 1994.

Performance of Groundnut Tolerance to Chlorotic Symptoms

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About 66% of the total area under groundnut in Indonesia is grown under rainfed conditions. Tuban district is one of the main production centers for groundnut in Indonesia. Although groundnut is the main cash crop in the area, the average yield remains low. Drought stress during reproductive phase and chlorosis are the main factors contributing to low yield. In Tuban, leaf chlorosis can reduce groundnut yield up to 85% (Adisarwanto 1997). This loss can be reduced, and groundnut yield in Tuban can be increased by using chlorosis-tolerant varieties. Efforts to improve groundnut yield and tolerance to chlorosis started at the Research Institute for Legumes and Tuber Crops (RILET) in 1993/94. We identified 28 genotypes which merit further evaluation in Tuban.

These 28 genotypes were sown in a trial at Senori village on calcareous soil in Tuban during the 1996 dry season, in a split-plot design with two replications. Two fertilizer levels were the main plots and the genotypes subplots. Two levels of fertilizers were P0 = no fertilizer and P1 = fertilized with 100 kg ha^{-1} ammonium sulfate (ZA) + 75 kg ha^{-1} triple superphosphate (TSP) + 75 kg ha^{-1} potassium chloride (KCl). Each genotype was sown in a 1.2 × 5.0-m plot, 40 × 10-cm sowing distance, and 1 plant $hill^{-1}$. ICGV 86031, an ICRISAT Fe-efficient line, was used as the control. Number of chlorotic plants were recorded three times, i.e., 4, 6, and 8 weeks after sowing (WAS).

Chlorotic symptoms were not visible until 6 WAS, and the symptoms in the plant did not persist throughout the plant's growth. Analysis of variance indicated that only genotypic effects were significant, and that the effect of fertilizer and genotype × fertilizer interactions were nonsignificant for chlorotic symptoms. Adisarwanto (1997) reported that Fe, Cu, and Mn content in chlorotic plants were significantly lower than those in healthy plants, but Ca and Mg were significantly higher than those in healthy plants. Imbalance in levels of Ca and Mg can reduce availability of Fe for groundnut as indicated by the chlorotic leaves. Number of chlorotic plants was highest in ICGV 86031 (88.8%). ICGV 88252/LM-92-B-4

Table 1. Performance of 28 groundnut genotypes grown under two fertilizer levels in Tuban, Indonesia, dry season 1996.

Genotype	Dry pod yield (t ha^{-1}) PO	P1	Average[1]	Plant height (cm)	Harvest index (%)	Pod type[2]	No. chlorotic plants 6 WAS	8 WAS
ICGV 90057	0.63	0.67	0.654 j	48.7	28.2	G	0 (0.2)[3]	2 (1.5)
Zebra	2.31	2.29	2.299 bcde	55.2	41.9	K	5 (4.4)	26 (21.7)
Mahesa	2.32	2.36	2.342 bcde	60.5	39.6	G	12 (10.2)	48 (40.2)
Gunung Kidul	2.22	2.51	2.365 bcde	56.8	41.0	G	12 (10.0)	57 (47.7)
G/PI 259747-92-B-28	2.44	2.51	2.474 bcd	49.6	34.8	K	5 (3.9)	24 (20.0)
K/PI 390595/K-90-B2-54	2.54	2.47	2.504 bcd	56.5	44.4	K	7 (5.6)	30 (25.2)
G/C//LM-88-B-56-2	2.51	2.67	2.593 ab	57.3	41.7	G	14 (11.7)	69 (57.7)
ICGV 88252/LM-92-B-4	2.82	3.23	3.026 a	55.9	43.1	K	7 (5.4)	33 (27.5)
Average	1.99	2.09	2.04	69.6	36.2	-	7.8 (6.5)	35 (29.5)

P0 = Nonfertilized; P1 = Fertilized with 100 kg ZA ha^{-1} + 75 kg TSP ha^{-1} + 75 kg KCl ha^{-1}.
1. Duncan's Multiple Range Test, $P = 0.05$.
2. G = spanish type; K = valencia type.
3. Number in parentheses indicates percentage of chlorotic plants over the expected population.

was the top yielder with a low number of plants with chlorotic symptoms (Table 1). It yielded an average 3.03 t ha^{-1} followed by G/C//LM-88-B-56-2 (2.59 t ha^{-1}), K/PI 390595//K-90-B2-54 (2.50 t ha^{-1}), and G/PI 259747-92-B-28 (2.47 t ha^{-1}). Local varieties had the following yields: Gunung Kidul 2.37 t ha^{-1}, Zebra 2.30 t ha^{-1}, and Mahesa 2.34 t ha^{-1}.

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Update on Transformation of Groundnut and Potential Genes for Enhancement of Quality

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Groundnut is unique among oilseeds since it can be consumed and utilized in diverse ways. Groundnuts are rich in oil and protein, and also contain some carbohydrates. The quality of the oil is determined by its fatty acid composition, and that of the protein by its amino acid composition. Among carbohydrates, starch and sucrose are important from the organoleptic point of view, whereas oligosaccharides like raffinose and stachyose are considered noxious since they cause flatulence. The kernels are often contaminated by aflatoxins which are produced by seed colonization by the fungus *Aspergillus flavus*.

Efforts aimed at improving the quality of groundnuts by employing traditional plant-breeding techniques have met with some success. The advent of biotechnological tools including marker-assisted selection, and gene transfer across the species barrier has opened up novel opportunities for enhancing the seed-quality of high-yielding crop varieties. Using these techniques, in the past few years, phenomenal success has been achieved in manipulation of fatty acid composition of vegetable oils by expressing either a foreign gene or antisense of a native gene in the target species (Ohlrogge 1994).

The transformation protocols for groundnut are now well established, and development of a transgenic groundnut expressing desirable foreign genes is on the anvil. An update of the recent developments in this area is given in Table 1. These developments have emboldened researchers to pursue the development of transgenic groundnut plants capable of producing high quality groundnuts with a tailor-made fatty acid composition.

Accordingly, an effort was made to identify a few genes which control the crucial biochemical steps leading to the synthesis of constituents that determine the quality

Table 1. Update on transformation of groundnut (*Arachis hypogaea* L.).

Gene(s) introduced	Gene delivery system employed	Target tissue	Regeneration status	Reference
GUS and *nptII*	*Agrobacterium* mediated	Stem internode, seedling explants	Tumors	Lacorte et al. 1991
GUS and *hph*	Microprojectile	Embryogenic callus	Transgenic plants	Ozias-Akins et al. 1993
GUS and *nptII*	*Agrobacterium* mediated	Leaf disc	Transgenic plants with shrivelled seeds	Eapen and George 1994
GUS, *bar* and TSWV nucleo capsid protein	ACCELL (biolistic)	Shoot meristem of embryonic axis	Transgenic plants, up to R2 generation	Brar et al. 1994
GUS and *nptII*	*Agrobacterium* mediated	Cotyledon explants	T2 generation, viable seeds	ICRISAT 1994
Bar and PStVgenome	*Agrobacterium* mediated	Embryonic axis	Putative transformants	Cassidy and Ponsamuel 1996
GUS and *nptII*	*Agrobacterium* mediated	Seedling explants	Second generation callus colonies	Li et al. 1996
GUS and *nptII*	Electroporation	Protoplast	Protoplast derived callus colonies	Li et al. 1996
PStV coat protein	Electroporation	Protoplast	Protoplast derived callus colonies	Li et al. 1996
GUS, *nptII* and PCV coat	*Agrobacterium* mediated	Cotyledon and leaf explants	T2 generation with viable seeds	ICRISAT 1996

GUS: gene encoding glucuronidase activity; *hph*: gene conferring resistance to hygromycin; *npt II*: gene conferring resistance to neomycin and kanamycin; *bar*: gene conferring resistance to herbicide glufosinate; TSWV: tomato spotted wilt virus: PStV: peanut stripe virus; PCV: peanut clump virus.

Table 2. Genes for enhancing quality of groundnuts by genetic engineering.

Objective of modifications	Modifications required	Name of gene/activity to be engineered	Success in developing transgenic species with a similar approach
Prolongation of shelf-life	Increase in oleic acid	Stearoyl desaturase	Transgenic tobacco with yeast (Polashock 1992) and rat (Garyburn 1992) genes
Reduction in the risk for atherosclerosis	Reduction in long chain saturated fatty acids	Antisense of stearoyl-CoA: β-ketoeicosanoyl CoA synthetase	Transgenic *Brassica* by antisense expression of stearoyl-ACP desaturase gene (Knutzon et al 1992)
Reduction in flatus properties	Reduction in raffinose and stachyose	Galactinol:sucrose-6 -galactosyl transferase	Not yet attempted
Reduction in aflatoxin load	Increase in stilbenes	Stilbene synthase	Transgenic tobacco (Hain et al. 1990)
Improvement in nutritive value of protein	Increase in polypeptides rich in S-containing amino acids	Gene encoding Brazil nut methionine-rich protein	Transgenic tobacco (Altenbach et al. 1989)

of groundnuts (Table 2). Some of these genes have already been incorporated into other species through genetic engineering. The rationale behind identification of each of these genes is explained in the following discussion.

Improvement in quality of oil. The long chain saturated fatty acids (LSFAs)—amyl arachidic (20:0), behenic (22:0), and lignoceric (24:0) present predominantly in *sn*-3 position have been reported to contribute to atherosclerosis (Kritchevsky et al. 1971). If further elongation of stearic acid can be prevented, groundnut oil would be free from these hazardous fatty acids. The elongation of chain behind C_{18} is catalyzed by membrane bound enzyme steoryl-Co-A:∝-ketoeicosanoyl-CoA synthetase (Stumpf 1987). Engineering a gene coding for antisense RNA in groundnut may help reduce activity of this enzyme and hence of LSFA. For enhancing shelf life of groundnut products, a higher oleic/linoleic (O/L) ratio is considered desirable (Worthington et al. 1972). This can be attained by increasing the protein of oleic acid in groundnut oil. The introduction of the first double bond in the plant fatty acids occurs by the action of enzyme stearoyl-ACP desaturase (Jaworksi 1987). Expression of additional copies of gene for this enzyme may enhance the content of oleic acid and hence O/L ratio.

Improvement in quality of protein. Groundnut protein is considered to be poor in sulfur-containing amino acids besides lysine, threonine, and isoleucine. A Brazil-nut polypeptide with 18% methionine has been identified. The gene for this polypeptide has been successfully transferred to tobacco and expressed in developing seeds resulting in a 30% increase in methionine content of transgenic tobacco seeds. Thus the gene encoding Brazil-nut methionine rich polypeptide has the potential to improve the quality of groundnut protein.

Improvement in composition of carbohydrates. When a galactose moiety is linked to a sucrose molecule, raffinose is synthesized, and when another galactose moiety is linked to raffinose, stachyose is obtained. Thus, obstructing the synthesis of the former alone will be enough to check production of both the oligosaccharides. The enzyme galactinol : sucrose-6-galactosyl transferase (GST), catalyses the crucial step in the synthesis of raffinose (Kandler and Hopf 1980). This step can be obstructed by engineering expression of a gene encoding antisense RNA of GST.

Reduction in aflatoxin-load. Groundnuts produce stilbene phytoalexins in response to fungal infection. Stilbenes inhibit fungal growth and spore germination of *Aspergillus* species and aflatoxin contamination does not occur as long as kernels have the capacity to produce stilbenes (Cole and Dorner 1991). Stilbene synthase has been identified as the key enzyme for the biosynthesis of stilbene backbone. The gene encoding of this enzyme has already been characterized and even successfully expressed in tobacco (Hain et al. 1990). Organ specific expression of multiple copies of gene for stilbene synthase is likely to enhance production of stilbenes in groundnut kernels and hence make them less prone to colonization by *Aspergillus flavus*.

The information provided in this article may be useful in conceiving and formulating research projects aimed at improving quality of groundnut through genetic engineering.

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Pollen Viability and Longevity in Cultivated Groundnut

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High flower drop is a conspicuous phenomenon in legumes. In cultivated groundnut, though abundant flowers are produced, only 30–50% of the flowers develop into fruits (Bledose and Harris 1960). The fertilization rate ranges from 49–58.9% in spreading, and 21.9–67.5% in bunch types, and of the fertilized ovaries, 63.5% elongate as pegs (Smith 1954). As a result, considerable variation in flower to pod ratio is found in groundnut. But the reasons for such variation in fertilization has not been understood. Though factors like embryo abortion and failure in seed development at different stages contribute to very low pod setting, one of the possible reasons may be the variation in pollen viability. Hence, to find out the pollen viability at two phenophases, the present study was conducted with selected groundnut genotypes. The pollen viability under an extended period of storage in ambient and low temperature conditions was also studied. This information may be useful in artificial hybridization.

Five genotypes, four poor yielding, and one high yielding (based on the field trials of the previous year) from each of the virginia bunch and virginia runner types (spp *hypogaea* var *hypogaea*) were selected from a field trial laid out in an augmented blocks design in rainy season 1995 at NRCG. The plots were 3-m long single rows. The interrow spacing was 75 cm, and interplant spacing 10 cm. On the 15th and 30th days of flowering, 3 to 4 flowers were collected from three individual plants, between 0700–0800 h. The pollen mass from the flowers was dusted on the germination medium of Malik and Chabbra (1976). From each sample about 300 pollen grains from term microscopic fields were counted to compute the percentage of germination. The total pod yield was recorded one month after the harvest and yield per plant was computed.

For the pollen storability study, pollen mass was collected at random from flowers of cvs GG 11 and ICGS 11, and stored in screw-cap vials at two temperatures, ambient (28–30°C) and at 4°C. The viability was recorded six times at intervals given in Table 2.

The genotypes showed variation in germination percent ranging from 69–85 in bunch and 78–85 in runner habit types (Table 1). In runner types, the germination of pollens was higher at 30th day whereas in bunch types a similar trend was not observed. The percentage of germination was the highest in the high-yielding cultivars of each habit group, but in the rest of the genotypes, percentage of germination and yields per plant did not appear to be related. This may be because of the production of abundant pollen and cleistogamous nature of the groundnut flowers. Therefore, difference in germinability may not be a good criterion for assessing the pod yield.

Table 1. Mean in vitro pollen germinability in different genotypes at two stages after flowering.

NRCG[1] no./Variety	Pollen germinability (%) 15 DAF[2]	30 DAF	Varietal mean	Yield plant^{-1} (g)
Virginia bunch				
939	64.2 ± 3.1	75.1 ± 1.9	69.6	6.6
5758	74.0 ± 3.0	80.0 ± 0.9	77.0	5.1
623	80.2 ± 2.3	81.5 ± 1.6	80.8	6.4
952	82.9 ± 1.4	77.1 ± 2.3	80.0	9.1
ICGS 11	87.5 ± 1.4	83.5 ± 2.6	85.0	14.2
Virginia runner				
1816	68.7 ± 2.1	86.6 ± 0.8	78.1	6.5
9944	78.5 ± 1.8	83.7 ± 1.5	81.1	4.0
453	78.7 ± 1.6	85.5 ± 1.0	85.0	3.0
5725	84.2 ± 1.8	85.9 ± 0.9	85.0	11.5
GAUG 10	83.8 ± 1.5	86.7 ± 1.3	85.2	14.8

1. National Research Centre for Groundnut, Gujarat, India.
2. DAF = Days after flowering.

Table 2. In vitro germinability of pollens under two storage conditions.

Duration (h)	Pollen germination (%) ICGS 11 AT	ICGS 11 4°C	GG 11 AT	GG 11 4°C
0	85.4 ± 1.3	85.4 ± 1.3	87.7 ± 1.5	87.7 ± 1.4
4	84.0 ± 1.4	NR	87.6 ± 1.7	NR
8	24.3 ± 4.3	NR	56.3 ± 3.9	NR
24	0.0	81.8±2.9	0.0	87.9 ± 2.7
48	0.0	69.9 ± 5.1	0.0	62.4 ± 3.8
72	0.0	33.8 ± 6.1	0.0	0.0

AT = Ambient temperature (28–30°C); NR = Not recorded.

Germination drastically reduced between 4th and the 8th hour of storage at ambient temperature (Table 2), but the cv GG 11 retained more than 50% viability. At 4°C, the pollens retained viability up to 24 h and thereafter showed a decline in germination. Interestingly, cv GG 11 retained higher viability under ambient conditions than cv ICGS 11 but the situation reversed under storage at 4°C after 24 h of storage. By manipulating the temperature and daylight hours, emasculation and pollination are done at the same time (Banks 1976, Reddy 1988). Stigma becomes receptive much prior to anther dehiscence (Hassan and Srivastava 1966). Hence, enhanced longevity of pollen under storage at low temperatures allows simultaneous emasculation and pollination.

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Screening of Rosette-resistant Short-duration Groundnut Breeding Lines for Yield and Other Characteristics

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Rosette virus disease causes considerable losses on groundnut in southern and eastern Africa. In association with drought (much of the region is drought-prone), the virus can cause yield losses of up to 100%. Host-plant resistance is the most cost-effective control measure against rosette, and the identification and utilization of stable resistance is a high priority for ICRISAT's groundnut research team based at the Chitedze Research Station in Malawi. The long-term objective of these efforts is to develop groundnut genotypes with multiple disease resistance.

Since 1990/91 the Southern Africa Development Community (SADC)/ICRISAT Groundnut Project has worked in collaboration with the Genetic Resources Division, ICRISAT-Patancheru, India, on an intensive program to screen global germplasm for resistance to rosette. Over 100 resistant accessions of African, Indian, and South American origin have been identified, including several short-duration spanish accessions (Subrahmanyam et al. 1996). Short-duration varieties are particularly important for southern and eastern Africa. However, the lack of such varieties, and the low yield of available rosette-resistant varieties, has been an obstacle to progress.

Three yield trials (at low, medium, and high rosette disease pressure) were sown at Chitedze Research Station during the 1996/97 season. A randomized block design with three replications was used. Eight short-duration breeding lines and five control varieties were tested. High and medium disease pressures were simulated using the infector row techniques described by

Table 1. Performance of 13 short-duration groundnut varieties at three levels of rosette disease pressure, Chitedze Research Station, Malawi, 1996/97.

	Seed yield (kg ha^{-1}) under			Average	Yield as	Average		100-seed	Rosette
Variety	LDP	MDP	HDP	seed yield (kg ha^{-1})	% of JL 24	haulm yield (kg ha^{-1})	Shelling (%)	mass (g)	incidence (%) under HDP
ICGV-SM 93524	1775	654	599	1009	114	2489	64	36	4
ICGV-SM93530	1514	478	503	832	94	2510	58	32	3
ICGV-SM 93535	1815	707	633	1051	120	2613	58	40	0
ICGV-SM 93557	1915	404	344	888	100	2742	60	38	4
ICGV-SM 93561	1943	315	355	871	98	2654	64	44	3
ICGV-SM 94584	1589	485	546	873	99	2794	62	31	1
ICG 12988	2799	966	966	1577	178	3329	76	33	1
ICG 12991	3080	1062	923	1688	190	3004	76	32	1
Resistant control									
KH 241 D	1226	40	62	443	50	2588	53	30	2
Susceptible controls									
JL 24	2419	130	105	885	100	2016	62	38	45
Malimba	2148	37	25	737	83	2682	55	27	40
Sellie	2072	99	52	741	84	2675	60	30	35
ICGMS 5	2190	46	46	761	86	2910	52	38	37
Average	1672	417	397	829	94	2693	62	35	14
SED	187	93	61	69		450	3.1	1.4	4.7
CV%	13.7	31.9	21.0	21.0		34	11	9	79

1. LDP, MDP, HDP = low, medium, high disease pressure.

Nigam and Bock (1990). To simulate medium disease pressure, heavily infected spreader plants were raised in the greenhouse and transplanted to the infector rows. For high disease pressure the same procedure was followed but more viruliferous aphids reared in the greenhouse were transferred to the infector rows. Early leaf spot disease was observed in the high and medium disease pressure trials, while both rosette and early leaf spot were insignificant at low disease pressure. All trials were sown under rainfed conditions. The trials were harvested 119 days (high disease pressure), 120 days (medium), and 131 days (low disease pressure) after sowing.

Results are presented in Table 1. The short-duration varieties gave an average seed yield of 1672 kg ha^{-1} under low disease pressure, 417 kg ha^{-1} under medium disease pressure, and 397 kg ha^{-1} under high disease pressure. In the low disease pressure trials, because of the near absence of diseases the growth period was 12 days longer than for the high disease pressure trial. Yield differences between the low and high disease pressure trials were because of the difference in rosette disease incidence combined with growth period.

Two lines (ICG 12988, ICG 12991) performed well in all three trials. Under low disease pressure, they significantly outyielded the other varieties including the widely adapted JL 24. They were similarly outstanding under medium and high disease pressures with yields of over 900 kg ha^{-1} compared with only 130 and 105 kg ha^{-1} for JL 24. The highly significant yield superiority under medium and high disease pressures may be ascribed to resistance of ICG 12988 and ICG 12991 to rosette virus disease. Only 1% rosette disease was observed on these two lines at high disease pressure, compared with 45% incidence on JL 24.

ICG 12988 and ICG 12991 are landraces that were identified at ICRISAT-Malawi during the global screening program. They are spanish types with small, two-seeded pods and a tan seed testa. Seed of these two genotypes will be produced during the 1997 off-season, and will be available for breeding programs and on-farm trials by end 1997. For further information, and for small quantities of seed, contact:

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Performance of ICRISAT Short-duration Groundnut Varieties on Sandy Regosols in Eastern Sri Lanka

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Groundnut, an economically important valuable oilseed and cash crop, is now cultivated on a large scale in several countries. In Sri Lanka it was cultivated on 10 394 ha in 1994 with a total production of 5730 t. It has potential for improvement in eastern Sri Lanka where it occupied 1087 ha in 1994 with pod yield of 1 t ha^{-1} which is rather low. The primary reason for low yield in this region is the nonavailability of suitable varieties for cultivation. In view of this fact, the Eastern University at Chenkalady, located in eastern Sri Lanka has been testing groundnut varieties through a collaborative program with ICRISAT. This paper describes the performance of 15 groundnut varieties (ICGVs) of ICRISAT origin (Table 1) and a local control variety MI-1.

The varieties were sown on sandy Regosols, in a randomized complete block design, at the Agronomy farm of the Eastern University on 25 Apr 1996. The crop was managed using recommended practices (Sri Lanka 1990). Until 15 Aug 1996, during the experimental period, 134.2 mm rainfall was recorded; supplementary irrigation was provided as needed. The mean temperature during experimentation was 30–31°C. All the varieties were harvested in 100–102 days after sowing (DAS) for yield estimation. Biomass and leaf area were observed at 75 DAS on five plants in each replication.

Table 1. Performance of short-duration groundnut varieties at Chenkalady, Sri Lanka, 1996.

Varieties	Pod yield ($t\ ha^{-1}$)	Shelling (%)	100-seed mass (g)	Biomass $plant^{-1}$ (g)	Leaf area (cm^2)
ICGV 91114	3.2 a[1]	76.9 a	46.5 ab	50.0 a	33617.4 a
ICGV 91117	3.1 a	77.6 a	50.2 a	49.8 a	3478.3 ab
ICGV 91151	3.0 ab	75.8 ab	44.1 bc	50.0 a	3224.4 abc
ICGV 91112	2.9 abc	74.7 abc	42.3 bcd	47.4 ab	3025.7 abc
IVGV 91146	2.7 bc	73.2 bc	44.1 bc	43.4 abc	2958.6 abc
ICGV 91124	2.6 bcd	73.4 bc	41.5 cd	42.5 abcd	2722.1 bcd
ICGV 91109	2.6 bcd	72.0 c	42.4 bcd	39.8 bcde	3098.5 abc
ICGV 89023	2.6 bcd	71.5 c	38.7 de	40.5 bcd	2804.8 abcd
ICGV 92209	2.5 cdef	71.5 c	42.0 bcd	33.0 de	2602.2 cd
MI-1 (Control)	2.4 cdef	72.0 c	42.1 bcd	35.1 cdef	2692.0 bcd
Chico	2.3 defg	73.1 bc	32.9 f	30.4 f	2125.5 d
ICGV 91123	2.3 defg	73.3 bc	39.2 cde	48.0 abc	2991.5 abc
ICGV 92269	2.2 efg	69.3 d	36.1 ef	43.1 abcd	3032.7 abc
ICGV 92268	2.2 efg	65.3 d	36.3 ef	39.8 bcde	3071.2 abc
ICGV 92242	2.0 gh	72.5 bc	37.5 def	34.4 def	2879.5 abcd
ICGV 91116	1.8 h	71.8 c	40.7 cde	30.8 f	2521.6 cd

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

Three varieties, ICGVs 91114 (3.2 $t\ ha^{-1}$), 91117 (3.1 $t\ ha^{-1}$), and 91151 (3.0 $t\ ha^{-1}$), produced significantly greater pod yields than the control cultivar, MI-1 (2.4 $t\ ha^{-1}$) They had significantly higher shelling percentage (75.8–77.6) and 100-seed mass (44.1–50.2 g) compared to MI-1 (72.0% shelling, 42.1 g 100-seed mass. ICGVs 91114, 91117, and 91151 produced greater leaf area and biomass at 75 DAS (Table 1). These varieties flowered early (20–21 days for first flowering, and 25–27 days for 100% flowering).

This study reveals that the ICRISAT groundnut varieties ICGVs 91114, 91117, and 91151, significantly outyielded the control variety MI-1, and were superior in many agronomic traits, particularly shelling percentage and seed size. These elite varieties are the potential candidates to introduce in the farming system of eastern Sri Lanka where most of upland soil is sandy Regosols. However, they need further evaluation in farmers' fields before they are recommended.

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Evaluation of ICRISAT Groundnut Varieties in Mpumalanga, South Africa, 1995–97

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The evaluation of groundnut varieties from ICRISAT-Patancheru, India, started in 1991 with a replicate of the Fourth International Foliar Disease Resistant Variety Trial. Although most of these varieties showed significantly lower infection levels of the foliar disease complex (FDC) of early and late leaf spots and rust, their seed yields were not significantly greater than those of the susceptible South African cultivar Anel, because of poor pod filling (Mathews and Beck 1994). Therefore, the farmers preferred the local variety Anel to the foliar disease resistant varieties ICGV 86594 and ICGV 86590 (Mathews and Smith 1995).

The international variety evaluation program in collaboration with ICRISAT, was expanded from the 1993–94 season to identify varieties adapted for rainfed production by the 15 000-strong smallholder farmer community in the Mpumalanga Province of South Africa. Therefore, in addition to the continued evaluation of FDC-resistant varieties, trials of new lines with resistance to drought and insect pests and of short- and medium-duration were undertaken with varieties obtained from ICRISAT-Patancheru. In addition, 20 varieties selected on their performance at ICRISAT-Malawi, were introduced and evaluated from 1994, using Anel as the local control. None of the FDC- and drought-resistant and medium-duration varieties evaluated during this period gave significantly higher seed yields than Anel, and these groups were discarded.

Twelve outstanding varieties were identified from the 1993–95 trials for seed yield, earliness, and testa color. Of these, three varieties (ICGV 86436, ICGV 86518, and ICGV 87468) were from the Fifth International Insect Pests Resistant Groundnut Variety Trial, and one variety (ICGV 87885) was from the Fifth International Short-duration Groundnut Variety Trial. The remaining seven varieties were from the ones introduced from Malawi. These selected varieties were evaluated further at seven locations in 1995–96 and five locations in 1996–97 in Mpumalanga. The results from these trials are given in Table 1.

In all, two varieties (ICGV 86436 and ICGV 86518) from ICRISAT-Patancheru, and two varieties (JL 24 and ICGV 92194) from ICRISAT-Malawi, produced greater seed yields than Anel. Although JL 24 gave 6.8% greater seed yield than Anel during 1995–96 season, the increase was not large enough to be significant. ICGV 86436 and JL 24 significantly outyielded Anel in the following season, with an increase of up to 27% over Anel ($P = 0.05$).

In a joint analysis of the data from the two seasons, JL 24 was the highest yielding with a mean seed yield 18% greater than Anel ($P = 0.05$). The varieties ICGV 92194, and Anel gave the most stable yields across both locations and seasons. All the varieties were susceptible to the foliar disease complex. The shelling percentage was the lowest (67%) in ICGV-SM 93514 and none of the varieties had significantly different shelling percentage compared to Anel. JL 24 reached maturity significantly earlier than Anel ($P = 0.05$). ICGV 87003, JL 24, and ICGV 92194 had significantly larger seed mass than Anel ($P = 0.05$).

Based on the above studies carried out during the 1995–97 seasons, the varieties JL 24, ICGV 86436, ICGV 92194, and ICGV 86518 were identified for further evaluation under farmer-managed conditions for final selection of the variety or varieties acceptable to the farmers. The selected variety will be recommended for wider adoption by the groundnut growers in the province.

Table 1. Performance of selected ICRISAT varieties in Mpumalanga, South Africa, 1995–97.

Variety	Seed yield ($t\ ha^{-1}$) 1995–96[1]	1996–97[2]	Mean[3]	Pod yield[3] ($t\ ha^{-1}$)	Shelling[3] (%)	100-seed mass[3] (g)	Maturity[4]
JL 24	2.39	1.95	1.98	2.77	70.44	40.32	117
ICGV 86436	2.06	1.96	1.85	2.74	67.44	34.52	131
ICGV 92194	2.28	1.61	1.84	2.57	70.36	36.06	118
ICGV 86518	2.04	1.89	1.82	2.63	69.66	35.00	127
Anel	2.24	1.54	1.67	2.38	69.80	31.94	128
ICGV 87003	2.05	1.60	1.66	2.33	70.38	42.24	119
ICGV 92260	1.99	1.65	1.65	2.38	70.08	33.40	117
ICGV 92245	2.16	1.44	1.62	2.21	72.74	33.44	116
ICGV 87885	2.08	1.41	1.58	2.16	72.10	28.74	119
ICGV 87468	1.93	1.40	1.55	2.31	67.92	34.86	134
ICGV-SM 93514	2.15	1.29	1.50	2.20	67.00	34.70	117
ICG 221	2.06	1.29	1.50	2.02	73.44	28.54	120
ICG 6275	1.89	1.19	1.45	2.13	67.68	31.36	121
Mean	2.10	1.55	1.67	2.37	69.93	34.24	122
SE	NS	±0.09	±0.09	±0.11	±1.38	±1.19	±2.18
CV (%)	17.67	13.41	12.47	10.73	4.40	7.75	2.48

1. Pooled mean of 7 locations.
2. Pooled mean of 5 locations.
3. Mean of two seasons (1995-97).
4. Mean of two sites in 1996-97.

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Identification of Confectionery Groundnut Variety Adapted to the Vidarbha Region of Maharashtra, India

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The area under rainy season groundnut in the Vidarbha region of Maharashtra state has declined progressively, and reduced to 72 000 ha with production of 66 000 t ha^{-1} during 1993–94. However, cultivators are eager to grow large-seeded, hand-picked selected (HPS) groundnut varieties under protective irrigation during the rainy season. Local markets show high demand for HPS type groundnut for major cities. Because of the General Agreement on Trade and Tariffs (GATT), export trade is once again picking up, and the price of Indian groundnut in the international market may become more competitive to promote export of HPS-graded groundnut kernels.

Based on its superior pod yield (16%) over M 13, a nationally released variety, TKG 19 A was identified as a suitable variety for the region. TKG 19 A belongs to the spanish botanical group, and matures in 115–120 days in the rainy season. Its shelling ranges from 68–70%, sound mature kernels from 90–93%, and 100-seed mass from 75–80 g (Table 1).

TKG 19 A was developed in a collaborative program between Bhabha Atomic Research Center (BARC), Mumbai, and Konkan Krishi Vidyapeeth, Dapoli, India. It was derived by pedigree selection from a cross made at BARC between TG 17 (spanish bunch) and TG 1 (Vikram) (virginia bunch).

Distinguishing morphological characters are large pod size with moderate beak, moderate reticulation, and moderate constriction. Seeds are larger in size, oblong in shape, and tan in color. Plant height is 25–30 cm. Leaflets are broad and dark green. It has a 25–30 day dormancy, which is normally not observed in spanish bunch varieties.

Table 1. Pod yield (kg ha^{-1}) of TGK 19A and controls in the Vidarbha region of Maharashtra, India, during rainy seasons.

Year	Location	TKG 19A[1]	ICGV 86564[2]	M 13[3]	SEm	CV (%)
1992	Akola	2902[4]	2776	2757	±197.1	15.9
1993	Akola	1334[4]	1108	761	±151.7	13.4
	Nagpur	3836[4]	2933	2319	± 71.8	11.3
	Yavatmal	1442[4]	1376	1430	± 46.0	6.9
1994	Akola	619[4]	410	583	± 52.3	9.2
	Nagpur	2119[4]	1732	1772	± 70.1	8.3
	Yavatmal	805[4]	637	792	± 44.6	13.4
1995	Akola	1765[4]	1331	1746	±100.7	12.7
	Nagpur	2178	2541	2421	±154.5	13.9
	Yavatmal	345	422	338	± 47.8	23.7
Average		1735	1527	1492		
% Increase			13.6	16.3		

1. Spanish botanical group.
2. Virginia botanical group.
3. Virginia runner botanical group.
4. Significantly superior to M 13.

Yield Comparisons of Two Groundnut Varieties: Farm Level Evidence from Senegal

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In Senegal, as in several other West African countries, groundnut production is the main source of rural employment, and accounts for a major share of the total cultivated land, besides being the most important source of foreign exchange. Despite the economic significance of this crop, productivity is quite low and the Senegalese share in the world trade of groundnut oil has diminished, while environmental degradation from groundnut farming has been substantial (Badiane and Kinteh 1994). More recently, as a component of structural adjustment measures, the Government has eliminated input subsidies to groundnut producers, and is considering privatization of oil-producing plants. Despite these problems, an important and challenging policy objective is to achieve 80% food self-sufficiency by the year 2000 (Jammeh 1988). If this challenge is to be met, it is critical that farmers improve productivity through skilled management, and that they adopt higher quality seeds along with adequate fertilization rates (Badiane and Kinteh 1994).

The purpose of this note is to compare the yields of two groundnut varieties, 55-437 (traditional) and La Fleur 11 (modern), using farm level data. The data were collected between Aug and Nov 1996 as a component of the regular training given to first-year students at the Ecole nationale d'economie appliquée (ENEA, National School of Applied Economics) located in Dakar, Senegal. (For more details on data collection procedures, see Thiam 1994).

As shown in Table 1, the data were collected from four villages located in the Department of Tivaoune, in Thiès. The sample comprised 47 farms, 36 sown with variety 55-437, 11 sown with both varieties, and 2 which did not produce groundnuts. No farm was found to be cultivating only La Fleur 11. The Mann-Whitney test was used to examine the null hypothesis that the average yields for the two seed varieties are the same (Blalock 1960). This nonparametric test was chosen because the small sample size does not make it appropriate to invoke the normality assumption (Kmenta 1971).

As presented in Table 2, the average yield for the 11 farmers using La Fleur 11 is 515.07 kg ha^{-1} (subsample A). The average yields for variety 55-437 were calculated for three subsamples: the 36 farmers using this variety who attained 396.26 kg ha^{-1} (subsample B); the 11 farmers producing both varieties who reached 413.31 kg ha^{-1} (subsample C); and the 25 farmers using only the traditional variety who attained 388.75 kg ha^{-1} (subsample D).

Three pairs of yield comparisons were performed (Table 2). The results show that the yields for La Fleur 11 are statistically significant and different in two of the three cases (subsample A versus B and A versus D). These results are consistent with those obtained from experimental data by Grosshans and Mayeux (1996).

Table 1. Performance and distribution of two groundnut varieties, Tivaoune, Senegal, Aug–Nov 1996.

Village	55-437	La Fleur 11	Total
Mékhé (no. of farms)	10	3	13
Méouane (no. of farms)	10	0	10
Risso (no. of farms)	9	7	16
Tilmakha (no. of farms)	7	1	8
Total (no. of farms)	36	11	47
Average area with groundnuts (ha)	3.6	1.6	3.1
Average production (kg)	1441.5	771.8	1284.7
Average yield (kg ha^{-1})	396.3	515.1	424.1
Total groundnut acreage (ha)	128.9	17.7	146.6

Table 2. Mann-Whitney tests of yield comparison between the groundnut varieties 55-437 and La Fleur 11, Tivaoune, Senegal, Aug–Nov 1996.

Subsample	Variety	No. of farms	Sum of ranks	Mean rank	Average yield (kg ha^{-1})
Users of La Fleur 11 versus All users of 55-437					
A	La Fleur 11	11	341	13.18	515.07
B	55-437	36	787	21.86	396.26
		U = 121	U = 275	Z = -1.94	$P = 0.05$
Users of La Fleur 11 versus Users of both varieties					
A	La Fleur 11	11	145	13.18	515.07
C	55-437	11	108	9.82	413.31
		U = 42	U = 79	Z = -1.22	$P = 0.22$
Users of La Fleur 11 versus Users of 55-437 only					
A	La Fleur 11	11	262	23.82	515.07
D	55-437	25	404	16.16	388.75
		U = 79	U = 196	Z = -2.01	$P = 0.04$

It is important to point out that the Institut sénégalais de recherches agricoles (ISRA), which developed La Fleur 11, has high expectations that this variety will increase productivity and production substantially in Senegal. Our data, however, indicate that only 29% (11/38) of the farmers have adopted this variety in 12% (17.7/146.6) of the total land devoted to groundnut production (Table 1). Moreover, it appears that the yield potential of La Fleur 11 is higher than that achieved by the farmers in our sample. Hence, if the full potential of this new variety is to be obtained, considerable efforts are needed. These include dissemination of the variety in other potential areas, increase of seed production to meet the demands, educating farmers on appropriate cultivation practices.

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Luhua 15: A High-yielding, Small-seeded Groundnut Cultivar with Improved Seed Quality

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In groundnut trade, Chinese "hsuji type" (small-seeded) groundnut has encountered keen competition from the runner type of USA and Argentina, and the natal type of South Africa. American runner varieties are not adopted under Chinese growing conditions because of low yield, and a runner growth habit. The low oleic : linoleic (O/L) ratio of the hsuji type groundnut results in a short shelf-life, thus making it less competitive in the international market. Research on development of cultivars with improved O/L ratio began in 1986 at the Shandong

Peanut Research Institute (SPRI). The breeding methods included induced mutation and hybridization. A new variety Shanlan 1 was identified, and named Luhua 15 by the Shandong Crop Variety Evaluation Committee in 1997.

Luhua 15 derived from the cross of (78961 × Florunner) F_2 with irradiated Florunner (dry seeds treated by 60_{Co}; (25 KR Gamma rays) (M_1). It was selected following the pedigree method. The seeds of Florunner were obtained from ICRISAT.

Luhua 15 matures during the spring season. It has an erect growth habit, sequential flowering, and dark green leaves. The main height of the plant is 40 cm, and the average length of branches is 44 cm. Six to seven of the 8 branches are fruiting ones. The pods are calabash shaped, with slight reticulation. The seeds are characterized by a peach shaped, pale red seed coat, and golden yellow inner testa. The 100-pod mass is 142 g, and the 100-seed mass 62 g with a shelling percentage of 73. Luhua 15 is considered resistant to web blotch *(Didymella arachidicola)*. The variety is clearly superior to Baisha 1016 in seed quality traits (Table 1). It is an important breakthrough in quality breeding of export small-seeded groundnut in China after the 1950s.

Table 1. Seed quality traits of groundnut varieties Luhua 15, Baisha 1016, and Florunner, China.

Variety	Protein content (%)	Oil content (%)	Oleic (%)	Linoleic (%)	Oleic/ linoleic ratio
Luhua 15	28.63	50.89	44.72	34.11	1.31
Baisha 1016	30.82	53.52	38.38	39.55	0.97
Florunner	26.57	53.62	44.83	34.34	1.31

In 2 years (1992/93) of cooperative varietal trials, Luhua 15 produced an average of 19% greater pod and seed yields over the local control, Baisha 1016. In location trials (5 sites and 2 years) in Shandong province in 1994/95, Luhua 15 ranked first and produced 4 t ha^{-1} pods (13.8% more than Baisha 1016), and 2.9 t ha^{-1} seeds (14.6% more than Baisha 1016). In 1996, Luhua 15 was the only variety selected to enter in production test at 5 locations in Shandong. The average pod yield of the variety from the test was 3.2 t ha^{-1} (11.72% more than the control Luhua 12), and the seed yield was 2.4 t ha^{-1}, which was 14.43% more than that of Luhua 12 (Table 2).

Since Luhua 15 has desirable characteristics of yield, improved seed quality, and resistance to web blotch, it is recommended for cultivation in small-seeded groundnut producing areas. The seed rate should be around 165 and hills per ha with two seeds in each hill for the spring sowing, and 180 thousand hills per ha for the summer sowing.

Table 2. Average pod and seed yield (t ha^{-1}) of groundnut varieties Luhua 15 and controls in regional trials (1994/95) and production test (1996) in Shandong Province, China.

Variety	Pod yield	Pod yield increase over control (%)	Seed yield	Seed yield increase over control (%)
1994/95				
Luhua 15	3.960	13.8[2]	2.879	14.6[2]
Baisha 1016 (control)	3.479		2.511	
1996				
Luhua 15	3.221	11.72	2.373	14.43
Luhua 12	2.883		2.074	

1. Average of five locations.
2. Highly significant.

Reference

Qiu Qingshu, Lu Rongrong, Yu Shanlin, and **Duan Shufen.** 1990. The selection and application of an early maturing peanut cultivar Luhua 6. Oléagineux 45:131–134.

Preliminary Performance of Introduced Groundnut Breeding Lines from ICRISAT in Vietnam

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Seven sets of international groundnut varietal trials were grown at VASI, Hanoi, during the 1996 spring season. They belong to the 6th series and include trials for (i) short-duration varieties, (ii) medium-duration spanish bunch varieties, (iii) medium-duration virginia bunch varieties, (iv) varieties resistant to insect pests, (v) varieties resistant to foliar diseases, (vi) varieties resistant/tolerant to drought, and (vii) varieties with large seed size and good quality. All the trials were grown in a randomized block design with three replications. The plot size was 1.4 m^2, with an interrow spacing of 35 cm, and an intrarow

Table 1. Range of pod yield of the selected varieties and controls, Hanoi, Vietnam, 1996.

Trial	Range of pod yield (t ha^{-1})	Control cultivar	Pod yield (t ha^{-1})		Varieties retained for further evaluation
Short duration	1.55–2.53	Ly Cam Ranh	1.82	(8.25)[1]	ICGVs 89023, 91112, 91116 91124, 91146, 92209, 92242
Medium duration (spanish bunch)	1.83–2.19	V 79	1.4	(5.72)[1]	ICGVs 91023, SB 11 × 95
Medium duration (virginia bunch)	1.69–2.42	BG 78	1.82	(5.26)[1]	ICGVs 90057, 91003, 91077
Confectionery	0.99–2.29	BG 78	2.36	(6.25)[1]	ICGVs 90173, 90208, 90212, 88408, 91099, 91106
Resistance to insect pests	1.72–2.03	SB 17	2.3	(6.35)[1]	ICGVs 90226, 91215, 90228
Resistance to foliar diseases	1.83–2.94	SB 11	2.3	(5.33)[1]	ICGVs 87846, 88256, 91234, 91246
Tolerance to drought	1.60–2.25	Cu Nghe An	1.29	(7.8)[1]	ICGVs 87846, 90127

1. LSD 5%.

spacing of 10 cm. While the drought trial was grown under rainfed conditions in an upland field, the other trials were grown under irrigated conditions. The soil was sandy and of poor fertility. A basal dose of farmyard manure at the rate of 10 t ha^{-1} and 500 kg ha^{-1} single superphosphate were applied during field preparation. Top dressings of urea (70 kg ha^{-1}), and KCl (100 kg ha^{-1}) were done at the first weeding. Total rainfall during the season was 650 mm, which was 225 mm greater than that in the 1995 spring season. Because of the heavy rains, the crop suffered 3–4 times from waterlogging. Total radiation during the season was much lower than the average for the previous many years. The high rainfall and low radiation resulted in excessive plant growth, and the plants suffered from lodging at pod development stage. The minimum temperature during the growing season ranged between 18–26°C, while the maximum ranged between 20–29°C.

Range of pod yield (t ha^{-1}) of the selected varieties along with the control cultivars is presented in Table 1. They recorded similar or greater pod yield than the controls. They were also comparable to controls in shelling percentage (73–81% compared with 74–80% in controls). ICGVs 91234, 91246, 90212, and 88408 showed much lower (57–65%) sound mature seeds (SMS) than controls (87–95%). The SMS of the other varieties ranged between 71–93%. The varieties resistant to insect pests and foliar diseases (except ICGV 88256), and the confectionery varieties showed greater 100-seed mass (60–92 g) than controls (35–55 g). The 100-seed mass of the short-duration varieties was comparable to controls (41 g).

ICGVs 87846, 88256, 91234, 91246, 90226, 90227, and 90228 showed resistance (a score of 2–4 on a 1–9 scale, where 1 = highly resistant, 2–3 = resistant, 4–5 = moderately resistant, 6–7 = susceptible, and 8–9 = highly susceptible) to rust and late leaf spot. The control cultivar recorded a score of 7 for rust and late leaf spot. All the short-duration varieties were found susceptible to rust and late leaf spot.

ICGVs 90057, 91077, 91099, and 91106 were not affected by lodging. Other varieties showed varying degree of lodging at pod development stage.

While the short- and medium-duration (spanish bunch type) varieties were harvested in 130 days, other varieties were harvested in 139–142 days.

These varieties are currently under advance evaluation trials in 1997 spring season in northern Vietnam.

A New High-yielding Groundnut Variety Luhua 14

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Luhua 14 is derived from a multicross of [(Kainong 8 × Hunju 5) × (Kainong 8 × Youmal-1)] made in 1983 at the Shandong Peanut Research Institute, China. It was released by the Shandong Crop Variety Approval Committee in 1995, and the Crop Variety Approval Committee of Hebei province in 1996.

Table 1. Foliar disease reactions of Luhua 14, China, 1996.

	Disease score[1]			
Variety	Web blotch	Late leaf spot	Early leaf spot	PStV[2]
Luhua 14	1	1	2	3
Controls				
Luhua 11	4	2	2	8
Luhua 9	3	2	1	8
Luhua 10	7	1	5	9

1. Scored on a modified 1–9 scale where 1 = highly resistant; 2–3 = resistant, 4–5 = moderately resistant, 6–7 = susceptible, and 8–9 = highly susceptible.
2. Peanut Stripe Virus disease.

During 1992/93, in Shandong provincial trials, the seed yield of Luhua 14 averaged 3.88 t ha^{-1} over 14 locations; 10.3% more than variety Luhua 9 (control). In summer sowing trials of Hebei province in 1994, its pod yield averaged 2.82 t ha^{-1} over 5 locations; 32.6% more than Jinyou 6 (control). In demonstration tests and wheat-groundnut intercropping trials in Shandong province, Luhua 14 gave 12.2% and 20.93% more yield than controls. Its average seed yield in demonstrations test was 4.64 t ha^{-1} (mean of 6 locations). In intercropping trials, its pod yield averaged 4.56 t ha^{-1}. In Wu Lian county of Shandong province in a yield-maximization demonstration on 0.143 ha in 1994, Luhua 14 produced 10.6 t ha^{-1} yield, setting a new record of high yield for a short-duration groundnut variety in China.

Luhua 14 matures in 130 days in the spring sowing, and in 100 days in the summer sowing. It has an erect growth habit and sequential flowering. Its elliptical leaves are small and dark green. The main stem of Luhua 14 is 35-cm high. It has 4–6 primary and 2–3 secondary branches. Two-seeded pods account for 70% of the pods. The 100-pod mass is 274 g, and the 100-seed mass is 116 g. Its shelling percentage 75.2. Its seeds contain 52.2% oil and 26.99% protein. The O/L ratio is 1.7%.

Reaction to foliar disease for Luhua 14 was evaluated by the Plant Protection General Station of Shandong province in 1996. Luhua 14 showed high resistance to many diseases (Table 1).

The variety should be sown on sandy soil with good drainage. During soil preparation, around 37 t ha^{-1} of farmyard manure, 0.15 t ha^{-1} of ammonium sulfate, 0.3 t ha^{-1} of superphosphate, and 0.15 t ha^{-1} of potassium chloride should be applied. These fertilizer recommendations may vary with soil type, and other climatic factors. There should be 150 000–180 000 holes ha^{-1} each planted with two seeds. The soil should be heaped up at the plant base and interrow should be hoed, if necessary.

Performance of Groundnut Genotypes in a Scarce Rainfall Zone Under Rainfed Conditions in India

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In Andhra Pradesh, groundnut is cultivated on an area of about 2.35 million ha with a production of 2.55 million t. Among the four rainfed and scarce-rainfall districts of Rayalaseema (Anantapur, parts of Chittoor, Cuddapah, and Kurnool), Anantapur alone accounts for 80% of the groundnut area. Groundnut is grown only under rainfed conditions during the rainy season in red soils of poor fertility; the crop is usually subjected to drought conditions with consequent reduction in crop yields. The objective of this study was to identify the most suitable genotype to the tract which can yield better than such local varieties as TMV 2 and JL 24 under drought conditions (average annual rainfall 620 mm).

Twenty genotypes with two controls were grown in a randomized block design with four replications for 3 consecutive rainy seasons 1994 (275 mm rainfall), 1995 (580 mm), and 1996 (780 mm) at the Agricultural Research Station, Kadiri. The average rainfall over the past 10 years was 388 mm. The net plot area was 34 m^2 with an interrow spacing of 30 cm, and an intrarow spacing of 10 cm. The recommended agronomic package was adopted. Data on pod yield and ancillary characters were recorded.

Through the rainfall received during the crop growth period of 1996 was more than that in 1995, the mean pod yields were low because there was excess rainfall during the seed filling and pod maturity periods (Sep: 238 mm, Oct: 304 mm) which resulted in poor mean shelling outturn. Average pod yield over 3 rainy seasons was 1.39–1.91 t ha^{-1}. The genotypes TCGS 91 (1.89 t ha^{-1}), K 134 (1.88 t ha^{-1}) and ICGV 86347 (1.91 t ha^{-1}), were significantly superior in their pod yields over the control TMV 2 (1.67 t ha^{-1}) (Table 1). The mean seed yield of TCGS 91 and K 134 (Vemana) was significantly higher than those of TMV 2. TCGS 25 with a shelling percentage of 70 was significantly superior to the control. However, ICGV 86347 had a poor shelling percentage (63.3), and

Table 1. Average performance of groundnut genotypes at Agricultural Research Station, Kadiri, Andhra Pradesh, India, during rainy seasons 1994, 1995, and 1996.

Genotype	Pod yield ($t\ ha^{-1}$) 1994	1995	1996	Mean pod yield ($t\ ha^{-1}$)	Shelling turnover (%)	Seed yield ($t\ ha^{-1}$)	100-seed mass (g)	Sound mature seed (%)
ICGV 86347	1.11	2.78	1.83	1.91	63.3	1.21	29.4	75.5
TCGS 91	1.11	2.88	1.67	1.89	68.2	1.29	29.5	91.4
K 134 (Vemana)	1.21	2.71	1.72	1.88	69.7	1.29	29.9	86.5
TCGS 25	1.11	2.76	1.70	1.86	70.0	1.30	32.4	90.9
TCGS 84	0.98	2.68	1.82	1.83	68.9	1.26	32.9	91.0
K 150	0.86	2.69	1.78	1.78	69.5	1.24	28.6	83.4
TCGS 29	1.07	2.63	1.60	1.77	69.9	1.23	33.2	93.1
TCGS 26	1.04	2.45	1.82	1.77	69.4	1.23	30.2	90.5
K 1128	1.11	2.57	1.60	1.76	69.0	1.21	27.4	86.5
TCGS 61	1.05	2.37	1.84	1.75	69.7	1.23	31.9	89.9
ICGV 86300	0.77	2.71	1.77	1.75	67.8	1.18	29.1	82.9
TCGS 76	1.19	2.31	1.70	1.74	71.2	1.24	31.6	90.8
TCGS 67	0.97	2.61	1.57	1.72	70.7	1.21	30.1	91.2
TPT 1	1.05	2.60	1.45	1.70	72.4	1.23	28.2	89.5
TCGS 30	0.80	2.58	1.65	1.68	69.6	1.17	31.1	87.2
TCGS 37	0.97	2.54	1.53	1.68	68.6	1.15	31.3	87.1
TCGS 27	1.12	2.33	1.44	1.63	71.0	1.16	26.5	87.4
TCGS 88	0.76	2.46	1.53	1.58	71.2	1.13	34.0	90.4
TCGS 13	0.91	2.20	1.62	1.58	70.6	1.12	28.9	90.2
TG 26	0.46	2.02	1.70	1.39	69.7	0.97	26.5	82.9
Controls								
TMV 2 (C)	1.21	2.30	1.50	1.67	71.5	1.19	28.2	90.0
JL 24 (C)	1.18	2.14	1.59	1.64	69.0	1.13	32.5	91.4
SE	±0.05	±0.13	±0.07	±0.08	±0.62	±0.04	±0.50	±0.71
LSD ($P = 0.05$)	0.15	0.30	0.20	0.21	1.20	0.09	1.02	1.46
CV (%)	10	9	4	8	10	7	10	9

poor sound mature seed (75.5%) in spite of its top rank in pod yield. The superiority in pod and kernel yields of TCGS 25, TCGS 91, and K 134 over TMV 2 (C) might be because of either superior 100-seed mass or sound mature seed or both.

The present study indicated that in addition to the already recommended and released variety Vemana (K 134), the genotypes TCGS 25 and TCGS 91 gave consistently superior pod and kernel yields for 3 rainy seasons over the controls TMV 2 and JL 24. Although TCGS 25 and TCGS 91 performed well, they need to be tested on a larger scale in the zone.

Breeding Groundnut for Drought Adaptation in Senegal

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In Senegal, drought characterized by a general decrease and an irregular rainfall pattern has been responsible for the decrease in groundnut yield observed since 1970.

A crop duration of 65–80 days is best for an ideotype in the northern part of the groundnut basin (Annerose 1991). This is not the case for the cultivars released to date. For the central part of this region, the crop duration of the ideotype should be 90 days. It must however possess the physiological capability to overcome water deficit stresses especially when there is terminal drought (Annerose 1991) (Fig. 1).

Multidisciplinary approach. The groundnut improvement program established in Senegal since 1985 includes, in particular, studies on the agro-physiological basis for groundnut adaptation to drought (Khalfaoui 1985). The aim of this program is to associate short-duration with physiological characteristics which are likely to improve the plant's adaptation to end-of-season drought. In the case where genetic variability was observed for the drought adaptation agro-physiological trait, screening tests were established for breeding purposes. The physiological selection tests available for screening materials involve (i) the size and morphology of the root system, (ii) leaf area, (iii) stomatal regulation, and (iv) protoplasmic membrane resistance.

On the other hand, genetic studies on short-duration and adaptative characters were conducted in order to adopt the most appropriate breeding methodology. Pod ripening, the main component of short-duration, is governed by a small number of genetic factors. This character is easily transferable using the backcross breeding method. Inheritance was polygenic with low heritability, but had preponderant additive effects for the adaptative characters. This indicates that recurrent selection might be efficient (Khalfaoui 1988).

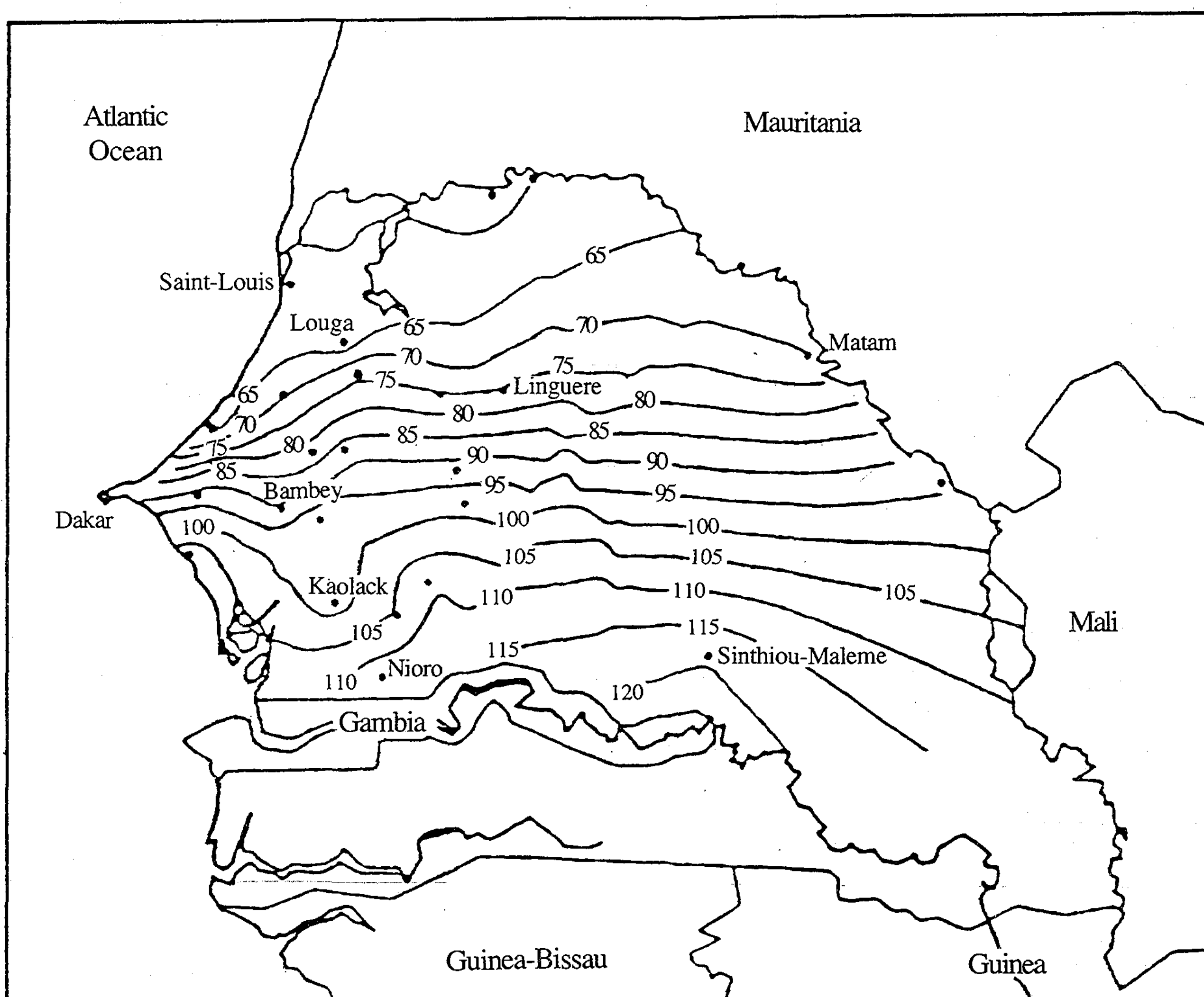

Figure 1. Crop durations (1968–87) for Senegalese groundnut cultivars (Annerose 1991).

Results. Based on these results, two breeding approaches were developed:

1. A short-term program consisting of backcrosses for (i) transfering earliness from Chico, which matures in 75 days, to cv 73-30 and 55-437, both 90-days long; (ii) transfering the character "small seed" from 55-437 to 57-422, in which favorable physiological traits for adaptation to drought had previously been found.

This program resulted in a pre-release of an 80-day variety, GC8-35, for the northern region. Production was about 20% more than that of the area control, 55-437. This variety also performed well in Brazil. In the case of the transfer of seed character, the program was advanced until the fifth backcross. Twenty-four original stable lines resulting from a genealogical selection from the previous backcrosses are available for statistical evaluation.

2. A long-term recurrent selection program for the north-central part of the basin is in progress. Recurrent selection is the only available breeding method which allows the combination, in the same genotype, of multiple favorable alleles dispersed in numerous lines. In addition, it enables us to generate new variability by creating a genetically broad population from diverse genetic sources. The population is subjected to continuous intrapopulation improvement. Each selection cycle involves manually intercrossing about 40 to 50 S3 segregating lines previously selected according to a double process: field evaluation for production characters, and laboratory screening for physiological criteria.

The first two cycles of selection showed significant progress compared to the original population. The third cycle of selection will be completed in 1997. Advanced breeding lines were developed using genealogical selection from the first population in Senegal, Burkina Faso, Botswana, and Brazil. These lines, which are at least as productive as the control, are now available for multilocational evaluation in these four countries.

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Pathology

Occurrence of Groundnut Aphids (*Aphis craccivora* Koch) and Rosette Disease in Irrigated Dry Season Groundnut in Central Malawi

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Aphis craccivora Koch causes damage to groundnut by sucking plant sap and transmitting a number of virus diseases including rosette (Reddy 1991). Currently rosette is considered to be one of the most serious diseases of groundnut in sub-Saharan Africa. The seasonal and regional variations in rosette incidence are not fully understood. It is not known if the seasonal carry-over of rosette depends primarily on groundnut itself or on alternative hosts. While rosette occurs sporadically wherever groundnut is cultivated in the semi-arid tropics of sub-Saharan Africa, reports in the literature indicate that rosette outbreaks are more common in areas with bimodal rainfall and double cropping (Evans 1954, Harkness 1977), suggesting that groundnut plays a major role in the disease cycle. We also have observed high incidence of rosette (>50%) in groundnut farms in Karonga, Northern Malawi, where groundnut is cultivated throughout the year (P Subrahmanyam, unpublished data). However, the role of indigenous hosts of rosette as primary source of inoculum is yet to be determined (Hildebrand et al. 1991).

The occurrence of aphids and rosette in groundnut bait plots in Central Malawi, an area with monomodal rainfall and an extended dry season, was studied during the 1996 dry season. The preceding wet season saw high rosette incidence in this area. It was assumed that if alternative hosts for rosette existed in the region, they would act as a source of inoculum for transmitting rosette to groundnut bait plots sown in the dry season. We collaborated with vegetable growers in "dambo" areas (moist valleys with waterlogging) in a 30-km radius around Chitedze, Central Malawi. Thirty-seven plots in five villages, were sown with Malimba, a short-duration cultivar, during the last week of Aug 1996. Groundnut was sown at 30 × 30 cm in raised beds in an area of 100 m^2 per farm, in soil varying from heavy black clay to light sandy loams. The plots were irrigated with well water. Pesticides were not applied. Populations of *A. craccivora* and incidence of rosette were recorded until the end of dry season. Aphids were first noticed during the last week of Oct (about 2 months after sowing), in 29 % of the fields. The crop was in the flowering stage. However, the canopy was not fully covered. Aphid infestation ranged from 6 to 32%, and on each plant the size of colony did not exceed 50 individuals. Aphid populations disappeared 2 weeks later, and did not reappear. Rosette symptoms were not noticed. Crop growth was satisfactory in all the locations.

Results show that rosette did not occur during the 1996 dry season in Central Malawi despite the presence of the vector. Surveys in farmers' fields in the Chitedze area also did not reveal rosette symptoms on groundnut volunteers (Bottenberg and Subrahmanyam 1997). In addition, rosette was not noticed during two visits in Oct 1996 to a 6-ha irrigated vegetable farm with about 2 ha of groundnut near Salima, 100 km east from Chitedze (Bottenberg, unpublished data). These observations support our conclusion that rosette is not harbored by alternative hosts in Central Malawi during the dry season.

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Dry Season Survival of Groundnut Volunteer Plants and Ground Keepers (*Arachis hypogaea* L.) in Central Malawi

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One of the deficiencies in our understanding of the epidemiology of groundnut rosette, a major virus disease of groundnut in Africa, is where the virus complex survives during the dry season. The vector *Aphis craccivora* Koch has been recorded from a wide variety of alternative hosts during the dry season but none have been shown to carry any of the rosette viruses

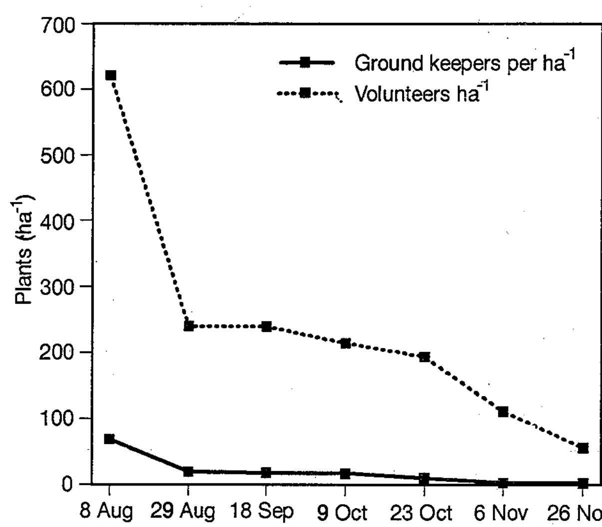

Figure 1. Densities of groundnut volunteers and ground keepers in farmers' fields (n = 21) in Central Malawi during the 1996 dry season.

components under natural conditions (Adams 1967, Reddy et al. 1985). Groundnut volunteer plants and "ground keepers" may survive during the dry season depending on the cultivar used and local climatic conditions. Volunteer plants originate from seeds of short-duration spanish/valencia cultivars that were left in the ground after harvest in soils with residual moisture. Ground keepers are plants or their parts not lifted during harvest, thus left in the ground. Such plants may be short- or long-duration types. Under favorable conditions, volunteers and ground keepers may carry aphid colonies and provide rosette inoculum (Evans 1954). Currently the importance of volunteers and ground keepers in Central Malawi in perpetuating the rosette inoculum is not known (Bock and Nigam 1988, Hildebrand et al. 1991). The objective of this study was to monitor the survival of ground keepers and volunteers in farmers' fields during the dry season to assess their importance in providing a source for the survival of aphids and in perpetuating the rosette disease inoculum.

During an initial survey in Aug 1996, 21 fields out of a random sample of 104 harvested groundnut fields within a 30-km radius around Chitedze, Central Malawi, were found to have ground keepers and groundnut volunteers. In each of these fields, the number of groundnut plants was counted in a centrally located sample area of 0.1 ha; the condition and growth stage of each plant and the presence of aphids and rosette was also noted. Assessments were made every 2–3 weeks until the end of the dry season.

Volunteer plants persisted throughout the dry season (Fig. 1). Densities decreased from 622 plants ha^{-1} in early Aug to 57 plants ha^{-1} by the end of Nov. Growth stage ranged from 2-leaf stage to flowering stage; many plants showed profuse branching because the central shoot was chewed off by goats and cows. Very little growth was noted during the period of observation. Ground keepers were less common. There were 69 plants ha^{-1} in early Aug which dropped to 3 plants ha^{-1} in late Nov. Ground keepers often had a withered and tattered appearance and consisted mostly of one or two branches with a partial root system. Plant mortality resulted from drought, browsing by animals (if the entire plant was destroyed), and physical removal by farmers during land preparation at the end of the dry season. There were a total of three localized, light showers (<5 mm) during Oct and Nov which may have provided sufficient moisture for germination of some remnant groundnut seed. However, volunteers that developed early in the dry season were always more vigorous than those that germinated at a later date, presumably because 'early' volunteers had a more extensive root system than 'late' volunteers and were therefore less sensitive to drought. In addition, removal of the primary shoot by browsing animals, reduced the plant size with lateral branches closely hugging the ground that may have further increased drought resistance of early volunteers. Land preparation was started in Sep (one field partially tilled); by the end of Nov, 9 out of 21 fields were partially or completely tilled. No rosette symptoms were noticed on volunteers or ground keepers. Small aphid colonies (less than 50 aphids) were found on volunteer plants only in 3 fields (3 out of 83 plants) on 18 Sep and in one field (one out of 66 plants) on 8 Oct.

This survey showed that groundnut volunteer plants can survive during the dry season, and do not support the data from previous studies suggested (Bock and Nigam 1988, Hildebrand et al. 1991). However, the role of groundnut volunteers as carriers of aphids and rosette inoculum in Central Malawi is yet to be determined.

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Detection of Tomato Spotted Wilt Tospovirus Infection of Groundnut by Immunocapture RT-PCR

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Tomato spotted wilt tospovirus (TSWV) is a major constraint to groundnut production in southern USA. Rapid and sensitive detection of TSWV infection of groundnut by such molecular techniques as reverse transcription and polymerase chain reaction (RT-PCR) has been hampered by technical difficulties in obtaining suitable RNA preparations from groundnut tissue. Immunocapture RT-PCR (IC-RT-PCR) is another highly rapid and sensitive technique widely being used for the detection of plant virus infections of many crop plants. After introducing some modifications, we assessed the potential application of this technique for the detection of TSWV in groundnut.

IC-RT-PCR was performed in pre-treated microfuge tubes (200 µL capacity, thin-walled tubes, Research Products International, Mount Prospect, IL, USA). To ensure the binding of the primary antibody, the tubes were treated for 15 min each in 0.1 N hydrochloric acid and 4 N sodium hydroxide. After each treatment, tubes were rinsed with PBST buffer (0.137 M sodium chloride, 8 mM sodium phosphate-dibasic, 1.7 mM potassium phosphate-monobasic, 2.7 mM potassium chloride, and 0.05% (v/v) Tween-20) and finally washed with 95% ethanol for 15 min, before they were air-dried at room temperature (B.G. Cassidy, personal communication).

Pre-treated tubes were first coated with 100 µL of the antibody (1:200 dilution) specific to the nucleocapsid protein (Agdia Inc., Elkhart, IN, USA) by incubating overnight at 4°C. The antibody solution was discarded and the tubes were washed three times with sterile distilled water before adding the tissue extract. Groundnut plants were collected from the fields in south Georgia. Leaves and roots were processed separately by grinding in an extraction buffer (0.01 M sodium sulfite, 2% polyvinylpyrrolidone, MW 24–40 000, 0.2% sodium azide, 0.2% powdered egg albumin, and 2% Tween-20 dissolved in 1 L PBS, pH adjusted to 7.4). The extract was clarified and the supernatant (100 µL each) was added to the antibody-coated microfuge tubes. The tubes were incubated at room temperature for 3 h, rinsed three times with sterile distilled water, followed by the addition of 64 µL sterile distilled water to each tube. The tubes were subjected to three cycles of freezing (-80°C for 10 min) and thawing (70°C for 5 min). The tubes were then transferred to ice before adding RT-PCR components. RT and PCR were done in the same tube without any buffer changes as described by Pappu et al. (1993), except that Q Taq (Qiagen Inc., Chatsworth, CA, USA) was used as the DNA polymerase. The primer pair specific to the TSWV-nucleocapsid gene (N gene), and RT-PCR conditions used were those described previously (Pappu et al. 1996).

RT-PCR showed the presence of a major DNA fragment of ca. 800 bp expected as a result of specific amplification of TSWV-N gene (Fig. 1). Occasionally, a smaller, ca. 600 bp fragment was seen, possibly due to non-specific amplification. However, this did not interfere with the interpretation of the results. Both roots as well as leaves from infected groundnut plants provided a template suitable for TSWV detection by IC-RT-PCR

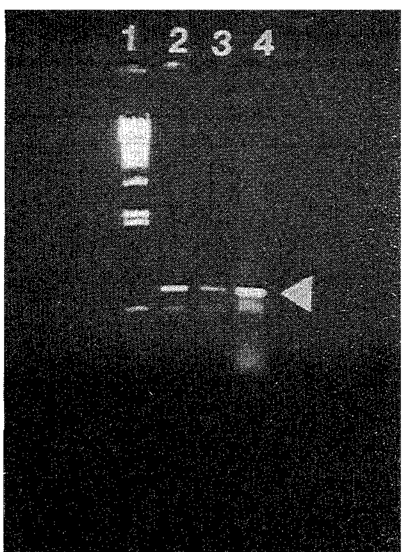

Figure 1. Agarose gel (0.8%) electrophoresis of immunocapture RT-PCR reaction products. Lane 1, Lambda DNA digested with HindIII; Lane 2, tissue extract from infected peanut leaf; Lane 3, tissue extract from infected groundnut root; Lane 4, TSWV N gene amplified from a DNA clone used as a size standard. Presence of the ca. 800 bp DNA fragment (with the arrowhead) in Lanes 1 and 2 indicated TSWV infection.

(Fig. 1). The identity of the amplified DNA was further confirmed by cloning and sequencing, and by comparing with published sequences of TSWV-N gene (data not shown). TSWV was also successfully detected by using primers specific to the large RNA of the genome (data not shown).

IC-RT-PCR provides a rapid and sensitive method for the diagnosis of TSWV infection of groundnut. By combining both reverse transcription and polymerase chain reaction in the same tube without buffer changes, the procedure is well suited to processing a large number of samples. Moreover, the procedure did not require the use of organic solvents or multiple nucleic acid precipitation steps. Microfuge tubes and microtiter plates (ELISA plates) were compared for their efficiency and tubes generally yielded more PCR product. Moreover, the use of tubes was more practical since immunocapture followed by RT and PCR could be done in the same tube. A large number of tubes can be coated with the antibody and stored at 4°C until use in IC-RT-PCR. Consequently, immunocapture, RT-PCR, and gel analysis can be done in 1 day (approximately 8–10 h depending on the make and model of the thermal cycler). The procedure was also successful in detecting peanut stripe potyvirus infection of groundnut (not shown). By using appropriate antisera and primer pairs, IC-RT-PCR should be applicable to the diagnosis of other groundnut viruses as well.

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Survey of the Effect of Intercropping of Groundnut with Cereals on the Incidence of Groundnut Rosette Virus Disease in Northern Nigeria

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Groundnut rosette virus disease (GRV) is the most destructive disease of groundnut (*Arachis hypogaea* L.) in Nigeria. The incidence and severity of GRV is reduced by early sowing and close spacing. When an epidemic of rosette disease occurred in Nigeria in 1975 these cultural control measures did not help in reducing the losses.

Roff and Ho (1991) reported reduced incidence of a chili virus on chili pepper when the latter was intercropped with maize. Similar results were obtained by van Rheenen et al. (1981) who observed a reduction in the incidence of common mosaic of *Phaseolus* bean in a maize/bean intercrop in eastern Africa. This survey was conducted to determine the effect of intercropping groundnut with tall cereals (sorghum, maize and millet) on the incidence of GRV. Groundnut is often intercropped with cereals in northern Nigeria.

The survey was conducted on four farmers' fields each in Kaduna, Kano, Katsina, and Zamfara states of northern Nigeria in Sep 1996. Plot sizes ranged from 0.7 to 1.2 ha, and the farms were at least 20 km apart. Each field had four to six rows of groundnut followed by two to three rows of either maize, millet or sorghum. Four quadrants were set up each of the set of farms visited. The number of groundnut plants and the percentage infected by GRV in all the quadrants in each field were determined.

Groundnut/sorghum intercrop showed the lowest incidence of GRV followed in increasing order by groundnut/maize, groundnut/millet and sole crop of groundnut. (Table 1). The cereals may have served as a barrier for the aphid vector of GRV, thus contributing to reduction in rosette incidence.

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Table 1. Effect of intercropping groundnut with tall cereals on the incidence of groundnut rosette virus (GRV) disease, Nigeria, 1996.

Cropping system	GRV-infected plants (%)	Stage of crop at the time of survey	Average size of farm (ha) sowing
Groundnut/sorghum	8.14 d	Mature groundnut, heading sorghum	0.85
Groundnut/maize	13.91 c	Mature groundnut, almost mature maize	0.91
Groundnut/millet	21.02 b	Mature groundnut, millet being harvested	0.88
Solecropped groundnut	30.12 a	Mature groundnut	0.93

In each column numbers followed by the same letters are not significantly different from one another at $P = 0.05$ using Duncan's Multiple Range Test.

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Entomology

Biological Suppression of Root-knot Nematode - White Grub Pest Complex Attacking Groundnut

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Root-knot nematodes (*Meloidogyne* spp) and white grubs (*Holotrichia* spp) attack many crops such as groundnut, cotton, vegetables, cereals, and reduce their yield, especially when grown in sandy loam soils. The recurrent occurrence of these pests has forced farmers to give up cultivation of susceptible crops in central Gujarat.

In India, presowing treatments are usually given of phorate (2.5 kg ha^{-1}) for the management of white grubs, and carbofuran (1 kg ha^{-1}) for the management of root-knot nematodes (Yadava and Vijayvergia 1994, Dasgupta and Gaur 1986). Attempts were made in 1994 and 1995 to use fungal bioagents, *Paecilomyces lilacinus*, *Metarhizium anisopliae*, and *Beauveria brongniartii* for effective management of root-knot nematode (*Meloidogyne javanica*) and white grub (*Holotrichia consanguinea*) on groundnut.

Earthen pots (15-cm dia) were washed with water and 4% formaldehyde (Formalin 40 EC). The pots were filled with 1.6 kg soil, infested by *M. javanica* (race 2) at the rate of 300 J2 per 200-g soil. Spore dusts based on grain carrier of *P. lilacinus* (Pl), *M. anisopliae* (Ma) and *B. brongniartii* (Bb) were mixed with the infested soil at the rate of 35-g pot^{-1} to achieve a calculated dose of 5×10^{14} conidia ha^{-1} in each pot. In combined fungal treatments, spores of individual fungal agents were adjusted to 5×10^{14} conidia ha^{-1}. Two treated controls of carbofuran and phenamiphos were applied each at the rate of 1 kg ha^{-1} in pots for comparison. A treatment without any bioagent and pesticide served as control. Thus a total of 10 treatments were applied in a completely randomized design with four replications. Five seeds of groundnut cv GG 2 were sown in each pot, and the pots were kept in a nethouse. One month after sowing 25-day old laboratory reared *H. consanguinea* larvae were released, 2 larvae pot^{-1} in two replications to study the treatment effects on *M. javanica* and white grub. Observations on plant girdling due to white grub attack were recorded at 15-day intervals. Plant height, fresh shoot and root mass, number of dead or alive grubs, number of pods $plant^{-1}$, root-knot index (RKI) using a 0–5 scale (0 = free, 5 = maximum galling), and rhizobium nodulation index using a 0–3 scale (0 = no root nodulation, 3 = maximum root nodulation) 3 months after sowing were recorded.

Results (Table 1) revealed that soil application of three biocontrol fungi individually and in combinations, as well as nematicides showed positive effect on plant growth over control. Significant differences were also obtained because of different treatments for shoot length, shoot and root mass; fungal treatments had a better effect on promoting plant growth over nematicidal treatments. Phenamiphos effectively reduced root-knot disease giving minimal RKI (0.4) over all other treatments under test. Application of *P. lilacinus* and *M. anisopliae* alone gave better control of root-knot disease than *B. brongniartii* and their combinations. The untreated

Table 1. Evaluation of fungal agents against root-knot nematode and white grub attacking groundnut in pots.

	Pooled (1994 and 1995)						
Treatment	Shoot length (cm)	Shoot mass (g)	Root mass (g)	Pods plant-1	White grubs killed (%)	Root-knot index (0–5)	Nodule index (0–3)
P. lilacinus (Pl)	31.18[ab]	4.92[b] (24.21)[1]	2.49[ab] (6.20)[1]	1.88[cd] (3.53)[1]	8.81[ab] (2.35)[2]	1.06[bc] (1.12)[1]	3.00[a]
B. brongniartii (Bb)	29.71[ab]	5.49[ab] (30.14)	2.82[a] (7.95)	1.93[ab] (3.72)	69.92[a] (88.21)	1.41[b] (1.99)	2.92[a]
M. anisopliae (Ma)	33.97[a]	5.46[ab] (29.81)	2.32[ab] (5.38)	1.72[bc] (2.99)	67.49[a] (85.34)	0.99[bc] (0.98)	2.59[a]
Pl + Bb	31.50[ab]	5.96[a] (35.52)	2.90[a] (8.41)	1.96[ab] (3.84)	38.60[abc] (38.92)	1.31[b] (1.72)	3.00[a]
Pl + Ma	28.04[b]	5.05[b] (25.50)	2.48[ab] (6.15)	1.99[ab] (3.96)	40.12[abc] (41.52)	1.15[b] (1.32)	3.00[a]
Bb + Ma	28.57[ab]	5.43[ab] (29.46)	2.66[ab] (7.08)	1.71[bc] (2.92)	69.92[a] (88.21)	1.43[b] (2.04)	3.00[a]
Pl + Ma + Bb	29.03[ab]	5.59[ab] (31.25)	2.85[a] (8.21)	2.01[ab] (4.04)	28.87[bcd] (23.31)	1.32[b] (1.74)	3.00[a]
Carbofuran	29.43[ab]	5.04[b] (25.40)	2.90[a] (8.41)	1.84[ab] (3.39)	61.10[ab] (76.64)	1.18[b] (1.39)	2.69[a]
Phenamiphos	26.65[bc]	5.22 (27.25)	2.15[b] (4.62)	2.25[a] (5.06)	40.12[abc] (41.52)	0.64[c] (0.41)	2.50[a]
Control	22.06[c]	3.92[c] (15.37)	2.63[ab] (6.92)	1.36[c] (1.85)	00.00[d] (00.00)	2.05[a] (4.20)	2.84[a]
SE	±1.68	±0.24	±0.18	±0.14	±9.69	±0.15	±0.18
CV (%)	11.1	8.3	12.7	15.8	43.8	10.3	2.4

1. Figures in parentheses are square root transformations.
2. Figures in parentheses are arcsine transformations.
Means in the same column followed by the same letter are not significantly different at $P = 0.05$.

control had RKI of 4.2 (Table 1). Both *B. brongniartii* (88.21%) and *M. anisopliae* (83.34%) individually, as well as in combination (88.21%), effectively controlled white grubs as compared to carbofuran (76.64%) and phenamiphos (41.52%). Treatments of biocontrol fungi either individually or in combination, and nematicides effectively protected groundnut plants from nematode and white grub damage than the control. *Paecilomyces lilacinus* failed to control white grub. Rhizobium nodulation was not altered by various treatments (Table 1).

This study indicated that all three biocontrol fungi are useful in the management of root-knot nematodes. However, two entomopathogenic fungi are effective for *M. javanica* management besides white grub control. Entomopathogenic fungi, *B. brongniartii* and *M. anisopliae* have been reported pathogenic to *M. incognita* eggs in laboratory (Vyas et al. 1995). *B. bassiana* was found to be effective against the potato cyst nematode (*Globodera pallida*), and *M. anisopliae* was found to be promising for the management of the cyst nematode (*Heterodera schachtii*) (Alam 1980, Franco et al. 1989).

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Aspects of Socioecological Studies of Groundnut Soil Pests: Farmers' Perspectives

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Reports by extension and research personnel working with the national agricultural research systems, and incessant complaints by groundnut farmers have continued to send signals on the increasing economic importance of soil pests in groundnut production in Western and Central Africa, and the need for research to be directed towards the development of control measures. The present report is based on responses from interviews with 70 groundnut farmers, and field visits spread across Mali, Burkina Faso, Niger, and Nigeria on their farm histories, cultural practices, control measures during the 1996 cropping season, and the relationship between their responses and field observations on soil pests. Observations on soil pests were made on soil and plant samples taken simultaneously along the diagonals (or transec lines) of each sampled farm.

In the surveyed areas, groundnut is sown sole or as intercrop with cereals and other legumes depending on market and domestic needs of the localities. Farmers in Mali, Burkina Faso, and Niger rated termites as the most damaging soil pest in groundnut production, followed by white grubs and millepedes; most Nigerian groundnut farmers (70%) rated millepedes and termites as the most damaging groundnut soil pest. Sampling for soil pests during surveys also showed the same trends. The termite genera *Microtermes* and *Odontotermes* which damaged groundnut also infested mature sorghum.

The latter factor should be taken into account while designing control measures. Farmers cared less about burning stubbles and stems of cereals after harvest thereby creating a conducive environment for termite spread. White grub, *Schyzonycha* spp and millepede, *Peridontopy* spp were the most common species associated with groundnut damage; cereal components of the intercrop were not affected.

Continuous land cultivation associated with intensive agriculture, as indicated by the number of years a farm was cultivated, slightly reduced termite populations ($r = -0.33$; $P<0.05$), since by tilling the soil a certain proportion of termites are exposed to desiccation and predators. However, because of their subterranean habit, *Microtermes* species can only be significantly reduced by increased depth of tillage, unlike the mound-building species whose nests can be easily destroyed externally. There was no significant relationship between the number of years a farm was cultivated and its white grub or millepede population.

The percentage of interviewed farmers who used compost manure was too low (25%) for any relationship to be computed, despite their complaints of high incidence of white grub being linked to excessive use of manure. However in parts of Kita area in Mali where compost manure was widely used, 67% of farms were infested with white grubs. The use of chemical fertilizer by farmers was low. This was attributed to financial constraints. Farmers in the surveyed localities were not aware of any effect of chemical fertilizer on soil pest damage. However, the role of fertilizers in soil pest management is likely to be in the improvement of plant vigor, making such plants less susceptible to pest attack.

Methods of land clearing across the surveyed areas included slashing (17%), slashing and burning (57%), and plowing weeds under the soil to decay in situ by the use of tractors or by animal traction (26%). Farmers who burn the slashed weeds during land preparation claimed to have reduced soil pest problems. This aspect needs further experimentation since no relationship could be derived between farmers responses and sample data.

Conventional pest control methods such as the use of chemical pesticides is not popular among groundnut farmers of western Africa because of financial constraints. In cases where these were practised, broad-spectrum pesticides were used even when they were not ideal for the target pests. Damage studies showed that the few farms claimed to be treated recorded high soil pest damage, indicating wrong control approaches. Farmers sometimes use chemical pesticides meant for foliar pests and diseases on soil pests, or apply dosages below those recommended by the manufacturers with the aim of economizing for future use. These factors could have contributed to control failures. Farmers estimated yield losses of 10–75% because of soil pests. However, our estimation showed yield losses of 21.1–38%.

The survey shows that termites, white grubs, and millepedes are major production constraints in western Africa. Farmers were helpless, not knowing effective control measures in combating these increasingly menacing pests. Some of their farm practices such as non-removal of residues of the previous cereal crops, lack of fertilizer application leading to the production of less vigorous plants, the practice of shallow plowing which does not adequately expose some of the soil pests to desiccation and predators also seem to contribute to soil pest abundance and spread.

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Effect of Plant Age on Resistance to Aphids (*Aphis craccivora* Koch) and Rosette Virus in Groundnut

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Rosette, an important virus disease of groundnut in Africa, can be contained by planting resistant groundnut cultivars. Resistance to rosette is most effective (Subrahmanyam et al. 1994) but resistance to the vector *Aphis craccivora* Koch (Padgham et al. 1990) can also lower disease incidence and provide additional protection (Wightman et al. 1990). Plant age can affect host plant resistance. Older plants are generally less susceptible to virus infection and aphid infestation than younger plants (Gibbons and Farrell 1966, Farell 1971). In addition, infected plants may support larger aphid populations than healthy plants.

We tested the effects of plant age and resistance to aphids or rosette disease. The preliminary studies on vector population growth and disease expressions were conducted in greenhouse at Chitedze, Malawi. Five long-duration, virginia type cultivars were used: Chalimbana and CG7 (susceptible to both virus and aphids); RMP 12 and ICGV-SM 90704 (resistance to rosette but resistant to aphids). Three plant ages tested were: 14, 23, and 43 days after sowing (DAS). There were a total of 10 plants for each of treatment, arranged in a split-plot design. The impact of rosette infection on aphid population growth, and the effect of aphid feeding on rosette symptom expression was also tested. Aphid infestation was done in the early morning with a fine painter's brush in groups of three 4th instar nymphs per plant. Viruliferous and healthy aphids were obtained from ICRISAT's stock cultures maintained on a susceptible Malimba cultivar at Chitedze in separate greenhouse. Three days after infestation, the plants with viruliferous aphids were divided into two groups. In one group all plants were sprayed with Actellic® 50EC (pirimiphos-methyl) to kill the aphids; in the other group the aphids were left undisturbed and allowed to multiply. All plants were covered with perforated plastic sleeves (Krisp® bags) and arranged in a single greenhouse. Aphid counts were made every other day from 7th until 25th days after infestation when all plants were sprayed with Actellic® 50 EC. The plastic sleeves were removed and rosette symptom expression was followed for another 15 days. Aphid infestation was expressed as the cumulative total counted from 7 until 25 days after infestation; virus infection as the percentage plants with visual symptoms at 40 days after infection. Temperature varied from 15–35°C; RH from 70–100%. The data were analysed using Genstat® 5 for Windows® 3.2 (Lawes Agricultural Trust, Rothamsted Experimental Station, UK).

Table 1. Cumulative aphid count per groundnut plant at 25 days after infestation, and rosette infection at 40 days after inoculation as affected by plant age and cultivar.

	Cumulative aphid count	Rosette infection treatment (%)
Plant age at infestation (DAS)		
14	2159	47.7
23	1711	50.0
43	1242	36.8
Cultivar		
CG 7	1727	80.7
Chalimbana	1702	78.2
EC 36892	1511	44.4
ICGV-SM 90704	1738	17.9
RMP 12	1707	0.0
LSD (5%)	174	14.8

Plant age. Aphid populations were largest on plants infested at 14 DAS, followed by plants infested at 23 and 43 DAS. Clearly, young plants are physiologically more suitable to aphid development and reproduction than older plants. Rosette infection was significantly lower in the 43 DAS group than in the younger age groups.

Cultivar. Aphid population growth was lowest on EC 36892, an aphid-resistant line. The other cultivars showed statistically similar population levels (Table 1). Rosette infection was highest on CG 7 (80.7%) and Chalimbana (78.2%), both susceptible to aphids and rosette. Rosette infection was considerably lower in EC 36892 (44.4%). This difference cannot be explained by the anti-xenosis mechanism of resistance in this variety because the plastic sleeves prevented aphids from crawling away and settling on preferred cultivars. Perhaps the mode of feeding was affected in such a way that the probability of infection was reduced. The rosette-resistant lines ICGV-SM 90704 ranked fourth with 17.9% infection while RMP 12 did not show any rosette symptoms.

Cumulative aphid counts were somewhat higher on rosetted plants (1781) than on healthy plants (1615) ($LSD_{5\%}$ = 86) suggesting that infected plants were nutritionally more favorable to aphid development than healthy plants. Rosette infection was also higher when aphids were allowed to remain on the plant and multiply for an additional 25 days following the 3-day inoculation feeding period (54.4%) compared to plants where the aphids were killed after inoculation feeding (37.9%) ($LSD_{5\%}$ = 7.6). This may indicate that the optimal inoculation feeding period was in this experiment was longer than 3 days. There was no interference with symptom development although the plastic sleeves made visual assessment of symptoms difficult.

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Performance of Insect Pest Resistant Groundnut Varieties from ICRISAT in Indonesia

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Fifteen ICRISAT insect pest resistant varieties and an Indonesian improved cultivar "Mahesa" were evaluated at Muneng Research Station (10 masl). The soil type is Mediteran Ortic. The plot size consisted of 4 rows of 5 m

Table 1. Percent leaf damage caused by thrips on groundnut genotypes, Muneng, Indonesia, dry season 1995 and 1996.

ICGV genotype	Percent leaf damage at 28 DAS 1995	1996	Average	42 DAS 1995	1996	Average
90226	35.5	27.7	31.6	39.3	40.4	39.9
90227	38.4	26.4	32.4	43.0	38.0	40.5
90228	32.2	25.8	14.5	45.2	38.8	42.0
90261	29.1	30.5	29.8	37.8	46.4	42.1
90265	23.3	11.9	17.6	29.1	14.2	21.7
91167	21.9	9.7	15.8	19.7	11.4	15.6
91171	31.1	25.8	28.5	35.6	32.5	34.1
91173	33.0	24.8	28.9	39.4	33.8	36.6
91176	22.1	12.0	17.1	25.4	16.6	21.0
91180	33.3	29.2	31.3	34.4	33.3	33.9
91185	32.7	25.9	29.3	39.1	31.8	35.5
91190	26.6	17.9	22.3	32.8	29.2	16.5
91192	25.3	18.0	21.7	30.5	20.3	25.4
91205	33.4	22.3	27.9	41.0	27.4	34.2
91215	42.5	24.5	33.5	36.4	37.0	36.7
Mahesa	40.8	15.6	28.2	47.0	23.0	35.0
Average	31.3	21.8	26.6	36.0	29.7	32.9
SE	±0.882	±0.714		±0.956	±0.643	
CV (%)	16.4	12.6		24.6	14.8	

Table 2. Performance of varieties included in the Sixth International Insect Pest Resistant Groundnut Varietal Trial from ICRISAT, Muneng, Indonesia, dry seasons 1995 and 1996.

	Pod yield ($t\ ha^{-1}$)			Shelling percentage		Seed mass (g 100-seed^{-1})		Sound mature seeds (%)		Seed appearance and uniformity[1]	
Genotype	1995	1996	Average	1995	1996	1995	1996	1995	1996	1995	1996
ICGV 90226	2.1a	2.0a	2.05a	58.3	65.7	67.1	64.1	94.6	91.6	8	9
ICGV 90227	1.9a	1.8b	1.85a	53.4	68.4	66.2	58.2	90.9	90.5	7	9
ICGV 90228	1.9a	1.8b	1.85a	58.5	63.5	66.4	52.2	89.9	82.2	7	9
ICGV 90261	1.8a	1.4c	1.60b	52.7	66.6	51.0	41.2	90.0	88.0	9	3
ICGV 90265	2.0a	0.9d	1.45b	56.4	65.1	51.4	53.9	94.4	85.8	2	2
ICGV 91167	1.6a	1.5c	1.55b	55.2	65.9	70.8	54.9	86.1	96.6	6	4
ICGV 91171	1.8a	1.2d	1.50b	56.1	61.9	55.0	45.3	93.2	88.0	2	2
ICGV 91173	1.8a	1.5c	1.65b	58.7	61.1	70.1	57.1	94.6	82.9	8	3
ICGV 91176	2.4a	1.2d	1.80a	54.5	57.9	60.5	53.0	94.6	89.1	6	4
ICGV 91180	1.7a	1.2d	1.45b	53.5	64.3	55.7	51.2	86.8	92.2	4	4
ICGV 91185	1.6a	1.2d	1.40b	49.1	55.5	61.1	39.3	90.8	89.7	7	4
ICGV 91190	1.8a	1.5c	1.65b	48.9	58.7	57.4	63.0	85.8	90.8	4	2
ICGV 91192	1.9a	1.1d	1.50b	52.3	61.5	50.3	42.1	91.7	90.3	3	2
ICGV 91205	1.9a	1.4c	1.65b	59.5	62.7	57.8	51.3	95.8	76.4	4	3
ICGV 91215	1.9a	1.1d	1.50b	58.9	60.8	62.3	52.8	90.4	86.8	8	9
Mahesa	1.7a	1.3d	1.50b	58.8	63.6	60.0	51.6	95.3	72.8	1	1
Average	1.9	1.4	1.6	55.3	62.7	60.2	51.9	91.6	87.1	5.4	4.4
SE	±0.002	±0.001	±0.002								
CV (%)	14.7	14.8	14.9								

Figures followed by the same letter were not significantly different at $P = 0.05$, based on cluster analysis (Scott A.J. and M. Knott, 1974).

1. Scored on a 1–9 scale where 1= excellent appearance and uniformity, and 9 = poor appearance and uniformity.

with an interrow spacing of 40 cm, and an intrarow spacing of 10 cm. The experiment was grown in 4 × 4 lattice. Basal fertilizers of 23 N : 46 P : 50 K ha^{-1} were applied. The trial was grown under natural insect pest infestation, with 5 irrigations.

Thrips were the dominant pests observed during the growing season. In the present study no attempt was made to identify the thrips species. Three species of thrips, i.e., *Scirtothrips dorsalis, Caliothrips indicus*, and *Frankliniella schultzei* were reported in groundnut in Indonesia (Supriyatin 1990). The thrip damage intensity in the 1995 dry season was higher than that of the 1996 dry season. ICGV 90265, 91167, and 91176 showed moderate resistance to thrips (Table 1). The former two genotypes derived from the same male parent ICG 2271. ICG 2271 was reported to have multiple resistance to thrips, termites, and jassids (Dwivedi et al., 1992).

Average pod yield in the 1995 dry season was higher than that of the 1996 dry season. The lower yield in 1996 was largely caused by the variable final plant stand (30–60% of the expected population). Pod yield of the most genotypes was higher than that of the local control Mahesa. ICGV 90226 produced the highest average pod yield of 2.05 t ha^{-1} and showed consistency in performance during the two seasons. ICGV 90226, 90227, and 90228 produced an average pod yields 1.85-2.05 t ha^{-1} compared to 1.5 t ha^{-1} of Mahesa.

Seed appearance and uniformity (SAU) score placed Mahesa as the most preferred genotype. Among the exotic genotypes only ICGV 90265 and 91171 have SAU scores comparable to Mahesa (Table 2). ICGVs 90265, 91167, 91176, 90226, 90227, and 90228 will be included in the advanced trial.

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Evaluation of Aphid Resistance in Some Groundnut Genotypes

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Groundnut production has declined in western Africa because of groundnut rosette virus disease which is transmitted by the aphid *Aphis craccivora* (Wightman and Amin 1988). Severely infected plants display stunting and leaf distortion. Losses can reach up to 80% (Bata et al. 1987). Aphid-resistant cultivars may help in reducing the rosette disease incidence in groundnut.

Five groundnut cultivars (SAMNUT 10, 14, and 16, ICG 5725, and ICG 5240) were evaluated for resistance to *Aphis craccivora* at the Institute for Agricultural Research, Samaru, Nigeria, in 1996. Viruliferous aphids were reared in a screen house. In the second screen house, seeds of each genotype under investigation were sown in plastic pots of 20-cm diameter. Two seeds pot^{-1} were sown. The pots were labelled and kept in rows on the screen house bench with adequate space to prevent the foliage of each plant touching that of the adjacent ones. Another replicate was kept in the second screen house.

Each seedling was infested with five wingless aphid adults at 7 days after emergence, using a moistened camel-hair brush. All aphids on each plant were counted at 7 and 14 d after infestation. The plants were observed for rosette disease symptoms up to 4 weeks after infestation and aphid damage was evaluated on a 1–5 visual scoring scale of Ansari et al. (1990), where 1 = highly resistant, and 5 = highly susceptible.

All data were collated and analyzed statistically to evaluate the reaction of various genotypes.

The results show that ICG 5240 had significantly fewer aphids than the other genotypes. This genotype was given a score of 3, indicating a moderate resistance while the others were given scores of 4 and 5, suggesting high susceptibity to aphids.

The presence of antifeedant chemicals in the phloem sap of groundnut is an important factor in host resistance to aphids. Grayer et al. (1992) reported that a high concentration of procyanidin (a secondary plant metabolite) in the plant sap has a negative effect on aphid fecundity. This chemical was found by Padgham et al. (1990) to be more abundant in ICG 5240 than in the other varieties tested.

The quicker multiplication and the higher number of aphids observed on SAMNUT 10, 14, 16, and ICG 5725 than on ICG 5240 suggest a lower concentration of procyanidin in the phloem sap of susceptible varieties. This conclusion needs experimental evidence.

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Table 1. Reaction of groundnut varieties to aphid infestation, Samaru, Nigeria, 1996.

			Mean number of aphids plant^{-1} 14 days after infestation	
Variety	Source	Reaction to rosette	Test 1	Test 2
ICG 5725	ICRISAT, India	Susceptible	129	132
SAMNUT 10	IAR, Nigeria	Resistant	116	122
SAMNUT 14	IAR, Nigeria	Susceptible	99	117
SAMNUT 16	IAR, Nigeria	Resistant	86	87
ICG 5240	ICRISAT, India	Susceptible	29	26
Mean			92	97
SE			±13.7	±10.0

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Status of Integrated Management of Groundnut Insect Pests in Vietnam

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In 1995, Vietnam produced 334 000 t of groundnut in shell on 259 000 ha, with an average productivity of 1.28 t ha^{-1}. In the past 10 years, there has been a gradual increase in area under groundnut because of increased exports, and high internal demand for groundnut. Foliar insect pests such as *Spodoptera litura*, *Maruca testulalis*, aphids, thrips, jassids, and *Helicoverpa armigera* are important constraints to increased productivity of groundnut in the country. In river bed regions, white grubs (*Lepidiota signata*, *Anomala* sp), a soil insect, are also important. In this paper, the status of different insect pest management strategies (IPM) for the groundnut crop in Vietnam is discussed.

Host-plant resistance. The National Institute of Plant Protection (NIPP) has identified genotypes with high levels of resistance to jassids, thrips, aphids, and *Spodoptera*, and higher yields than local varieties (Table 1).

Chemical control. At present, pest management strategies largely depend on chemical control. Farmers apply to the groundnut crop as many as 10–15 insecticidal sprays in South Vietnam, and 3–5 insecticidal sprays in North Vietnam during a crop season. Overuse of pesticides has led to the outbreaks of pests such as defoliators because of the destruction of natural enemies, development of resistance in insects to insecticides, and degradation of the environment.

Biological control. In the past, the role of natural enemies in groundnut pest management was not given much importance. In recent years, with increased awareness about the harmful effects of pesticides, the importance of natural enemies has attracted attention. Studies conducted on natural enemies on various insect pests at NIPP indicated low occurrence of egg and larval parasites and high incidence of diseases. Observations during 1995/96 in farmers' fields on various insect pests of groundnut revealed low insect activity. Due to low insect pressure, the differences in foliar damage between insecticidal sprayed and nonsprayed plots were also not significant. This indicated the futility of insecticidal sprays which add to the total cost of production and affect the environment adversely. The application of fungal (metarhizium) and viral (nuclear polyhedrosis virus) pathogens resulted in 45% mortality of *Spodoptera* and 75% mortality of white grubs in the groundnut fields.

Cultural control. In the past, farmers were not aware of the importance of intercrops or trap crops. Recent demonstrations of IPM which included sunflower as a trap crop on the borders of groundnut fields clearly showed the ovipositional and larval preference of *Spodoptera* and *Helicoverpa* on sunflower. The egg masses and the larvae on sunflower could be easily collected and destroyed. Thus, the farmers realized the importance of sunflower in the management of *Spodoptera* and *Helicoverpa* on groundnut. This technology was first initiated in 1995 on 2000 m^2. In 1997, farmers adopted this technique on 165 ha (Table 2). Thus, the farmers who were totally dependent on insecticides in the past have now completely stopped using insecticides without sacrificing yields.

Recommendations for further research. Farmers in Vietnam continue to depend greatly on insecticides for control of most groundnut insect pests. However, there is increasing awareness of the deleterious effects of pesticidal residues in terms of environmental degradation and operational hazards Hence, future areas of research in groundnut insect pest management should concentrate on

- the role of cultural practices on insect pest populations
- the role of natural enemies in reducing pest populations
- evaluating selected insecticides and insect pathogens such as NPV and *Metarhizium* and their effect on pests as well as natural enemies

Table 1. Performance of some promising groundnut genotypes against insect pests in Vietnam during 1996 and 1997.

Genotype	Insect damage				Pod yield (t ha^{-1})	
	Aphids $plant^{-1}$	Thrips $terminal^{-1}$	Jassids $plant^{-1}$	*Spodoptera* defoliation (%)	1995	1996
ICGV[1] 86030	0.36	15.7	5.3	4.7	1.87	2.20
ICGV 86510	0.50	17.1	3.5	3.0	1.95	1.87
ICGV 87128	0.26	20.9	3.1	3.0	1.79	2.30
ICGV 87141	0.35	17.9	5.2	3.7	2.43	3.80
ICGV 87157	0.41	19.7	6.5	4.0	2.32	1.60
ICGV 90224	0.50	11.6	3.6	2.5	1.89	1.80
ICGV 90228	0.90	10.3	8.7	4.9	1.98	1.60
ICGV 90263	0.70	8.3	5.2	2.1	1.83	1.60
ICGV 91173	0.60	15.3	9.8	5.3	1.78	1.45
LVT[2]	0.70	30.5	32.8	6.4	2.01	1.93
Sen NA (local)	0.90	35.5	12.5	3.6	1.78	1.45
4329 (local)	0.60	31.7	10.8	6.7	1.63	1.51

1. ICRISAT Groundnut Variety.
2. From China.

Table 2. Progress of integrated pest management of groundnut in Vietnam.

Province	Area (ha)		
	1995[1]	1996	1997
Nghe An	2100 m^2 (1)	80 (100)	100 (100)[2]
Ha Tay	2100 m^2 (1)	66 (168)	65 (168)

1. On-farm demonstration.
2. Figures in the parentheses indicate number of farmers involved.

- the role of host-plant resistance on insect pest management.

These studies must be conducted in different cropping systems in order to assess the overall effect of insect management practices on the whole groundnut production system and its sustainability. Groundnut IPM, initiated in 1995, has gained good momentum with the active involvement of farmers and ICRISAT. The IPM technology was accepted by all farmers who attended the demonstrations. Further spread of the technology, and its success and sustainability, will depend entirely on the involvement of various national and international organizations with common goal of improving nature.

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Metarhizium anisopliae (Metschn.): A Potential Biocontrol Agent for Groundnut Leafminer

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The groundnut leafminer (GLM) *Aproaerema modicella* (Deventer) (Lepidoptera: Gelichiidae) is an important pest of groundnut in south and southeast Asia. It has a limited host range of which soybean and groundnut are the most important. The adult is a brownish grey moth with about 10 mm wing span. It lays single, shiny white eggs, usually on the underside of the leaflets, close to the midrib, which are just visible to the naked eye. Each female lays about 200 eggs. As soon as they hatch, the young larvae mine into the leaf and feed on the chlorophyllus tissue. The mines enlarge as the larvae grow. When the larvae grow larger than the size of the mine, they come out and web the adjacent leaflets together and continue to feed on the leaf tissue from inside the webbed leaves. Pupation takes place inside the webbing. Three to four generations have been observed in a single groundnut cropping season. Though it attacks the crop throughout the year, it is more severe under moisture stress conditions (Wightman and Ranga Rao 1994).

Amongst the various control options, natural control agents play a significant role in the population suppression of this species. Shanower et al. (1992) listed 38 species of natural enemies associated with GLM, of which 17 were reared from larvae. They also indicated that diseases caused up to 30% larval mortality. Oblisami et al. (1969) indicated the infection of leafminer larvae by *Aspergillus flavus* under field conditions. The occurrence of diseases on GLM is well known. However the impact of these diseases on the population dynamics of GLM is not known. Though natural control processes do contribute to the suppression of GLM population, chemical control is the most popular strategy followed by farmers. Indiscriminate use of chemicals have led to the outbreaks of other defoliators such as *Spodoptera* in groundnut crops. Thus, it is necessary to explore alternatives to chemical control in the management of GLM.

During the 1996 groundnut cropping season, several dead larvae of GLM infected by fungus were observed in the field at ICRISAT-Patancheru. The fungus was isolated and successfully multiplied on potato dextrose agar. Healthy final instar GLM larvae collected from the field were sprayed with the conidial suspension prepared in distilled water under laboratory conditions. The larvae died in 24 h and the sporulation started from the 7th day onwards. These studies were repeated twice under laboratory conditions for confirmation. Later, the fungus was sent to the International Mycology Institute (IMI), London, UK, for identification. The IMI identified this fungus as *Metarhizium anisopliae* (Metschn.) which is the first report on GLM. Initial studies on the multiplication of the fungus on artificial media showed encouraging results. This fungus can be mass multiplied on sterilized broken sorghum grain in 7 days at 25°C. This fungus is known for its effectiveness in humid areas on other lepidoptera. Its quick action on the leafminer could be because of the congenial microclimate provided by the pest. Further studies on the epidemiology, field evaluation, and mass production on low cost media need to taken up. Considering its effectiveness in a short period, and its easy mass multiplication, this fungus can be used as an effective natural control component in future integrated groundnut pest management programs.

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Physiology

Effect of Polythene-mulching on Flowering and Yield of Groundnut in Korea

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Growth, development, and pod yield in groundnut are affected by low temperatures. Extensive studies were conducted in 1970 at the National Crop Experiment Station, Suwon, South Korea, to evaluate the effect of polythene-mulching on crop growth and productivity. These results remained largely confined to Annual Reports of the station in the vernacular language. With increasing interest in polythene-mulching in other Asian countries, it was considered appropriate to give wide circulation to some of the important results obtained from these studies. Suwon is situated at 37°16' N latitude and 126°59' E longitude. Soils in Suwon are well-drained sandy loams, with medium fertility. About 15 t compost and 1 t lime ha^{-1} were added to the soil prior to final cultivation. The experiment was conducted in a split-split plot design with three replications. The main plot and sub-plot treatments were as follows:

Main plot	:	Sowing dates – 10 Apr and 1 May 1970
Sub-plots	:	Polythene (0.03 mm) mulched, and nonmulched (control)
Sub-sub-plots	:	Fertilizer application levels:
		i) 30 N, 70 P_2O_5, 100 K_2O ha^{-1}
		ii) 45 N, 105 P_2O_5, 150 K_2O ha^{-1}
		iii) 60 N, 140 P_2O_5, 200 K_2O ha^{-1}

A semi-erect cultivar (Chunyupbanrip) was used. Two seeds $hill^{-1}$ were dibbled at a spacing of 50 × 20 cm. Plot size was 6 × 3 m.

Table 1. Comparison of flowers, pegs, pods, and kernels per plant between polythene-mulched and nonmulched plots of groundnut, Suwon, South Korea, 20 Aug 1970.

Sowing date	Cultural treatment	No. of flowers $plant^{-1}$ (=A)	No. of pegs $plant^{-1}$ (=B)	B/A[1]	No. of pods $plant^{-1}$ (=C)	C/A[2]	C/B[3]	No. of kernels $plant^{-1}$
10 Apr	Mulched	260	128	49	30	12	23	47
	Nonmulched	223	113	51	15	7	13	22
1 May	Mulched	199	119	60	29	15	24	43
	Nonmulched	179	92	51	13	7	14	20

1. Percentage of flowers developed into pegs.
2. Percentage of flowers developed into pods.
3. Percentage of pegs developed into pods.

Table 2. Comparison of pod and kernel yields between polythene-mulched and nonmulched plots of groundnut, Suwon, South Korea, 1 Oct 1970.

Sowing date	Cultural technique	Pod yield (t ha^{-1})	Shelling percentage	Kernel yield (t ha^{-1})	100-kernel mass (g)	Income (W)[1]
10 Apr	Mulched	5.36	56	2.98	66.0	39,262
	Nonmulched	3.72	52	1.90	63.5	26,355
1 May	Mulched	5.42	57	3.08	63.4	41,274
	Nonmulched (control)	2.83	54	1.55	60.5	19,495

1. 1 US$ = 900 Won.

Observations recorded were: temperatures at soil surface and 5-cm depth at 1000 h and 1400 h; flowers $plant^{-1}$ day^{-1}; plant growth parameters (measured on 13 Jun, 22 Jun, 20 Aug, and 1 Oct); and yield and yield components at harvest. Plant observations were recorded on randomly selected five plants.

Some of the salient results of the study are summarized below:

- Temperatures, both at soil surface and at 5-cm depth, were higher at 1000 h and 1400 h in mulched plots than in nonmulched plots. At 1000 h temperatures in mulched plots at soil surface were 2.8–9.4°C higher, and at 5-cm depth 0.9–7.3°C higher than in nonmulched plots. Similar differences in temperature were observed at 1400 h. However, this increase in temperature in mulched plots was noticed only up to the 3rd week of June after which the temperatures declined as compared to nonmulched plots.
- Compared to nonmulched plots, the seedling emergence in mulched plots was earlier by 11–15 days in the 10-Apr sowing, and by 4–5 days in the 1-May sowing.
- Both, fresh and dry plant mass were higher in mulched plots than in nonmulched plots. In the 10-Apr sowing, plant mass was 91–98% greater 63 days after sowing (DAS), and 48–50% greater 141 DAS than those in nonmulched plots. In the 1-May sowing, plant mass was 16–26% greater 42 DAS, and 58–65% greater 110 DAS than those in nonmulched plots. In both sowing dates, the length of the main stem was also greater in mulched plots.
- In both, 10 Apr and 1 May-sown plots, flowering initiation was 11–15 days earlier in mulched plots than in nonmulched plots. Plants in 10-Apr sowing had 27% more flowers and 14% more pegs than those in 1 May sown plots. Plants in mulched plots had 16%

more flowers in the 10-Apr sowing and 11% more flowers in the 1-May sowing than those in nonmulched plots (Table 1). Accumulation of additional flowers in the 10-Apr sowing was in the early part of the flowering period, whereas in the 1-May sowing it was spread throughout the flowering period.

- Plants in mulched plots in both sowing dates had greater number of pods and kernels and higher 100-kernel mass than those in nonmulched plots. A higher percentage of flowers and pegs developed into pods in mulched plots (Table 1).

- Early sowing (10 Apr) gave higher pod (31%) and kernel (22%) yields than the late sowing (1 May) under nonmulched conditions. However, the reverse was true under mulched conditions, although the difference between the two sowing dates was only marginal (Table 2).

- In the 10-Apr sowing, pod yield was 44% higher and kernel yield 56% higher in mulched plots than nonmulched plots. Superiority in pod yield was 91%, and in kernel yield 98% in mulched plots over nonmulched plots in the 1-May sowing. There was a 2.5–4% improvement in shelling percentage and 100-kernel mass under mulched conditions. Although, the mulched conditions generated more income, between the two sowing dates, the increase was higher in the 1-May sowing (112%) than in the 10-Apr sowing (48%) (Table 2).

- Under nonmulched conditions, higher doses of fertilizers did not increase kernel yield. However, under mulched conditions an increase was observed in kernel yields as the fertilizer dose increased. Over 30–70–100 fertilizer dose in the 1-May nonmulched sowing (standard practice), the 10-Apr mulched sowing with 60–140–200 fertilizer dose recorded 82–99% increase in kernel yield.

Effect of Seed Maturity Class and Plant Geometry on Growth and Yield of Rainfed Groundnut

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In India, inadequate plant stand contributes significantly to low productivity in groundnut. Ungraded seed lot, which contains on an average 30% immature seeds, is one of the main factors responsible for poor crop stand. Very few attempts have been made to analyze the influence of seed maturity class on yield and associated yield attributes in groundnut. Further, the variation in yield of individual plants in the same plot/field also affects the productivity of the crop. Therefore, the required plant population needs to be defined not only in terms of number of plants per unit area (plant density) but also in terms of the arrangement of these plants on the ground (plant rectangularity) to reduce the variation in yield of individual plants.

The experiment was laid out in split-plot design with three replications. The four plant geometries (2 plant populations, 0.11 and 0.22 million ha^{-1} along with two rectangularities of 1:2 and 1:4 of seed to seed within a row versus row spacing) were used as main-plots and 3 seed maturity classes as sub-plots. Seeds of cv Somnath were grouped into immature, mature, and over-mature.classes. The color (white to dark brown) of the inner surface of the pod shell was taken as an index of degree of maturity as reported by Miller and Burns (1971). The seeds were sown on 23 Jun 1995 with the above treatments. The rainfall during the 1st (30 Jun–6 Jul) and 2nd (7–12 Jul) weeks of July was 314.9 and 33.5 mm. It rained everyday in July. A basal dose of 12.5 kg N and 60 kg $P_2O_5 ha^{-1}$ was applied.

The rectangularity 1:2 (15 × 30 cm) gave significantly higher pod yield $plant^{-1}$, and pod yield ha^{-1}, and the lowest mortality compared to the other combinations (Table 1). The rectangularity 1:4 (15 × 60 cm) gave the lowest pod yield. Continuous rains at the time of emergence and at the seedling stage were perhaps the reasons for low initial plant stand of groundnut in this study. Although the plant geometry of 1:4 (15 × 60 cm) combination maintained higher plant stand than 1:2 (22.5 × 45 cm) combination, higher pod yield was obtained in the latter, because of high yield $plant^{-1}$ which is the result of plant rectangularity. Significantly higher pod yield

Table 1. Influence of plant geometry and seed maturity on plant stand, growth and yields of groundnut, Gujarat, India, 1995.

Treatment	Initial plant stand (million ha^{-1})	Plant mortality (%) 15–45 days	45–75 days	75–harvest	Final plant stand (million ha^{-1})	100-seed mass (g)	Pod yield plant^{-1} (g)	Pod yield (kg ha^{-1})
Plant geometry								
(Plant density × rectangularity)[1]								
0.09 × 1:2 (22.5[2] × 45[3] cm)	0.063	4.0	10.1	12.3	0.044	44.70	6.7	701.2
0.11 × 1:4 (15 × 60 cm)	0.073	3.7	14.2	8.2	0.053	47.02	4.7	651.8
0.22 × 1:2 (15 × 30 cm)	0.115	5.1	11.8	3.1	0.094	49.91	9.4	982.3
0.19 × 1:4 (11.25 × 45 cm)	0.132	7.3	19.3	7.4	0.087	48.13	7.7	829.1
SE						±1.31	±0.53	±43.87
Maturity class								
Immature	0.095	5.6	16.5	12.0	0.073	44.9	6.3	670.0
Mature	0.092	4.0	11.9	4.3	0.073	47.7	8.7	888.8
Over-mature	0.099	5.5	13.2	0.0	0.086	49.7	7.5	814.5
SE						±1.13	±0.41	±37.99
CV (%)						8.30	13.52	16.64

1. Million ha^{-1}.
2. Intrarow distance.
3. Interrow distance.

and low plant mortality were observed in mature class over immature class (Table 1) and was reflected in higher pod yield ha^{-1}. Higher yield in the mature class was also reported by Devi Dayal and Ghosh (1996). The initial plant stand in the immature class was almost the same as in the mature class but their food reserves were not enough to sustain the seedling growth and resulted in lower yield plant^{-1}. Nagaraj et al. (1989) reported lower levels of oil and protein reserves in immature kernels. The immature class had a higher proportion of fungus infected kernels compared with the mature class (Devi Dayal et al. 1993) which, in turn, was the cause of high plant mortality. The study thus suggests that sowing groundnut seed of the mature class with a 1:2 plant rectangularity (15 × 30 cm) can improve the plant stand and productivity of groundnut. However, these results need further confirmation.

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Effect of Cutting Groundnut Seed for ELISA on Seed Germination and Seedling Vigor

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For enzyme-linked immunosorbent assay (ELISA) indexing of groundnut seeds without destruction of the seeds, a small portion of the distal end of the seed is cut and taken as a sample (Reddy et al. 1988, Sudarshan et al. 1990). When a large quantity of seed is involved, normally the practice is first to complete the indexing for the whole lot, and then do the sowing. In this process some seeds lose viability and result in poor germination in the field. In any case, shelled groundnut seeds lose viability quite fast. Hence, a small experiment was conducted with four groundnut cultivars to examine the trend of loss of viability of cut seeds when stored under ambient temperature conditions.

The pods of four cultivars (two each from *Arachis hypogaea* ssp *fastigiata* var *vulgaris*, and *Arachis hypogaea* ssp *hypogaea* var *hypogaea*) produced during Jul–Oct (rainy season) 1995, and stored in gunny bags, were taken for the study. The pods were shelled during Sep (rainy season) 1996, and 3000 seeds for each cultivar were randomly selected. The seeds were divided into two equal lots. In the first lot, a small portion of the distal end of each seed was removed (cut-seed) with a sharp blade as required for ELISA indexing. The second lot was the control (non-cut seed). One hundred each of cut-seeds and non-cut seeds were sown immediately in germination trays containing soil (to provide the exact environment of field sowing) following the International Seed Testing Association (ISTA) rules, 1985. To avoid infection by fungus, both cut-seeds and non cut-seeds were treated with carbendazim (Bavistin® BASF) at the rate of 2–3 g kg^{-1} of seed every time before sowing. This was replicated thrice. The remaining cut seeds and non-cut seeds were kept separately in sealed polythene bags, and stored at the ambient temperature (25–30°C). For a germination test every 10 days, 100 seeds from each lot were drawn and sown in the trays as described earlier. This continued for 40 days. Each time, fresh soil was used for the germination test. The germination percent of normal seedlings was measured on the tenth day after sowing following the ISTA rules. Root length was measured on 15 normal seedlings in each replicate. Seedling vigor index (SVI) was calculated according to Abdul-Baki and Anderson (1973) as follows:

$$SVI = \text{percentage germination} \times \text{mean root length}$$

Difference in germination percentage and vigor index were assessed immediately after shelling (Table 1). Lower germination was found in cut seeds than in the control. During storage also, loss in germination percentage was more in cut seeds after 10 days of storage, falling to an average 45%, as compared to 54% in the control.

After 40 days of storage, the average germination percentage came down to 6% for cut seeds and 15% for

Table 1. Effect of cutting groundnut seed for ELISA on germination, seedling vigor, and root length after various durations of storage.

	Germination (%) Days after storing					Seedling vigor index Days after storing					Root length Days after storing				
	0	10	20	30	40	0	10	20	30	40	0	10	20	30	40
Cut seed															
Girnar 1	78.7	55.3	24.0	4.3	2.7	563	365	130	10	3	7.16	6.61	5.42	2.20	1.00
GG 2	72.0	60.0	21.0	16.0	12.7	527	409	115	85	48	7.32	6.81	5.47	5.32	3.77
Kadiri 3	64.0	41.0	15.3	12.7	7.3	467	290	94	70	33	7.30	7.08	6.12	5.52	4.50
M 13	40.0	21.7	3.3	1.7	0.0	252	72	9	2	0	6.31	3.33	2.67	1.33	0.00
Mean	63.7	44.5	15.9	8.7	5.7	452	284	87	42	21	7.02	5.96	4.92	3.59	2.32
Control (whole seed)															
Girnar 1	86.0	64.0	31.3	16.0	13.0	635	431	204	92	55	7.38	6.74	6.52	5.77	4.20
GG 2	81.3	67.3	47.3	35.0	30.0	683	555	359	255	210	8.40	8.24	7.59	7.29	7.00
Kadiri 3	72.0	50.0	21.3	18.7	10.0	535	351	140	113	60	7.43	7.02	6.56	6.06	6.00
M 13	48.3	33.3	13.3	8.0	6.7	298	199	199	34	25	6.17	5.96	5.71	4.20	3.68
Mean	71.9	53.7	28.3	19.4	14.9	538	384	226	124	88	7.35	6.99	6.60	5.83	5.22

the control. A similar trend was observed for SVI. The difference between the cut seeds and non-cut seeds was a little less pronounced for root length, possibly because a seed which is fit to germinate will tend to produce a normal root. There was a marked variation among the four cultivars for germination percentage, root length, and SVI (Table 1). There was a drastic fall in germination percentage in Girnar 1 for cut seeds between 20th and 30th days after storage. In M 13 the fall was drastic between 10th and 20th days after storage. In GG 2 and Kadiri 3 the fall in germination was gradual. GG 2 retained longer viablity for non-cut seed as well. M 13 lost viability drastically after 20th day for non-cut seed. The trend in SVI was similar.

Thus cut seed should be sown immediately after ELISA indexing for virus, unless there is a cold-storage facility.

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Production and Management

Evaluation of Summer Groundnut Based Cropping Systems for Productivity and Economic Returns in India

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Although India has achieved great success in cereal production, there is a great gap between the demand and supply of edible oils. It is estimated that more than 32 million t of oilseeds are needed every year. One possibile way to increase oilseed production is to include efficient oilseed crops in existing cropping systems. Since summer groundnut cultivation has been recently recommended in the state of Punjab, there is need to study the feasibility of introducing summer groundnut in cropping sequences. Hence, this study to evaluate different cropping systems based on summer groundnut.

We report here the data from a field study involving eight cropping systems conducted for 3 years (1993–96) on fixed plots to evaluate the productivity and economics of these cropping systems. The cropping systems were, rice-wheat (CS1); maize-wheat (CS2); maize-potato-sunflower (CS3); summer groundnut-wheat (CS4); kharif groundnut-wheat (CS5); summer groundnut-swedish rape (CS6); summer groundnut-potato-wheat (CS7); summer groundnut-Indian rape-wheat (CS8). Summer groundnut cultivar SG-84 and recommended cultivars of other crops were grown with recommended inputs in different cropping systems. The performance of summer groundnut based cropping systems were compared with the more prevalent rice-wheat, maize-wheat, and highly profitable maize-potato-sunflower cropping systems. The experiment was conducted on a sandy loam soil with neutral pH, low in EC, low in organic carbon, high in available P, and medium in available K. The experiment was laid out in a randomized block design with four replications. Yield of individual crops were recorded and groundnut equivalent yields were calculated for each cropping systems as

$$\text{Groundnut equivalent yield} = \frac{\begin{array}{c}\text{Yield of crop (a)} \times \\ \text{support price of crop (a)} + \\ \text{Yield of crop (b)} \times \\ \text{support price of crop (b)}\end{array}}{\text{Price of groundnut}}$$

Table 1. Production potential and economic returns of summer groundnut based cropping systems, Punjab, India, 1993-96.

Cropping system	Grain yield[1] (t ha^{-1}) I	II	III	Groundnut equivalent yield (t ha^{-1})	Net returns[2] (Rs ha^{-1})	Benefit to cost ratio	Land use efficiency (%)	Production (t ha^{-1})
CS1	47.7	56.7	-	3.19	15.0	1.64	0.73	1.19
CS2	45.2	59.3	-	3.25	17.8	1.84	0.72	1.24
CS3	48.3	307.4[3]	24.5	7.56	34.7	1.62	0.87	1.24
CS4	23.3	58.8	-	4.09	26.0	2.12	0.84	1.34
CS5	25.5	56.7	-	4.25	27.9	2.21	0.82	1.43
CS6	23.0	20.1	-	3.84	24.9	2.17	0.66	1.60
CS7	23.9	243.6[3]	38.1	6.58	22.8	1.41	0.94	1.92
CS8	23.6	13.8	37.0	4.48	24.3	1.82	0.96	1.27

1996 Prices (Rs t^{-1}): Rice - 3750, Maize - 3900, Groudnut - 12000, Wheat - 3600, Sunflower - 10500, Indian rape - 8800, Swedish rape - 9200, Potato - 1500.
1. I, II, and III refer to the sequence of crops in each cropping system; 2. US$ = Rs 36.4; 3. Potato tuber.

where
a = rainy-season crop
b = postrainy-season crop

Productivity and economic returns

The yield of wheat when sown at the appropriate time was more after maize and summer groundnut than after rice. However, under late-sown conditions, wheat yield was more after potato than after Indian rape. This may be attributed to more residual nutrients after potato, maize, and summer groundnut. Sidhu et al. (1994) reported that cropping systems with potato or a legume as one of the components increased organic carbon, available P and K status of the soil. Sikka et al. (1994) also reported that after potato there was sufficient residual effects of applied nutrients. Yield of potato was less in summer groundnut-potato-wheat because of the short duration of the crop as compared to the maize-potato-sunflower cropping system. In the former system potatoes were dug out 81 days after sowing whereas in the latter cropping system potatoes were dug out 95 days after sowing.

Yield of summer groundnut was almost similar in different cropping systems. The highest groundnut equivalent yield was obtained from the maize-potato-sunflower cropping system (7.56 t ha^{-1}) followed by the summer groundnut-potato-wheat (6.58 t ha^{-1}) and summer groundnut-Indian rape-wheat (4.48 t ha^{-1}) cropping system. These cropping systems produced 136, 106, and 40.5% more groundnut equivalent yield than the more prevalent rice-wheat cropping system. Maximum net returns were obtained from the maize-potato-sunflower (Rs 34 700 ha^{-1}; US$ 1002.9 ha^{-1}) whereas minimum net returns were obtained from rice-wheat cropping system (Rs 14 985 ha^{-1}; US$ 433.09 ha^{-1}). It is clear from the data (Table 1) that returns obtained from all groundnut-based cropping systems. Benefit to cost ratio was also better in summer groundnut based cropping systems. Further, the land use and production efficiencies of all groundnut-based cropping systems were higher than the presently adopted rice-wheat and maize-wheat cropping systems.

Thus, it may be concluded that summer groundnut based cropping systems like summer groundnut-wheat, summer groundnut-swedish rape, summer groundnut-potato-wheat, and summer groundnut-Indian rape-wheat are more economical and will help in reducing the gap between the demand and supply of edible oils in the country. These cropping systems will improve the soil health from the nutrient point of view.

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Yield and Irrigation Use Efficiency of Groundnut With and Without Intercropping with Maize on an Alfisol

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The groundnut area in East Java-Indonesia consists of 40% sole cropping and 60% mixed cropping with maize (van Hoof 1987). Lack of irrigation water frequently decreases groundnut and maize yields. However, the decrease in groundnut yield was less than that of maize when they experienced the same degree of drought stress. Pahalwan and Tripathi (1984) reported that the groundnut crop required more frequent irrigation from pegging to pod formation than from pod development to maturity, and sowing to flowering stages. According to Sandhu et. al. (1972) groundnut yield increased because of one or two irrigations at flowering and pod filling periods, whereas Wright et al. (1986) reported that irrigation decreased groundnut yield when the rainfall was nearly normal.

Table 1. Effect of intercropping and irrigation water on groundnut yield on an Alfisol, East Java, dry season 1996.

Treatment	Plant height (cm)	No. of filled pods plant^{-1}	Seed size (g 100-seeds^{-1})
Mixed cropping			
Monoculture	21.78 a	14.06 a	36.82 a
Groundnut 100% + maize 80%	26.08 a	12.50 a	38.87 a
Irrigation rates			
0 mm	19.10 b	8.36 b	36.26 a
150 mm	19.46 b	13.53 a	38.60 a
300 mm	26.18 ab	14.73 a	38.06 a
450 mm	30.98 a	16.50 a	38.46 a

Values within a column followed by the same letter were not significantly different at $P = 0.05$.

A field experiment was conducted in east Java during 1996 on an Alfisol to determine effect of irrigation on yield and water use efficiency on groundnut when grown either as monoculture or intercropped with maize. A split-plot design with three replications was used in this experiment. Two sowing methods were assigned to the main plot, i.e., groundnut monoculture, intercropping groundnut (100%) + maize (80%). Four irrigation treatments were randomly assigned for the subplots. Irrigation treatment consisted of no irrigation; and irrigated with 150, 300, and 450 mm, during the groundnut growth period. The irrigation was applied five times, 15 days after sowing (DAS) (15%),30 DAS (15%), 45 DAS (25%), 60 DAS (25%), and 75 DAS (20%). The plot size was 4.8 × 6.0 m. Plant spacing was 40 × 10 cm for groundnut (1 plant hill^{-1}), and 200 × 20 cm for maize (2 plants hill^{-1}). In order to promote light interception for groundnut, maize was defoliated at the beginning of seed maturing of maize. Basal dressing of fertilizer was applied at the rate of 37.5 kg N + 25 kg P_2O_5 + 25 kg K_2O ha^{-1} for groundnut and 125 kg N + 100 kg P_2O_5 + 50 kg K_2O ha^{-1} for maize. Irrigation water use efficiency was calculated using the formula described by Gilley (1993) in Rahardjo et al. (1995).

Table 2. Pod yield, maize seed yield and irrigation water use efficiency in groundnut monoculture and intercropping on an Alfisol, East Java, dry season 1996.

	Yield (t ha^{-1})			WUE index (kg m^{-3})	
		Intercropping			
Irrigation water (mm)	Groundnut monoculture (dry pod)	Groundnut (dry pod)	Maize (grain)	Monoculture	Intercropping
0	0.34 c	0.29 c	0.35 d	0	0
150	1.26 b	0.77 b	1.70 c	0.57	0.70
300	1.72 a	0.91 ab	3.20 b	0.62	1.02
450	1.71 a	1.10 a	4.61 a	0.48	1.44

WUE = Water use efficiency.
Values within a column followed by the same letter were not significantly different at $P = 0.05$.

$$\text{WUE-irg} = \frac{(\text{P.ir} - \text{P.nir})}{(\text{ET.ir} - \text{ET.nir.})}$$

Where

WUE-irg = Irrigation water use efficiency (kg m^3)
P.ir = Yield under irrigation (kg)
P.nir = Yield under no irrigation (kg)
ET.ir = Actual evapotranspiration under irrigation (m^3)
ET.nir = Actual evapotranspiration under no irrigation (m^3)

The results indicated that there was no interaction between intercropping and irrigation water on groundnut pod yield and irrigation use efficiency (Table 1 and 2). Plant height, number of filled pods and seed size (g 100-seeds^{-1}) of groundnut when intercropped with maize were the same as for monoculture. The dry pod yield decreased by 38% under intercropping than under monoculture. To produce high groundnut yield, more irrigation water was required when groundnut was intercropped with maize compared to monoculture. Irrigation water-use efficiency of groundnut monoculture increased in the 150–300 mm irrigation application range, and decreased when the amount of irrigation was more than 300 mm. Highest pod yield (1.72 t ha^{-1} dry pod yield) and irrigation water-use efficiency were obtained when 300-mm irrigation was given during the growth period. However under intercropping, the groundnut and maize seeds yields, and irrigation water use efficiency increased up to 450 mm of irrigation (Table 2). Rahardjo, et al. (1995) reported that the highest soybean + maize intercropping yields were obtained when 250 mm of irrigation was provided.

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Sowing Time and Fertilization Effects on Groundnut After Maize on an Alfisol Upland in Indonesia

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The annual harvested area of groundnut in Indonesia is about 650 000 ha, and about 65% of this falls on dry lands in the maize-groundnut cropping system (CBS 1994). Water shortage and nutrient deficiencies are the main constraints to this groundnut production system. Rahmiana and Harsono (1992) reported that NPK fertilization on Alfisol in Tuban (East Java) increased groundnut yield by 59% and S, Fe, and Zn fertilization increased the yield by 44%. The clay-mineral in Alfisols is dominated by 1 : 1 type with low P availability (Fanning and Fanning 1989). The increase in groundnut and maize yields by phosphorus fertilization in Alfisol uplands were reported by Harsono et al. (1994), Isgiyanto and Adisarwanto, (1992), Taufik and Sudaryono (1995).

In order to determine optimum sowing time and nutrient applications on groundnut on upland Alfisols in a dry climate (3–4 wet months, and 5–6 dry months per year), a field experiment was conducted at Probolinggo (East Java) during the wet season of 1995/96, under a maize-groundnut cropping system. A split-split plot design with three replications was used in the study. The main plots consisted of three fertilizer applications for maize: 125 kg N ha^{-1}; 125 kg N + 100 kg P_2O_5 ha^{-1}; and 125 kg N + 100 kg P_2O_5 + 50 K_2O ha^{-1}. The subplot consisted of two groundnut sowing times: 70 days after maize sowing (DAS), and immediately after maize harvested. Five combinations of fertilizations for groundnut were arranged for the sub-subplots: control; 37.5 kg N ha^{-1}; 37.5 kg N + 25 kg P_2O_4 ha^{-1}; 37.5 N + 25 kg P_2O_5 + 25 kg K_2O ha^{-1}; and 37.5 N + 25 kg P_2O_5 + 25 kg K_2O + 10 kg

Fe-EDTA + 5 kg $ZnSO_4$ ha^{-1}. The plot size was 4 × 3 m. The maize cultivar used was Arjuna and groundnut cultivar used was Kelinci. Plant spacing for maize was 80 × 40 cm, two plants $hill^{-1}$, and for groundnut was 40 × 10 cm, one plant $hill^{-1}$. In order to promote light interception for groundnut, maize was defoliated at the beginning of seed maturing of maize. Weeds, insect-pests, and diseases were intensively controlled in this experiment.

The results indicated that compared to sowing groundnut immediately after maize was harvested, sowing groundnut 70 days after maize sowing could advance the groundnut sowing by 28 days. Perhaps for this reason, the existing rainfall (527 mm) could meet the groundnut water requirement, and increased groundnut yield by about 328%, from 0.35 t ha^{-1} to 1.5 t ha^{-1} (Table 1). Comparative rainfall in the groundnut crop which was sown immediately after maize harvested, was 210 mm. According to Doorenbos and Kassam (1979), the optimum water requirement to obtain high groundnut yield was 250–700 mm depending on the climate and soil type. The maize fertilized with 100 kg P_2O_5 ha^{-1} had significant residual effects on groundnut as indicated by the yield increase of 19% (Table 2). However, this positive effect was not observed in the potassium fertilization treatment. Fertilization of 37.5 kg N ha^{-1} on groundnut sown after maize which was fertilized by 125 kg N ha^{-1} did not increase groundnut yield. Compared to the control, a yield increase of 15% was observed when groundnut was fertilized with 37.5 kg N + 25 kg P_2O_5 ha^{-1}. Soil analysis indicated that availability of phosphorus on Alfisols at Probolinggo was low, whereas, groundnut yield in this soil in East Java was increased by phosphorus fertilization (Harsono et al. 1994, Isgiyanto and Adisarwanto 1992, Rahmiana and Harsono 1992). Fertilization of K, Zn, and Fe had no effect on the groundnut pod yield when compared to the groundnut fertilized only with 37.5 kg N + 25 kg P_2O_5 (Tables 1 and 2).

Based on the results of this experiment, the following package of technology can be recommended in order to produce high pod yields of groundnut under a maize-groundnut cropping system in dry climates on Alfisol (3–4 wet months $year^{-1}$): a) sowing groundnut about 30 days before harvesting of maize, b) applying at least 37.5 P_2O_5 ha^{-1} to groundnut, and c) defoliation of maize at the beginning seed maturity to promote light interception for groundnut.

Table 1. Effect of sowing time and fertilization on yield of groundnut after maize on an upland Alfisol, East Java, wet season 1995/96.

Fertilization for groundnut	Dry pod yield (t ha^{-1}) 70 DAS[1] maize	Immediately after maize harvest	Average dry pod yield (t ha^{-1})
Control	1.35	0.35	0.85 bc
N	1.28	0.17	0.73 c
N+P	1.58	0.37	0.98 ab
N+P+K	1.66	0.44	1.05 a
N+P+K+Zn+Fe	1.67	0.42	1.05 a
Mean	1.51 a	0.35 b	

1. Days after maize sowing.
Means within a column or row followed by the same letter are not significantly different at $P = 0.05$.

Table 2. Effect of fertilization of maize and groundnut on groundnut yield in the maize-groundnut cropping system in dry land Alfisol, East Java, wet season 1995/96.

Fertilization for groundnut	Dry pod yield (t ha^{-1}) Fertilization for maize N	N+P	N+P+K	Average dry pod yield (t ha^{-1})
Control	0.64	1.00	0.90	0.85 bc
N	0.57	0.82	0.79	0.73 c
N+P	0.91	1.10	0.93	0.98 ab
N+P+K	1.02	1.06	1.08	1.05 a
N+P+K+Zn+Fe	1.05	1.00	1.09	1.05 a
Mean	0.83 b	0.99 a	0.96 a	

Mean within a column or row followed by the same letter are not significantly different at $P = 0.05$.

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Role of Potassium, Calcium, and Magnesium Application in Increasing Groundnut Productivity on a Red Mediteran Soil in Indonesia

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Groundnut productivity on dryland Red Mediteran soils in Indonesia is low (0.8–1.1 t ha^{-1}). Chlorotic symptoms apparently caused by nutrient deficiency usually appear in the groundnut crops in the field. These chlorotic symptoms in groundnut differ among locations. In Red Mediteran soil in Tuban district, young leaves exhibit interveinal chlorosis, and are sometimes pale yellow or white, as is characteristic of iron (Fe) deficiency. In Lamongan and Blitar districts, there is interveinal chlorosis in both young and old leaves, suggestive of potassium (K) deficiency. Exchangeable calcium (Ca) in the topsoil (0–15 cm) of the Red Mediteran soil at Lamongan and Tuban is higher than exchangeable K and magnesium (Mg) (Taufiq et al. 1994, Poerboyo et al. 1992). Exchangeable Ca in Red Mediteran soil at Tuban varied from 16 to 40 me 100 g^{-1}, and at Lamongan from 1.2 to 6.9 me 100 g^{-1} soil, but the cation exchange capacity (CEC) of soil at both locations was similar at 27.4 and 24.5 me 100 g^{-1}. The ratio of Ca:(K+Mg) in soil at both locations was similar at around 1:0.2. Cox et al. (1982) reported that an ideal Ca:(K+Mg) ratio for growth of groundnut was 1:3. Thus an imbalance of macro-cations may contribute to the low groundnut yield in Red Mediteran soil in East Java.

A field experiment to study effect of K, Ca, and Mg application to groundnut productivity was conducted on Red Mediteran soil in Lamongan and Blitar districts, East Java, Indonesia, during the rainy season (Nov–Mar) of 1995/96. Chemical characteristics of Red Mediteran soil at Lamongan and Blitar were similar (Table 1). The treatments comprised combinations of K, Ca, and Mg applications at the rate of 0, 5, 10, 15, 20, and 25% of in situ exchangeable K, Ca and Mg. A randomized block design with three replications was used. A local groundnut variety of Tuban was used in the study. The Basic Cation Saturation Ratio (BCSR) concept described by McLean (1977) was adopted to calculate the K, Ca, and Mg that should be applied. In this study, the ratio of soil K, Ca, and Mg was not changed, but their availability was relatively increased by applying potassium fertilizer (KCl,

Table 1. Top soil (0–15 cm) chemical characteristics of Red Mediteran soil from Lamongan and Blitar districts, East Java, Indonesia, 1995/96.

Parameter	Lamongan	Blitar
pH-H_2O	5.4	6.4
N-total (%)	0.14	-
C-organic (%)	0.30	0.87
P-Bray I (ppm)	3.84	-
K-exchange (me 100 g^{-1})	0.37	0.29
Ca-exchange (me 100 g^{-1})	4.47	4.93
Mg-exchange (me 100 g^{-1})	0.52	0.31
Ca: (K+Mg)	1:0.2	1:0.1
CEC (me 100 g^{-1})	24.51	28.56
K-saturation (%)	1.5	1.00
Ca-saturation (%)	18.3	17.20
Mg-saturation (%)	2.1	1.1

Table 2. Effect of K, Ca, and Mg application on yield and its components of groundnut in Red Mediteran soil, East Java, Indonesia, rainy season 1995.

K, Ca, Mg increment (%)	Fodder (t ha^{-1})	Seed yield plant^{-1} (t ha^{-1})	Empty pods plant^{-1}	Filled pods
Lamongan				
0	2.31	1.66	7	8
5	2.89	1.50	12	14
10	2.73	1.71	12	15
15	3.21	2.86	15	15
20	2.88	2.78	14	14
25	3.86	1.91	12	12
LSD 5%	0.86	0.34	5	4
CV (%)	13.4	7.3	22.3	20.3
Blitar				
0	5.66	1.66	11	13
5	5.80	2.23	13	18
10	6.11	2.12	9	13
15	6.20	2.65	11	19
20	6.77	3.03	12	22
25	6.30	2.69	10	19
LSD 10%	ns[1]	-	ns	3.4
LSD 5%	-	0.95	-	-
CV (%)	13.1	18.5	29.5	6.7

1. ns = Not significant.

Table 3. Concentration of K, Ca, and Mg in the shoot of groundnut at pod filling stage. Lamongan district, Indonesia, rainy season 1995.

K, Ca, Mg increment (%)	K (%)	Ca (%)	Mg (%)
0	0.35	0.90	1.11
5	0.41	0.40	0.79
10	0.46	0.64	0.72
15	0.65	0.77	0.78
20	0.67	0.73	0.71
25	0.71	0.72	0.62

46% K_2O) and agricultural lime (CaO, 55% Ca and MgO, 33% Mg).

Application of K, Ca and Mg to 15% more than soil levels of exchangeable K, Ca, and Mg increased seed yield and filled pods per plant, but the number of empty pods (pops) was not reduced by increasing application (Table 2). Jones et al. (1991) reported that sufficient macro-cation concentration in the plant at pod filling stage is 1.7–3% (K), 1.25–1.75% (Ca), and 0.3–0.8% (Mg). Based on those figures, concentration of Ca and K in the shoot at pod-filling stage in this experiment (Table 3) were below the sufficient levels, and Mg was above the sufficient level.

The seed yield at 15% K, Ca, Mg application, increased by 72% at Lamongan, and by 60% at Blitar, compared to the control. Correlation between yield and concentration of K 0.73*, Ca 0.37^{ns}, and Mg -0.28^{ns} in the shoot at pod filling stage. This indicated that the effect of K was dominant over Ca and Mg. A similar result was reported by Rahmiana and Harsono (1992), in a Red Mediteran soil at Tuban district (East Java) that application of K increased groundnut yield by 17%.

These data show that application of K, Ca, and Mg on Red Mediteran soil significantly increased growth and productivity of groundnut. The results suggest that K is the major cation. However, it is necessary to study the effect of K, Ca, and Mg applied separately in order to identify the roles of each of these elements in improving groundnut productivity in Red Mediteran soil.

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Improvement of Yield of Summer Groundnut through Mulching and Criss-cross Sowing in Gujarat, India

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In the Saurashtra region of Gujarat, summer groundnut is sown between 15 Jan and 15 Feb depending on the prevailing temperature. If the sowing is done late in Feb, because of low temperature prior to this period, the crop is likely to be affected by premonsoon or early monsoon showers. If the sowing is done early, germination, plant stand, and plant growth are affected because of low temperature. Suboptimal plant population of groundnut in the farmers' field leads to low productivity. Bidirectional sowing has proved effective in groundnut (Devi Dayal et al. 1994). In the present study organic and synthetic mulch, and criss-cross sowing were tested alone and in combination during the summers of 1995 and 1996 at the National Research Centre for Groundnut, Junagadh. The experiment was laid out in a randomized block design with 6 treatments replicated thrice. The treatments were: control (no mulch and no criss-cross sowing), criss-cross sowing, wheat straw 5 t ha^{-1} as mulch, black polythene, criss-cross sowing + wheat straw, and wheat straw + black polythene. The crop was sown during the 2nd fortnight of Jan with 25 kg N and 60 kg P_2O_5 ha^{-1} as basal application. Chopped wheat straw was applied (to treatment plots) uniformly on the surface immediately after sowing. Care was taken during irrigation so that straw was not disturbed. Polythene was spread over the entire plot immediately after sowing, and was rearranged to cover interrow spacing after germination. It was removed at pod development stage. In the criss-cross sowing, 50% of the seed was sown in one direction at 30-cm spacing, and then the remaining half was sown at 90° to the original direction by adopting the same row spacing.

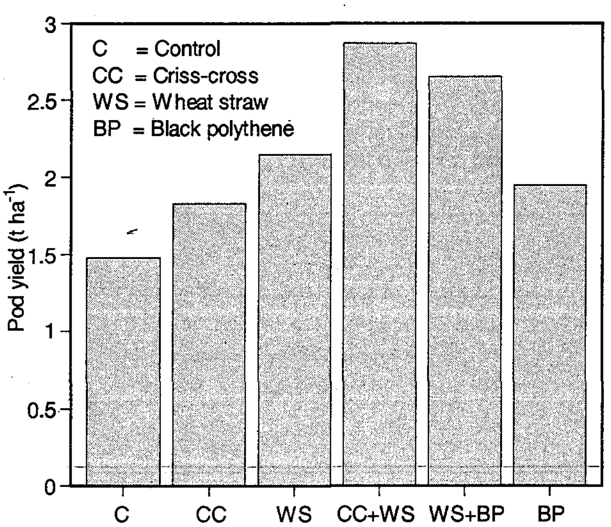

Figure 1. Effect of criss-cross sowing and mulching on yield of summer groundnuts, 1995 and 1996, Junagadh, Gujarat, India.

Results indicate that wheat straw mulching treatment yielded 2.15 t ha^{-1}, black polythene 1.95 t ha^{-1}, and criss-cross sowing recorded 1.83 t ha^{-1} pod yield compared to 1.48 t ha^{-1} of control (Fig. 1). The pod yield increase under wheat straw mulch was mainly because of the more favorable soil temperature maintained by wheat straw during the crop season as it raised soil the temperature by 2–3°C at germination and early stages of crop growth, but lowered temperature by 3–5°C at pod development stage (Devi Dayal et al. 1992). Minimizing interplant competition in criss-cross method might be responsible for yield improvement. Hence, when both the components (wheat straw mulch and criss-cross sowing) were combined, the highest pod yield of 2.87 t ha^{-1} was recorded (Fig. 1). Early germination (5–6 days) and maintaining optimum soil moisture around the root zone under polythene sheet resulted in higher pod yield over control, but not as high as with wheat straw. Thus, the combination of wheat straw (a locally available plant by-product costing Re. 1 kg^{-1}) and criss-cross sowing (at no extra cost), can boost up the productivity of summer groundnut.

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Effect of Source Dose, Time, and Mode of Sulfur Application to Groundnut on Lateritic Soils, Orissa, India

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Groundnut is a major oilseed crop of Orissa contributing 57% of the total oilseed production of the state. Groundnut in Orissa is mostly cultivated on red lateritic and alluvial soils. In spite of recommended application of N, P, and K nutrients to groundnut along with improved package of practices, the productivity of this crop is low on red and lateritic soils. Investigations on the sulfur status of soils of Orissa (Misra et al. 1990, Sahu et al. 1991) showed that 55–60% soils of red and lateritic group were deficient in sulfur. Considering sulfur to be one of the constraints to groundnut productivity on lateritic soils, field trials on dose, source, time, and mode of application of sulfur were undertaken during the 1994 postrainy season at the Central Research Station, Orissa University of Agriculture and Technology, Bhubaneswar. Eight treatments of the first trial on source and dose (Table 1) and six treatments on time and mode of application of sulfur (Table 2) with the second trial were replicated four times with a randomized block design.

The soil of the experimental site was sandy loam (Aeric Haplustalf) with 5.6 pH, 0.315% organic carbon, and medium with available P and K. Extractable monocalcium phosphate of the soils was 12 mg kg^{-1}, and 0.15% $CaCl_2$ extractable sulfur was 5 mg kg^{-1}. As sources of sulfur, phosphogypsum contained 15% S, farmyard manure (FYM) contained 0.1% S, and single superphosphate contained 12% S. Groundnut variety TG 3 was sown for both the trials with 20 kg N, 17.5 kg P, and 33.2 K ha^{-1}. Diammonium phosphate, urea, and muriate of potash were the sources of N, P, and K as needed. The treatment FYM did not receive N, P, and K. Phosphogypsum at 30 kg S ha^{-1} was distributed at the ratio of 100:0, 50:50, 75:25, 25:75, and 0:100 of sowing and peg initiation in second trial.

The data (Table 1) showed that application of S from any source significantly increased the pod yield and shelling percentage of groundnut. Phosphogypsum as a source of sulfur increased the yield significantly up to 40 kg S ha^{-1}, and then declined non-significantly at 50 kg S ha^{-1}. The yield due to single superphosphate at 30 kg S ha^{-1} and phosphogypsum at 40 kg ha^{-1} were statistically at par. The yield and shelling turnover because of FYM, SSP and phosphogypsum at 30 kg S ha^{-1} were almost similar. The yield response and percentage increase over control showed a similar trend.

The data (Table 2) showed that phosphogypsum of 30 kg S ha^{-1} applied in equal proportions at sowing and at

Table 1. Effect of source and dose of sulfur on yield and shelling turnover of groundnut, Bhubaneswar, Orissa, India, postrainy season 1994.

Treatment	Pod yield (kg ha^{-1})	Response (kg ha^{-1})	Increase over control (%)	Shelling percentage
S_0	1473	-	-	61.9
S_{20} (phosphogypsum)	1620	147	10.0	65.3
S_{30} (phosphogypsum)	1733	260	17.6	69.0
S_{40} (phosphogypsum)	1850	377	25.6	70.4
S_{50} (phosphogypsum)	1840	367	24.9	71.3
S_{60} (phosphogypsum)	1743	270	18.3	61.0
S_{20} (farmyard manure)	1747	274	18.6	69.3
S_{30} (single superphosphate)	1777	304	20.6	68.7
SE	±27.3	-	-	±0.99

Table 2. Effect of time and mode of sulfur application on yield and shelling turnover of groundnut, Bhubaneswar, Orissa, India, postrainy season 1994.

Distribution of 30 kg S (%) Sowing + pegging	Pod yield ($kg\ ha^{-1}$)	Shelling percentage
0 + 0	1390	62.8
100 + 0	1640	69.0
50 + 50	1705	69.3
75 + 25	1682	67.0
25 + 75	1680	69.2
0 + 100	1600	68.1
SE	±20	±0.89

peg initiation produced the maximum pod yield and shelling turnover. Full application of gypsum either at sowing or at peg initiation did not prove superior to split application in sandy loam lateritic soils.

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Weed Management in Groundnut Through Soil Solarization

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A field experiment was conducted during the 1995 rainy season at the Main Research Station, University of Agricultural Sciences, Dharwad, Karnataka, India, to examine the effect of soil solarization on weed control in groundnut. Soil solarization is a technique to control soil-borne pests including weeds. It involves covering the wet soil with a thin transparent polyethylene film during the summer months (Katan 1980).

The experiment consisted of 14 treatments replicated thrice in a randomized block design. The treatments consisted of two colors (black and transparent) of polyethylene sheet, three thicknesses of the sheet (0.05, 0.1, and 0.125 mm), two durations of solarization (30 and 60 days) and two soil conditions (dry and wet soil) (Table 1). The polyethylene sheets in solarized plots were spread manually on 10 Apr 1995. They were removed after the respective periods of solarization (i.e., 30 and 60 days). Groundnut cv JL 24 was sown on 15 Jun 1995 as a test crop with an interrow spacing of 30 cm, and intrarow spacing of 15 cm under rainfed conditions. After sowing, no weeding was done in solarized and nonweeded control plots. Weeds were removed as and when they emerged in the weed-free control treatment. The data on weed count and weed dry mass were transformed before statistical analysis.

Major competing weeds. Monocotyledonous weeds in the experimental field were *Cyperus rotundus*, *Cynadon dactylon*, *Digitaria marginata*, *Echinocloa crusgalli*, *Panicum repens*. The common dicotyledonous weeds noticed were *Acanthosperum hispidum*, *Amaranthus spinosus*, *Amaranthus viridis*, *Abutilon indicum*, *Acalypha indica*, *Corchorus trilocularis*, *Commelina benghalensis*, *Cynotis cristata*, *Euphorbia hirta*, *Portulaca oleracea*, *Parthenium histerophorus*, *Phyllanthus niruri*, and *Solanum nigrum*.

Soil temperature. Ranking of treatments for soil temperature was in the order of TP 0.05 mm > TP 0.1 mm > BP 0.125 mm > noncovered control (Table 1). TP_1W_2 (54°C; 10°C higher than in noncovered control), TP_2W_2 (45.8°C; 7°C higher), and BP_2W_2 (42.3°C; 4°C higher) on a day of maximum air temperature of 37.7°C. Black polyethylene treatments recorded lower temperature than the transparent polyethylene ones. These results are in agreement with those of Horowitz et al. (1983).

Weed population and weed dry mass. Solarization treatments with TP_1W_2 and TP_2W_2 significantly reduced weed count and weed dry mass before sowing and during crop growth (Table 1). The reduction in weed count and dry mass was more due to 0.05 mm TP than 0.1 mm TP. Rise in soil temperature recorded in this study was also of the same order. The higher temperature in 0.05 mm TP might have caused the death or damage of the weed seed resulting in reduced weed growth. Similar reduction in weed growth because of solarization has been reported (Grinstein et al. 1979).

Table 1. Influence of solarization treatments on soil temperature weed population (90 DAS) and pod yield of groundnut, University of Agricultural Sciences, Dharwad, Karnataka, India, rainy season 1995.

Treatment		Mean maximum soil temperature (37.7°C)	Weed-count m^{-2} after solarization before crop sowing	90 DAS Weed-count (m^{-2})		90 DAS Weed dry mass ($g\ m^{-2}$)		Pod yield ($t\ ha^{-1}$)
TP (0.05 mm) Dry soil[1]	(TP_1D_1)	52.8	55.4	5.13	(25.41)	0.977	(7.50)	1.59
TP (0.05 mm) Dry soil[1]	(TP_1D_2)	53.3	40.6	4.39	(18.35)	0.927	(6.47)	1.93
TP (0.05 mm) Wet soil[1]	(TP_1W_1)	53.9	30.1	4.28	(17.35)	0.825	(4.70)	2.29
TP (0.05 mm) Wet soil[2]	(TP_1W_2)	54.0	1.9	3.60	(12.04)	0.756	(3.73)	2.88
TP (0.1 mm) Dry soil[1]	(TP_2D_1)	44.0	53.5	5.68	(31.66)	1.095	(10.46)	1.50
TP (0.1 mm) Dry soil[2]	(TP_2D_2)	44.1	40.9	4.58	(20.04)	0.984	(7.66)	1.70
TP (0.1 mm) Wet soil[1]	(TP_2W_1)	44.1	36.5	4.51	(19.37)	0.942	(6.67)	2.12
TP (0.1 mm) Wet soil[2]	(TP_2W_2)	45.8	7.9	4.08	(15.70)	0.804	(4.39)	2.71
BP (0.125 mm) Dry soil[1]	(BP_1D_1)	39.8	60.3	8.59	(73.06)	1.915	(80.34)	1.11
BP (0.125 mm) Dry soil[2]	(BP_2D_2)	40.9	47.0	7.89	(61.08)	1.861	(70.72)	1.42
BP (0.125 mm) Wet soil[1]	(BP_1W_1)	42.3	50.4	7.78	(59.73)	1.727	(51.38)	1.43
BP (0.125 mm) Wet soil[2]	(BP_2W_2)	42.5	46.6	6.69	(40.99)	1.519	(31.08)	1.52
Nonweeded control		37.8	96.7	12.42	(153.34)	2.060	(112.99)	0.91
Weed-free control		39.1	86.1	1.00	(0.00)	0.301	(0.00)	2.91
SE		±0.13	±0.29	±0.070		±0.010		±0.71
CD 0.05		0.37	0.85	0.204		0.028		2.14

1 = 30 days; 2 = 60 days.
TP = Transparent polyethylene; BP = Black polyethylene.
Figures in parentheses indicate original values.

Pod yield. Highest pod yield of 2.88 t ha^{-1} was obtained with TP_1W_2 which was on par with the weed-free control (Table 1). Reduced weed competition in the TP_1W_2 may have resulted in better availability of resources resulting in pod yield advantage (Grinstein et al. 1979).

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Variation of Yield of Succeeding Wheat Because of Various Groundnut Genotypes

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Groundnut is rotated with wheat in north India (Punjab, Haryana, and Uttar Pradesh; hot and dry climate with moderate to high soil moisture availability, and 750–900 mm annual rainfall), and in western parts of India (Gujarat and Maharashtra; hot and dry climate with little to moderate soil moisture availability, and 650–700 mm annual rainfall). Different genotypes of groundnut have differing patterns of dry matter accumulation, nodulation and N_2-fixation (Reddy et al. 1980, Ghosh et al. 1996). Wheat, therefore, responds differently when grown after different groundnut genotypes. Information about this is practically negligible. Two field studies were conducted separately, one with 10 bunch genotypes (spanish, maturing in 100–110 days), and second with 10 spreading genotypes (virginia, maturing in 135–140

Table 1. Yield of wheat and groundnut and soil N as influenced by different groundnut genotypes, Junagadh, India, 1995/96 and 1996/97.

Genotype	Pod yield ($t\ ha^{-1}$)	Grain yield of wheat ($t\ ha^{-1}$)	Nodule dry mass ($mg\ plant^{-1}$)	Soil N ($kg\ ha^{-1}$) after groundnut harvest		
				NH_4^+	NO_3^-	Total
Bunch types						
ICGS 76	1.31	3.41	36.1	74.3	86.4	160.7
TGK 19A	1.20	3.65	32.0	70.0	89.0	159.0
GG 2	1.26	3.40	22.5	69.1	89.4	154.5
ICGS 11	1.26	3.56	31.8	69.0	84.6	153.6
ICGS 44	1.19	3.56	34.2	72.5	79.1	151.6
Dh 3-30	1.09	3.30	23.2	65.0	83.2	148.2
JL 24	0.88	2.88	20.5	69.0	75.0	144.0
CO 1	1.01	2.97	18.9	64.4	78.2	142.6
ICGS 21	1.16	2.90	21.8	65.7	72.0	137.7
CO 2	1.21	2.60	19.2	59.0	77.8	136.8
Mean	1.16	3.22	26.02	67.8	81.47	148.8
SE	±0.041	±0.113	±2.11	±1.39	±1.88	±2.63
CD 0.05	0.126	0.353	6.28	4.13	5.58	7.80
Spreading types						
M 335	1.05	3.06	32.0	69.7	83.0	152.7
R 141	0.77	2.91	33.7	71.4	79.3	150.7
M 37	1.03	2.91	28.7	70.4	76.0	146.4
K 2	0.70	2.77	30.2	63.0	81.4	144.4
BG 1	0.81	2.90	31.5	65.9	76.3	142.2
Punjab 1	0.83	2.80	26.6	65.0	75.8	140.8
ICGS 1	0.80	2.84	25.8	69.7	70.2	139.9
BG 3	0.90	2.84	26.3	64.3	73.0	137.3
Somnath	0.78	2.68	23.8	62.3	75.0	137.3
BG 2	0.85	2.85	24.9	63.1	71.1	134.2
Mean	0.85	2.86	28.35	66.50	76.11	142.6
SE	±0.035	±0.031	±1.06	±1.10	±1.32	±1.90
CD 0.05	0.108	0.099	3.15	3.26	3.92	5.62

days) during the rainy and summer seasons of 1995/96 and 1996/97 at the National Research Centre for Groundnut, Junagadh. Both the experiments were conducted in a RBD with three replications, and each genotype was supplemented with 12.5 kg N and 25 kg P_2O_5 ha^{-1}. After harvest of the groundnut, wheat (cv GW 496) was sown in the same plot on 17 Nov in 1995/96, and on 21 Nov 1996/97, with 80 kg N, 40 kg P_2O_5, and 40 kg K_2O ha^{-1}. The soil (Vertic Ustrochrept) was clay loam (7.6 pH), containing 1.17% organic carbon, 146 kg ha^{-1} available N, 7.6 kg ha^{-1} P, and 214.3 kg ha^{-1} K. Average rainfall at Junagadh during the period of experimentation was 809.6 mm.

Pooled results indicated wide genotypic variation in nodule mass per groundnut plant (18.9–36.1 mg in spanish types and 23.8–33.7 mg in virginia types). Similarly, available N pool in soil after groundnut harvest varied considerably with groundnut genotypes, and it ranged from 136.8 to 160.7 kg ha^{-1} after spanish types, and from 134.2 to 152.7 kg ha^{-1} after virginia types. Wide variation in grain yield of wheat (1.06 t ha^{-1}) was observed when grown after bunch types, the highest (3.66 t ha^{-1}) being after TGK 19A, and lowest (2.59 t ha^{-1}) after CO 2 (Table 1). Yield of wheat did not significantly differ because of genotypes GG 2, TGK 19A, ICGS 11, ICGS 44, and ICGS 76. On the other hand, differences in grain yield of wheat due to virginia genotypes was narrow (only 0.37 t), the highest being after M 335 (3.06 t ha^{-1}) and lowest after Somnath (2.68 t ha^{-1}). Wheat yield was significantly higher when grown after M 335, than when grown after other spreading genotypes (Table 1). Our results, thus, indicate that variation in grain yield of wheat because of different groundnut genotypes was possibly due to variations in nodule mass and soil N.

Considering the yield performance of both the crops in the rotation, and the significant trend among the genotypes, TGK 19A, ICGS 11, ICGS 44, ICGS 76, and GG 2 among the bunch types, and M 335 among spreading types should be preferred where groundnut-wheat rotation is followed.

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Effect of Liming on the Performance of Groundnut Grown on Acid Soil in Congo

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Groundnut is grown in diverse agroclimatic environments characterized by spatial and temporal variations in rainfall and by soils of varying physical and chemical properties. Most soils of groundnut cropping areas in Congo are acidic (Mandimba and Djondo 1996). A trial on the effect of liming on soil pH, nodulation, and yield was initiated to study the performance of groundnut.

A field trial was conducted during the 1994/95 rainy season at the Mfilou-Gamaba district near the town of Brazzaville. Important properties of the experimental soil include sand (66%), loam (17%), and clay (17%). The soil is acidic with a pH of 4.7, a cation exchange capacity of 5.01 meq 100-g-soil^{-1}, and an organic matter of 2.05%. Total rainfall during the experiment was 443.23 mm. The experimental material consisted of a short-duration groundnut variety, Talon-Dame, and six fertilizer liming treatments: (i) nonfertilized and nonlimed treatment as control, (ii) fertilized with 80 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1} as fertilizer, (iii) liming with 2 t CaO ha^{-1} as Lime 2, (iv) liming with 4 t CaO ha^{-1} as Lime 4, (v) liming with 6 t CaO ha^{-1} as Lime 6, (vi) liming with 8 t CaO ha^{-1} as Lime 8. The trial was sown in a randomized block design with replications. The plot size was 4 × 6 m. All limed plots were fertilized with 80 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1}. Agricultural limestone (CaO 56.2%), single superphosphate (P_2O_5 18%), and potassium chloride (K_2O 60%) were applied.

At mid-flowering stage 33 days after sowing (DAS), five plants of each replicate were randomly selected for determining nodulation, shoot mass, and N content. Nodulation, and shoot mass were determined by methods outlined by Wang et al. (1993), N content was determined by the Kjeldahl digestion. Yield potential and net return were determined at crop maturity. Yields of crop were adjusted to 14.5% moisture. All results were analyzed statistically by ANOVA procedures, and the means were compared by the Newman-Keuls test at $P = 0.05$.

Both phosphorus and lime applications have a significant effect on soil pH. The application of phosphorus alone increases the soil pH to 5.61 compared to control plot (4.74). The increase in soil pH can be attributed to the reactivity of soil to P application in agreement with the view of Sahu et al. (1995). Among limed treatments, the differences in soil pH were more pronounced with the increasing dose of lime application. Lime application at a

Table 1. Nodulation traits of groundnut crop at mid-flowering stage (33 DAS), Mfilou-Gamba, Congo, rainy season 1994/95.

Soil management	Nodule mass (mg plant^{-1})	Shoot mass (g plant^{-1})	N accumulation in shoot (mg plant^{-1})
Control	53.40c[1]	22.92b	49.57ab
Fertilized	75.32bc	25.80ab	43.68b
Lime 2	94.93abc	29.42ab	60.25ab
Lime 4	100.13abc	30.05ab	57.47ab
Lime 6	123.14ab	35.82a	72.24a
Lime 8	148.93a	36.85a	70.66a
Mean	99.31	30.14	58.98
SE	±28.11	±5.55	±10.68
CV (%)	28.3	18.4	18.1

1. Values in a column followed by the same letter are not different at $P = 0.05$ using the Newman and Keuls test.

Table 2. Yield potential and net profit of groundnut at crop maturity, Mfilou-Gamba, Congo, rainy season 1994/95.

Soil management	Pod yield (kg ha^{-1})	Seed yield (kg ha^{-1})	Harvest index (%)	Net profit (US $)
Control	1600c[1]	782d	37.10a	517.70
Fertilized	2007c	1057c	43.93a	584.90
Lime 2	2407b	1412b	47.75	190.70
Lime 4	2610ab	1537b	53.16a	(355.50)[2]
Lime 6	2725ab	1952a	43.65	(709.70)
Lime 8	2907a	1985a	48.84a	(1317.30)
Mean	2396	1454	45.74	
SE	±23.97	±143.9	±8.96	
CV (%)	10.0	9.9	19.6	

1. Values in a column by the same letter are not different at $P = 0.05$ using the Newman and Keuls test.

2. Values in parentheses are negative profits resulting from the high cost of inputs.

level of 8 t CaO ha^{-1} has the highest value of soil pH (7.32), while difference between Lime 4 and Lime 6 treatments were not significant (soil pH 6.7 at Lime 4 and 6.82 at Lime 6. As the experiment advanced, the soil pH decreased from 6.51 at 20 DAS to 5.93 at 60 DAS. Interaction between liming × DAS was significant. Similar results were reported by Waliyar et al. (1992) on sandy soils in Niger.

The significant effects of P and lime applications and their interaction are also expressed in nodule mass and N accumulation (Table 1). Liming increases nodule mass from 95 mg $plant^{-1}$ to 149 mg $plant^{-1}$. This is evidence of the symbiotic effectiveness of soil rhizobia under field conditions, confirming previous results of groundnut nodulation in Congo soils (Mandimba et al. 1993, Mandimba 1995). However, increased lime application has little effect on shoot mass and N accumulation. In the limed plots, application of lime was able to double the seed yield from 100 kg ha^{-1} to 200 kg ha^{-1} (Table 2).

The results of this experiment suggest that groundnut production in acidic soil undoubtedly requires a considerable input of phosphorus fertilizers and potassium in addition to lime for increased profitability. Increased lime application did not increase the net profit. Compared to the control, phosphorus application alone showed 13% increase in net profit. The application of more than 2 t CaO ha^{-1} greatly decreased the net profit because of the high cost of agricultural limestone (Table 2).

Thus, the importance of phosphorus to groundnut production in acidic soil is obvious because of its high phosphate fixing capacity. This provides evidence for the influence of soil type on the performance of groundnut.

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Performance of Groundnut Genotypes Under Rainfed Conditions in Northern Hills of Chhattisgarh, Madhya Pradesh, India

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The part of the northern hills of Chhattisgarh called Surguja belongs to tribals. Groundnut grown in uplands comprises 20% of the total cultivated land. The area under groundnut in Surguja is about 6000 ha with a productivity of 0.678 t ha^{-1}, which is lower than the average production of Madhya Pradesh (0.743 t ha^{-1}). The

Table 1. Performance of ICRISAT groundnut genotypes under rainfed conditions, Zonal Agricultural Research Station, Ambikapur, Madhya Pradesh, India.

Variety	Pod yield (t ha^{-1}) 1994	1995	1996	Mean	100-seed mass	Pod $plant^{-1}$ (g)	Shelling (%)	Maturity (days)
ICGV 87206	2.44	1.39	1.04	1.62	39.3	14	68	116
ICGV 87232	1.96	1.49	2.10	1.85	42.9	16	71	109
ICGV 87281	2.14	2.19	2.70	2.34	30.9	26	72	112
ICGV 87282	2.09	1.93	2.57	2.20	38.6	17	81	111
ICGV 86884	3.01	1.93	2.22	2.39	47.0	15	68	110
ICGV 86926	2.20	2.19	2.78	2.39	36.2	15	65	114
ICGV 86934	2.68	2.15	2.54	2.46	42.0	14	67	108
ICGV 89317	2.20	2.14	2.81	2.38	41.2	16	69	109
ICGV 91123	2.27	1.29	2.15	1.90	27.2	11	70	112
ICGV 91124	3.43	2.06	2.07	2.52	29.5	15	64	112
ICGV 91129	2.38	0.87	2.27	1.84	35.6	14	74	115
Mean	2.44	1.78	2.29	2.17	37.3	15.2	69.9	112
SEm	±0.04	±0.07	±0.21	±0.24	±0.34	±2.10	±0.50	±0.53
CD (5%)	0.12	0.20	0.60	0.72	1.05	6.05	1.49	1.62
CV (%)	19.0	22.0	16.2	19.5	1.7	22.7	1.3	0.82

nonavailability of suitable high-yielding varieties is the main cause of the low productivity.

Groundnut is sown in uplands during the monsoon (Jun–Nov). Generally the crop suffers from drought because of the break in monsoon in mid-Sep. Suitable high-yielding genotypes need to be identified which can escape drought. The genotypes received from ICRISAT mature in less than 120 days, and can cope with drought.

Eleven groundnut genotypes were sown on uplands in a randomized block design with three replications at the Zonal Agricultural Research Station, Ambikapur. The sowing was done in the last week of Jun with a 30-cm interrow spacing, and a 10-cm intrarow spacing. Fertilizer was applied at the rate of 100 kg DAP ha^{-1} The trial was conducted for 3 years, i.e., 1994, 1995, and 1996. Pod yield and yield attributing characters were recorded. Pod yields were 1.96–3.43 t ha^{-1} in 1994, 0.87–2.19 t ha^{-1} in 1995, and 1.04–2.81 t ha^{-1} in 1996. The highest yielding varieties were ICGV 91124 (3.43 t ha^{-1}) in 1994, ICGV 86926 (2.19 t ha^{-1}) in 1995, and ICGV 89317 (2.81 t ha^{-1}) in 1996. On the basis of mean pod yield ICGV 91124 (2.52 t ha^{-1}) ranked first followed by ICGV 86934 (2.46 t ha^{-1}) (Table 1). The mean shelling percentage was 64–81. ICGV 86884 had the highest 100-seed mass of 47 g, and mean pod yield of 2.39 t ha^{-1}, ICGV 87282 produced only 2.2 t pods ha^{-1}. However, its shelling percentage was highest (81) and was selected for further evaluation with other genotypes.

Response of Groundnut Cultivars to *Rhizobium* Inoculation in West Bengal, India

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Groundnut is currently not a major oilseed crop in West Bengal, but it is gaining popularity in this state. It is cultivated during the rainy season as a rainfed crop in the drier tracts of West Bengal. During the postrainy season it is cultivated mostly on residual moisture in river beds/*char* areas, and after paddy with protective irrigation. In summer, the groundnut crop gives a higher yield with irrigation. The crop sequences followed are rape/mustard-summer groundnut, kharif paddy-summer groundnut, potato-summer groundnut, etc. It is necessary to have the relevant *Rhizobia* in the soil to cultivate a legume like groundnut successfully. Cox et al. (1982) reported that nitrogen limitation could inhibit growth and productivity of bunch varieties of groundnut. Nambiar and Dart (1983) conducted experiment at ICRISAT, and found that excess or insufficient moisture reduced N fixation in groundnut. In certain soils, particularly those of the tropical and subtropical regions, it is difficult for *Rhizobia* to survive because of unfavorable environmental conditions (Podder et al. 1996).

Table 1. Response of groundnut cultivars to inoculation with *Rhizobium* strain (JCG 1 + IGR 6) on yield components, yield and number of nodules $plant^{-1}$, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India, summer 1994.

Variety	100-kernel mass (g)	Shelling (%)	Yield (kg ha^{-1}) Pod	Haulm	Kernel	No. of nodules $plant^{-1}$ at 45 DAS
K 150	58	74	4333	6703	2385	19.6
TGS 1	50	64	3333	8110	1596	34.5
TAG 24	56	66	3555	4962	1733	15.8
ICGV 86015	53	67	2851	6517	1447	19.9
JL 24	56	76	4148	7888	2393	25.5
ICGS 44	59	75	4592	6740	2558	30.3
R 8806	58	79	3777	8295	2256	18.8
SEm	±2.45	±2.46	±22.2	±49.5	±15.9	±1.65
CD 5%	5.98	6.18	65.2	141.4	34.9	3.62
Inoculated	55	72	3883	7181	2126	24.5
Non-inoculated	56	71	3714	6877	1977	22.4
SEm	±0.85	±1.31	±11.7	±26.4	±8.3	±0.78
CD 5%	NS	NS	34.14	58.11	18.2	NS

DAS = Days after sowing. Interaction between variety and inoculation was not significant.

Therefore, an experiment for evaluation of the response of groundnut varieties to inoculation of *Rhizobia* was undertaken. The field experiment was conducted on sandy loam alluvial soil at the Central Research Farm Gayeshpur, Regional Research Station, New Alluvial Zone, Bidhan Chandra Krishi Viswavidyalaya (BCKV), during summer 1994. The experiment was conducted in a Factorial Randomized Block Design with seven varieties; and with and without inoculation. The soil of the experimental plot had a pH 6.85, total N 0.038%, organic carbon 0.42%, available P_2O_5 18 kg ha^{-1}, and K_2O 120 kg ha^{-1}. The crop was sown on 29 Jan 1994, and was harvested during end of May 1994. The crop received 20 kg N as urea, 60 kg P_2O_5 as single superphosphate, and 40 kg K_2O ha^{-1} as muriate of potash. Gross plot size was 5 × 2.1 m, and the spacing adopted was 30 × 10 cm. The inoculation of seed was done with the *Rhizobium* strain (JCG 1 + IGR 6) before sowing of the crop. The source of the *Rhizobium* was Nodule Research Laboratory of BCKV. The seeds were moistened with water and then the charcoal based *Rhizobium* culture was mixed with groundnut seeds. The seeds were dried in the shade for 4 h, and then were sown. Two intercultural operations and four irrigations were given to the crop. Plant protection measures were undertaken only when required.

Varieties differed significantly for all the characters included in the study (Table 1). ICGS 44 recorded the highest pod and kernel yields. The highest haulm yield was recorded by R 8806. However, the number of nodules $plant^{-1}$ were the highest in TGS 1. Inoculation with *Rhizobium* had no influence on 100 kernel mass, shelling percentage, and number of nodules $plant^{-1}$. But significantly higher haulm, kernel, and pod yields were obtained with inoculation (Table 1). The beneficial effects of *Rhizobium* inoculation in groundnut have been reported by Nambiar and Dart (1983), and Podder et al. (1996).

The result of the experiment indicate that ICGS 44, K 150, and JL 24 may be cultivated during summer season for obtaining higher yield of groundnut. Inoculation of seed with *Rhizobium* culture will also help in enhancing the yield.

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Optimum Rates of Nitrogen Fertilizer in Cropping System of Wheat (Winter) and Groundnut in Shandong Province, China

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In recent years, the area of groundnut under spring-planting has been decreasing continually while a cropping system of wheat (winter) followed by groundnut has expanded rapidly covering more than 40% of the groundnut cropping area in Shandong. In order to develop a package of fertilizing practices and cultural techniques under this system, studies were conducted at Shandong Peanut Research Institute (SPRI) in China with support of Cereals and Legumes Asia Network (CLAN), ICRISAT. This paper reports the results of a study on application of nitrogen (N) fertilizer under a double-cropping system.

A field experiment was conducted at SPRI during 1993/94 using a split-plot design with three replications. The main treatment, Annual Rate of Total Nitrogen (ARTN) comprised three rates of N: 150 kg ha^{-1} (A_1), 300 kg ha^{-1} (A_2) and 450 kg ha^{-1} (A3). The subtreatment consisted of three methods of N application: (MNAs): B_1 – all N as basal dressing of wheat (BDW); B_2 – 2/3 N as BDW, and 1/3 N as additional fertilizer to wheat at elongation stage (AFWES); and B_3 – 1/5 N as BDW, 2/5 N as AFWES, and 2/5 N as basal dressing of groundnut (BDG) (Table 1). Urea (46% N) was used as N source. The soil was sandy loam with organic matter 0.8%, available N 42 mg kg^{-1}, available P 20 mg kg^{-1}, and available K 58 mg kg^{-1}. A wide-ridge planting method was used (Wang Caibin et al. 1992). Besides N treatments, 60 t ha^{-1} of farmyard manure, 1.1 t of calcium superphosphate (12% P_2O_5) and 0.45 t ha^{-1} of potassium sulphate (59% K_2O) were incorporated into soil before

Table 1. Experimental treatments of fertilizer to wheat and groundnut, China, 1993/94.

Main treatment (ARTN)	Rates (kg ha^{-1})	B_j	BDW (kg ha^{-1})	AFWES (kg ha^{-1})	BDG (kg ha^{-1})
		B_1	150	0	0
A_1	150	B_2	100	50	0
		B_3	30	60	60
		B_1	300	0	0
A_2	300	B_2	200	100	0
		B_3	60	120	120
		B_1	450	0	0
A_3	450	B_2	300	150	0
		B_3	90	180	180

ARTN = Annual rate of total N.
MNA = Methods of nitrogen application.
BDW = Basal dressing of wheat.
AFWES = Additional fertilizer to wheat at elongation stage.
BDG = Basal dressing of groundnut. BDG was applied 10–15 cm under the groundnut ridge surface 2 weeks prior to sowing of groundnut.

Table 2. Yields of wheat, groundnut and annual total (AT) under various main and subtreatments, China, 1993/94.

Treatment		Wheat (kg ha^{-1})	Groundnut (kg ha^{-1})	Annual total (kg ha^{-1})
Main	A_1	4713.0 a	4777.5 b	9490.5 b
	A_2	4800.0 a	5074.5 a	9874.5 a
	A_3	4030.5 b	4350.0 c	8380.5 c
SE		±41.27	±53.62	±58.31
Sub	B_1	4360.5 c	4653.0 a	9012.0 a
	B_2	4497.0 b	4894.5 a	9391.5 a
	B_3	4686.0 a	4656.0 a	9342.0 a
SE		±51.29	±88.08	±111.31

Table 3. Yields and annual benefit (AB) from wheat and groundnut at various fertilizer combinations, China, 1993/94.

Treatment (A_iB_j)	Wheat (kg ha^{-1})	Groundnut (kg ha^{-1})	Annual total (kg ha^{-1})	Annual benefit (Yuan ha^{-1})
A_1B_1	5139.0 a	4500.0 cde	9639.0 b	20118.0 a
A_1B_2	4698.0 b	5149.5 ab	9847.5 b	20667.0 a
A_1B_3	4300.5 d	4683.0 bcd	8983.5 c	20147.0 ab
A_2B_1	4489.5 c	5008.5 abc	9498.0 b	20814.0 a
A_2B_2	4672.5 b	5008.5 abc	9679.5 b	20733.0 a
A_2B_3	5236.5 a	5208.5 a	10440.0 a	22050.0 a
A_3B_1	3450.5 f	4450.5 de	7839.0 e	17070.0 c
A_3B_2	4120.5 e	4525.5 cde	8646.0 d	18075.0 bc
A_3B_3	4521.0 c	4075.5 e	8596.5 d	17117.0 c
SE	118.05	191.78	237.40	675.18

Annual benefit = Price of wheat × yields of wheat + price of groundnut × yields of groundnut - N fertilizer cost. (Wheat costs 1.7 Yuan kg^{-1}, groundnut costs 3.2 Yuan kg^{-1}, and pure N costs 5.0 Yuan kg^{-1}; 1 US$ = 8.27 Yuan.)

wheat was sown in autumn. The area of each subplot was 20 m^2, but only 15 m^2 for yields record (excluding the border plants). Wheat was sown on 2 Oct 1993 and harvested on 18 Jun 1994. Groundnut was sown on 20 Apr 1994 and harvested on 5 Sep 1994. Varieties Hesheng No 2 (winter wheat) and Luhua No 13 (groundnut) were used.

Results from the main treatment showed that yields of wheat, groundnut, and annual total were higher at A_2 than A_1, although the differences were not significant. Yield decreased at A_3. There were significant differences in wheat yields between three MNAs with an order of $B_3>B_2>B_1$. A highest yield of wheat was obtained by application of N twice in a year. In contrast to wheat, it seemed that groundnut was less sensitive to MNA wheat indicating that the yield of groundnut was mainly determined by ARTN rather than MNA, and a similar performance was found for the AT (Table 2).

From factor combination analyses (Table 3) we can see that the best rate N for wheat was 150–180 kg ha^{-1} (A_2B_3 and A_1B_1), and the yield difference in groundnut was less than that of wheat when ARTN was 300 kg ha^{-1}, though A_2B_3 could produce the highest yield. Data from Table 3 indicated that A_2B_3 was the best one for both Annual total and Annual benefit.

It can be concluded that yields of both wheat and ground were greatly affected by rate of N applied. The optimum rate of N for wheat was 150–180 kg ha^{-1}. Yields of groundnut were mainly determined by ARTN, with a little influence from MNA. As groundnut can obtain N from rhizobia to meet its growth requirement, all N can be applied to wheat to ensure the yield of wheat when the ARTN is not enough for two crops. N fertilizer can be applied to two crops (both wheat and groundnut, three times a year) when ARTN is sufficient (over 150 kg ha^{-1}).

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Effect of Seed Rate and Row Spacing on Confectionery Groundnut in West Bengal, India

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India is the largest producer of groundnut in the world. Research on confectionery groundnut has only started in recent years, and is very meager (Nugrahaeni et al. 1996). Jadhao et al. (1992) reported that 30 × 15-cm, and 45 × 10-cm spacings gave higher groundnut yields than 30 × 10-cm, 30 × 20-cm, 45 × 15-cm, and 45 × 20-cm spacings in the summer season. Nandania et al. (1992) observed an increase in pod yield from 1.36 to 1.62, and an increase in fodder yield, from 2.13 to 2.52 t ha^{-1}, with an increase in seed rate from 80 to 120 kg ha^{-1} in the rainy season. The objective of the present experiment was to study the effect of seed rate and spacing on growth and yield of confectionery groundnut during summer season in West Bengal.

A field experiment was carried out at the Regional Research Station, Gayeshpur, Nadia, Bidhan Chandra Krishi Viswavidyalaya during summer season of 1997. The soil of the experimental plot was sandy loam with 46% sand, 34% silt, and 17% clay, with pH of about 6.85. The experiment was laid out in a 4 × 3 factorial Randomized block design with three replications. The net plot size was 4 × 2.4 m. There were 12 treatment combinations comprising four seed rates and three levels of row spacing. Variety TGS 1 was sown at 30, 40, and 50 cm row spacings with seed rates of 80, 100, 120, and 140 kg ha^{-1}. The crop received 20 kg N, 60 kg P_2O_5, and 40 kg K_2O ha^{-1}. Nitrogen and phosphate were applied through diammonium phosphate and potash through muriate of potash. Besides these, each plot also received gypsum at the rate of 400 kg ha^{-1}. All the fertilizers and 1/2 of the gypsum were applied as basal; the other half of gypsum was applied at the time of pegging. The crop was sown on 31 Jan 1997 and harvested on 6 Jun 1997. At the time of sowing seeds were treated with Dithane® M-45. Ten plants were dug out from each net plot, and the pods were stripped from those plants to record plant observations.

Table 1. Effect of seed rate and row spacing on plant height, yield components, and yield of confectionery groundnut, West Bengal, India, summer 1997.

Treatment	Final plant stand plot^{-1}	Plant height (cm)	Filled pods plant^{-1}	100-kernel mass (g)	Shelling (%)	Pod yield (t ha^{-1})	Kernel yield (t ha^{-1})	Haulm yield (t ha^{-1})
Seed rate (kg ha^{-1})								
80	101.34	30.05	9.31	73.79	64.49	1.85	1.19	3.75
100	108.00	33.22	14.51	72.01	65.99	2.64	1.74	5.33
120	133.34	31.13	8.79	73.06	68.43	2.18	1.49	4.27
140	168.00	35.08	9.10	71.46	71.56	2.29	1.63	4.58
SE	±2.28	±0.157	±0.22	±0.57	±0.25	±0.37	±0.26	±0.76
CD at 5%	6.76	0.46	0.64	NS	0.73	1.08	0.76	2.22
Row spacing (cm)								
30	129.50	32.33	13.48	72.51	67.06	2.24	1.51	4.19
40	128.50	32.79	9.93	72.48	67.79	2.37	1.6	4.97
50	125.00	32.05	7.87	72.76	68.00	2.11	1.43	4.3
SE	±1.852	±0.18	±0.19	±0.49	±0.21	±0.32	±0.22	±0.66
CD at 5%	NS	0.53	0.56	NS	0.61	0.94	0.64	1.93

NS = nonsignificant.

Effect of seed rate and row spacing on plant height, yield components, and yield is presented in Table 1. Height of the plant was significantly higher with the 140 kg ha^{-1} seed rate followed by the 100 kg ha^{-1} seed rate. Plant population significantly differed with seed rate. Final plant stand plot^{-1} increased with increase in seed rate. The trend was similar in shelling percentage. Number of filled pods plant^{-1} was significantly higher with the 100 kg ha^{-1} seed rate then in the other seed rates. Pod and kernel yields were significantly higher with the 100 kg ha^{-1} seed rate over all other rates. There was no significant difference in pod yield between the 120 and 140 kg ha^{-1} seed rates. The increased pod yield with 100 kg ha^{-1} seed rate was mainly because of increased number of filled pods plant^{-1}. Lowest pod and kernel yield were observed with the 80 kg ha^{-1} seed rate. In the case of haulm yield, highest yield was recorded with the 100 kg ha^{-1} seed rate followed by the 140 kg ha^{-1} seed rate. It was significantly higher over the 120 kg ha^{-1} seed rate. Height of the plant at harvest was significantly higher at 40-cm row^{-1} spacing. There was no significant difference in final plant stand, and the 100-seed mass among different spacing treatments. Shelling percentage was comparatively high when sowing was done at wider spacing (50 cm row to row). Pod and kernel yields were highest at 40-cm row spacing, and they were significantly higher over 30-cm and 50-cm row spacings. Highest haulm yield was observed with a 40-cm row spacing. Number of filled pods plant^{-1} decreased progressively with increasing spacing. Panwar and Bhosale (1992) reported that M 13, a confectionery variety, gave more dry pod yield with a 45-cm row spacing over a 30-cm row spacing. Dwivedi and Gautam (1992) also observed more pod yield with 40 × 20-cm spacing than with 30 × 20-cm and 50 × 20-cm spacings. Interaction between seed rate and spacing on pod yield was significant (Table 2). Pod yield was significantly higher with a 100 kg ha^{-1} seed rate and 40-cm row spacing, followed by 120 kg ha^{-1} seed rate

Table 2. Interaction effect between seed rate and row spacing on pod yield (t ha^{-1}) of confectionery groundnut, West Bengal, India, summer 1997.

	Pod yield			
Row spacing (cm)	80	100	120	140
30	1.75	2.42	2.45	2.34
40	1.87	3.14	2.10	2.35
50	1.93	2.36	1.98	2.16

SEm = ±0.45; CD at 5% = 1.32.

with 30-cm row spacing. Lowest yield was recorded with a 80 kg ha^{-1} seed rate at 30-cm row spacing. It can be concluded that for confectionery groundnut, a 100 kg ha^{-1} seed rate and 40-cm row to row spacing can be adopted to obtain higher yields in West Bengal.

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Food Quality

Arachilipometer – A Simple Device to Determine Oil Content of Groundnut Seeds

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Oil content and the specific gravity of groundnut kernels have an inverse relationship (Misra et al. 1993, Yadav and Misra 1994). Utilizing this principle, a densitometer was developed to determine the oil content of groundnut samples.

Materials used to fabricate arachilipometer (ALM)

Calibration cup: Screw-cap of a polythene sample-bottle (outer diameter (OD) 1.5 cm, height 1.2 cm).

Stem: Copper tubing (length 21 cm, OD 0.3 cm, and internal diameter (ID) 0.2 cm).

Buoy: Stainless steel container with lid (OD 4 cm, height 6.3 cm, stainless steel sheet thickness 0.5 mm).

Pan: A perforated stainless steel cup (OD 5.5 cm, height 2.0 cm, stainless steel sheet thickness 0.15 mm) with an attached galvanized iron-wire-hook.

All the parts were fastened together by lead brazing as shown in Figure 1. The ALM thus fabricated weighed 56.34 g.

Calibration

The specific gravities (SG) of 16 kernel samples containing 40 to 55% oil content, were calculated using the following equation given by Misra et al. (1993).

$$SG = \frac{239.65 - \text{Oil}(\%)}{176.81}$$

From the SG value, the volume of a 10-g sample (VS), weight of equivalent volume of kerosene (WtEQVK), and weight of a 10-g sample when immersed in kerosene (WtSK) were calculated using the following formulae:

$$VS = \frac{10}{SG}$$

WtEQVK = VS × (specific gravity of kerosene = 0.786)

WtSK = 10 - WtEQVK

Table 1. Physical parameters of 16 samples of groundnut containing 40–50% oil.

Oil (%)	Predicted value of SG	WtSK[1]	Decrease over preceding WtSK (mg)
40	1.12918	3.03920	--
41	1.12352	3.00413	35.07
42	1.11787	2.96877	35.36
43	1.11221	2.93299	35.78
44	1.10655	2.89684	36.15
45	1.10090	2.86038	36.46
46	1.09524	2.82349	36.89
47	1.08959	2.78628	37.21
48	1.08393	2.74861	37.67
49	1.07828	2.71061	38.00
50	1.07262	2.67215	38.46
51	1.06696	2.63328	38.87
52	1.06131	2.59406	39.22
53	1.05575	2.55435	39.71
54	1.05000	2.51429	40.06
55	1.04434	2.47371	40.58

WtSK = weight of a 10-g sample when immersed in kerosene.

Table 2. Comparison of performance of arachilipometer (ALM) with that of standard Soxhlet (SOX) extraction method in 23 genotypes of groundnut.

Genotype	Oil content (%)		Residual
	Oil_{SOX}	Oil_{ALM}	
Dh 48	44.1	43.5	- 0.6
TG 12	43.8	44.5	0.7
OG 933	47.6	46.5	- 1.1
JL 220	44.7	45.5	0.8
DRG 21	42.1	43.0	0.9
BAU 12	45.1	46.0	0.9
BAU 13	49.1	47.5	- 1.6
TG 22	43.5	44.0	0.5
DRG 9	41.1	42.5	1.4
GG 2	50.5	49.0	- 1.5
Girnar 1 (a)	54.1	52.5	- 1.6
(b)	53.9	51.5	- 2.4
JL 24	50.6	49.5	- 1.1
Gangapuri	49.1	48.0	- 1.1
ICGS 11	51.1	50.5	- 0.6
TMV 2	50.9	49.5	- 1.4
ICGS 44 (a)	50.2	49.0	- 1.2
(b)	51.8	51.0	- 0.8
S-2-30	49.2	50.0	0.8
SB XI	47.0	46.0	- 1.0
TMV 10	52.1	51.5	- 0.6
M 337	50.5	51.0	0.5
M 13	49.4	48.0	- 1.4
Mean	48.3	47.8	
Minimum	41.1	42.5	
Maximum	54.1	52.5	
CV (%)	0.7		
r	0.97**		

The values of WtSK (Table 1) were used to graduate the stem of ALM as follows:

1. Weights equal to WtSK corresponding to 55% oil (2.474 g) were placed in the calibration cup. A metal piece (weighing 4.833 g in this instance) was fastened permanently as counterpoise with the pan so that upon floating ALM in kerosene, the pan, float, and about 1 cm of the stem remained immersed in kerosene while the rest of the stem remained above the meniscus. The ALM was allowed to float freely and stabilize. The point on the stem coinciding with the meniscus was marked 'A'.
2. Weights equal to the next lower value of oil content (or the next higher value of WtSK) were placed in the calibration cup, the ALM allowed to float and stabilize, and the point of the stem coinciding with meniscus was marked. Similarly, graduations were completed up to point B – representing the mark for a sample containing 40% oil (WtSK = 3.039 g).
3. The weights kept in the calibration cup were removed. Seeds of 23 genotypes were split, and the two cotyledons were placed in separate pools to determine oil content by Soxhlet method (oil_{SOX}) and by ALM (oil_{ALM}). Splitting of seeds into constituent cotyledons is a prerequisite for determining oil (ALM), since the relationship between specific gravity and oil content does not hold good for whole kernels (Misra et al. 1993). Oil_{ALM} was determined as follows;
   1. A precisely weighed 10-g sample was transferred to the pan.
   2. The ALM was then lowered in kerosene, agitated gently to release air bubbles if any, and allowed to stabilize. The graduation mark on stem coinciding with meniscus of kerosene was read as the oil content.

Oil_{SOX} of 23 samples ranged from 41.1% (DRG 9) to 54.1% (Girnar 1) with a mean of 48.3%, and a CV of 0.7%. (Table 2). The oil_{ALM} ranged from 42.5% (DRG 9) to 52.5% (Girnar 1) with a mean of 47.8%, and a CV of (Table 2). The correlation between oil_{SOX} and oil_{ALM}

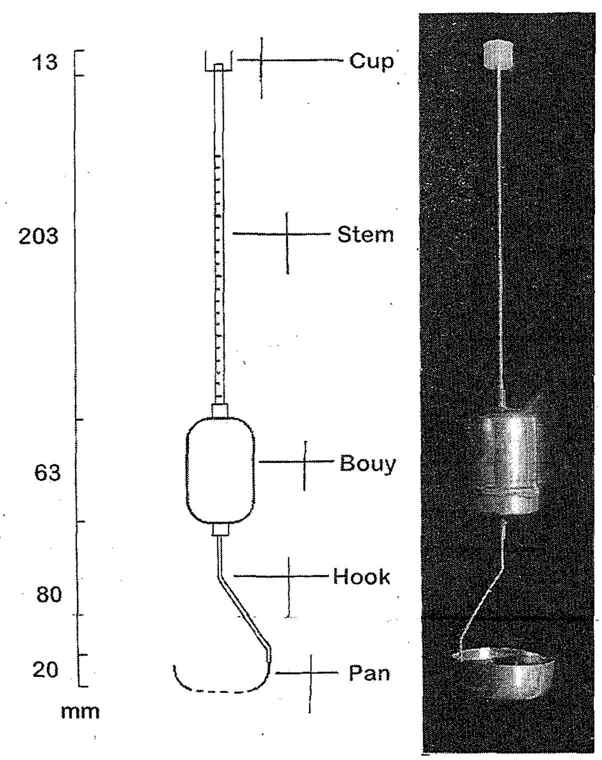

Figure 1. Line diagram and photograph of arachilipometer.

values was very high (r = 0.972**) and the residuals (-2.4 to +1.4%) were randomly distributed about the mean, showing that ALM could be used for oil content determination of groundnut samples. Compared to NMR spectrometry (Jambunathan et al. 1985), which is widely used to determine oil content in groundnut, the ALM technique is very simple and economical. There, however, exists scope for improvement in the design of ALM. Though ALM essentially determined the specific gravity of the groundnut seeds, it was christened 'arachilipometer' to highlight its applicability (*"Arachis"* the generic name of groundnut; and "lipid" oily substances).

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Frozen Unshelled Groundnut Product

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Quick-freezing and low temperature storage technique is widely used for food processing to keep freshness and quality of the product. This technique was applied to fresh, unshelled groundnut to develop a new type of product which could maintain fresh taste and nutritive values even after several months of storage.

A groundnut variety, Daepungtangkong, was grown in the experimental field of NCES in 1996. Immature pods were harvested around 10 to 20 days before full maturity, washed, and steamed at 105°C for 5 min to stop enzyme activity. After vacuum packing (at –760 mm Hg for 10 min) in 0.08 mm polyvinyldichloride film, the pods were immediately frozen at –70°C for 24 h and stored at -20°C for use. Physico-chemical properties of frozen groundnut were investigated at 2 months after storage and compared to those of conventionally dried groundnut.

When thawed after 2 months storage, the kernels were very palatable with softness and fresh taste.

Acid value, and hardness (measured as the compression force on the probe of a texture analyzer) were much lower in frozen groundnut than those in the air-dried ones. Presence of free sugars is one of the important factors affecting groundnut taste. In frozen groundnut their amount was considerably reduced compared to freshly harvested groundnut. But in dried groundnut no free sugar was detected (Table 1).

The above results suggest that frozen groundnut can be consumed after the steaming and freezing technique described above. However, such groundnut will require transportation under cold storage to deliver this product safely to consumers.

Table 1. Changes in physico-chemical properties of groundnut by steaming and freezing treatments.

Treatment	Moisture (%)	Acid value (KOH mg g^{-1})	Soluble tannin	Hardness (g 3.14-mm^{-2})	Free sugars (%)
Fresh groundnut at harvest	47.6	0.3	50.7	1623	1.60
Frozen groundnut after 2 months' storage	41.8	0.3	14.2	953	0.12
Dried groundnut	7.4	12	14.6	2285	ND[1]

1. Not detected.

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- Groundnut elite germplasm ICGV-SM 86715. Plant Material Description no. 75. ISBN 92-9066-371-5. Order code PME 075.

  Gives brief description of the high-yielding interspecific backcross derivative resistant to rust, late leaf spot and pepper spot. Released in Mauritius as Veronica, it has also performed well in Malawi, Swaziland, and Niger.

Brouwer, J., and Bouma, J. (eds.) 1997. Soil and crop growth variability in the Sahel: highlights of research (1990-95) at ICRISAT Sahelian Center. Information Bulletin no. 49. 48 pp. ISBN 92-9066-365-0. Order code IBE 049. Price US$ 7 (LDC), US$ 16 (HDC), Rs 150 (India). Also available in French.

Soil and crop growth variability in the Sahel are essential to the survival of Sahelian ecosystems and agroecosystems. The role of water, plants, animals, farmers, pastoralists, and agronomic researchers in causing, maintaining, and changing such variability, over distances of a few meters up to hundreds of kilometers, was investigated in a 5-year project. Examples are given of how the resulting improved understanding of this variability can help increase agricultural production in the Sahel, contribute to sustainable land use, and increase the effectiveness of local agricultural research.

Laryea, K.B., and **Katyal, J.C.** (eds.) 1997. Measuring soil processes in agricultural research. Technical Manual no. 3. 100 pp. ISBN 92-9066-359-6. Order code TME 003. Price US$ 12 (LDC), US$ 30 (HDC), Rs 290 (India).

Soil and crop management strategies are location- and season-specific in the way they affect soil processes and resource utilization by crops. Research findings on these effects therefore need to be modeled if they are to be extrapolated to other locations with similar soils and climatic conditions. This manual presents practical methods for assessing management effects on such soil processes as water infiltration and erosion by water, and on water, air, and nutrient use by crops. It covers the basic elements of soil physical characterization, and deals principally with the role of soil structure on water infiltration and percolation (and, as a consequence, on water balance in the soil profile), on heat flow (and therefore on the soil thermal regime), on aeration, and on the mobility of roots and soil microorganisms.

The use of PERFECT software in simulation modeling is described in detail.

Renard, C. (ed.) 1997. Crop residues in sustainable mixed crop/livestock farming systems. 336 pp. ISBN 92-9066-231-8. Order code CPE 078. Price US$ 28 (LDC), Rs 980 (India).

In many tropical areas the main constraint to increased output of livestock products is the inability of producers to feed animals adequately throughout the year. Yet opportunities exist to enhance ruminant livestock feed supplies by using crop residues, such as cereal straw and legume haulms. Greater emphasis is therefore now being placed on vegetative production in plant breeding research. Crop residues also play an important role in conserving soil moisture, preventing erosion and providing products such as fuel or thatch for smallholders.

This book provides a multidisciplinary perspective on crop residues, bringing together crop, animal, and social scientists from six continents. It has been developed from papers presented at a workshop held in April 1996 at ICRISAT Asia Center, as part of the Systemwide Livestock Program of the Consultative Group on International Agricultural Research (CGIAR) convened by the International Livestock Research Institute (ILRI), based in Africa. It will appeal to a wide readership in disciplines as diverse as agronomy, soil science, plant breeding, animal nutrition, and socioeconomics.

Copies also available from: ILRI, P O Box 30709, Nairobi, Kenya. Price US$ 28 (LDC), and CAB International, Wallingford, Oxon OX10 8 DE, UK. Price £ 49.95 (HDC).

Singh, A.K., Mehan, V.K., and Nigam, S.N. (eds.) 1997. Sources of resistance to groundnut fungal and bacterial diseases: an update and appraisal. Information Bulletin no. 50. 48 pp. ISBN 92-9066-367-7. Order code IBE 050. Price US$ 6 (LDC), US$ 16 (HDC), Rs 165 (India).

Groundnut foliar fungal diseases, stem and pod rots and wilt cause severe pod yield losses worldwide, while aflatoxin contamination causes serious quality problems. This information bulletin updates the list of sources of resistance to six important fungal and bacterial diseases and provides information on some of their agronomic traits and reaction to other diseases. Merits and demerits of these resistance sources are highlighted, that may influence their usage in different situations.

SATCRIS listings

The following two listings of 1996 and 1997 publications have been generated from ICRISAT's electronic bibliographic database SATCRIS – the Semi-Arid Tropical Crops Information Service. Copies of entries followed by JA or CP numbers can be obtained by writing to

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Groundnut publications

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Information for IAN contributors

Publishing objectives

The *International* Arachis *Newsletter* (IAN) 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* L.) 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 600 words) about matters of interest to its readers.

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How to format contributions?

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