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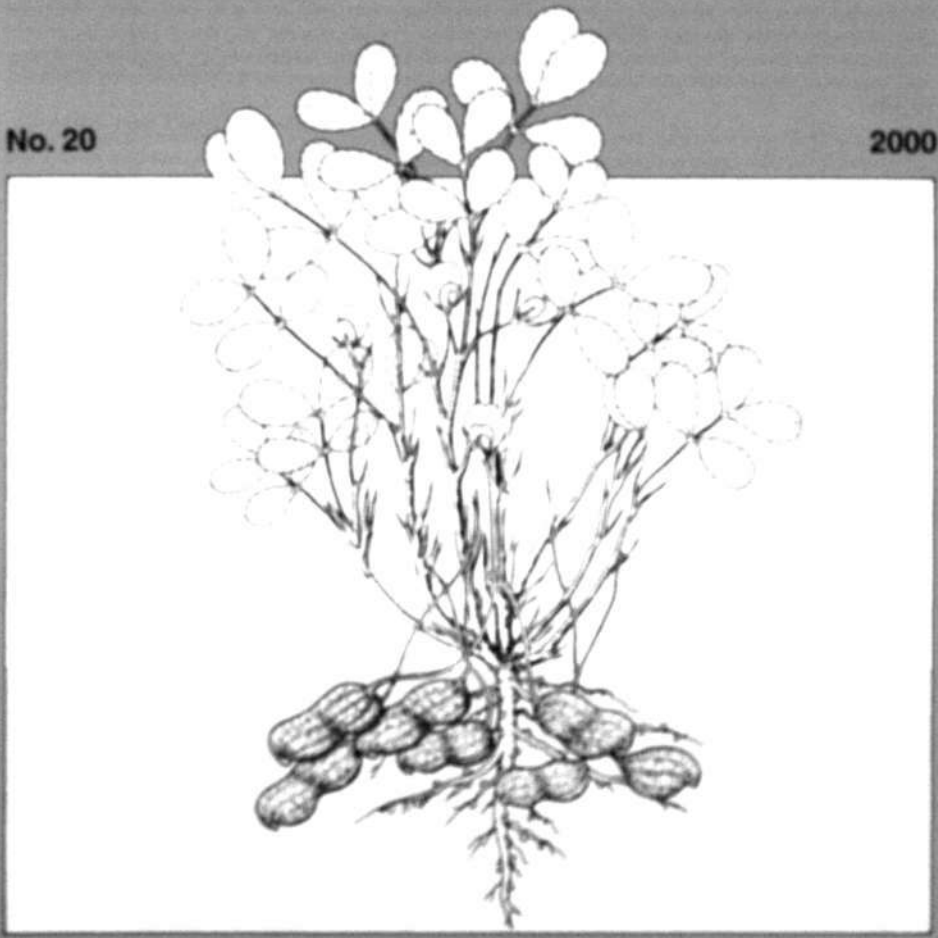

International *Arachis* Newsletter

Co-publishers

Peanut CRSP
Peanut Collaborative Research Support Program
(http://www.griffin.peachnet.edu/pnutcrsp.html)

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

About Peanut CRSP

The Peanut Collaborative Research Support Program is an international program supported by 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, postharvest processing, and utilization). Peanut CRSP also works to foster human resource development and the communication of research results.

The Peanut CRSP provides support for collaborative research, training, and exchange of information through grants to 10 universities in USA linked to 14 host countries in the developing world. Both host countries and USA are expected to benefit from the activities of Peanut CRSP. Peanut CRSP actively collaborates with other organizations with interest in advancing development through the application of science and technology.

About ICRISAT

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

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the SAT. 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. ICR1SAT 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 16 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 United Nations Development Programme (UNDP), and the World Bank.

IAN Scientific Editor

S N Nigam

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From the Editor

The world groundnut community suffered a great setback this year when it lost two of its colleagues to cruel hands of death. Dr Marfo from Ghana and Dr Escano from the Philippines played a significant role in promoting groundnut research and development in their countries. Their presence in regional fora and other meetings always brought life and depth to discussions because of their vast experience not only in groundnut crop but also in general agriculture of their countries. The IAN fraternity sends its condolences to the two families.

With so many things happening this year in succession at ICR1SAT, the publication of this issue of IAN, in spite of our good intentions, got delayed. We will make our best effort in 2001 to bring back the schedule of publication to September/October. There is a general concern about the lack of impact of groundnut research on on-farm productivity, particularly in less favorable areas, among the development investors. I am sure there are several success stories lying unnoticed and unsung with researchers, extension workers, and crop processors in these areas. We will be very happy to include them in IAN. Similarly, sharing one's on-farm research/farmers' participatory research experiences through the medium of IAN will be enlightening to readers of IAN.

I would like to acknowledge the contribution of R Bandyopadhyay, S Chandra, S L Dwivedi, C Johansen, N Kameswara Rao, J V D K Kumar Rao, N Mallikarjuna, E M Minja, S Pande, G V Ranga Rao, D V R Reddy, L J Reddy, T J Rego, O P Rupela, P Subrahmanyam, R P Thakur, and H D Upadhyaya as reviewers of the contributions to this issue of IAN, and Learning Systems Unit, Information Resource Management Program, ICRiSAT for compiling the SATCRIS listing and verifying the references cited in this issue.

I look forward to your contributions to the 2001 issue of IAN.

S N Nigam

Obituary

K O Marfo

Dr K O Marfo, an outstanding groundnut physiologist from the Savanna Agricultural Research Institute in Tamale, Ghana, was among those who were killed on 5 June 2000 at Accra in the crash of a domestic airliner. An important collaborator and friend of ICRISAT, Dr Marfo provided valuable contributions to groundnut research. He published several joint papers with ICRISAT scientists. As part of this collaboration, he spent 6 months at ICRISAT-Niger in 1995 as a visiting scientist.

Dr Marfo was not only an outstanding researcher but also a good friend. His colleagues and friends remember him for making every occasion special and extend sincere sympathy to his family.

C R Escano

Dr Crisanto R Escano, Director, Crops Research Division (CRD), the Philippine Council for Agriculture and Resources Research and Development (PCARRD), Los Banos, Philippines and Philippines Country Coordinator for Cereals and Legumes Asia Network (CLAN), ICRISAT died on 14 August 2000. Cris, as friends and colleagues fondly called him, had been determined to excel in his studies. Through a graduate teaching fellowship, he obtained his Master of Science degree in Soil Fertility and Chemistry at UP Los Banos (UPLB) in 1971. After graduation, he got a graduate research fellowship from the Benchmark Soils Project of PCARRD and the University of Hawaii for a PhD in Agronomy and Soil Science.

Escaflo's professional career began when he served as Instructor at UPLB. In 1974, he was transferred to PCARRD as Program Specialist and was promoted as Senior Program Specialist in 1976, and in September 1980, he was designated as Assistant Director of CRD after

serving as Team leader of the National Soil Resources Commodity. As Assistant Director of CRD, he became coordinator of various development projects of soybean, groundnut, and mung bean. Cris was appointed as Director of CRD in 1986, and was in this position till he passed away.

Escano's effective leadership contributed much to the smooth implementation of CRD's R&D projects. He also became the National Coordinator of the UNDP-FAO Project on Regional Cooperative Programme for the Improvement of Food Legumes and Coarse Grains in Asia and the USAID-Peanut Collaborative Research Support Program (P-CRSP) in the Philippines.

Escaflo was designated Country Coordinator of CLAN from 1986 to August 2000 for which he spearheaded various projects on legumes particularly on groundnut and chickpea that paved the way for a wide utilization by farmers of groundnut varieties, with parent materials having originated from the ICRISAT program. Likewise, a low-cost postharvest storage system on groundnut, which was developed through the collaborative activities with ICRISAT, is now widely used in major groundnut-growing regions in the Philippines.

Because of his dedication to R&D, Escano was appointed as ChiefTechnical Adviser (CTA) ofthe UNDP/FAO-PCARRD/DOST "Accelerated Soybean Production and Utilization Program" during 1992-96. He actively promoted soybean production in Regions 1,2, and 3, which are non-traditional soybean-growing areas leading to increased production due to expansion of growing area and higher yields. Several soybean processing plants have been established, and are being managed by cooperatives. The consumers also benefited by having access to nutritious and delicious soybean-based food products. Because of his accomplishments, many people consider him as "Father of Soybean" in the Philippines.

Escaflo was a well-known personality in national and international communities. His death is a great loss to the scientific community, especially the legumes community.

Peanut CRSP News

In 1999-2000 the Peanut Collaborative Research Support Program (CRSP), USA was reviewed by the External Evaluation Panel (EEP). The team of reviewers visited projects in most locations and arrived at the conclusion that many projects are making good progress. The EEP has recommended that the successful projects be continued for another 5 years, and those that are to end in 2001 be replaced in an open competitively bid process. The Program is in the process of selecting the replacement projects and will shortly develop the proposal for the next phase. The recommendations of the EEP are to continue with research in the four major areas offood safety, production efficiency, socioeconomic constraints, and postharvest processing.

The EEP report lists a number of major accomplishments from the past 5 years. These include:

1. The research conducted at Purdue University, USA (Project PUR10U) and the Food Research Institute in Ghana has shown that the high energy content of groundnuts (peanuts) is offset by the high satiety value of the commodity. This means that consumers are not at higher risk for obesity and cardiovascular problems from a high calorific intake of groundnuts. The research has also shown that groundnut oils are healthy and have positive cardiovascular health benefits. In developing countries and for humanitarian response efforts of the United States Agency for International Development (USAID), the information that groundnut is a very hunger-satisfying food, with high protein and high energy suggests that this crop should be exploited more in times of civil crisis and famine since more hunger prevention is delivered per payload than from the commonly used emergency rations.

   This research has received attention in USA where it has been used to promote groundnut consumption, which has helped reverse a 5-year (18%) decline in consumption. One industry representative states that consumption ofgroundnut in USA has increased 13% since this research began and the impact has been estimated to be worth US$ 500 million annually.

2. Research on germplasm of Bolivian origin (Project UFL16P) in Florida and Georgia in USA and Bolivia has resulted in the identification of new sources of resistance to the tomato spotted wilt virus (TSWV) disease which has become one of the most limiting diseases in USA. Besides having high yield potential, these lines also have multiple resistance to foliar diseases and other prevalent diseases in USA. A breeding program to exploit this opportunity has been initiated and advanced lines are now available.

   In Bolivia the research has shown that productivity is limited more by management and labor availability than by genetic potential. Labor-saving technologies for harvest have been proposed and are being developed. Extension documents to promote improved management have been prepared and production is increasing.

3. In Malawi, Peanut CRSP (Project UGA28P) is focused on developing and exploiting virus resistance. Peanut CRSP has supported the testing by the national program of lines resistant to groundnut rosette developed by ICRISAT. These lines are now being released and are being multiplied for distribution to farmers, with support from the USAID/Malawi mission. The potential benefits to Malawi farmers are the elimination of rosette epidemics that decimate production every 5-7 years. This will provide greater food stability, higher mean yields, and encourage more farmers to produce groundnuts since the risk of loss will be decreased.

   Studies of the variability of groundnut rosette virus across Africa indicate that resistance based on viral coat-protein of the groundnut rosette assistor virus should be stable. Research in Georgia has produced transformants using a synthetic gene.

4. In Senegal (Project TAM17P), the cultivar Fleur 11 developed by scientists of the Institut Senegalais de recherche agricole (ISRA) and Centre de Cooperation International en Recherche Agronomique pour le Developpement (CIRAD) is being adopted by farmers. On-farm socioeconomic studies by another Peanut CRSP project (UCN36S) shows that farmers find this line maintains 25% yield advantage over the established variety. Presently, adoption is limited by seed volumes, but the potential impact will be an additional US$ 18 million annually to groundnut farmers in Senegal.

5. In the Philippines 35% of children are deficient in vitamin A. This situation causes blindness and decreases child survival. Market research conducted with Peanut CRSP support (Project UGA04U) has shown that peanut butter is consumed by all sectors of the population, a fact that makes it an ideal vehicle for micro-nutrient health interventions. Scientists supported by Peanut CRSP (UGA04U) worked with commercial groundnut processors and developed a vitamin A-fortified peanut butter. This product has been commercialized and now has 35% market share in the Metro Manila area and is sold nationwide. Commercial competition is encouraging other groundnut processors to develop competing products.

6. Liver cancer rates in Southeast Asia are 36 times those observed in USA. Aflatoxin and hepatitis B interact to greatly increase the risk of this cancer in these areas. Researchers in the Philippines (Peanut CRSP Project UGA04U), worked with a groundnut-based food industry and developed sorting techniques to control aflatoxin contamination. This has allowed companies to exploit the worldwide market opportunities for ethnic Filipino sauces and expand food processing operations. Production has increased 40% in the year since the technology was deployed, and other companies are positioning themselves to adopt this technology. The impact of widespread adoption of this technology will be less aflatoxin-contaminated groundnut foods in the Philippines, and therefore a healthier population. Commercial competition will ensure widespread adoption of the technology.

7. Consumer market research in Bulgaria has shown that a strong market for groundnuts and groundnut products can be developed. The Peanut CRSP (Project UGA11U) has helped establish a food processing pilot plant in Bulgaria to allow local industries to scale up their operations, by providing training to technicians to familiarize with the major groundnut processing technologies.

8. Scientists in USA (Peanut CRSP Project UGA04U) have transferred the technology of a groundnut snack product that is successful in the Philippines to the US market. A North Carolina groundnut company is test marketing the snack product.

9. Peanut CRSP supported research (Project NCS 19P) contributes to the pest advisory system that is currently the basis for integrated pest management recommendations for groundnut farmers in North Carolina. This system maximizes farm profitability and minimizes environmental damage through the elimination of unnecessary pesticide applications.

10. Basic research at Texas A & M University, Texas, USA (Project TAM33A) supported by Peanut CRSP has identified two genes that are critical to the production of aflatoxins by aspergilli fungi. These genes may allow the use of molecular engineering techniques to eliminate or greatly diminish aflatoxin contamination of groundnuts when infected by the fungus.

11. Peanut CRSP has established an impact assessment and adoption program (Project NCS07) as part of the new socioeconomics thrust. On the other hand technologies for production adopted by the farmers as part of the groundnut program are still being used.

    In the Philippines, Peanut CRSP cultivars are being planted more in the major groundnut region, and their use is a major component of the Philippine's Government agricultural programs. The EEP encourages Peanut CRSP to continue and expand the important work of this project.

12. Socioeconomic research in Senegal (UCN36S) mobilized the Ecole Nationale d'Economie Appliquee (ENEA) to focus on economic problems in farm-level groundnut production. The University of Connecticut, USA has been involved with this development over a 10-year period. The research has determined that the pricing policies, fiscal practices, and market structure measures followed by the Government of Senegal are not fully serving the groundnut sector of the country. Additionally, farm-level efficiency, environmental quality, high seed quality, and input to enhance productivity were considered as the key to future success. The project has encouraged positive interaction between ENEA and 1SRA. This effort has more fully contributed the strengths of ENEA to the agricultural sector.

13. An internet-based management information system was developed. In the 4 years of the present phase, Peanut CRSP has evolved from a largely document and paper-based management to a largely database and electronic medium system. All report requirements and administration can occur through the internet.

Groundnut Training Courses in Malawi

ICRISAT-Lilongwe has recently organized two training courses on groundnut production technologies in Malawi. The first one was organized in partnership with the United States Agency for International Development (USAID)/Malawi at the Natural Resources College near Lilongwe from 20 to 22 March 2000. A Mtukusu, Director, Department of Agricultural Research and Technical Services, Ministry of Agriculture and Irrigation inaugurated the course. Forty-nine participants including nine women participated in this course. The second one was organized in partnership with PLAN International in Mzuzu from 10 to 12 April 2000. Mr Phiri, Deputy Program Manager, Mzuzu Agricultural Development Division inaugurated the course. Over 70 participants including 19 women participated in this course. P Subrahmanyam, Site Leader, ICRISAT-Lilongwe welcomed the guests and participants.

Participants visiting groundnut fields near Ekwendeni, Malawi.

The main objectives of these courses were to develop and upgrade the skills of research technicians, assistants, and community volunteers in improved groundnut production technologies to increase groundnut production in Malawi. The courses facilitated cross-fertilization of ideas between various participants through field visits and in problem-solving group discussions. The courses were designed to address the major issues related to groundnut production, utilization, and marketing.

Both courses were coordinated by A J Chiyembekeza. Demonstration of hand-operated groundnut strippers, shellers, and peanut butter maker by P J A van der Merwe and H Tembenu drew special attention of the participants, especially women. Participants greatly benefited from these courses in obtaining latest technologies in groundnut production. The courses were rated "very high" by all the participants.

Certificate of attendance was awarded to all participants by Wayne McDonald, Mission Environmental Officer, USAID/Malawi and Narinder Verma, Country Director, PLAN/Malawi.

Genetics and Plant Breeding

Palynological Survey in *Arachis* species of Section *Arachis*

K Chandran[1] and S M Pandya[2] (1. National Research Centre for Groundnut, Ivnagar Road, PB No. 5, Junagadh 362 001, Gujarat, India; 2. Department of Biosciences, Saurashtra University, Rajkot 360 005, Gujarat, India; Present address: 7/5 Jay Street, Saurashtra Kalakendra Society, Rajkot 360 005, Gujarat, India)

Pollen grains, meant for perpetuating the plant species, have received special attention of nature during the course of evolution and specially nourished to combat the vagaries of environment (Sivarajan 1984). These unique structural adaptations have significant taxonomic importance as they are specific to a taxon. In comparative morphology for taxonomic purposes the apertural characters have been used as the base to which other characters such as exine ornamentation, and pollen size and shape have been collated for separation up to species level (Nair 1980). Palynologically the genus *Arachis* is less investigated. Raman and Kesavan (1962, 1963a, 1963b) and Raman (1958a, 1958b, 1959, 1965) studied the size of the pollen grains in different species of *Arachis* and reported that tetraploid species had generally bigger grains than other species. Significant difference in pollen grain size was also reported among the diploid species of *Arachis.* Pen et al. (1987) studied pollen grains under the electron microscope in different forms of cultivated groundnut (*Arachis hypogaea)* and reported the presence of three taxonomical groups of grains: prolate, spheroidal, and columnar spheroidal. In their studies on cytopalynology of *Arachis* species and their interspecific hybrids, Chaturvedi et al. (1990) observed that the species of *Arachis* are stenopalynous, being 3-zonocolporate and reticulated. They also observed that the size and shape of the lumina in the reticulum are of basic significance in distinguishing species.

To study the palynological relationship among the species of section *Arachis,* 35 accessions belonging to 13 species of *Arachis* of the section *Arachis* were procured from ICRISAT, Patancheru, India and grown in unreplicated plot (2.8 x 3.5 m^2) during 1996-97. Pollen grains were collected from unopened flowers of 105- to 110-day-old plants and acetolyzed by Erdtman's method (1966). Permanent slides were prepared from acetolyzed pollen grains by mounting in glycerin jelly (Nair 1970). For describing pollen grains, the terminologies from Erdtman (1966) and Nair (1964) have been used. The apertural morphoforms were studied under the light microscope. The polar length (P) and equatorial length (E) of 50 pollen grains at random were measured using ocular micrometer. For determining the pollen shape, P/E ratio was calculated and the classification described by Erdtman (1966) was used (Table 1). The thickness of sexine and nexine was measured by enlarging the image using an image analyzer. The average length of the longest axis, i.e., P was used for classifying the size of the pollen grains (Table 1) (Erdtman 1966).

The pollen grains are 3-zonocolporate with reticulated exine. In most of the species the pollen grains are of medium size except in ICGs 287, 8959, and 8197 where the pollen grains were large according to Erdtman's classification (Table 2). In majority of the accesions the pollen grains

Table 1. Shape and size of pollen grains.

Shape		Size	
Designation	P/E ratio[1]	Class	Polar length (urn)
Prolate	>1.00	Minute grain	<10
Perprolate	≥2.00	Small grain	10-24
Euprolate	1.34 -1.99	Medium grain	25-49
Subprolate	1.15-1.33	Large grain	50-99
Prolate spheroidal	1.01-1.14	Gigantic grain	>200
Spherical	1.00		

1. P/E = Polar length/equatorial length.
Source: Erdtman (1966).

were euprolate (Fig. 1A and E). Three accessions of *A. duranensis* (ICGs 8200, 8201, and 8205) and *A.valida* (ICG 11548) showed subprolate pollen grains (Table 2 and Fig. 1C). The pollen grains on polar view were tricircular (Fig. 1B), circular (Fig. 1D), or triangular oblate (Fig. 1F) in shape. In both amphidiploid species (*A. hypogaea* and *A. monticola)* the polar view was triangular oblate. ICG 8216 (*A. cardenasii)* and ICG 8132 *(A. correntind)* also showed triangular oblate pollen grains. In *A. duranensis* accessions, both tricircular pollen grains (ICGs 8123,8139,8196,8200, 8207, 8208, and 8956) and circular pollen grains (ICGs 8205,8201, and 8957) were observed. The thickness of the

Table 2. Mean values for palynological traits in various species of section *Arachis*.

Species	ICG no.	P[1] (µm)	(µm)	P/E ratio	Sexine (µm)	Nexine (µm)
A. batizocoi	8124	42.0 ± 2.1	24.2 ± 1.9	1.7 ± 0.1	0.73 ± 0.03	0.63 ± 0.03
	8209	37.0 ± 2.7	22.2 ± 2.5	1.7 ± 0.2	0.43 ± 0.21	0.52 ± 0.02
	8210	36.0 ± 1.9	23.6 ± 0.8	1.5 ± 0.1	0.54 ± 0.02	0.54 ± 0.02
	8958	41.4 ± 1.7	25.6 ± 2.8	1.6 ± 0.2	0.59 ± 0.04	0.78 ± 0.04
A. cardenasii	8216	40.7 ± 1.6	26.2 ± 2.9	1.6 ± 0.2	0.52 ± 0.03	0.57 ± 0.03
A. correntina	8132	40.1 ± 2.3	25.4 ± 2.8	1.6 ± 0.2	0.67 ± 0.00	0.57 ± 0.04
	8918	44.1 ± 2.9	29.1 ± 1.8	1.5 ± 0.1	0.85 ± 0.04	0.83 ± 0.04
A. diogoi	4983	41.8 ± 4.3	28.2 ± 2.4	1.5 ± 0.1	0.75 ± 0.07	0.86 ± 0.00
A. duranensis	8123	34.8 ± 1.6	24.0 ± 1.6	1.5 ± 0.1	0.47 ± 0.03	0.45 ± 0.03
	8139	35.9 ± 1.8	24.3 ± 2.1	1.5 ± 0.1	0.90 ± 0.03	0.93 ± 0.03
	8196	40.9 ± 2.4	26.3 ± 2.9	1.5 ± 0.2	0.58 ± 0.03	0.68 ± 0.03
	8200	35.8 ± 1.6	28.8 ±1.8	1.2 ± 0.1	0.70 ± 0.03	0.60 ± 0.30
	8201	36.9 ± 2. 7	28.9 ± 1.6	1.3 ± 0.1	0.76 ± 0.03	0.73 ± 0.03
	8205	36.6 ± 2.5	27.5 ± 2.8	1.3 ± 0.2	0.86 ± 0.04	0.93 ± 0.05
	8207	39.8 ± 2.5	28.1 ± 2.5	1.4 ± 0.1	0.72 ± 0.00	0.75 ± 0.00
	8208	35.8 ± 1.6	24.9 ± 2.5	1.4 ± 0.1	0.68 ± 0.03	0.71 ± 0.03
	8956	40.6 ± 2.5	26.1 ± 2.9	1.6 ± 0.2	0.68 ± 0.03	0.71 ± 0.03
	8957	41.3 ± 0.8	26.7 ± 2.0	1.6 ± 0.2	0.71 ± 0.04	0.81 ± 0.04
A. helodes	8955	40.7 ± 1.6	27.8 ± 2.7	1.5 ± 0.1	0.62 ± 0.03	0.88 ± 0.03
A. hoehnei	8190	45.9 ± 2.4	28.7 ± 1.9	1.6 ± 0.1	0.75 ± 0.03	0.81 ± 0.04
A. hypogaea						
Virginia bunch	5813	46.1 ± 2.5	31.6 ± 2.9	1.5 ± 0.1	0.81 ± 0.04	0.81 ± 0.04
Virginia runner	5770	46.1 ± 3.2	29.6 ± 3.1	1.6 ± 0.2	0.65 ± 0.03	0.75 ± 0.05
Spanish bunch	287	52.5 ± 2.0	36.2 ± 2.2	1.5 ± 0.1	0.76 ± 0.03	0.89 ± 0.04
Valencia	3704	42.3 ± 2.4	29.1 ± 1.4	1.5 ± 0.1	0.80 ± 0.03	0.74 ± 0.00
A. kempff-mercadoi	8164	40.9 ± 1.2	24.8 ± 2.5	1.7 ± 0.2	0.60 ± 0.03	0.65 ± 0.03
	8959	50.2 ± 3.4	30.7 ± 2.7	1.6 ± 0.2	0.76 ± 0.03	0.84 ± 0.03
A. khulmannii	8954	42.0 ± 2.7	23.9 ± 1.4	1.8 ± 0.2	0.62 ± 0.03	0.58 ± 0.03
A. monticola	8197	50.2 ± 2.9	32.9 ± 2.9	1.5 ± 0.1	0.72 ± 0.03	0.75 ± 0.04
	8198	42.8 ± 3.1	23.5 ± 0.0	1.8 ± 0.1	0.54 ± 0.02	0.62 ± 0.03
	8135	45.4 ± 2.6	30.3 ± 3.0	1.5 ± 0.2	0.81 ± 0.06	0.86 ± 0.04
A. stenosperma	8125	35.5 ± 2.3	24.6 ± 2.3	1.4 ± 0.2	0.59 ± 0.03	0.61 ± 0.00
	8126	36.9 ± 2.6	24.3 ± 2.1	1.5 ± 0.2	0.61 ± 0.03	0.61 ± 0.03
	8137	41.0 ± 0.8	28.9 ± 1.6	1.4 ± 0.1	0.83 ± 0.07	0.95 ± 0.03
	8906	45.9 ± 2.3	30.0 ± 1.8	1.5 ± 0.1	0.77 ± 0.00	0.77 ± 0.00
A. valida	11548	35.6 ± 1.8	27.9 ± 2.6	1.3 ± 0.1	0.96 ± 0.04	1.25 ± 0.05

1. P = Polar length.
2 E = Equatorial length.

exine was maximum in *A. valida* with an average 0.96 |im sexine and 1.25 µm nexine.

Morphological traits common to all species were nature of colpi and exine ornamentation. The shape of the pollen grain and its shape in polar view show some trends as observed in *A. hypogaea* and *A. monticola.* Presence of triangular oblate pollen grains in the diploid species (*A. correntina* and *A. cardenasii)* indicate that one of these species might have contributed to the evolution of the tetraploid species. Since intra-specific variation for many of the traits were also observed, distinction at species level was very difficult. Tetraploid species are reported to have

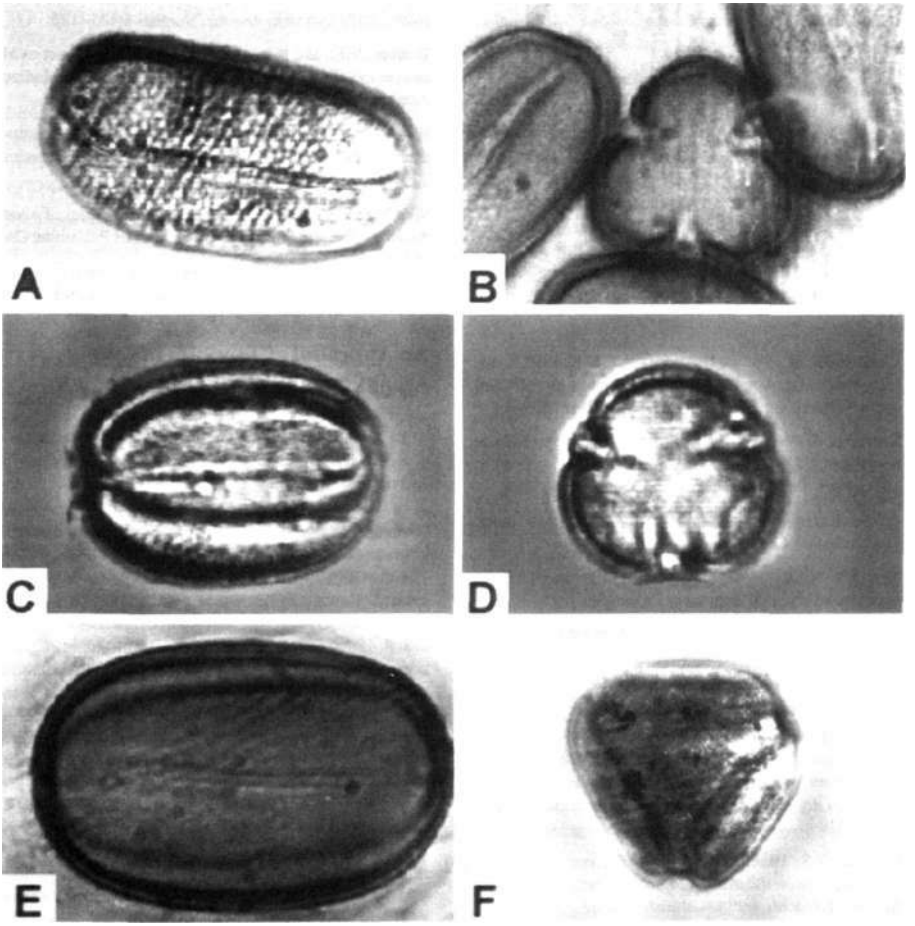

Figure 1. Pollen grains of three *Arachis* species: (A) ICG 8209 (*A. batizocoi),* equatorial view (1730x); (B) ICG 8209, polar view (1470x); (C) ICG 8205 *(A. duranensis),* equatorial view (1430x); (D) ICG 8205, polar view(1320x); (E) ICG 5770 (*A. hypogaea),* equatorial view (1575x); (F) ICG 5770, polar view (1310x).

very large pollen grains compared to diploid species (Raman 1965). Our study showed that many diploid species (*A. batizocoi*, *A. kempff-mercadoi*, *A. hoehnei*, and *A. correntina)* also had almost the same length of grain but the equatorial axis was shorter than that of *A. hypogaea* and *A. monticola* accessions. Based on apertural morpho-forms and exine ornamentation the genus *Arachis* was described as stenopalynous (Chaturvedi et al. 1990). Our studies based on light microscopy indicate that variation is present in pollen morphology in the genus *Arachis* and further investigation under scanning electron microscope may reveal further information for using these traits for systematic studies.

Acknowledgments. The authors are thankful to Dr A K Singh (formerly in ICRISAT, Patancheru) for providing the germplasm and Dr A Bandyopadhyay, Director, National Research Centre for Groundnut (NRCG), Junagadh, India for providing the facilities for conducting this study.

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An Appraisal of Triploids of Amphidiploids in the Genus *Arachis*

P Vindhiyavarman, A Mothilal, K N Ganesan, and S E Naina Mohammed (Regional Research Station, Vridhachalam 606 001, Tamil Nadu, India)

Groundnut (*Arachis hypogaea)* is a tetraploid (2n=4x=40), whereas, most of its wild relatives are diploid (2n=2x=20). The desirable attributes are dispersed in different wild species. Hence production of synthetic amphidiploids will combine the desirable features from at least two species (Singh 1986) which can be utilized for further introgression to the cultivated groundnut. Four perennial diploid wild species, *A. stenosperma*, *A. cardenasii*, *A. villosa,* and *A. kempff-mercadoi,* belonging to section *Arachis* were utilized to produce three amphidiploids. They were *A. stenosperma x A. kempff-mercadoi*, *A. stenosperma x A. cardenasii*, and *A. cardenasii x A. villosa.*

The three amphidiploids were hybridized with cv VRI 4 of *A. hypogaea* in reciprocal ways to produce six triploids (2n=3x=30). The four diploid wild species were hybridized simultaneously with cv VRI 4 to produce four triploids: VRl 4 *x A. stenosperma,* VRI 4 *x A. cardenasii,* VRI 4 x *A. villosa,* and VRI 4 *x A. kempff-mercadoi.* All the ten triploids were studied for pollen stainability.

Among the four triploids of *A. hypogaea x* diploid wild species studied, the triploid *of A. kempff-mercadoi* exhibited

Table 1. Pollen fertility and vegetative vigor in different combinations of triploids of *Arachis* species.

Parentage of triploids	No. of plants studied	Pollen fertility (%)	Radius of the canopy coverage (cm)	Leaflet size (cm)
***A. hypogaea* x diploid wild species**				
VRI 4 x *A. stenosperma*	8	7.0	95	2.8 x 1.8
VRI 4 x *A. kempff-mercadoi*	9	7.5	110	2.9 x 1.7
VRI 4 x *A. cardenasii*	7	10.0	90	3.1 x 2.2
VRI 4 x *A. villosa*	6	13.7	73	2.7 x 1.7
***A. hypogaea* x synthetic amphidiploids**				
Direct crosses				
VRI 4 x (*A. stenosperma* x *A. kempff-mercadoi)*	7	6.0	199	3.3 x 1.6
VRI 4 x (*A. stenosperma* x *A. cardenasii)*	6	5.0	185	3.2 x 2.0
VRI *4 x (A. cardenasii* x *A. villosa)*	7	30.5	170	3.0 x 2.3
Reciprocal crosses				
(A. stenosperma x *A. kempff-mercadoi)* x VRI 4	3	10.5	135	4.6 x 2.4
(A. stenosperma x *A. cardenasii)* x VRI 4	2	38.0	141	4.7 x 2.0
(A. cardenasii x *A. villosa)* x VRI 4	3	38.5	132	4.4 x 2.3

vegetative luxuriance as measured by canopy coverage, whereas the triploid of *A. villosa* was compact and had higher pollen stainability (Table 1).

The VRI 4 x amphidiploid crosses showed high vegetative vigor for canopy cover and leaf size compared to the triploids derived from VRI 4 x diploid wild species (Table 1). Among the triploids of amphidiploids, the canopy coverage was high when the amphidiploid was used as male parent whereas, the reciprocals were less vigorous with broader, light green leaves. Singh (1986) reported that the chromosome pairing was more disturbed in the hybrids when synthetic amphidiploids were used as the female parents, compared to that in the reciprocal crosses indicating the existence of cytoplasmic differences. Further the presence of multivalents in the hybrids of *A. hypogaea* x amphidiploids is indicative of high intragenomic as well as intergenomic pairing.

Both direct and reciprocal combinations of the triploids of amphidiploid A *cardenasii* x *A. villosa* recorded highest pollen fertility of 30.5% and 38.5% respectively. However, the reciprocal effect was evident in the combination *A. stenosperma* x *A. cardenasii* for pollen fertility. The direct cross recorded 5% whereas the reciprocal recorded 38% pollen fertility (Table 1).

Gardner and Stalker (1983) reported that pollen fertility in the hybrids between *A. hypogaea* x amphidiploid ranged from 43.6% to 54.7% in the crosses *A. chacoense* x *A. correntina, A. duranemis* x *A. cardenasii,* and *A. stenosperma* x *A. chacoense.* In general the triploids of amphidiploids had bigger leaflets and standard petal than their corresponding two triploids of cv VRI 4 x diploid wild species.

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Genetic Analysis of Pod and Seed Characters in Crosses of Large-seeded Virginia Genotypes of Groundnut

D L Parmar, A L Rathna Kumar, and P S Bharodia
(National Research Centre for Groundnut, Ivnagar Road, PB No. 5, Junagadh 362 001, Gujarat, India)

In groundnut, many economically important traits are quantitatively inherited. Exploitation of genetic variability for these traits is the primary focus in most of the groundnut breeding programs. Although, information on the inheritance of various quantitative traits is available, studies pertaining to the gene action governing pod and seed characters in crosses between large-seeded genotypes are limited. An understanding of genetic systems controlling the expression of pod and seed characters becomes essential before formulating a suitable breeding program. Twenty-eight crosses involving eight large-seeded groundnut genotypes were produced in a diallel fashion excluding reciprocals. The F_1s and F_2s along with parents were raised in a randomized complete block design with 3 replications.

Analysis of genetic components of variance (Hayman 1954) for four characters revealed that additive genetic effects (D) and non-additive effects (H_1 and H_2) were significant in F_1 and F_2 generations for pod yield, shelling percentage, and 100-seed mass indicating the importance of both additive and dominance components in the inheritance of these traits (Table 1). However, there was no agreement between F_1 and F_2 on the preponderance of genetic component. In F_2, dominance components were greater in magnitude than additive components for these traits. The percentage of sound mature seeds was controlled predominantly by non-additive genetic effect in both the generations. Over dominance was observed for 100-seed mass both in F_1 and F_2 generations while for pod yield and shelling percentage, it was observed only in F_2. Narrow sense heritability was moderate to high for shelling percentage, 100-seed mass, and pod yield but low for sound mature seeds. Low heritability for the latter was due to predominantly non-additive gene effect responsible for the expression of the trait. The over dominance in 100-seed mass is due to interacting non-allelic loci rather than the over dominance by itself.

Considering the segmental polyploid nature of groundnut and control of several qualitative traits by duplicate genes (Hammons 1973), presence of epistasis cannot be overruled in the inheritance of these traits. Hence, pedigree breeding followed by biparental mating and inter-mating of elite segregants in early generations should be useful to harness both additive and dominance gene effects. Selection at later generations should aid in identification of desirable recombinants.

Table 1. Estimates of components of genetic variance for pod yield, shelling, sound mature seeds, and 100-seed mass in groundnut[1].

Genetic component	Pod yield (g plant^{-1})		Shelling (%)		Sound mature seeds (%)		100-seed mass (g)	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
D	23.16**	23.21**	51.05**	51.12**	41.25	41.56	53.76**	53.42**
	±2.82	±1.85	±1.83	±3.84	±28.10	±27.34	±4.73	±3.54
H_1	20.05*	134.22**	19.14**	188.53**	256.72**	1130.58**	86.29**	274.88**
	±6.48	±17.02	±4.20	±35.28	±64.60	±251.40	±10.87	±32.57
H_2	19.64*	131.36**	16.78**	173.70**	195.37*	880.09**	71.82**	226.01**
	±5.64	±14.80	±3.66	±30.69	±56.21	±218.72	±9.46	±28.34
h_2	34.62**	69.63**	0.53	9.35	42.32	14.62	57.92**	30.30**
	±3.78	±2.48	±2.45	±5.15	±37.69	±36.67	±6.34	±4.75
F	-6.03	-1.60	4.84	39.95	81.65	176.67	29.86*	66.55**
	±6.66	±8.74	±4.32	±18.13	±66.40	±129.20	±11.18	±16.74
$(H_1/D)^{1/2}$	0.93	2.40	0.61	1.92	-	-	1.27	2.27
Heritability (narrow sense) (%)	45.9	39.6	77.1	64.8	18.3	17.0	48.0	58.1

1. * Significant at *P* - 0.05%; ** Significant at *P* - 0.01%.

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A Perennial Forage Groundnut of Interspecific Origin

P Vindhiyavarman, A Mothilal, K N Ganesan, and S E Naina Mohammed (Regional Research Station, Vridhachalam 606 001, Tamil Nadu, India)

To feed a balanced diet to animals for milk and meat production, the grass fodder should be supplemented with nutritious forage legumes. However, such forage legumes suitable for either mixed cropping with cereals or grasses or for monocropping are very limited. Perennial legumes such as *Stylo, Siratro, Calatro,* and *Centro,* though recognized as promising perennial forage legumes, have limitations in their large-scale cultivation due to soil preferences, climate, rainfall, and other factors. The search is on for the identification of a suitable high-yielding fodder legume for the semi-arid areas of Tamil Nadu in India.

Groundnut (*Arachis hypogaea)* is an important oilseed crop. The haulms of this crop are dried, stored, and utilized as a good source of rich cattle feed. One of the desirable attributes present in the wild species is the high fodder value. Hence, an attempt was made at the Regional Research Station, Vridhachalam, Tamil Nadu to develop perennial forage groundnut by interspecific hybridization. A diploid (2n=2x=20) wild species, *Arachis cardenasii* (ICG 11563), was utilized as a pollen parent and a cross was made with cv VRI 4 of *A. hypogaea* (2n=4x=40). A total number of 15 triploid (2n=3x=30) hybrids were obtained. The pollen fertility of the triploids was assessed by staining with acetocarmine. About 10-15% of the pollen was round and darkly stained.

The pollen of the partially fertile triploids was utilized for backcrossing with cv VRI 4. In the resultant BC_1F_1, five hybrids were obtained. The BC_1F_1 hybrid plants were vigorous and prostrate with dark green broader leaves. Although the flowering was profuse there was no seed setting. Since the vegetative growth was luxuriant, the material was tested for amenability for cutting and the success rate of vegetative propagation, the two major prerequisites for perennial forage type. The results revealed that the plants were amenable for multiple cutting. Under favorable moisture conditions, up to 98% success was observed for vegetative propagation when mature stem cuttings were used. Then the materials were planted in a large-scale plot of 0.2 ha and 17 t of green fodder was harvested from that area in a year. The palatability of the fodder was tested by feeding to cattle. It was observed that cattle relished the fodder. The genotype was designated as VG(F) 9873 and supplied for multilocational testing in different research stations of the Tamil Nadu Agricultural University.

Though the establishment of the stem cuttings was initially slow, growth was remarkable later. The crop could be cut for green fodder in about 90 days after planting and the subsequent harvest could be had at 45-day intervals. In each cut, green fodder yield of about 12 t ha^{-1} could be obtained and hence from 7-8 cuttings a total quantity of 80-851 ha^{-1} was harvested in a year. The sterile nature of the genotype has an advantage as there is no depletion of photosynthates which is conserved without diversion to pod formation. Development of rhizomatous roots helps easy multiplication; water stored in those rhizomes helps to tide over adversities and makes it drought resistant. The profuse adventitious roots help in binding the soil and prevent erosion. The dense foliage helps to smother weeds. Like any other legume, this genotype enriches soil fertility through root nodules. Further, it was immune to foliar diseases such as rust and leaf spots. As the groundnut crop has wide adaptability, this genotype may also adapt to varying ecological niches of this vast country.

Acknowledgments. The supply of wild species *A. cardenasii* (ICG 11563) by ICRISAT, Patancheru, India is gratefully acknowledged. The authors are thankful to the Indian Council of Agricultural Research (ICAR), New Delhi, India for the financial support rendered for the program.

Storability of Groundnut Seeds in Different Packaging Media

K Rajgopal and K Chandran (National Research Centre for Groundnut, Ivnagar Road, PB No. 5, Junagadh 362 001, Gujarat, India)

The germplasm of cultivated groundnut is generally stored in the form of pods in ambient conditions where cold storage facility is not available. Different packaging media, depending on availability, cost, and convenience

in handling, are normally used for storage of pods. Under normal storage conditions, the viability of groundnut seeds is retained for one year (Sankara Reddi 1988). The frequent regeneration of germplasm accessions affects the purity of the accessions. Therefore, the identification of an ideal packaging medium for ambient storage could prove to be beneficial to genebank curators to retain the seed viability for a longer duration and in maintaining the working collection at breeding centers as this would reduce the expenses on frequent regeneration of accessions.

This study was undertaken with four released groundnut cultivars (J 11, GG 2, GAUG 10, and GG 20) at the National Research Centre for Groundnut, Junagadh, India. To regenerate adequate quantity of pods, the four cultivars were sown in rainy season of 1994 and harvested during October and November 1994. The pods were dried (moisture content 3.61-3.91%) in the sun for 10 days. Well-developed and healthy pods were stored immediately after drying in five pakaging media: (1) kraft paper bags (KRB); (2) tar-coated kraft paper bags (TKB); (3) polyethylene bags of 700 gauge thickness (PLB); (4) tri-layered aluminium foil pouches (TLP) with 12 µ each of aluminium and polyester and 250 gauze polylamination; and (5) transparent polyethylene containers (PCN) with screw caps. In the first four treatments 20 packets (50 pods each) were stored whereas in the last treatment, four containers of 2 kg capacity were used to get sufficient material for testing over the period. The initial germination percentage and the moisture content were estimated before storage of pods (ISTA 1976).

The KRB and TKB were closed by stapling as sealing with synthetic glue does not last long during storage, whereas the PLB and TLP were hermetically sealed. The temperature ranged from 11.3°C to 40°C and the relative humidity from 30.8% to 90% during the period of storage. Fifty seeds per treatment replicated twice were tested for germination in a germinator at 30°C at 6-month intervals. The normal seedlings produced after six days of incubation were used for computing the germinability (Tables 1 and 2). Root length was measured in ten random seedlings and

Table 1. Influence of three factors on germination and seedling vigor index of groundnut[1].

		Germination (%)		Seedling vigor index	
Factor	df	MSS	SE	MSS	SE
Packages (A)	4	24033.9**	0.64	969517.6**	6.02
Error	4	16.7		1448.1	
Cultivars (B)	3	894.1**	0.69	113359.2**	10.22
AxB	12	204.3**	1.06	42813.1**	22.84
Period (C)	4	12642.2**	0.78	1072593.8**	11.42
AxC	16	772.8**	1.74	22200.0**	25.55
BxC	12	86.5**	1.56	23708.9**	22.85
AxBxC	48	111.7**	3.49	7764.4	51.09
Error	95	24.3		5220.4	

1. df = Degrees of freedom; MSS = Mean sum of square; SE - Standard error; ** Significant at 1% level.

Table 2. Mean seed viability and seedling vigor index of four groundnut cultivars in different packaging media under five storage periods (in months).

	Germination (%)					Seedling vigor index				
Package[1]	6	12	18	24	30	6	12	18	24	30
KRB	68.4	38.3	26.9	10.3	0.7	411	142	113	35	2
TKB	64.6	51.4	41.8	13.8	4.3	314	201	130	40	13
PLB	87.2	80.8	75.7	72.3	57.1	742	596	524	431	351
TLP	93.1	86.9	84.0	76.8	72.9	842	696	616	490	462
PCN	89.5	79.0	74.5	61.0	33.5	750	521	512	276	143

1. KRB = Kraft paper bags; TKB = Tar-coated kraft paper bags; PLB - Polyethylene bags; TLP - Tri-layered aluminium pouches; PCN = Polyethylene containers.

the seedling vigor index (SVI) was calculated by multiplying the root length with germination percentage as suggested by Abdul-Baki and Anderson (1973). The observations continued for 30 months at 6-month intervals, till the viability was reduced to about 70% in all the treatments, which was set as the minimum standard for regeneration.

The three factor ANOVA indicated highly significant influence of the packages, cultivars, and storage period on germination and SVI (Table 1). All interactions were found to be highly significant ($P<0.001$). Though the significant difference between the cultivars was observed for viability and SVI, the trend was same in all the cultivars. Hence, the data was pooled to identify the suitable package media for pod storage.

Initial germination ranged from 98.7% to 100% and SVI ranged from 880 to 1020. Seeds stored in KRB and TKB lost both viability and seedling vigor at a faster rate irrespective of cultivars (Table 2). The viability was 68.4% in KRB and 64.6% in TKB after 6 months and was reduced to 0.7% and 4.3% respectively at 30 months of storage. The longevity of seeds was retained above 70% up to 24 months of storage in hermetically sealed PLB and up to 18 months only in PCN. The maximum viability (72.9%) at 30 months was recorded in seeds stored in TLP; also SVI was high. The SVI showed corresponding decrease with germination percentage.

The study confirms that groundnut pods can be coveniently stored in hermetically sealed TLP for 30 months. Thus regeneration cost of germplasm could be reduced by using simple storage media for conservation in ambient conditions. Bass (1968) reported that under ambient conditions groundnut seeds stored in permeable envelops lost viability within 6 months but those stored in impermeable material retained full viability for more than three years.

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Identification of Male Sterile Mutant in Groundnut

R K Mathur and P Manivel (National Research Centre for Groundnut, Ivnagar Road, PB No. 5, Junagadh 362001, Gujarat, India)

One of the handicaps in studying groundnut (*Arachis hypogaea)* genetics and carry out breeding is the small size of segregating population that is generally available with the breeder. This is mainly due to difficulties in artificial hybridization, which are generally associated with low success in getting F_1 seeds. One of the possible ways to tackle this problem could be the identification of male sterility system in groundnut. This system will facilitate the breeders to avoid the tedious process of emasculation and getting more success in artificial hybridization. In groundnut, the male sterility in segregating generation of certain intraspecific crosses and its inheritance has been reported by Upadhyaya and Nigam (1996). Mutagens have also been used for inducing male sterility in several crops (Burton and Hanna 1976, Jan and Rutger 1988). In this article we report a male sterile mutant selected from segregating population of the Spanish bunch groundnut (*Arachis hypogaea subsp fastigiata* var *vulgaris)* cultivar Girnar 1 treated with ethyl methane sulfonate (EMS).

The dry and uniform sized seeds of cultivar Girnar 1 were pre-soaked in distilled water for 12 h and then transferred to different concentrations of diethyl sulfonate (DES) and EMS in aqueous medium and kept for 4 h (Table 1). For combination treatments of DES and EMS, the pre-soaked seeds were soaked in individual mutagenic solution in sequence for 4 h each. Treated seeds were washed for 30 min in running water and sown in the field along with the untreated control in the experimental plot of the National Research Centre for Groundnut, Junagadh, India, during rainy season (kharif) 1994 and summer 1995. The M_2 generation was raised in plant to progeny row method during rainy season 1995.

While harvesting the M_2 generation in rainy season 1995, some podless plants with reduced height and small leaves were noticed. On closer examination they were found to have only fresh flowers without any pegs or pods. The anthers of these plants were translucent white

and contained no or very few sterile pollen grains when studied under the microscope using acetocarmine and in the in vitro pollen germination test (Malik and Chabbra 1976). This mutant was noticed only in two EMS treatments (Table 1). It was observed in one out of 161 progeny rows in EMS 0.01 % treatment and one out of 224 progeny rows in EMS 0.20% treatment. In the progeny in EMS 0.01%, 5 out of 18 plants were male sterile whereas in the progeny in EMS 0.20%, 10 out of 27 plants were male sterile. In both cases the x^2 test was applied and it fits in the ratio of 3:1 formale fertile:male sterile indicating the recessive nature of male sterility. In rainy season of 1996 (M_3) and 1997 (M_4) the progeny bulks were grown in which such plants were again noticed and found sterile.

In M_5 generation (1998 rainy season), some sterile plants were pollinated with pollen from different genotypes, viz., Girnar 1 (parent variety), M 13 (a popular Virginia runner variety), and PBS 11003 (dominant marker for reddish flower and stem color). On all the plants, pollinated flowers developed into gynophores and resulted into pods and seeds. The non-pollinated flowers did not result into gynophores. It clearly indicated that these plants are female fertile and male sterile. This male sterile mutant was designated as Girnar 1 ms. The hybrid seeds obtained from pollinated flowers were sown in concrete cement blocks (2.5 m x 1 m) during March 1999. The resulting F_1 plants were normal in phenotype (like male parent) and all were fertile. They produced normal gynophores, pods, and seeds. By digging the soil surrounding the F_1 plants (with minimum disturbance) the mature pods were collected during July 1999. Because these plants were still green and were producing continuous flowers besides containing many hanging pegs, some additional soil was applied around the plants. During September 1999, second harvesting of

Table 1. Treatments and frequency of male sterile mutant in M_2 generation in groundnut

Mutagen treatment[1]	No. of M_2 progeny rows	Plant population	Frequency of mutant (%)	Total number of plants in segregating progeny (M_2)		c^2 value (3:1 ratio)	Probability
				Sterile	Fertile		
DES 0.01%	-	2983	-	_	_	_	_
DES 0.02%	-	3510	-	-	-	-	-
DES 0.05%	-	6742	-	-	-	-	-
DES 0.10%	-	6779	-	-	-	-	-
DES 0.20%	-	654	-	-	-	_	-
EMS 0.01%	161[2]	2861	0.17	5	18	0.13	0.50-0.75
EMS 0.02%	-	2842	-	-	-	-	-
EMS 0.04%	-	2085	-	-	-	-	-
EMS 0.05%	-	5771	-	-	-	-	-
EMS 0.10%	-	6060	-	-	-	-	-
EMS 0.20%	224[2]	6642	0.15	10	27	0.08	0.75-0.90
DES 0.01% + EMS 0.01%	-	1564	-	-	-	-	-
DES 0.01% + EMS 0.02%	-	2161	-	-	-	-	-
DES 0.01% + EMS 0.04%	-	2460	-	-	-	—	-
DES 0.02% + EMS 0.01%	-	2004	-	-	-	-	-
DES 0.02% +EMS 0.02%	-	2507	_	-	-	-	-
DES 0.02% +EMS 0.04%	-	2155	-	_	-	-	-
DES 0.05% + EMS 0.05%	-	6115	-	-	-	-	-
DES 0.05% +EMS 0.10%	-	6533	-	-	-	-	-
DES 0.10% +EMS 0.05%	-	6262	-	-	-	-	-
DES 0.10% +EMS 0.10%	-	6994	-	-	-	-	-
Total				15	45		0.95-0.99

1. DES = Diethyl sulfonate; EMS = Ethyl methane sulfonate.
2. Male sterile plants were observed in one progeny.

Table 2. Salient features of male sterile mutant Girnar 1 ms and its parent Girnar 1[1].

Salient characteristics	Girnar 1 ms	Girnar 1
Height of main axis (cm)	6.50	25.30
Maximum branch height (cm)	8.20	29.00
Number of primary branches	4.00	4.07
Number of secondary branches	1.30	1.30
Number of nodes on main axis	9.70	9.90
Number of leaves plant^{-1}	42.00	43.00
Internode length (cm)	0.60	2.55
Leaflet length (cm)	1.03	3.50
Leaflet width (cm)	0.48	1.70
Petiole length (cm)	2.16	4.40

1. Observations are based on 100 plants in Girnar 1 ms and SO plants in Girnar 1.

these F_1 plants was done. The pods harvested from each plant were kept separately. The inheritance studies based on the F_2 results will be studied in rainy season 2000.

Quantitative observations were recorded on 100 male sterile plants and on 50 plants in parent Girnar 1 (Table 2). The male sterile mutant Girnar 1 ms was dwarf having small and rounded leaves. The number of nodes on the main axis was same in both mutant and parent; intemodes were shorter in mutant plants and hence resulted in short stature.

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Quantitative Studies on Mating System of Groundnut

T Radhakrishnan and P Paria (National Research Centre for Groundnut, Ivnagar Road, PB No. 5, Junagadh 362 001, Gujarat, India)

The amount and nature of genetic variability in a population depend in part on its mating system. In addition to self-fertilization, autogamous species undergo varying degree of intermating. Allard and Workman (1963) and Harding and Tucker (1964) have given methods for estimating out-crossing when selection is present and/or equilibrium gene frequencies cannot be assumed. These methods are based on estimates of the frequency of dominant individuals appearing in the progeny of recessive individuals taken at random from the population. Groundnut *(Arachis hypogaea)* is mainly a self-pollinated species. The extent of natural cross-pollination in this species was highly variable (Hammons and Leuck 1966, Culp et al. 1968, Coffelt 1989, Nigam et al. 1990). Whether cross-pollination is random or not has not been studied so far. The purpose of the present investigation was to study the mating system involved in certain artificial population of this species using different markers and seasons and years.

True breeding "golden yellow leaf and "puckered leaf mutants were planted with TAG 24 (homozygous dominant) in alternate rows in separate plots. The spacing in all the plots was 30 cm x 10 cm. The experiment was conducted at the National Research Centre for Groundnut, Junagadh, India, in rainy season (kharif) and summer crop season of 1997 and rainy season of 1998. Since mutants and the homozygous normals (TAG 24) were equally frequent in both the artificially constructed populations, the gene frequency 'q' in both the cases was assumed to be 0.5.

The estimation procedure developed by Harding and Tucker (1964) was adopted. Let 'a' and 'b' denote the number of heterozygotes and recessive homozygotes respectively in the offsprings generated by recessivse homozygotes of a population. The maximum likelihood (ML) estimate of the outcrossing proportion is then given by:

$$\hat{t} = \frac{a}{a+b}$$

with variance:

$$\text{var}(\hat{T}) = \frac{ab}{(a+b)^3}$$

However, since not all the crosses will be observed, and as homogeneous matings will give rise to homozygotes, an adjusted ML estimate of total outcrossing, $\hat{\alpha}$, given below, should instead be used:

$$\hat{\alpha} = \frac{\hat{T}}{(1-q)}$$

where q is the gene frequency of selected homozygote. Provided q is known, the ML estimate of var$(\hat{\alpha})$, the variance of a, can be computed from:

$$\text{var}(\hat{\alpha}) = \frac{\alpha(1-\alpha q)}{Np} = \sigma^2(\hat{\alpha})$$

where p+q = 1 and N = a+b. Since, q=p=0.5 is known and $\hat{T}$ did not exceed 0.15 in the present study, the above formula was utilized for computation of variance of $\hat{\alpha}$.

Table 1 presents the frequencies of heterozygotes (a), total offsprings (N), estimates of outcrossing $(\hat{\alpha})$, and their standard deviations $[\sigma(\hat{\alpha})]$ for five artificially constructed populations of two different leaf markers in two different seasons and years. The estimates of outcrossing, pooled over years and seasons, for golden yellow leaf (0.0116) and puckered leaf (0.0330) were heterogeneous as revealed by x^2 test (x^2_{1df} = 102.8; P<0.001). Seasonal variation in outcrossing rates in puckered leaf mutant was negligible (x^2_{1df}=0.7691; *P>0.005)* while it was considerable in golden yellow leaf mutant (x^2_{1df} = 23.2; P<0.001). The differences in degree of seasonal fluctuations in outcrossing rate among the two mutants might be the expression of variable genotype x environment interaction in these two mutants. The experiments with both the mutants were conducted in a common experimental field in both the seasons. Hence, the observed degree of seasonal fluctuations of outcrossing in them cannot be ascribed to differences in insect (pollinator) populations available in the experimental plots. However, the preferential visit of insects to selected flower forms cannot be ruled out and possible differences in the flower form in the mutants are supposed to be genetically controlled. The outcrossing during rainy season in two years in golden yellow leaf was homogeneous (X^2_{1df}=0.0059; *P>0.005)*

The composite estimate of outcrossing $(\hat{\alpha})$ for puckered leaf (0.0330) was almost three times higher than that in golden yellow leaf (0.0116). The approximate expected range $[\alpha \pm 2\sigma(\alpha)]$ due to random fluctuation leaf was -0.0062 to 0.0294 for golden yellow and was -0.0106 to 0.0766 for puckered leaf. But if the observed fluctuations were used the approximate range $[\alpha \pm 2s(\alpha)]$ for golden yellow leaf and puckered leaf was -0.0010 to 0.0242 and 0.0182 to 0.0478 respectively where $s^2(\hat{\alpha})$ was computed as $s^2(\hat{\alpha}) = [1/(n-1)][\Sigma\alpha_i^2 - (1/n)(\Sigma\alpha_i)^2]$; n = 3 for golden yellow leaf and n = 2 for puckered leaf. The observed fluctuation in a for golden yellow leaf was approximately 1.5 times less than the fluctuations expected on the basis of random chance alone $[\sigma(\alpha)/s(\alpha) = 1.41]$. Similarly for puckered leaf $\sigma\alpha/s\alpha$ was 4.45. In bom the mutants, the observed fluctuations were less than the fluctuations expected due to chance alone. Hence, it could be concluded that the outcrossing in all the populations was a random event.

Table 1. Estimation of outcrossing $(\hat{\alpha})$ in groundnut using golden yellow leaf and puckered leaf mutants as markers at Junagadh, India[1].

Marker	Year/Season	a	N	q	$\hat{\alpha}$	$\sigma\hat{\alpha}$
Golden yellow leaf	1997 rainy season	8	1147	0.5	0.0139	0.0416
	1997 summer crop season	9	5822	0.5	0.0031	0.0185
	1998 rainy season	126	17714	0.5	0.0142	0.0105
Total		143	24683	0.5	0.0116	0.0089
Puckered leaf	1997 summer crop season	12	619	0.5	0.0388	0.0563
	1998 rainy season	56	3506	0.5	0.0319	0.0237
Total		68	4125	0.5	0.0330	0.0218

1. a = Frequency of heterozygotes; N = Total offsprings; q = Gene frequency; $\sigma\hat{\alpha}$ = Standard deviation.

The mating system is commonly considered to be the chief factor determining the genetic structure and evolutionary potential in a population. The mating system of present populations of *A. hypogaea* was a mixed system of random mating and self-fertilization. One of the important features of the variability in inbreeding species is genetic differentiation between populations within the species. Clinal variation is frequently observed in association with progressive changes in rainfall, temperature, and other factors of the physical environment and such local differentiation appears to provide the scope of massive storage of genetic variability. It is true that population structure in inbreeding species is much more complicated than has been commonly supposed and probably it does not take the same form in all inbreeding species or even in different populations of the same species. For example, in *Phaseolus lunatus,* heterozygotes and homozygotes of *S/s* locus were equal in fitness when all three genotypes were equally frequent in population (Harding et al. 1966). However, when heterozygotes were rare in the population, their fitness increased to homozygotes. Thus, the maintenance of stable nontrivial polymorphism depends on a complex set of interaction between genetic factors, mating systems, and ecological factors. The observed variability of outcrossing in groundnut under different ecological-conditions (different years and seasons) in different marker stocks may well contribute to a complex population structure. Workman (1964) and Allard et al. (1968) have discussed in detail the evolutionary consequences and significance of such a mating system.

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Genetics and Interrelationship of Oil and Protein Contents in Crosses Involving Confectionery Genotypes of Groundnut

D L Parmar, A L Rathna Kumar, and P S Bharodia
(National Research Centre for Groundnut, Ivnagar Road, PO Box No. 5, Junagadh 362 001, Gujarat, India)

With the changing scenario in the global trade in general, and in agriculture in particular, the emphasis in the groundnut breeding program in India is shifting towards the development of large-seeded genotypes with low oil, high protein, and high sugar contents to meet the standards for international trade. An understanding of relationship and genetic control of oil and protein contents should facilitate the breeding strategies to select for improved seed quality traits. Hence genetic analysis was carried out on 28 non-reciprocal diallel crosses involving large-seeded confectionery Virginia genotypes of groundnut following Hayman's (1954) approach. The F_1s and F_2s of these crosses were grown in a randomized block design with three replications.

Data on protein and oil contents were recorded on twenty randomly selected plants in F_1 and F_2 generations for each cross. Protein content was estimated based on total nitrogen content of seed by microKjeldahl method (Jackson 1967), and oil content was estimated following specific gravity method (Misra et al. 1993). Correlation coefficients and heritability estimates (in narrow sense) were estimated.

Table 1. Estimation of genetic components of variance for oil and protein contents in groundnut

Charater	Generation	Genetic components of variance[1] D	H_1	H_2	h_2	F	$(H_1/D)^{1/2}$	Heritability (narrow sense) (%)	t^2
Oil	F_1	2.15	11.21*	9.99*	0.50	1.63	-	18.3	6.004
		±1.55	±3.57	±0.11	±0.08	±0.67			
	F_2	2.16	54.67*	36.67**	0.05	7.76	-	18.0	3.263
		±0.98	±9.02	±7.85	±1.32	±4.64			
Protein	F_1	35.40**	76.83**	64.18**	36.12*	12.75	1.47	35.5	6.153
		±8.11	±18.65	±16.23	±10.88	±19.17			
	F_2	35.40**	324.58**	194.37**	17.63*	127.22**	3.03	66.7	0.061
		±4.70	±43.20	±37.58	±6.30	±22.20			

1. * Significant at P = 0.05%; ** Significant at P = 0.01%.

Genetic analysis of oil content indicated the significance of only non-fixable genetic components of variance (H_1 and H_2) in both F_1 and F_2 generations indicating the preponderance of non-additive gene effects in the inheritance of oil content (Table 1). Both additive and non-additive genetic variances were found important in the inheritance of protein content. However, non-additive genetic variances were higher in magnitude than additive components in the two generations studied. Over dominance $[(H_1/D)^{1/2}]$ was observed for protein content in both F_1 and F_2 generations.

The heritability estimate for oil content was low and for protein content was moderate to high in both the generations. Oil and protein contents showed strong negative relationship (r = -0.74) indicating that selection for low oil should result in high protein content.

Breeding procedures that mop up non-additive variance effectively, like biparental mating or reciprocal recurrent selection, should be followed to select for high protein or low oil content (Brim and Burton 1979).

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Evaluation of Bold-seeded Groundnut Accessions for Confectionery Attributes

K Rajgopal, K Chandran, J B Misra, P K Bhalodia, and R S Mathur (National Research Centre for Groundnut, Ivnagar Road, PB No. 5, Junagadh 362 001, Gujarat, India)

Although groundnut in India is primarily used as an oilseed, it is also consumed directly as food because of its palatability. Besides oil (about 48%) and protein (about 22%), groundnut seeds contain carbohydrates (10%), minerals (3%), and B complex vitamins especially thiamin (1 mg $100g^{-1}$) and niacin (17mg $100g^{-1}$)- Hand-picked selected (HPS) seeds of groundnut are important for export. The seed size (seed mass) is one of the most important trade attribute for export of HPS groundnut. A minimum mass of 44 g for 100 seeds is essential for a groundnut sample to qualify its grading as HPS (Sankara Reddi 1988). Of late, other sources of oil have started competing with groundnut in India. For ensuring a better profitability to groundnut farmers, it is desirable to find alternate uses of groundnut for food and food products. The large seed size is of considerable importance for direct consumption.

Among the cultivated forms, varieties belonging to the subsp *hypogaea* var *hypogaea* have shown considerable variation in seed mass (21-116 g 100^{-1} seeds) in the primary gene pool (Bhagat et al. 1985, Simpson et al. 1992). Thus, there exists a considerable scope for improvement of the cultivated groundnut cultivars for confectionery purposes.

Of the 118 bold-seeded accessions evaluated for two years, 12 accessions were further evaluated along with controls for pod yield and seed quality at the National Research Centre for Groundnut (NRCG), Junagadh, India. The trial was conducted for two years during rainy season

Table 1. Pod yield and quality attributes of some bold-seeded accessions pooled over two years (1991 and 1992).

NRCG no.	Other identity	Pod yield (kg ha^{-1})	Physical attributes: Shelling (%)	Sound mature seeds (%)	100-seed mass (g)	Chemical attributes: Oil (%)	Protein (%)	Sucrose (%)
Virginia bunch								
7276	JL 55	1593	68.2	86.3	57.2	49.4	22.2	5.3
7239	JL 60	1515	67.9	87.7	54.1	50.6	21.1	6.2
8939	BAU 12	2095	64.8	90.5	69.9	50.0	20.3	5.5
5505	RS 1	2318	67.2	82.8	56.3	50.5	20.7	6.2
839	NC AC 1855	1613	67.8	82.7	54.8	51.4	21.1	4.9
2863	UF 780-14	1415	66.6	81.1	54.2	50.7	23.5	5.1
Mean		1758	67.1	84.1	56.2	50.5	21.4	5.4
Virginia runner								
2746	Florispan runner	1240	66.6	78.3	52.9	50.7	21.1	5.6
698	NCAC 2831	1437	65.6	81.0	50.2	50.3	22.8	6.0
5850	Var61-R	1650	60.5	82.3	57.5	48.4	19.4	6.1
734	NCAC 324	1428	66.4	79.9	49.4	50.6	22.3	6.0
912	NCAC 2938	1498	65.9	78.3	53.7	49.1	19.3	7.1
750	NCAC 6755	1607	66.2	79.3	56.3	48.6	22.0	6.0
Mean		1476	65.2	79.7	53.1	49.4	21.2	6.2
Control	GG 11	1401	67.1	77.5	46.8	51.0	21.1	4.7
Control	M 13	1320	65.5	78.7	51.5	48.1	20.8	6.6
SEm		±86	±1.3	±2.1	±1.6	-	-	-
CD (0.05)		311	3.6	5.9	4.6	-	-	-

of 1991 and 1992 in randomized block design with three replications. A 4-m plot size with interrow and intra-row spacings of 60 cm and 10 cm, respectively was adopted. Each plot comprised three rows. Standard cultural practices were followed to raise a good crop. Observations on pod yield, shelling percentage, sound mature seeds (SMS), and 100-seed mass were recorded. The seed samples of one season were analyzed for oil, protein, and sucrose contents following Kuck and St. Angelo (1980), Ballentine (1957), and Ashwell (1957), respectively.

The average pod yield ranged from 1240 kg ha^{-1} to 2318 kg ha*'. Accessions NRCGs 5505,8939, and 5850 produced significantly greater pod yield than controls (Table 1). All the accessions studied showed uniform maturity. Although the accessions interacted with seasons, it did not much affect the relative rankings for pod yield (detailed data not presented). NRCG 5505 ranked first and NRCG 5850 ranked fourth in both seasons. However, NRCG 8939 ranked second in 1991 and fourth in 1992. Shelling percentage was relatively narrow with a minimum of 60.5% for NRCG 5850 and maximum of 68.2% for NRCG 7276, with no significant variation among accessions (except for NRCG 5850). The SMS percentage was highest for NRCG 8939 (90.5%) and lowest for control GG11 (77.5%). NRCGs 8939,7239, and 7276 gave significantly higher SMS than both the controls. The 100-seed mass ranged from 46.8 g for GG 11 to 69.9 g for NRCG 8939. NRCGs 8939, 5850, 7276, 5505, and 750 gave a significantly higher 100-seed mass than the control M 13. The oil content ranged from 48.1% (M 13) to 51.4% (NRCG 839), protein content from 19.3% (NRCG 912) to 23.5% (NRCG 2863), and sucrose from 4.7% (GG11) to 7.1% (NRCG 912).

The SMS percentage and the oil content of seeds of Virginia bunch genotypes were significantly higher than those of Virginia runner genotypes while the reverse was true for sucrose content.

For confectionery purpose, besides higher 100-seed mass and SMS, seeds with lower oil content and higher protein and sucrose contents are preferred. The accessions NRCGs 2863, 5505, 7276, and 8939 have low oil, high protein, and high sucrose contents and were identified for confectionery purpose. The latter two accessions also produced

higher pod yield. They may therefore be used for genetic enhancement for improving the seed quality traits along with pod yield.

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Evaluation of Some Confectionery Type Advanced Breeding Lines of Groundnut

P Manivel, R K Mathur, A Bandyopadhyay, M Y Samdur, and J B Misra (National Research Centre for Groundnut, Ivnagar Road, PB No. 5, Junagadh 362 001, Gujarat, India)

Groundnut is one of the important oilseed crops of India and also an important exportable agricultural commodity. With an annual groundnut production of about 83 million t, India ranks second, after China, among groundnut producing countries and contributes about 26.7% to the world groundnut production. India's share in international export of shelled groundnuts has been growing for the last few years and with an export of 255,0001 in 1997, it's share is 22% (FAO 1999).

With the growth of other conventional and non-conventional vegetable oilseed crops in the past two decades in India, the pressure on groundnut crop as a source of vegetable oil has eased considerably and it can now be looked upon as an item of highly nutritive food besides an oil. However, it would be necessary to develop groundnut varieties more suitable for direct consumption and processing. Hand-picked and selected (HPS) groundnuts are premium edible grade nuts and in great demand all over the world. Various physical, sensory, chemical, and nutritional factors determine the quality of edible groundnut (Nigam et al. 1989). Groundnut with large seed, low oil but with high oleic acid/linoleic acid (O/L) ratio is preferred. Therefore the National Research Centre for Groundnut (NRCG), Junagadh, Gujarat, India has undertaken a program to develop cultivars more suitable for direct consumption and processing. Twelve advanced breeding lines were evaluated along with 3 controls (B 95, Somnath, and ICGV 89211) for pod yield and seed quality traits.

A replicated trial was conducted in rainy season (kharif) 1998. Seeds of each genotype were sown in 5-row plots (row length 5 m; interrow spacing 60 cm; and plant spacing 10 cm). Standard cultural practices recommended for the region were followed for raising the crop. The crop was harvested at 110-120 days depending on its maturity. Observations on pod yield, and physical and chemical characteristics of seeds were recorded. The sound mature seeds of each genotype were analyzed for oil (Kuck and St. Angelo 1980), protein (Ballentine 1957), free amino acid (Spies 1957), and sugar (Ashwell, 1957).

Significant genotypic differences were observed in pod yield and seed quality traits (Table 1). Pod yield of PBS 29017 was high (2886 kg ha^{-1} compared to the control ICGV 89211 (1638 kg ha^{-1}). The shelling percentage also differed significantly and ranged from 58.2% (PBS 19003) to 70.7% (PBS 29026). As the rankings of the genotypes for pod yield and shelling percentage differed, the differences in pod yield were not proportionately reflected in the seed yield. The genotype PBS 29017 had high seed yield (2000 kg ha^{-1}) compared to the best control Somnath (1555 kg ha^{-1}). The 100-seed mass of the test genotypes and controls ranged from 53.9 g (PBS 29036) to 76.7 g (ICGV 89211). None of the genotypes were superior over the best control (ICGV 89211). However, PBS 29017 and PBS 29020 were statistically on par with the second best control, Somnath.

Table 1. Yield and quality characteristics of confectionery groundnut genotypes.

Genotype	Growth habit	Pedigree	Pod yield (kg ha^{-1})	Shelling (%)	Seed yield (kg ha^{-1})	100-seed mass (8)	Chemical attributes[1] (%)				
							Oil	Protein	Sucrose	FAA	RS
PBS 29017	Virginia	M 13 x NCAc 17500	2886	69.3	2000	69.3	51.6	26.0	5.66	0.21	0.23
PBS 29031	Virginia	M 13 x NCAc 17278	2715	70.2	1909	61.1	53.3	20.1	9.02	0.29	0.35
PBS 11039	Spanish	Dh 3-30 x NCAc 2214	2752	68.0	1874	58.6	53.8	32.9	7.39	0.33	0.16
PBS 20910	Virginia	M 13 x NCAc 17278	2576	70.4	1817	62.7	51.5	26.3	8.17	0.38	0.26
PBS 29020	Virginia	M 13 x NCAc 17278	2534	70.6	1793	64.1	52.6	23.6	6.15	0.23	0.21
PBS 29036	Virginia	M 13 x Robut 33-1	2538	66.3	1683	53.9	47.3	20.7	9.74	0.37	0.27
PBS 20093	Virginia	M 13 x NCAc 17278	2595	64.5	1673	55.5	53.0	28.5	6.47	0.27	0.20
PBS 29027	Virginia	M 13 x NCAc 17278	2317	69.9	1620	60.7	50.7	15.5	4.40	0.22	1.09
PBS 29033	Virginia	M 13 x NCAc 17494	2383	67.1	1600	55.2	50.6	21.3	5.21	0.29	0.26
PBS 29026	Virginia	M 13 x NCAc 17278	2162	70.7	1527	61.3	52.8	23.4	7.63	0.62	1.21
PBS 19003	Spanish	M 13 x PI 314817	2534	58.2	1474	55.0	52.7	28.1	7.97	0.33	0.22
PBS 29035	Virginia	M 13 x Robut 33-1	2107	68.8	1446	62.1	51.4	18.0	7.09	0.25	0.33
Control											
Somnath	Virginia		2206	70.4	1555	69.0	52.3	24.8	7.78	0.30	0.22
B 95	Virginia		1797	65.1	1170	63.2	53.8	29.6	7.46	0.30	0.24
ICGV 89211	Virginia		1638	66.4	1088	76.7	52.5	25.2	8.82	0.28	0.24
Mean			2383	67.0	1615	61.9	52.0	24.3	7.26	0.31	0.37
CD (5%)			702.1	1.73	485.6	5.46		6.67	0.11	1.51	0.59

1. FAA = Free amino acid; RS = Reducing sugar.

Among the test genotypes, oil content was highest in PBS 11039 and lowest in PBS 29036. The protein content ranged from 15.5% to 32.9% and PBS 11039 had higher protein content than the best control, B 95. The free amino acid content of seeds ranged from 0.21% (PBS 29017) to 0.62 % (PBS 29026). Seven genotypes had lower free amino acid content than the best controls (B 95 and Somnath).

The reducing sugar content ranged from 0.16% (PBS 11039) to 1.21% (PBS 29026). Five genotypes had lower reducing sugar content than the best controls (ICGV 89211 and B 95). However, the reducing sugar content of PBS 29026 was five times that of the best controls (B 95 and ICGV 89211). Sucrose content ranged between 9.74% (PBS 29036) and 4.40% (PBS 29027). PBS 29036 and PBS 29031 had higher sucrose content than the best control ICGV89211.

All the genotypes, except PBS 29036, had >50% oil content. A positive association between high oil content and seed size has been reported earlier (Kale et al. 1988, Dwivedi et al. 1990). PBS 29036 is the best genotype based on comparable pod/seed yield, low oil content, and high sucrose content man controls. PBS 11039 is another promising genotype due to its high seed yield, high protein content, and very low reducing sugar content. It belongs to Spanish bunch group and matures in 110 days while the controls mature in 125 days.

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Screening Foliar Disease Resistant Groundnut Genotypes for Tolerance to Lime-induced Iron Chlorosis

B N Motagi, M V C Gowda, and G K Naidu (Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad 580 005, Karnataka, India)

Chlorosis due to iron deficiency is one of the most important factors limiting groundnut productivity in large stretches of calcareous soils in India. An economic and practically feasible approach to alleviate this problem is to grow iron absorption efficient and productive cultivars. Visual scores for iron chlorosis and chlorophyll estimations of 50- to 60-day-old plant samples grown in potted calcareous soil were considered as reliable criteria to classify cultivars as iron-efficient and iron-inefficient (Kulkarni et al. 1995, Samdur et al.1999).

Most of the present-day varieties under cultivation are iron-inefficient and existing efficient lines are not suitable for commercial cultivation as they lack desirable agronomic features and productivity. Hence, there is a strong need to identify iron-efficient/tolerant genotypes combining other desirable attributes. The present investigation envisages to screen the foliar disease resistant productive genotypes for tolerance to iron-deficiency chlorosis.

Thirteen genotypes comprising foliar disease resistant mutants and cross derivatives and their susceptible sister lines along with ruling susceptible cultivars and resistant cultivar/germplasm were screened for iron-deficiency chlorosis in pot experiments during 1999 rainy season. Pots of uniform size were filled with normal soil (pH 7.6; 4.8% calcium carbonate) and calcareous soil (pH 8.9; 19.98% calcium carbonate). In each pot three seeds were dibbled in triangular fashion at equidistance. The pots were watered regularly up to field capacity and the plants were regularly protected against pests and diseases. Iron deficiency was measured by visual chlorotic rating on 1-5 scale (1= dark green, 2 = green, 3 = light green, 4 = light yellow, and 5 = yellow with chlorotic spots) at 60 days after emergence (DAE). The third leaf of main axis of each plant of a line was collected, bulked, and then total chlorophyll content (mg g^{-1} of fresh weight) was estimated at 60 DAE by following the procedure of Shoaf and Lium (1976). Based on visual chlorotic rating the genotypes were grouped into three categories: (1) Efficient (E): showing dark green to green leaves with visual chlorotic rating of <2.5; (2) Moderately efficient (ME): light green leaves with visual chlorotic rating of 2.5-3.5; and (3) Inefficient (IE): genotypes with light yellow to yellow leaves with visual chlorotic rating of >3.5 and plants showing some interveinal chlorosis (a typical symptom of iron deficiency) leading to complete chlorosis with appearance of white papery leaves at later stages.

The iron-absorption efficient genotypes GBFDS 272 and Dh 8 exhibited least (<30%) reduction in chlorophyll content (Table 1). The reduction ranged from 30% to 50% in the moderately-efficient genotypes, D 39d and its susceptible sister line D 39ds, susceptible ruling cultivars (JL 24, T M V 2, T A G 24), and the resistant cultivar ICG V 86590. On the contrary, mutants VL 1,28-2, and 28-2 (S), the cross derivative B 37c, and the susceptible cultivar R 8808 were inefficient and recorded more than 50% reduction in chlorophyll content.

Foliar disease resistant productive genotypes, GBFDS 272 and D 39d (Motagi et al. 2000) have efficient/moderately efficient status and can be grown in calcareous soils. These genotypes can serve as donors of iron-absorption efficiency in hybridization programs.

Table 1. Performance of foliar disease resistant groundnut genotypes for iron-absorption efficiency at Dharwad, Karnataka, India, rainy season 1999.

Genotype	Total chlorophyll content[1] (mg g^{-1} fresh weight)		Reduction in chlorophyll content	Visual chlorotic rating (1-5 scale)		Iron-efficiency status[2]
	Normal	Calcareous	(%)	Normal	Calcareous	
Mutants						
VL1	1.06fg	0.44g	58.19	1.5	4.0	IE
28-2	1.11f	0.34h	69.40	2.5	4.5	IE
28-2(S)	1.15e	0.15i	86.91	1.5	5.0	IE
Cross derivatives						
D 39d	1.18e	0.74d	37.42	1.5	3.0	ME
D 39d(S)	1.32c	0.74d	43.67	1.5	3.0	ME
B 37c	1.03g	0.45g	56.59	2.0	4.5	IE
Susceptible cultivars						
Dh 8	1.25d	0.88b	29.92	1.0	2.0	E
R 8808	1.65a	0.56e	66.11	2.0	4.0	IE
JL 24	1.18e	0.79bc	33.30	1.5	3.0	ME
TMV 2	1.08fg	0.57e	47.60	1.5	3.5	ME
TAG 24	1.44b	0.81bc	43.77	1.5	3.5	ME
Resistant cultivar/germplasm						
ICGV 86590	0.91h	0.58f	36.22	1.5	3.0	ME
GBFDS 272	1.16e	0.93a	19.62	1.0	2.0	E
Grand Mean	1.18	0.61	48.85	–	–	–
CD (5%)	0.03	0.02	–	–	–	–
CV (%)	1.28	1.65	–	–	–	–

1. Figures with same letters do not differ significantly at 5% level of probability.
2. E = Efficient; ME = Moderately efficient; and IE = Inefficient.

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Performance of Virginia Groundnut Varieties in the Northeastern Dry Zone of Karnataka, India

P Surendra[1], D M Mahalinga[2], S D Yeishetty[2], and M S Patil[3] (1. College of Agriculture, Bijapur 586 101, Karnataka, India; 2. Agricultural Research Station, Gulbarga 585 101, Karnataka, India; 3. Regional Research Station, Bijapur 586 101, Karnataka, India)

Groundnut (*Arachis hypogaea)* is an important oilseed crop in Karnataka, India. It is cultivated in an area of 1.3 million ha, with production being 1.0 million t and productivity 0.8 t ha^{-1} (Directorate of Agriculture 1997). Inadequate and unpredictable rainfall coupled with disease and pest problems makes rainfed upland groundnut cultivation unprofitable. Development and evaluation of drought resistant/tolerant varieties is one of the important breeding objectives in this region. The experiment was conducted during rainy season (kharif) (June-October) in 1995 and 1996 at the Agricultural Research Station, Gulbarga located in the northeastern Dry Zone of Karnataka. The average rainfall is 720 mm of which an average of 524 mm is received in the rainy season. The soil is medium black with pH of 7.0 to 7.5. Five Virginia (subsp *hypogaea* var *hypogaea)* varieties and a local cultivar were grown in a randomized block design with three replications. The plot consisted of five rows of 4.8 m each with 45 cm interrow and 15 cm intra-row spacing. Recommended agronomic practices were implemented and adequate plant populations were maintained. Data pooled over two years were analyzed using appropriate statistical methods (pooled analysis) to assess the significance of the data (Table 1). Incidence of rust and late leaf spot was scored using 1-9 scale (Subrahmanyam et al. 1995). Leaf miner incidence was recorded using 1-9 scale, where 1 = no damage and 9 = 81-100% defoliation.

Table 1. Mean performance of Virginia genotypes of groundnut at the Agricultural Research Station, Gulbarga, Karnataka, India, 1995 and 1996 rainy season[1].

Variety	Pod yield (t ha^{-1})	Shelling (%)	Oil content (%)	Oil yield (t ha^{-1})	Score		
					Rust[2]	Late leaf spot[2]	Leaf miner[3]
ICGV 86699	1.97**	59.8	47.2*	0.55**	1.4**	1.7*	1.03
ICGV 87165	1.96**	60.4*	47.6**	0.56**	1.6*	1.4*	1.07
GBFDS 272	1.82*	57.5	47.0*	0.59*	1.7*	1.9*	1.30
ICGS 76	1.56	65.4**	44.0	0.45	5.7	6.3	1.33
CSMG 84-1	1.44	59.1	43.6	0.37	2.5	3.3	0.97
S 230	0.94	59.3	46.1	0.26	4.3	4.7	0.67
Mean	1.58	59.0	45.6	0.48	3.33	4.67	0.93
SEm	±0.19	±2.93	±0.86	±0.08	±0.16	±0.20	±0.08
CV (%)	24.00	9.97	3.55	11.50	20.25	20.77	7.11

1. *Significant at 5%; **Significant at 1%.
2. Scored on a 1-9 scale, where 1 = no incidence, and 9 - >80% incidence.
3. Scored on a 1-9 scale, where 1 = no damage, and 9 - 81-100% defoliation.

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Performance of Local Spreading Type Groundnut Genotypes at Bijapur in Karnataka, India

B G Prakash, N Y Naykar, and K M Halaswamy (Regional Research Station, Bijapur 586 101, Karnataka, India)

Karnataka state of India grows groundnut on 1.24 million ha with a production of 1.03 million t. In Bijapur and

Bagalkot districts of Karnataka, the cultivation of groundnut is restricted to 0.23 million ha with a production of 0.14 million t. Almost 70% of the farmers in Bagalkot district (recently carved out of Bijapur district) continue to grow local spreading groundnut varieties (Table 1), in spite of recommended varieties S 230 and Pondicherry 8, in rainfed condition with protective irrigation. Farmers find local varieties higher yielding than recommended varieties. An extensive survey was made around Badami, Jamakhandi, Mudhol, Bilagi, and Hunugund taluks of Bijapur district

Table 1. Performance of spreading groundnut genotypes at the Regional Research Station, Bijapur, India, 1996 and 1998 rainy season.

Genotype	Bud necrosis[1] (%) (1996)	Disease rating[2] (1998)		No. of pods plant^{-1} (1998)	Pod yield (kg ha^{-1}) (1998)	Shelling (%) (1998)
		Late leaf spot	Rust			
ICG 1008	43.5	6.5	5.5	23	866	52.8
ICG 2773	48.2	8.0	9.0	25	755	62.3
(JH 60 x A-sel) x (NRCG 2144)	52.4	5.5	4.5	10	978	67.0
Mamdapur Local 1	63.6	4.5	3.5	22	799	56.5
Mamdapur Local 2	65.5	6.0	4.5	24	770	70.5
Kolar Local	55.0	5.5	4.0	13	1060	62.4
Chiknandi Local 1	52.0	4.5	5.0	14	1234	58.4
Mamdapur Local 3	42.5	4.0	5.5	19	1375	51.3
Shcttibhavi Local	45.8	6.5	6.5	31	997	63.9
Devoor Local	66.6	5.0	6.5	25	1060	65.5
Hanumnal Local	41.7	8.5	5.0	45	1268	72.9
Nilagol Local	47.0	5.0	7.0	16	1312	56.5
Hanumasagar Local	4.5	3.5	7.0	21	1481	50.6
Mustigere Local	56.2	5.0	5.5	29	1389	69.8
ICG 544	72.3	4.5	9.0	15	823	60.1
Horti Local 1	70.5	5.0	4.5	13	1007	62.3
Horti Local 2	64.8	6.0	3.5	31	1041	58.0
ICG 821	18.4	3.0	4.5	17	1344	65.5
ICG 9713	22.0	6.5	4.0	23	713	66.7
Khadak Local	55.4	7.0	4.5	22	1236	67.1
Chiknandi Local 2	8.6	5.0	5.5	21	833	56.5
Anagal Local	74.4	6.5	5.0	53	988	65.1
Muttalgeri Local	64.0	5.5	4.5	17	707	55.9
Bevoor Local 1	77.0	5.0	5.5	15	693	60.5
Bevoor Local 2	58.5	5.5	6.0	13	1036	67.3
Badami Local	65.0	6.5	9.0	18	815	56.5
Kushtageri Local 1	49.1	6.5	5.5	16	645	68.1
Kushtageri Local 2	70.3	5.0	5.5	14	869	66.9
Jalihal Local 1	65.4	7.5	6.0	10	820	66.4
Jalihal Local 2	55.0	4.5	6.5	28	1160	65.5
Ron Local	43.6	7.0	7.5	21	925	66.5
Sankeshwar Local	58.1	6.5	9.0	19	902	58.0
Sirur Local	62.5	4.5	4.5	29	863	64.0
S 230	57.6	7.0	7.0	21	934	59.6
SEm		±1.86	±1.65	±9.20	±44.2	±7.24
CD (5%)		5.02	4.51	24.38	115.1	19.54
CV (%)		-	-	4.78	22.8	9.15

1. Observations were recorded in the year (1996) when disease incidence was high. Yields were very low in 1996 rainy season.
2. Observations were recorded in the year (1998) when disease incidence was high.

during 1994-95 and 27 samples of spreading type groundnut were collected from farmers' fields to evaluate them with other varieties including control.

Twenty-seven genotypes from farmers' fields, five genotypes from ICRISAT, Patancheru, India, one genotype [(JH-60 x A-sel) x NRCG 2144] from the National Research Centre for Groundnut (NRCG), Junagadh, India, and control S 230 were evaluated at the Regional Research Station, Bijapur during rainy season in 1996 and 1998 in a randomized complete block design with two replications. The plot size was 5.00 m x 1.35 m with 45 cm interrow and 15 cm intra-row spacing. Recommended agronomic practices were followed. The ancillary observations were recorded on five plants and pod yield was recorded plot-wise in each replication. Disease incidence of late leaf spot and rust was recorded on a modified 1-9 scale (Subrahmanyam et al. 1995). Bud necrosis incidence was categorized as susceptible (S = 51-100%), moderately susceptible (MS = 40-50%), moderately resistant (MR = 11-39%), and resistant (R = 1-10%), based on the performance of infected plants.

The pod yield ranged from 645 kg ha^{-1} to 1481 kg ha^{-1} with Hanumasagar Local producing the highest pod yield (Table 1). The number of pods $plant^{-1}$ ranged from 10 to 53 with Anagal Local having maximum pods. The shelling percentage ranged from 50.6 to 72.9 with highest shelling recorded by Hanumnal Local. Hanumasagar Local, the genotype with highest yield was resistant to bud necrosis (4.5%) and late leafspot (3.5 score). Similarly, ICG 821, which was moderately resistant to bud necrosis (18.4%), resistant to late leafspot (3.0 score), and moderately resistant to rust (4.5 score), also recorded good yield (1344 kg ha^{-1}). Bud necrosis is a serious problem in Bijapur (Desai 1998) and there is a need to introduce such resistant genotypes in endemic areas as they not only check the spread of the disease, but are also high yielding. Mustigere Local was also high yielding (1389 kg ha^{-1}) with good shelling percentage (69.8%). It was moderately resistant to both late leaf spot (5.0 score) and rust (5.5 score) but susceptible to bud necrosis (56.2%). On the other hand, another high-yielding genotype Mamdapur Local 3 (1375 kg ha^{1}) was moderately resistant to late leaf spot (4.0 score) and rust (5.5 score) and moderately susceptible to bud necrosis (42.5%). From these results, it is clear that genotypes for Bagalkot district should have resistance/tolerance to bud necrosis, late leaf spot, and rust. The recommended variety, S 230, is susceptible to all the three diseases. This could be one of the reasons why farmers do not grow it.

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New Groundnut Cultivars for Gujarat, India

P S Bharodia (Groundnut Research Station, Gujarat Agricultural University, Junagadh 362 001, Gujarat, India)

Gujarat state accounts for 25% of the total area sown to groundnut in India. Groundnut occupies 20% of the total cultivated area in the state. The Groundnut Research Station, Gujarat Agricultural University at Junagadh, Gujarat is a pioneering research station in the country and has contributed several high-yielding groundnut varieties of the state and the nation. However, the groundnut research activities at the station suffered a major setback in 1987 when peanut stripe virus (PStV) was detected in groundnut material. The station was quarantined for groundnut crop. All the breeding and seed production activities were kept on hold. The virus is seedborne and is transmitted by the aphid *Aphis craccivora.* With concerted, systematic efforts based on scientific principles, we were able to eliminate PStV in groundnut materials and the quarantine on groundnut was lifted in 1998/99 season. During the period of quarantine, disease-free seeds of important breeding materials tested by enzyme-linked immunosorbent assay (ELISA) were generation advanced at other locations in the state and selection was carried out. In the last five years, two new promising varieties—Gujarat Groundnut 5 (GG 5) and Gujarat Groundnut 6 (GG 6)—were released and others are in pipeline.

The variety GG 5 was bred and developed from the cross 27-5-1 x JL 24. It was released in 1996 for rainy season

(kharif) cultivation in the main groundnut-growing areas of Saurashtra, Gujarat. It is early in maturity (101 days). It has erect growth habit and sequential-branching pattern. Leaves are obovate in shape and light green in color. Pods are generally two-seeded, with reticulation and without constriction. Seeds are medium in size (0.38-0.42 g seed^{-1}). They are light rose in color and contain 48.7% oil. GG 5 gives 33.5% and 23.7% higher yield than check varieties J 11 and GG 2 respectively. It has a shelling out-turn of 73.7%. Its reaction to diseases and pests is similar to check varieties.

The variety GG 6 was bred and developed from the cross CGC 3 x FESR 5-P_6B_1-B_1. It was released in 1999 for summer cultivation in Gujarat. It is early in maturity (109 days). It has erect growth habit and sequential branching pattern. Leaves are oblong elliptic in shape and light green in color. Pods are generally two-seeded, with reticulation and slight constriction. Seeds are oblong and medium in size (0.32-0.38 g seed^{-1}). They are light rose in color and contain 50.3% oil. GG 6 gives 22.9%, 17.5%, and 14.3% higher yield than check varieties J 11, GG 4, and GG 2 respectively. It has a shelling out-turn of 73%. Its reaction to diseases and pests is similar to check varieties.

A New Groundnut Variety for Vidarbha Region of Maharashtra State of India

S N Deshmukh, N S Shrikhandkar, G N Satpute, H S Gahukar, A Y Thakre, R B Ulemale, and W M Dabre
(Oilseeds Research Unit, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola 444 104, Maharashtra, India)

Groundnut area in rainy season (kharif) (June-October) is declining in the Vidarbha region of Maharashtra state of India. The average area in the 1990s (average of 1990-98) was 71,029 ha compared to 111,600 ha in the 1980s (average of 1980-89). The main reasons for the reduction in area are non-availability of high-yielding groundnut varieties having desirable traits and lack of transfer of improved technology of groundnut production to farmers. In response to this situation, varietal development of groundnut was given top priority in the University (Dr Panjabrao Deshmukh Krishi Vidyapeeth) at Akola in Maharashtra. As a result, AK 159 was developed, tested (Table 1), and released in 2000 for rainy season (kharif) as a high-yielding, medium-duration variety (PKV 2000).

Table 1. Pod yield of groundnut variety AK 159 and check cultivars in different trials in the Vidarbha region of Maharashtra, India.

Year	Trial[1]	No. of locations	Average pod yield (t ha^{-1})							
			AK 159	TAG 24[2]		TG 26[2]		JL 24[2]	
1994	PYT	1	1.13	0.88	(27.7)	1.06	(6.6)	0.53	(112.5)
1995	IET	2	2.64	2.26	(16.8)	2.44	(8.4)	2.13	(24.2)
1996	MVT	4	2.07	1.66	(24.8)	1.90	(9.2)	2.09	(-0.4)
1997	MVT	5	2.54	1.86	(36.5)	1.94	(31.0)	1.87	(36.0)
1998	MVT	5	2.51	1.73	(45.0)	1.79	(40.4)	1.85	(35.7)
1999	MVT	4	2.36	1.61	(46.8)	1.52	(55.4)	2.08	(13.3)
1996-99	MVT	18[3]	2.39	1.72	(38.5)	1.79	(33.1)	1.96	(22.0)
1998	Adaptive trial	2	2.36	-		2.00	(17.8)	–	
1999	Adaptive trial	9	1.63	1.06	(54.4)	–		–	

1. PYT = Preliminary Yield Trial; IET = Initial Evaluation Trial; MVT = Multiplication Varietal Trial.
2. Control; figures in parentheses indicate percentage increase in yield of AK 159 over control.
3. Pooled average of 18 environments. For pooled analysis, SEm = ± 0.062, CD at 5% level = 0.172, and CV (%) = 14.0.

AK 159, a Spanish bunch genotype, was derived from a cross between JL 24 (a locally adopted Spanish bunch variety) and a Spanish breeding line resistant to foliar diseases, CGC 4018 at Akola. JL 24 is a selection from EC 94943. CGC 4018 was derived by pedigree selection from 14-4-B-19-B *x* Nc Ac 17090. AK 159 was developed following pedigree method of selection.

Distinguishing morphological characters of AK 159 are normal plant type (30-40 cm height); dark green and broad leaflet; and medium to small pods with slight beak, slight constriction, and less reticulation. The seeds are whitish rose in color.

AK 159 matures in 100-105 days and has moderate shelling (68.3%), moderate seed size (100-seed mass 32.5 g), high sound mature seeds (92.8%), and average oil content (47.9%).

AK 159 was included in replicated yield trials in the areas under the jurisdiction of Dr Panjabrao Deshmukh Krishi Vidyapeeth from 1994 to 1999. On average over 18 environments, it yielded 2.39 tha^{-1} which was 38.5% more than that of TAG 24, 33.1% more than that of TG 26, and 22.0% more than that of JL 24. In adaptive trials also, AK 159 maintained its pod yield superiority (Table 1).

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Tirupati 4: A High-yielding Groundnut Variety for Andhra Pradesh, India

J Ramachandra Reddy, N Rajagopal, R P Vasanthi, L Prasanthi, and C Ramana Reddy (Regional Agricultural Research Station, Acharya N G Ranga Agricultural University, Tirupati 517 502, Andhra Pradesh, India)

Groundnut is an important edible oilseed crop in Andhra Pradesh, India. It is cultivated on about 2.2 million ha of which 70% is in the rainy season. TCGS 30, a derivative of JL 24 x Ah 316/s was developed by mass pedigree method at the Groundnut Breeding Unit, Regional Agricultural Research Station, Tirupati, Andhra Pradesh. It was released as Tirupati 4 by the Andhra Pradesh Agricultural University (now Acharya N G Ranga Agricultural University) in 1995 for cultivation in Andhra Pradesh.

Tirupati 4 is a Spanish bunch variety. It matures in 105 days after sowing (DAS) in rainy season and in 105-110 DAS in postrainy season on par with JL 24. Its leaves are green and pods are medium bold with prominent reticulation, slight beak, and moderate constriction. The seed is rose in color.

Tirupati 4 was evaluated in three rainy seasons (1990, 1991, and 1992) and three postrainy seasons (1991/92, 1992/93, and 1993/94) at Tirupati. Pod yield of Tirupati 4 was 19% more in the rainy season and 16% more in the postrainy season than JL 24 (Table 1). Seed yield was 20% more in the rainy season and 24% more in the postrainy season than JL 24. Tirupati 4 was earlier tested at 10 locations

Table 1. Performance of Tirupati 4 in rainy and postrainy seasons at Tirupati, Andhra Pradesh, India.

		Rainy season (kharif)				Postrainy season (rabi)			
Character	Variety	1990	1991	1992	Average	1991/92	1992/93	1993/94	Average
Pod yield (kg ha^{-1})	Tirupati 4	1786	1595	1628	1670	3326	1782	5505	3538
	JL 24	1425	1305	1472	1401	2489	1260	5381	3043
SE		±82	±117	±94		±272	±424	±212	
CV (%)		9	13	15		15	18	18	
CD (0.05)		168	239	195		563	-	428	
Seed yield (kg ha-')	Tirupati 4	1138	1212	1164	1171	1516	1158	4301	2325
	JL 24	948	953	1023	975	1062	756	3777	1865
100-podmass(g)	Tirupati 4	84	106	95	95	90	70	108	89
	JL 24	81	94	95	90	91	70	93	85
100-seed mass (g)	Tirupati 4	37	48	43	43	39	37	56	44
	JL 24	34	47	44	42	39	40	56	45

under the All India Coordinated Research Project on Oilseeds (AICORPO) in 1988/89 postrainy season; it produced 16% more pod yield (2490 kg ha^{-1}) than JL 24 (2148 kg ha^{-1}) and 19% more seed yield (1709 kg ha^{-1}) than JL 24 (1434 kg ha^{-1}).

Registration of Groundnut Cultivar Venus (ICGV 87853)

L J Reddy[1], S N Nigam[1], P Subrahmanyam[2], F M Ismael[3], N Govinden[3], and P J A van der Merwe[2]
(1. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India; 2. ICRISAT, PO Box 1096, Lilongwe, Malawi; 3. Mauritius Sugar Industry Research Institute, Reduit, Mauritius)

Purpose of description

The Mauritius Sugar Industry Research Institute recommended and released the groundnut *(Arachis hypogaea)* cultivar ICGV 87853 as 'Venus' for cultivation in 1998 (MS1RI 1998). Venus has significantly outyielded the popular cultivar Cabri by 48% and was more stable in yield than Cabri. The seeds of Venus are larger than those of Cabri and are accepted for boiled nuts. Venus is resistant to rust (*Puccinia arachidis)* and is recommended for cultivation both as a pure crop and as intercrop with sugarcane in Mauritius.

Origin and development

ICGV 87853 was developed from a cross between Kadiri 3 (ICG 799) and a stable interspecific derivative, CS-9. Kadiri 3 is a released Virginia cultivar grown in India. CS-9 is a derivative of a cross between PI 261942 and *Arachis cardenasii* with multiple disease and insect resistance and is registered as ICGV 87165 (Moss et al. 1997). ICGV 87853 was developed by bulk method of selection.

Performance

In the four foliar diseases resistance trials conducted at ICRISAT, Patancheru, India during rainy season in 1990 and 1991, ICGV 87853 with a mean pod yield of 1.58 t ha^{-1} outyielded the improved Virginia cultivar ICGS 76 by 43.7% and Kadiri 3 by 64.6% (Table 1). In another set of four drought tolerance trials conducted at ICRISAT during 1990-92 rainy and postrainy seasons, ICGV 87853 with a mean pod yield of 1.83 t ha^{-1} outyielded the popular Spanish cultivars, TMV 2 by 22.8% and ICGS 11 by 6.4%. In Mauritius, it has shown a mean pod yield superiority of 47% across 26 trials conducted at different locations during 1994-97 (Govinden and Ismael 1997) (Table 2). Venus with $Y = 1.08 x + 0.16$ ($r^2 = -0.90$) compared to $Y = 0.87 x - 0.38$ ($r^2 = 0.86$) of Cabri was more stable and predictable in its pod yield performance in Mauritius (Ismael and Govinden 1998).

Plant characters

ICGV 87853 belongs to the Virginia bunch botanical group *(Arachis hypogaea* subsp *hypogaea* var *hypogaea).* It has decumbent-3 growth habit; alternate flowering; and medium-sized, oval, dark green leaves. It has an average of six primary and four secondary branches. Its plant height is about 32 cm. The flower is yellow with orange crescent and red markings on the standard petal. ICGV 87853 matures in about 120 to 125 days during the rainy season and 135-140 days during the postrainy season at

Table 1. Pod yield of groundnut cultivar ICGV 87853 (Venus) and control cultivars at ICRISAT, Patancheru, India during rainy seaon in 1990 and 1991.

	Pod yield (t ha^{-1})				
Cultivar	1990 (HI)[1]	1990 (LI)[2]	1991 (HI)	1991 (LI)	Mean
ICGV 87853	1.55	1.02	2.11	1.65	1.58
ICGS 76 (control)	1.11	0.65	1.60	1.05	1.10
Kadiri 3 (control)	0.81	0.56	1.48	0.98	0.%
SE	±0.100	±0.174	±0.068	±0.162	
CV (%)		23	15	17	

1. HI = High input (60 kg P_2O_5 ha^{-1}; 400 kg gypsum ha^{-1}), supplemental irrigation, full protection from insects, and no protection from diseases.
2. LI - Low input (20 kg P_2O_5 ha^{-1}). rainfed, and no protection from insects and diseases.

Table 2. Pod yield at 8% moisture content of groundnut cultivar ICGV 87853 (Venus) and Cabri in various trials conducted in Mauritius from 1994 to 1997.

Year	Season	No. of trials	Mean pod yield (t ha^{-1}) ICGV 87853[1]	Cabri
1994	Second season	1	3.16	1.16
1995	First season	2	1.30	0.89
1995	Second season	5	4.16	2.19
1996	First season	4	2.08	1.87
1996	Second season	6	4.96	3.12
1997	First season	8	4.81	4.29
Overall mean (26 trials)			3.97	2.70
First season mean (14 trials)			3.53	2.81
Second season mean (12 trials)			4.48	2.57
LSD (0.05) First season			0.52	
LSD (0.05) Second season			0.66	

1. Mean pod yield superiority of ICGV 878S3 over Cabri in 26 trials is 47%.

Table 3. Reaction of ICGV 87853 and control groundnut cultivars to foliar diseases at ICRISAT, Patancheru, India during rainy season in 1990 and 1991.

Cultivar	Late leaf spot[1] 1990 (HI)[2]	1990 (LI)[3]	1991 (HI)	1991 (LI)	Rust[1] 1990 (HI)	1990 (LI)	1991 (HI)	1991 (LI)
ICGV 87853	7	6	6	7	3	3	4	3
ICGS 76 (control)	8	9	7	8	8	7	8	8
Kadiri 3 (control)	9	9	9	9	9	8	8	9
SE	±0.3	±0.4	±0.6	±0.5	±0.2	±0.3	±0.4	±0.3
CV (%)	7	8	11	10	6	9	5	11

1. Scored on a 1-9 scale, where 1 = no disease, and 9 = 81-100% foliage damaged.
2. HI = High input (60 kg P_2O_5 ha^{-1}; 400 kg gypsum ha^{-1}), supplemental irrigation, full protection from insects, and no protection from diseases.
3. LI = Low input (20 kg P_2O_5 ha^{-1}), rainfed, and no protection from insects and diseases.

ICRISAT, Patancheru. In Mauritius it took about 140-150 days to mature.

Pod and seed characters

ICGV 87853 usually has 2-seeded pods, which are characterized by a small beak, slight constriction, and moderate reticulation. The average pod length is 34 mm, and pod width is 10 mm. Its shelling turnover on average is 68%. Its 100-seed mass ranges from 32 g to 52 g depending on the season and location. The seeds of ICGV 87853 are tan and a higher proportion of them (57.5%) fall under the Virginia medium grade and a smaller proportion under Spanish no.1 and split grades.

Reaction to diseases and pests

In four trials conducted at ICRISAT, Patancheru, ICGV 87853 was resistant to rust (Table 3) with a mean score of 3.2 compared to a mean score of 7.8 for ICGS 76 and 8.5 score for Kadiri 3 on a 1-9 disease rating scale (Subrahmanyam et al. 1995). ICGV 87853 was moderately tolerant to late leafspot compared to the susceptible cultivar Kadiri 3 (Table 3).

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Huayu 16: A New High-yielding, Improved Quality Groundnut Cultivar with Wide Adaptability for Northern China

Li Zhengchao and Qiu Qingshu (Shandong Peanut Research Institute, Laixi 266601, Shandong, China)

China is one of the major groundnut (*Arachis hypogaedy* producing countries in the world. It ranks second in area and first in production of groundnut in the world. The average yield of groundnut in China increased by 188.5% in 1998 compared with 1949. Selection and extension of new groundnut cultivars has played an important role in increasing the productivity of groundnut in the country (Qiu Qingshu et al. 1996). But most of the current high-yielding cultivars in northern China, such as Luhua 14, Luhua 11, and Jiyou 4, have resistance only to the abnormal climatic conditions (drought or waterlogging), and their quality characteristics are not satisfactory. It is essential to develop new high-yielding cultivars with improved comprehensive characteristics.

Table 1. Average pod yield and seed yield of groundnut cultivar Huayu 16 in provincial trials and demonstration tests in Shandong and Hebei provinces, China.

Cultivar	Pod yield (t ha^{-1})	Pod yield increase over control (%)	Seed yield (t ha^{-1})	Seed yield increase over control (%)
A. Provincial trials[1]				
Shandong				
Huayu 16	3.97	11.36[2]	2.92	14.15[3]
Luhua 11 (control)	3.56		2.56	
Hebei				
Huayu 16	4.13	11.38[2]	3.12	16.5P
Jiyou 8 (control)	3.71		2.68	
B. Demonstration plots[4]				
Shandong				
Huayu 16	4.83	10.74[2]	3.54	13.21[3]
Luhua 11 (control)	4.37		3.13	
Hebei				
Huayu 16	3.77	7.48	2.88	12.09[2]
Jiyou 8 (control)	3.60		2.57	

1. Mean of 19 sites in Shandong in 1996/97 and 6 sites in Hebei in 1997/98.
2. Significant.
3. Highly significant.
4. Mean of 6 sites in Shandong and 3 sites in Hebei in 1998.

Huayu 16, a large-seeded groundnut cultivar, was developed in 1998 by the Shandong Peanut Research Institute in China, and released in 1999 by the Crop Cultivar Approval Committees of Shandong and Hebei provinces. It was derived from the cross of 8223 with Luhua 10 using the modified pedigree method. It belongs to Spanish group (*A. hypogaea* subsp *fastigiata* var *vulgaris*).

Average pod yield and seed yield of Huayu 16 and the control cultivars in provincial trials and demonstration tests in Shandong and Hebei provinces are presented in Table 1. In all trials and tests in the two provinces with 15 new groundnut cultivars, Huayu 16 always ranked first. In Anhui provincial demonstration tests in 1998, its average pod yield was 4.69 t ha^{-1}, 14.3% more than the control Luhua 9. In Laixi, Shandong province, in a yield maximization trial on 0.4 ha in 1999, it produced 9.54 t ha^{-1} pod yield.

Huayu 16 matures in 130 days in spring crop season. It has an erect growth habit, sequential flowering, and dark green leaves. The height of the main stem is 40 cm. The plant has 5-6 primary and 2-3 secondary branches. Pods are mostly two-seeded and clustered around the main taproot in the soil. The pod beak is short and the pod reticulation is thick and shallow. The 100-pod mass is 210 g and the 100-seed mass is 100 g with a shelling percentage of 75. Seed of Huayu 16 is rose in color and contains 52.89% oil and 29.66% protein, 1.80% and 3.81% more than that of Luhua 11, respectively. The oleic acid/linoleic acid (O/L) ratio is 1.7. In selenium, vitamin C, and vitamin B_1 contents, Huayu 16 ranked first among 10 advanced lines tested in 1999. The seed contains 0.086 mg kg^{-1} selenium, 7.38 mg $100g^{-1}$ vitamin C, and 14.84 mg kg^{-1} vitamin B_1, the contents being 0.004-0.014 mg kg^{-1}, 0.02-4.96 mg $100g^{-1}$, and 1.94-6.88 mg kg^{-1} more than other lines, respectively.

Huayu 16 is resistant to root rot (caused by *Macrophomina phaseolina*) and tolerant to peanut stripe virus (Table 2). The cultivar is resistant to drought and waterlogging, and has wide adaptability for northern China. Huayu 16 is one of the groundnut cultivars that has the best comprehensive characteristics in China.

Huayu 16 is suitable for sowing in medium or high fertility sandy loam soil. When the mean daily soil temperature at 5-cm depth in spring is 15°C for more than 5 days, it is an optimum sowing time for Huayu 16. Polythene mulching can help to achieve its high yield potential (Hu Wenguang et al. 1995). The optimum plant densities of Huayu 16 are 150,000 hills ha^{-1} with two seeds per hill for spring and 165,000 hills ha^{-1} for summer crop seasons.

Table 2. Reaction of groundnut cultivar Huayu 16 to production constraints in China, 1999.

	Score[1]			
Cultivar	Root rot	PStV[2]	Drought	Waterlogging
Huayu 16	1	3	2	1
Luhua 11 (control)	4	8	2	9
Luhua 14 (control)	4	3	2	8
Jiyou 4 (control)	5	9	7	

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.

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A New High-yielding Low Oil Content Groundnut Variety

Yu Shanlin, Cao Yuliang, Gu Shuyuan, and Min Ping
(Shandong Peanut Research Institute, Laixi 266601, Shandong, China)

A new high-yielding groundnut variety, Huayu 17, with low oil content, has been developed by the Shandong Peanut Research Institute, China. Huayu 17 was derived from the cross Luhua 9 x 79266 using modified pedigree method, and was released in 1999 by the Shandong Provincial Crops Approval Committee.

Yield performance

In the new groundnut lines tests of the Shandong Peanut Research Institute from 1993 to 1995, Huayu 17 outyielded the check Luhua 9 by 21.7% (Table 1). In Shandong Provincial New Groundnut Variety Trial (SPNGVT) from 1996 to 1997, Huayu 17 produced 12.5%

Table 1. Yield performances of groundnut variety Huayu 17 in various tests in China.

Test	Year	No. of sites	Average pod yield (kg ha^{-1})	Pod yield increase over control (%)
New lines tests	1993-95	3	5265	21.7
SPNGVT[1]	1996-97	14	3962	12.5
Large block yield test	1998	14	4947	13.3
High-yielding potential	1998	1	9079	
Uniform test in Northern China	1998-99	9	3554	14.3

1. Shandong Provincial New Groundnut Variety Trial.

more pod yield than the high-yielding control Luhua 11. In the uniform test conducted during 1998-99 at 14 sites of 6 provinces in northern China, Huayu 17 outyielded the control cultivar Luhua 9 by 14.3%. Under excellent conditions with good cultural practices and management of diseases, insect pests, and weeds, Huayu 17 created a new record of high yield in 1998 of 605.29 kg pods on 0.07 ha among early maturity groundnut varieties at Laizhou Agricultural Extension Station, Shandong Province.

Main characteristics

Huayu 17 is a Virginia bunch groundnut variety with jumbo pod and low oil content. It matures 3-5 days earlier than Luhua 9 (Table 2) and 10-12 days earlier than Luhua 11.

Table 2. Main characteristics of groundnut variety Huayu17[1].

Characteristics	Huayu 17	Luhua 9 (control)
Growth habit	Erect	Erect
Days to maturity	127	132
Length of main axis (n) (cm)	49.5	44.5
No. of n+1 branches (>5cm)	7.1	9.2
Length of n+1 branches (cm)	54.8	54.6
Leaf color	Light green	Dark green
No. of mature pods plant^{-1}	8.5	7.6
100-seed mass (g)	85.4	77.7
100-pod mass (g)	216.1	189
Shelling (%)	69.4	72.3
Seed color	Tan	Pink
Oil content (%)	44.6	51.2
O/L ratio[2]	1.62	1.39

1. Mean of data from uniform test in northern China, 1998.
2. O/L = oleic acid/linolcic acid.

Under natural conditions, Huayu 17 showed high resistance to late leaf spot (scoring 2-3 on a 1-9 scale, where 1 = no diesease, and 9 = 81-100% severity) and moderate resistance to peanut stripe virus.

Adaptation

Huayu 17 has been recommended for both spring and summer plantings in northern China. In order to obtain high yield, growers should choose good natural conditions with plastic mulching techniques. The plant density should be maintained at 150,000 to 180,000 holes with 2 seeds per hole.

Groundnut Variety CG 7: A Boost to Malawian Agriculture

P Subrahmanyam[1], P J A van der Merwe[1], A J Chiyembekeza[1], S Ngulube[1], and H A Freeman[2]
(1. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), PO Box 1096, Lilongwe, Malawi; 2. ICRISAT, PO Box 39063, Nairobi, Kenya)

Groundnut is an important legume crop in smallholder agriculture in Malawi, providing approximately 25% of the agricultural income. It is an important source of cash for smallholder farmers, especially women. Groundnut is also important in the diet, being the major source of vegetable protein and edible fat in rural Malawi. It is also a valuable component in crop rotation and improves soil fertility. Currently, farmers in Malawi grow mainly six groundnut varieties—Chalimbana, Chitembana, Mawanga, Malimba, Mani Pintar, and CG 7. Chalimbana is most widely grown, occupying about 82% of national groundnut area.

Development and release of CG 7

CG 7, also known as ICGMS 42 or ICGV-SM 83708, is a high-yielding Virginia bunch variety, jointly developed by the Department of Agricultural Research and Technical Services (DARTS) and ICRISAT. It was released for production in 1990, recommended for all groundnut-growing areas in Malawi. It is suitable for both confectionery use and oil extraction, and is more tolerant of drought and much easier to harvest than Chalimbana. Potential seed yield can exceed 2 tha^{-1}.

CG 7 adoption trends in Malawi

Analysis of CG 7 adoption trends is based on data obtained from the Famine Early Warning System (FEWS), Lilongwe, Malawi. The data were originally collected by the Department of Extension under the Ministry of Agriculture and Irrigation Development from different Extension Planning Areas (EPAs) in Malawi. The data were then aggregated by the Rural Development Project (RDP) and finally aggregated by the Agricultural Development Division (ADD). Information was available on area and production of different groundnut varieties for four consecutive seasons from 1996/97 to 1999/2000. The adoption rate of a particular variety was computed as a percentage, i.e., area under that variety as a proportion of total groundnut area during that season. Adoption trends of CG 7 over the past four seasons are presented in Figure 1. Adoption has increased in roughly geometric progression to the current level of 10.15%. These trends suggest that CG 7 area in the next season is likely to be almost double the current area.

Yield and economic contribution of different groundnut varieties

Table 1 shows the production, adoption, and economic contribution of different groundnut varieties. Chalimbana had the highest adoption (82%), followed by CG 7 (10%). The monetary value of this production was US$ 34.52 million for Chalimbana and US$ 6.42 million for CG 7. However, CG 7 is higher yielding, with pod yield advantage of 337 kg ha^{-1} and seed yield advantage of 236 kg ha^{-1} over Chalimbana, Mani Pintar, Malimba, and Mawanga. At current prices and exchange rate, the yield advantage of 236 kg ha^{*1} is worth MK 8246 (= US$ 118) per hectare. Thus, for every hectare of local varieties replaced by CG 7, national agricultural income would increase by US$ 118. If even half the area currently under local varieties is replaced by CG 7, the national agricultural income would increase by US$ 17 million per year. These calculations are based on the current price of MK 35 kg^{-1} and an exchange rate of US$ 1 = MK 70.

Further analysis was conducted, comparing the yield and economic contribution of CG 7 and Chalimbana at different adoption rates, assuming current yield levels for the two varieties (Table 2). The results clearly show the substantial economic benefit to be derived from replacing Chalimbana with higher-yielding varieties such as CG 7.

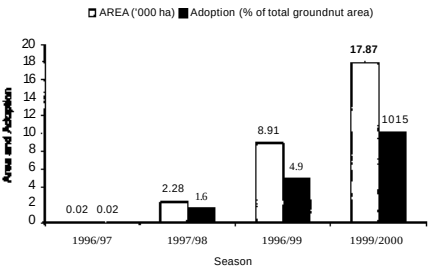

Figure 1. Adoption trends of groundnut variety CG 7 in Malawi, 1996/97 to 1999/2000.

Table 1. Production levels and value of output of different groundnut varieties in Malawi, 2000.

Variety	Area (ha)	Adoption (%)	Seed yield (kg ha-')	Production (t)	Value of output ('000 MK)	Value of output ('000 US$)
Chalimbana	144,731	82	681.46	69,040	2,416,411	34,520
CG 7	17,869	10	1025.69	12,830	449,036	6,415
Malimba	10,711	6	703.58	5,275	184,632	2,638
Mani Pintar	1,889	1	595.55	788	27,563	394
Mawanga	897	0.5	775.92	487	17,052	244
JL 24	3	0	1000.00	2	74	1
Total (national)	176,100			88,422	3,094,768	44,212

Table 2. Economic value of production from Chalimbana and CG 7 at different adoption rates in Malawi

Variety (Adoption rate)	Seed yield (t)	Income (US$ million)	Income gap (US$ million)
CG 7 (10%)	12,830	6.415	2.153
Chalimbana (10%)	8,523	4.262	
CG 7 (25%)	31,609	15.805	5.304
Chalimbana (25%)	21,001	10.501	
CG 7 (40%)	50,575	25.287	8.486
Chalimbana (40%)	33,602	16.801	

Since the yield gap is wide, farmers can obtain significant benefits even from small plots. Cash income will improve, particularly for women farmers, who produce a major share of groundnut in smallholder areas. Besides, the additional production will help improve the nutritional status of households. Further studies on CG 7 adoption and economic benefits will be carried out during the 2000/01 growing season by administering structured questionnaires.

Future trends

Until 1997, adoption of CG 7 remained rather low. There were several reasons, but the major bottleneck was non-availability of seed. There is no organized groundnut seed production and delivery system in place in Malawi, and almost no interest from private seed companies. However, in recent years several non-government organizations (NGOs) (ActionAid, SelfHelp Development, PLAN International, CARE Malawi, World Vision Malawi, NASFAM, Catholic Relief Services), and other developmental organizations such as MAFE and PROSCARP have been actively involved. Their efforts target the informal seed supply system (community-based or farmer-to-farmer seed exchange) for CG 7, which is gradually being distributed to communities where these organizations are active. The recently initiated Maize Productivity Task Force, specifically Action Group 2, was also largely involved in establishing the National Smallholder Seed Producer's Association (NASSPA), which is helping to accelerate the spread of improved crop varieties including CG 7.

Another factor is the establishment of two major projects funded by the United States Agency for International Development (USAID), the ICRISAT-DARTS-USAID Project on Groundnut and Pigeonpea, and the GALDAL Project. Ensuring the production and supply of breeder and basic seed of CG 7 is a key component of the ICRISAT-DARTS project. The GALDAL Project will be actively involved in promoting certified seed production through seed projects and other mechanisms. The goal is to maximize the number of farmers who receive CG 7 seed. As a result, we expect that non-availability of CG 7 seed will no longer be a major constraint in the near future.

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Partial Characterization of the cDNA Clone of a Low Temperature Induced Gene from Groundnut

R S Dave and R K Mitra (Nuclear Agriculture and Biotechnology Division, Bhabha Atomic Research Centre, Mumbai 400 085, Maharashtra, India)

Groundnut *(Arachis hypogaea)* plants show maximum growth at 28°C but experience severe metabolic perturbations when exposed to temperatures below 12°C (Bell et al. 1994). However, groundnut cultivar TAG 24 (bunch type developed at the Bhabha Atomic Research Centre, Mumbai, India) is able to withstand an abrupt temperature downshift (28°C to 12°C) and survive at the reduced temperature for several days without any apparent injuries. TAG 24 recovers rapidly from the stress and resumes normal growth at its optimal growth temperature (28°C). Growth of TAG 24 plants at the reduced temperature elicits several adaptive responses (e.g., accumulation of soluble sugars, soluble polysaccharides, amino acids, and proline; deviations from normal growth pattern such as increased growth of roots; and ability to carry out net photosynthesis) that are widely known to be associated with a tolerant phenotype (Dave and Mitra 1993). In order to understand the molecular basis of the adaptations described, a cDNA library was constructed to isolate low temperature induced genes as they are expected to play a critical role in modulating these adaptive responses.

Groundnut seedlings were grown at 28°C (12-h day/12-h night) for 15 days and then cold shocked for 10 days at 12°C (12-h day/12-h night). Cold shocked seedlings were deacclimatized at 28°C (12-h day/12-h night) for 2 days. Control seedlings were grown at 28°C (12-h day/12-h night) for 25 days.

A cDNA library was constructed in pUC 18 (Pharmacia) using mRNA obtained from leaves of cold shocked groundnut seedlings. Timesaver^{Tm} cDNA synthesis kit (Pharmacia) was used to synthesize double stranded cDNA using oligo (dT) primer. *Eco R1/Not1* adapters (Pharmacia) were ligated to either ends of the cDNAs, which were then cloned into the *Eco* R1 site of pUC 18. The cDNA library was screened by colony hybridization (using ^{32}P-labeled cold shocked cDNA as a probe). After primary and secondary screening with the cold shocked cDNA probe, twelve positive clones were identified. Of these, 5 clones designated as pRD1, pRD2, pRD8, pRD11, and pRD12 did not yield any insert either due to absence of an insert or the *Eco* R1 site may have been lost. The insert sizes of other clones are: pRD3 (0.3 kb), pRD4 (0.75 kb), pRD5 (0.32 kb), pRD6 (0.36 kb with an internal Hind III site), pRD7 (0.4 kb), pRD9 (0.2 kb), and pRD10 (0.2 kb). All these clones appeared to be partial. Northern analysis of these clones with the total control (28°C) and cold shocked mRNAs showed varied expression pattern. pRD3, pRD4, and pRD6 showed expression upon cold shock only, whereas pRD2 and pRD9 demonstrated expression both in control (28°C) as well as in cold shocked leaves. pRD5 showed down regulation upon cold shock. Of these clones pRD6 showed the strongest expression upon cold shock. We designate this clone as representative of a putative gene *Ahlti (Arachis hypogaea* low temperature induced). It is apparent that this clone of 0.36 kb is the gene induced due to cold shock and its transcripts persist at reduced level during deacclimation at 28°C (at least up to 48 h) (Fig. 1).

For further functional characterization, pRD6 was sequenced on both the strands with the M 13 forward (-40) and reverse (-50) sequencing primers using Sequenase PCR Product Sequencing Kit (USB-Amersham). Analysis of the nucleic acid sequence shows that it represents the

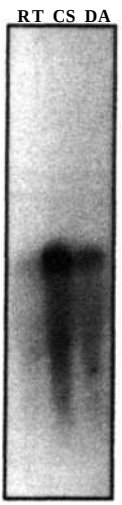

Figure 1. Northern blot analysis of *Ahlti* expression in groundnut (cv TAG 24) leaves. Total RNA (50 µg) from leaves of control (RT), cold shocked (CS), and deacclimatized (DA) plants was electrophoresed through a 1% formaldehyde agarose gel. RNA was transferred on to HybondN nylon membrane (Amersham) according to the manufacturer's instructions. Blot was probed with a ^{32}P-labeled cDNA insert pRD6. The probe hybridized to a 2.88 kb cold-induced transcript.

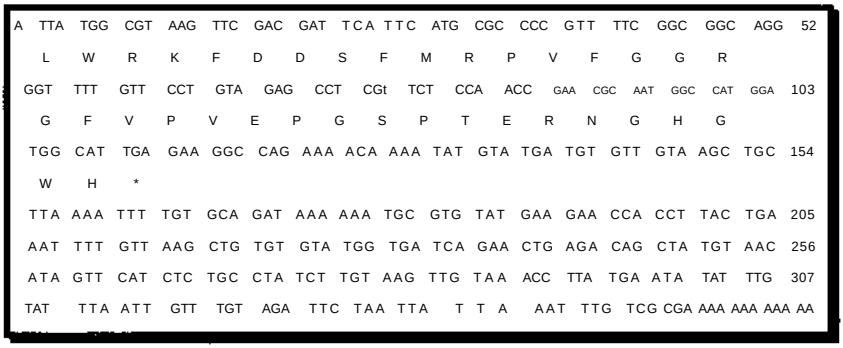

Figure 2. *Ahlti* sequence.
Note: Features of the sequence:
<1-360 mRNA
<1—109 coding sequence
2-82 Y-box binding motif
289-294 Hind III
304-309 Far Upstream Element of plant polyadenylation signal
318-323 Far Upstream Element of plant polyadenylation signal
336-341 Near Upstream Element of plant polyadenylation signal
352-360 Poly A tail

3' end of Ahlti (Fig. 2). The Far Upstream Element and the Near Upstream Element of plant polyadenylation signals are present upstream of the poly A tail.

Search for sequence homology in the Swiss-Prot database revealed that the partial coding sequence of Ahlti shows homology to eukaryotic CCAAT-binding (Y-box) protein family especially to human CCAAT-binding transcription factor subunit B (CBFB), elongation factor TU of Micrococcus luteus, and Brevibacterium linens and Escherichia coli cold shock protein CspA (Dave 1997). A Y-box is present in the promoter region of two temperature-induced genes from Arabidopsis thaliana, rd29A and rd 29 B (Yamaguchi-Shinozaki and Shinozaki 1994).

These observations suggest that Ahlti possibly encodes a cold induced CCAAT-binding transcription factor involved in the transcriptional activation of other cold induced genes. The transcription factor CBF1 has been shown to induce COR (cold regulated) genes and enhance freezing tolerance in Arabidopsis (Jaglo-Ottosen et al. 1998). Involvement of Ahlti in transcriptional activation might also in part be responsible for the tolerant genotype TAG 24. The nucleotide sequence reported appears in the EMBL, Gene Bank and DDJB Nucleotide Sequence Databases under the accession number Z84819.

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Sequence Assay and Expression in *E. coli* DH5α of Peanut Stripe Virus Coat Protein Gene

Li Guangcun[1], Bi Yuping[1], Guo Baotai[1], Chen Xiaoyan[2], Wang Xiuli[1], Dong Weibo[3], and **Lu Yanhui[1]**
(1. Biotechnology Research Center, Shandong Academy of Agricultural Sciences, Jinan 250100, China; 2. Shandong Cancer Hospital and Institute, Jinan 250117, China; 3. Shandong Peanut Research Institute, Laixi 266601, Shandong, China)

Peanut stripe virus (PStV) is a member of the potyvirus group and occurs in most of the regions of the world where groundnut is grown. Yield reductions of more than 20% have been reported (Zeyong 1988). None of the cultivated peanut genotypes are known to be resistant to PStV.

As part of a project aimed at producing coat protein (cp) mediated transgenic resistance to PStV in plant, we have cloned PStV-cp gene. Total RNA of PStV was isolated from leaves of groundnut collected in Shandong province in China and purified following the method described by Naidu et al. (1991). PStV-cp cDNA was obtained by reverse transcriptase polymerase chain reaction (RT-PCR) using primers synthesized according to the published sequence (Cassidy et al. 1993). The ds-cDNA was recovered from agarose gel, then directly ligated into pGEM-T vector. Clones containing PStV-cp cDNA sequences were further confirmed by PCR and restriction endonuclease mapping and recombinant cDNA clones with inserts of about 1.1 kb in length were selected. One such clone, designated as pGEM-StV7, was sequenced using the dideoxy chain termination method. The sequence analysis was performed using the PC/GENE Microsoft and compared with the published sequence (Cassidy et al. 1993, Gunasinghe et al. 1994, Flasinski et al. 1996). The inserted fragment of pGEM-StV7 contained the full capsid protein gene and the 3' untranslated region is shown in Figure 1 along with the predicted amino acid sequence. The cDNA sequence beginning from 5' terminal, contained an open reading frame (ORF) of 867 bp (including the start codon and the stop codon) and the 3' region contained a non-coding region of 223 bp. The ORF can code for PStV-cp of 287 amino acids with molecular mass of 33,500 Da. Comparison of the PStV-cp cDNA sequence with the published data revealed sequence identities up to 96-99.5%, with the end that the stop codon was TAG instead of TAA.

The inserts of pGEM-StV7 were subcloned into the *Escherichia coli* expression plasmid pBV220 (Zhang Zhiqing et al. 1988) with P_RP_L contact promoter (called pBV-StV). Exponentially growing cultures of transformed *E. coli* DH5 a (called pBV-StV-DH5 a) were placed in a water bath for 1,2,4,6,8,10, and 12 h. The samples were treated and electrophoresed in 12% polyacrylamide gels (SDS-PAGE) and transferred on to nitrocellulose membrane. The PStV capsid protein (33.5 KD) was detected using polyclonal antisera to PStV (Culver et al. 1989) in western blots (Fig. 2).

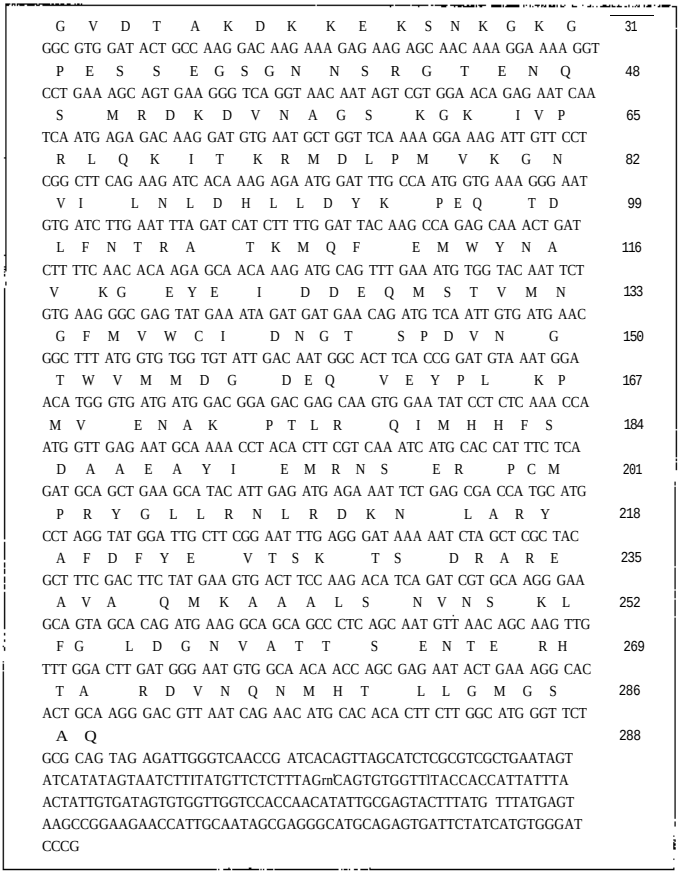

Figure 1. Nucleotide sequence of clone pGEM-StV7 of peanut stripe virus (PStV) capsid protein gene and deduced amino acid sequence. The initiation and termination codons are underlined.

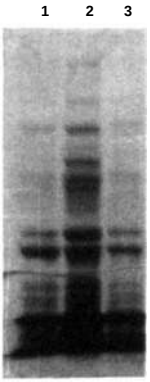

Figure 2. SDS-PAGE analysis of the expression of PStV-cp gene in *E. coli* DH5 α: (1) pBV-StV-DH5 a at 0 h induction; (2) pBV-StV-DH5 α at 4 h induction; and (3) control (pBV220-DH5 α) at 4 h induction.

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Pathology

Epidemiology of Late Leaf Spot and Rust of Groundnut in Guerrero, Mexico

D H Noriega-Cantu[1], J Pereyra-Hernandez[2], I C Joaqufn-Torres[1], G Mora-Aguilera[3], D Nieto-Angel[3], M A Cantu-Almaguer[1], and N O Gomez-Montiel[1] (1. Instituto Nacional de Investigaciones Forestales y Agropecuarias, Campo Exptal. Iguala, a.p. # 5, CP 40000, Iguala, Guerrero, Mexico; 2. Universidad Aut6noma de Guerrero, Esc. Sup. de Agricultura, Iguala, Guerrero, Mexico; 3. Colegio de Postgraduados, Montecillo, Mexico)

Late leaf spot caused by *Phaeoisariopsis personata* and rust *Puccini a arachidis* are the main foliar diseases of groundnut in Guerrero, Mexico. Both diseases are endemic in the groundnut-producing region of Guerrero and generally appear together causing severe defoliation and early pod maturity. Yield losses, due to the combined effect of these diseases, are about 35% (Martinez and Diaz 1985, Joaquin and Ayala 1996). The application of some fungicides reduces the incidence of both diseases and increases the production up to 1.01 compared to the untreated fields (Martinez and Diaz 1985). This study was conducted to assess three different fungicide programs to control late leaf spot and rust under the field condition of North Guerrero. An epidemiological approach was used to compare disease progress curves obtained as a result of fungicide treatments. Disease progress data were analyzed with the Gompertz, logistic, and monomolecular models as well as the area under disease progress curve (AUDPC) and the final disease intensity (Y_f) in order to summarize, compare, and classify the epidemics and to bring out features that were not obvious from the data alone (Campbell and Madden 1990).

Field trials were conducted during spring-summer (SS) cropping season of 1997 and 1998. A randomized block design was used with five replicates. Each replicate consisted of 20 m^2, with an interrow spacing of 80 cm and plant spacing of 40 cm. Groundnut cultivar Rio Balsas was sown during the third fortnight of June in 1997 and in first fortnight of July in 1998. Four fungicides were used for chemical protection: carbendazim at 200 g a.i. ha^{-1} (C), copper oxyhcloride at 500 g a.i. ha^{-1} (Cu), zineb at 480 g a.i. ha^{-1} (Z), and chlorothalonil at 1.13 kg a.i. ha^{-1} (CL). Treatments consisted of three sprays of the following fungicide combinations sprayed individually at 14-day intervals starting with visual

expression of symptoms: (1) C-Z-CL, (2) CL-Cu-Z, (3) Z-C-CL, and (4) Non-sprayed (control). Six plants per plot were selected in both cycles and disease incidence (in SS 1997) and severity (in SS 1998) was recorded every week. Late leaf spot and rust were scored with a seven-classes pictorical scale of severity (1 = 0-0.5%, 2 = 0.5-3%, 3 = 3-7%, 4 = 7-15%, 5 = 15-33%, 6 = 33-70%, and 7=70-100% leaf area damage). In addition to the epidemiological variables (epidemic rate r, AUDPC, and Y_f), damaged pods, dry mass, and pod yield were also recorded.

In SS 1997 and SS 1998, onset of late leaf spot and rust epidemic occurred at 92 and 100 days after sowing, respectively. The average epidemic duration was 35 days for both diseases. In SS 1997, all 20 late leaf spot epidemics (r^2 = 0.89-0.97) and 19 out of 20 of rust (r^2>0.8-0.9) were best described by the Gompertz model. In SS 1998, all 20 epidemics of late leaf spot (r^2= 0.88-0.99) and 11 out of 20 epidemics of rust (r^2= 0.89-0.99) were best described by the monomolecular model. Because more than one model fitted the epidemic data and the need of a correction for maximum disease intensity, epidemic rates were not suitable to compare treatments (Campbell and Madden 1990).

In SS 1997, the best late leaf spot and rust control was obtained with the C-Z-CL treatment resulting in the lowest AUDPC and Y_f (Table 1). Dry mass and pod yield were also higher in C-Z-CL even though statistical differences were not found among all treatments; yet, C-Z-CL improved the yield of the test cultivar by about 16% (Table 2).

In SS 1998, C-Z-CL was also the best late leaf spot control showing the lowest AUDPC and Y_f, similar to the previous season. However, the best rust control was achieved with CL-Cu-Z (Table 1). Regardless of the lack of statistical significance, dry mass was highest in C-Z-CL whereas pod yield was highest in CL-Cu-Z treatment. However, both treatments improved the yield test cultivar by about 45% (Table 2).

The results suggest the usefulness of carbendazim, a systemic fungicide, at the beginning of the epidemic suppressing the initial inoculum and latent infections followed by protective fungicides. This scheme appears to work better for late leaf spot. Additional studies are needed to determine the early-season effect of the environmental conditions on the onset and on the disease progress rate of the epidemics to improve the current disease management.

Acknowledgment. The authors are grateful to the Fundacion Produce de Guerrero, A.C. for the financial support.

Table 1. Effect of fungicide treatments on parameters of the curve of progress of late leaf spot and rust in groundnut cultivar Rio Balsas during spring-summer (SS) 1997 and 1998, Guerrero, Mexico.

Treatment[1]	Late leal spot[2]		Rust[2]	
	Y_f	AUDPC	Y_f	AUDPC
SS 1997				
C-Z-CL	20.40 a	173.1 a	21.76a	155.7 a
CL-Cu-Z	25.35 ab	210.4 a	27.79 b	192.5 b
Z-C-CL	26.17 ab	212.8 a	28.15 b	197.0 b
Control	30.42 b	239.3 a	31.14b	218.5 b
SS 1998				
C-Z-CL	6.26 a	74.62 a	5.84 b	50.39 a
CL-Cu-Z	8.09 a	98.27 a	4.01a	31.36a
Z-C-CL	7.17a	84.54 a	5.96 b	48.20 a
Control	32.30 b	288.54 b	6.43 b	76.12 b

1. C-Z-CL = carbendazim-zineb-chlorothalonil; CL-Cu-Z = chlorothalonil-copper oxychloride-zineb; and Z-C-CL = zineb-carbendazim-chlorothalonil.
2. Y_f is the final disease incidence (%) for SS 1997 and final disease severity (%) for SS 1998; AUDPC = Area under disease progress curve (proportion-day).

Figures with same letters are not significantly different. Multiple comparison of means by Student-Newman-Keuls multiple range test (P = 0.05).

Table 2. Effect of fungicide treatments on damage, dry mass, and pod yield of groundnut cultivar Rio Balsas during spring-summer (SS) 1997 and 1998, Guerrero, Mexico[1].

Treatment[2]	Damaged pods (number plant^{-1})	Dry mass (g plant^{-1})	Pod yield (t ha^{-1})
SS 1997			
C-Z-CL	4.14a	341.0a	2.801 a
CL-Cu-Z	3.05 a	335.4 a	2.575 a
Z-C-CL	4.48 a	307.2 a	2.411 a
Control	4.78 a	278.8 a	2.406 a
SS 1998			
C-Z-CL	3.84 a	668.3 a	3.023 ab
CL-Cu-Z	2.42 a	643.3 a	3.123 a
Z-C-CL	4.56 a	487.4 ab	2.275 bc
Control	6.12 a	366.2 b	2.127c

1. Multiple comparison of means by Duncan's test (P - 0.05). Figures with same letters are not significantly different.
2. C-Z-CL = carbendazim-zineb-chlorothalonil; CL-Cu-Z = chlorothalonil-copper oxychloride-zineb; and Z-C-CL = zineb-carbendazim-chlorothalonil.

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Changing Scenario of Groundnut Diseases in Andhra Pradesh, Karnataka, and Tamil Nadu States of India

S Pande and J Narayana Rao (International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India)

The states of Andhra Pradesh, Karnataka, and Tamil Nadu are among the largest producers of groundnut (*Arachis hypogaea)* in India. Groundnut is an important food, fodder and cash crop for small-holder farmers in these states. However, the yields are very low, up to 0.9 tha^{-1} (Government of India 1995). Among several biotic and abiotic constraints of groundnut production, diseases are the major cause for poor yields in these states. Informal surveys and casual observations of researchers and farmers have indicated an increased incidence of soilborne diseases and shift in the appearance of foliar diseases. To confirm these observations, systematic structured surveys on the incidence and severity of diseases of groundnut were conducted in selected villages in these three groundnut-growing states during 1999 rainy season.

A total of 85 farmers' fields in five districts (Mahbubnagar, Kurnool, Anantapur, Cuddapah, and Chittoor) in Andhra Pradesh, 44 fields in two districts (Kolar and Raichur) in Karnataka, and 10 fields in one district (Dharmapuri) in Tamil Nadu were selected for these surveys. Each field was visited thrice during the 1999 crop season. The crop growth stages at the time of survey were: (1) seedling, (2) flowering and pod formation, and (3) physiological maturity. Data on diseases were recorded on a questionnaire schedule form. Soilborne diseases such as collar rot and stem rot, and a viral disease called bud necrosis disease (BND) were recorded as number of plants dead and calculated as the percentage of killed plants. The foliar diseases, early leaf spot (ELS), late leaf spot (LLS), and rust were scored on a 1-9 rating scale where 1 = no disease and 9 = maximum disease (Subrahmanyam et al. 1995).

Majority of the farmers grew groundnut as a sole crop in these states. A few farmers intercropped groundnut with pigeonpea (*Cajanus cajan),* pearl millet *(Pennisetum glaucum),* cowpea *(Vigna unguiculata),* or lablab bean *(Lablab purpureus).* These crops were sown after every 5-20 rows of groundnut. During the 1999 rainy season, sowings were delayed in most of the villages because of late arrival of rains. Generally groundnut crop suffered from drought from seedling to pod formation stage. The diseases observed during our surveys were collar rot, stem rot, ELS, LLS, rust, and BND in different districts of these states. The incidence and severity of these diseases is further discussed.

Collar rot. Collar rot caused by the soilborne fungus *Aspergillus niger* was observed in all the fields surveyed. The mean incidence was up to 10% in the seedling stages and up to 6% at maturity stage of the crop. More than 10% collar rot was observed in the districts of Kolar and Raichur in Karnataka and Kurnool in Andhra Pradesh (Table1).

Stem rot. Stem rot caused by *Sclerotium rolfsii* was invariably present in all fields, irrespective of the cultivar and intercropping followed by the farmers. It was found to be a potentially important disease of groundnut. The mean incidence was low (up to 4%) in the seedling stage, moderate to high (up to 16%) during flowering and pod formation stage, and very high (21%) at maturity stage of the crop. The highest disease incidence (29%) was observed in Raichur district and lowest (10%) in Chittoor district (Table1).

Bud necrosis disease. Bud necrosis disease caused by peanut bud necrosis virus (PBNV) transmitted by thrips was observed in all the farmers' fields surveyed. The disease incidence was low (up to 5%) in seedling stage and reached maximum (up to 19%) at maturity. It was 25% in Chittoor and Cuddapah districts of Andhra Pradesh and 20% in Kolar district of Karnataka (Table 1).

Early leaf spot. Early leaf spot caused by *Cercospora arachidicola,* as its name implies, appears first or in early growth stage of the crop among the foliar diseases. The mean ELS severity was low (up to 3 rating) in the seedling

Table 1. The scenario of soilborne diseases at seedling, flowering and pod-filling, and near-maturity stages of groundnut in farmers' fields during 1999 rainy season surveys in Andhra Pradesh, Karnataka, and Tamil Nadu states of India.

District	No. of fields observed	Disease incidence[1] (range %)								
		CR			SR			BND		
		SS	FP	NM	SS	FP	NM	SS	FP	NM
Andhra Pradesh										
Mahbubnagar	12	3-9	5-9	5-6	0-4	1-10	5-18	0-5	1-6	4-16
Kurnool	16	3-10	4-7	4-5	2-9	4-16	3-27	1-5	3-9	6-15
Anantapur	21	2-8	2-5	2-6	0-2	2-18	2-15	0-4	2-8	3-18
Cuddapah	16	3-8	4-9	4-5	0-2	3-18	3-25	0-4	6-9	10-25
Chittoor	20	2-9	3-9	3-4	1-4	2-8	2-10	1-7	3-15	4-25
Karnataka										
Raichur	18	2-12	3-8	3-6	0-4	2-25	2-29	0-9	7-12	11-19
Kolar	26	2-14	2-8	2-6	0-3	2-16	3-23	0-5	3-10	5-20
Tamil Nadu										
Dharmapuri	10	2-9	2-8	2-8	0-3	2-14	3-24	0-4	4-12	6-19
Mean		2-10	3-8	3-6	0-4	2-16	3-21	0-5	4-10	6-19

1. CR = Collar rot; SR = Stem rot; BND = Bud necrosis disease; SS = Seedling stage; FP = Flowering and pod-filling stage; NM = Near-maturity stage.

stage and moderate (up to 5 rating) in the flowering and pod formation stage in all the districts (Table 2). It was found associated with defoliation at early growth stages of the crop and was not observed at later stages of crop growth. With the onset of favorable weather for foliar diseases, ELS was masked by LLS.

Late leaf spot. Late leaf spot caused by *Phaeoisariopsis personata* was commonly observed in all the farmers' fields at all the growth stages in all the three states. The disease progressed slowly in the beginning and its epidemic reached up to 8 rating at maturity in most of the farmers' fields. Its mean severities were around 2 rating during seedling stage, up to 4 rating in the flowering and pod filling stage, and high (up to 7) in near-maturity growth stage (Table 2).

Rust. Rust caused by *Puccinia arachidis* was observed in all the districts surveyed. Disease severity was low (2 to 3 rating) in the seedling stage except in Raichur and Mahbubnagar districts where the severity was rated 4 to 5. The higher severity of rust in the seedling stage in these two districts was due to early infection from an irrigated summer (March-April sown) crop. It appeared that the summer crop acted as an inoculum reservoir of ELS, LLS, and rust for infection and spread these diseases to rainy season crop. In general the mean severity of rust in other surveyed fields was moderate (up to 5 rating) during the flowering and pod formation stage and high (up to 8 rating) towards maturity (Table 2). The highest rust severity (9 rating) was recorded in the districts of Anantapur, Raichur, and Dharmapuri (Table 2).

Among soilborne diseases, collar rot appeared to be the predominant seedling disease and caused seedling mortality which resulted in poor plant stand. Though stem rot occurred in the seedling stage, its incidence increased as the crop grew older and reached maximum at maturity. It caused death of the plants as well as rotting of pods. Collar rot and stem rot diseases were earlier considered less important, but were now found to be potential constraints to groundnut production. During these surveys, the two diseases were found to cause substantial yield losses. Farmers considered stem rot as a disease of growing concern of groundnut. Among the foliar diseases, ELS appeared in the early growth stage to flowering and pod formation stage of the crop and later masked by LLS and rust. Hence it was not observed at later stages. LLS and rust generally appeared during the flowering and pod formation stage and continued to increase till maturity causing severe defoliation (up to 90%) and withering of

Table 2. The scenario of foliar diseases at seedling, flowering and pod-filling, and near-maturity stages of groundnut in farmers' fields during 1999 rainy season surveys in Andhra Pradesh, Karnataka, and Tamil Nadu states of India.

District	No. of fields observed	Disease score[1] (range)							
		ELS		LLS			Rust		
		SS	FP	SS	FP	N M	SS	FP	N M
Andhra Pradesh									
Mahbubnagar	12	1-3	2-4	1-2	3-4	4-8	2-4	3-7	5-8
Kurnool	16	1-3	2-4	1-2	2-3	4-7	2-3	2-6	4-7
Anantapur	21	1-2	2-5	1-3	1-3	4-7	1-3	1-4	4-9
Cuddapah	16	1-2	3-4	1-2	2-3	5-7	1-2	2-3	5-7
Chittoor	20	1-3	3-5	1-2	1-3	2-6	1-3	1-4	2-7
Karnataka									
Raichur	18	1-3	3-6	1-2	3-6	5-7	2-5	5-8	7-9
Kolar	26	1-3	2-4	1-3	1-5	4-8	1-2	1-5	4-8
Tamil Nadu									
Dharmapuri	10	1-2	2-4	1-2	2-4	6-8	1-2	2-4	6-9
Mean		1-3	2-5	1-2	2-4	4-7	1-3	2-5	5-8

1. Rating on 1-9 scale where 1 = no disease, and 9 = maximum disease.
ELS = Early leaf spot; LLS = Late leaf spot; SS = Seedling stage; FP = Flowering and pod-filling stage; NM = Near-maturity stage.

foliage in the susceptible groundnut cultivars commonly grown by farmers. The intercropping pattern currently followed by the farmers, irrespective of the crop species involved, did not have any influence on the incidence and severity of diseases of groundnut. However, groundnut rows adjacent to the intercropped row had more disease than the groundnut crop farthest from the intercropped row.

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Evaluation of Wild *Arachis* Germplasm Accessions for In Vitro Seed Colonization and Aflatoxin Production by *Aspergillus flavus*

R P Thakur, V P Rao, S V Reddy, and M Ferguson
(International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India)

A high level of stable resistance to aflatoxin contamination (infection by *Aspergillus flavus* and production of aflatoxin) has not been identified in cultivated groundnut (*Arachis hypogaea),* although several genotypes are reported to possess resistance to seed colonization, seed invasion and/or aflatoxin production (Mehan 1989, Waliyar et al. 1994, Upadhyaya et al. 1997). ICRISAT has a collection of 413 accessions of wild *Arachis* spp, the majority of which, have not been evaluated for resistance to aflatoxin contamination. Previously 16 species (9 belonging uniformly to section *Arachis,* 3 to *Erectoides, 2* to *Rhizomatosae,* and one each to *Extranervosae* and *Triseminatae)* were

Table 1. In vitro seed colonization severity *by Aspergillus flavus* and aflatoxin production in 35 wild *Arachis* accessions.

Accession no.	Section	*Arachis* species	Colonization severity[1]	Aflatoxin production[2]
ICG 144	*Arachis*	*A. villosa*	4.0	H
ICG 190	*Arachis*	*A. hoehnei*	3.5	M
ICG 8125	*Arachis*	*A. stenosperma*	4.0	H
ICG 8137	*Arachis*	*A. stenosperma*	4.0	H
ICG 8139	*Arachis*	*A. duranensis*	3.5	M
ICG 8193	*Arachis*	*A. valida*	2.5	M
ICG 8195	*Arachis*	*A. duranensis*	2.5	L
ICG 8197	*Arachis*	*A. monticola*	3.5	H
ICG 8201	*Arachis*	*A. duranensis*	2.5	H
ICG 8206	*Arachis*	*A. ipaensis*	4.0	H
ICG 8210	*Arachis*	*A. batizocoi*	4.0	H
ICG 8959	*Arachis*	*A. kempff-mercadoi*	2.5	H
ICG 8960	*Arachis*	*A. magna*	2.0	H
ICG 11551	*Arachis*	*A. benensis*	1.5	M
ICG 13173	*Arachis*	*A. stenosperma*	3.0	M
ICG 14861	*Arachis*	*A. kuhlmannii*	3.0	H
ICG 14855	*Caulorhizae*	*A. pintoi*	2.0	M
ICG 8130	*Erectoides*	*A. paraguariensis*	2.0	M
ICG 8192	*Erectoides*	*A. oteroi*	2.0	L
ICG 8215	*Erectoides*	*A. stenophylla*	3.5	H
ICG 8973	*Erectoides*	*A. paraguariensis*	4.0	H
ICG 13262	*Erectoides*	*A. major*	3.5	M
ICG 13212	*Heteranthae*	*A. pusilla*	1.0	N
ICG 14897	*Heteranthae*	*A. pusilla*	4.0	H
ICG 8127	*Procumbentes*	*A. appressipila*	2.0	M
ICG 8128	*Procumbentes*	*A. appressipila*	2.5	H
ICG 8129	*Procumbentes*	*A. appressipila*	2.5	M
ICG 8191	*Procumbentes*	*A. kretschmeri*	3.0	H
ICG 8904	*Procumbentes*	*A. rigonii*	2.0	H
ICG 8945	*Procumbentes*	*A. appressipila*	3.5	H
ICG 11557	*Procumbentes*	*A. matiensis*	1.5	M
ICG 11560	*Procumbentes*	*A. chiquitana*	1.0	N
ICG 8131	*Triseminatae*	*A. triseminata*	1.0	N
ICG 13261	*Triseminatae*	*A. triseminata*	1.5	L
ICG 14875	*Triseminatae*	*A. triseminata*	1.0	L
J 11 (control)	*Arachis*	*A. hypogaea*	4.0	H
JL 24 (control)	*Arachis*	*A. hypogaea*	4.0	H
Mean			2.74	H
SEm			±0.64	

1. *Aspergillus flavus* colonization severity on 1-4 rating scale (see text). Mean of 2 replications, with 30 seeds in each replication.
2. Aflatoxin estimation was done using 5 g seed per replication. H - High (>5000 µg kg^{-1} seed); M = Moderate (1001-5000 µg kg^{-1} seed); L = Low (100-1000 µg kg^{-1} seed); and N = Negligible (<100 µkg^{-1} seed).

evaluated and found to support the production of aflatoxin (34-110 µg g^{-1} seed) (Mehan 1989).

We report the evaluation of 35 germplasm accessions of wild *Arachis* belonging to 24 species in six sections for in vitro seed colonization by artificial inoculation with a recently identified highly aggressive and toxigenic strain of *A. flavus* (isolate *Af11*-4) and for aflatoxin production (Table 1). Sixty seeds (weighing 4-10 g depending on seed size) from each accession were surface sterilized with 0.1% aqueous solution of mercuric chloride for 2 min and washed in two changes of distilled sterilized water. Seeds were uniformly wounded by pricking with a sterile needle, to allow invasion by *A. flavus* spores. Seeds were placed in a sterilized petri dish (9 cm diameter) and spray inoculated with *A. flavus* spore suspension (1 x 10^6 spores mL^{-1}) using an atomizer. The petri dishes were shaken vigorously to roll the seeds allowing uniform distribution of inoculum on the seeds. The experiment was conducted in two replications with 30 seeds per replication. The petri dishes were placed at high humidity (>95% RH) in semi-rigid plastic boxes, lined with wet cotton wool and blotting paper, with closely fitting lids, and incubated at 25°C in the dark for 10 days.

Individual seeds were scored for surface colonization by *A. flavus* and for colonization severity using the following rating scale: 1 = <5% seed surface colonized with scanty mycelial growth and no sporulation; 2 = 5-25% seed surface colonized with good mycelial growth and scanty sporulation; 3 = 26-50% seed surface colonized with good mycelial growth and good sporulation; and 4 = >50% seed surface colonized with heavy sporulation. The seeds were then sprayed with ethanol and washed before using for aflatoxin estimation. An indirect competitive enzyme-linked immunosorbent assay (ELISA) method was used (Devi et al. 1999).

Large variation occurred both for seed colonization severity (1 to 4) and aflatoxin production [high (>5000 ug kg^{-1} seed) to negligible (< 100 µg kg^{-1} seed)] among accessions belonging to different sections and species (Table 1). Accessions ICG 13212 *(A. pusilla,)*, ICG 11560 (*A. chiquitana),* and ICG 8131 and ICG 14875 *(A. triseminata)* recorded low colonization severity and relatively low aflatoxin content compared with those of control susceptible cultivars J 11 and JL 24. Resistance of the above accessions needs to be evaluated for seed infection by *A. flavus*.

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Identification of Elite Short-duration, Rosette Resistant Lines in World Germplasm Collections

P Subrahmanyam[1]; P J A van der Merwe[1], L J Reddy[2], A J Chiyembekeza[1], F M Kimmins[3], and R A Naidu[4]
(1. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), PO Box 1096, Lilongwe, Malawi; 2. ICRISAT, Patancheru 502 324, Andhra Pradesh, India; 3. Natural Resources Institute, University of Greenwich, Chatham, Kent ME4 4TB, UK; 4. Department of Plant Pathology, 2102 Miller Plant Science Building, University of Georgia, Athens, GA 30602-7274, USA)

Groundnut rosette is a major constraint to groundnut production in sub-Saharan Africa and its offshore islands (Subrahmanyam et al. 1991,1997, Naidu et al. 1999a). It is caused by a complex of three agents: groundnut rosette assistor virus (GRAV), groundnut rosette virus (GRV), and satellite RNA of GRV. The disease is transmitted by aphids (*Aphis craccivora)* in persistent manner (Naidu et al. 1999a). Groundnut rosette is estimated to cause annual

yield losses globally worth US$ 156 million (ICRISAT 1992).

In the past, several medium- and long-duration rosette resistant groundnut varieties, such as RG 1, RMP 12, and RMP 91, have been developed and released for general cultivation. However, their adoption rate by fanners was low in most ofsub-Saharan Africa, characterized by short and erratic rainfall. The need for short-duration, rosette resistant varieties has been well recognized in the breeding programs, and attempts have been made in the past to breed such varieties by crossing rosette resistant sources with short-duration agronomically superior Spanish varieties. However, success in combining short-duration and rosette resistance in good agronomic background by breeding has not been met with desirable success, probably due to complex nature of inheritance of these traits (Reddy and Subrahmanyam 1997). Hence, a rigorous search was made to identify short-duration rosette resistant germplasm with good agronomic features by screening the world germplasm using the infector row technique (Bock and Nigam 1988, Subrahmanyam et al. 1998). This article describes the botanical features and performance of two short-duration, rosette resistant elite germplasm, ICG 12988 and ICG 12991.

Origin and development

ICGs 12988 and 12991 are germplasm lines collected in farmer's fields in Madhya Pradesh, India in October 1988 under the collector numbers US 22 and US 25, respectively. They were introduced into ICRISAT at the Chitedze Agricultural Research Station near Lilongwe, Malawi in 1994 for evaluation against rosette and early leaf spot (caused by *Cercospora arachidicola).* The original sources had some susceptible plants, which might have been due to mixtures or outcrossing. So we purified them by culling out the diseased plants for two seasons.

Morphological and agronomic characters

ICGs 12988 and 12991 belong to the Spanish botanical group with erect growth habit, sequential branching, and medium-sized, dark green, elliptic leaves. On average, ICG 12988 has 4.2 primary and 2.5 secondary branches and ICG 12991 has 4.5 primary and 2.6 secondary branches. They mature in 95-105 days after sowing (DAS) at Chitedze [1149 m asl (above sea level)] and in 90-100 DAS at Chitala (550 m asl), Malawi compared with JL 24 which matures in 110-120 DAS at Chitedze and 90-100 DAS at Chitala.

ICGs 12988 and 12991 have two-seeded small pods with thin shells and slight to medium reticulation. Pods of both lines have slight to medium constriction with no or little beak. Seeds are tan with a 100-seed mass of 31.5 g for ICG 12988 and 30.8 g for ICG 12991 and have no fresh seed dormancy. Both varieties have high shelling percentage: 76.5 for ICG 12988 and 76.0 for ICG 12991. Average oil content is 43.6% in ICG 12988 and 43.3% in ICG 12991. Average protein content is 26.7% in ICG 12988 and 27.1% in ICG 12991.

Disease reaction

The reaction of ICGs 12988 and 12991 to rosette in the disease nursery at Chitedze for four seasons is given in Table 1. The mean disease incidence in these trials was 6.0% for ICG 12988 and 4.5% for ICG 12991 (Fig. 1). The susceptible control varieties, Malimba and JL 24, showed

Table 1. Reaction ofgroundnut genotypes ICGs 12988 and 12991 and control cultivars Malimba and JL 24 under high rosette disease situation at Chitedze Agricultural Research Station, Malawi during 1994-98.

Genotype	Rosette incidence (%)					Disease index (1996)
	1994/95	1995/96	1996/97	1997/98	Mean	
ICG 12988	8	5	10	1	6.0	1.5
ICG 12991	9	0	6	3	4.5	1.4
Malimba (control)	100	93	92		95.0	2.8
JL 24 (control)	100	96	87	97	95.0	2.8
Trial mean	–	13.6	19.4	29.0		1.65
SE	–	±4.2	±5.3	±4.6		±0.09
CV (%)	–	26.7	25.3	5.1		6.0

Figure 1. Field reaction of groundnut genotype ICG 12991 against rosette at Chitedze, Malawi.

95% disease incidence. Rosette disease index (Olorunju et al. 1991) was lower for ICG 12988 (1.5) and ICG 12991 (1.4) compared to the susceptible varieties (2.8).

Reaction to the vector

Both ICG 12988 and ICG 12991 are resistant to the vector *A. craccivora* (Naidu et al. 1999b). Laboratory studies on aphid survival, reproduction, and feeding behavior showed low rate of nymphal development, reduced fecundity, and smaller-sized aphids on ICG 12991 compared to susceptible genotypes JL 24 and CG 7 (Minja et al. 1999). Resistance to aphids increases with age of the plants (Naidu et al. 1999b). Field resistance of ICG 12988 and ICG 12991 to rosette is attributed to resistance to vector aphids.

Yield performance

Both ICGs 12988 and 12991 were identified as short-duration, high-yielding lines with resistance to rosette during the 1994/95 crop season and subsequently in 1995/96, 1996/97, and 1997/98 at Chitedze, Malawi (Subrahmanyam etal. 1998).

The magnitude of differences in pod yield between rosette resistant germplasm (ICGs 12988 and 12991) and susceptible cultivars (Malimba and JL 24) was very high under high disease pressure (Table 2). In yield trials under high disease pressure at Chitedze, Malawi, during the 1996/97 and 1997/98 crop seasons, ICG 12988 and ICG 12991 gave a yield advantage of over 1020%. Under low disease pressure in the same years, ICG 12988 gave a yield advantage of 6.8% and ICG 12991 over 14.7%. Under high

Table 2. Performance of groundnut genotypes ICGs 12988 and 12991 and control cultivars Malimba and JL 24 under high and low rosette disease situations at Chitedze Agricultural Research Station, Malawi, 1996/97 and 1997/98 crop seasons.

	Pod yield (t ha^{-1})						Shelling (%)						100-seed mass (g)					
	HDP[1]			LDP[2]			HDP			LDP			HDP			LDP		
Genotype	1997	1998	Mean	1997	1998	Mean	1997	1998	Mean	1997	1998	Mean	1997	1998	Mean	1997	1998	Mean
ICG 12988	0.97	1.51	1.27	3.65	2.01	2.83	74	80	77	76	76	76	31	27	29	38	30	34
ICG 12991	0.92	1.55	1.24	3.96	2.12	3.04	74	77	76	78	75	77	30	26	28	37	30	34
Control																		
Malimba	–	0.02	–	–	2.88	–	–	61	–	–	74	–	–	31	–	–	34	–
JL 24	0.10	0.11	0.11	3.22	2.07	2.65	57	61	59	75	71	73	35	25	30	43	33	38
Trial mean	0.3	0.70		2.55	1.38		61	64		64	69		31	33		35	39	
SE	±0.06	±0.11		±0.26	±0.13		±4.0	±6.9		±2.0	±3.3		±1.9	±4.8		±2.4	±4.7	
CV (%)	21.0	20.6		12.6	24.1		8.0	14.0		5.3	6.8		7.5	14.4		8.4	11.9	

1. HDP = High disease pressure.
2. LDP = Low disease pressure.

Table 3. Performance of groundnut genotypes ICGs 12988 and 12991 and control cultivar JL 24 in on-farm trials at three locations in Karonga Agricultural Development Division, Malawi during the off-season, 1997.

	Pod yield (t ha^{-1})				Shelling (%)			
Genotype	Iponga	Katininda 1	Katininda 2	Mean	Iponga	Katininda 1	Katininda 2	Mean
ICG 12988	3.2	4.2	5.7	4.37	78	75	74	75.7
ICG 12991	4.1	3.6	3.7	3.80	76	69	76	73.7
JL 24 (control)	2.7	4.0	5.4	4.03	70	66	72	69.3
Trial mean	2.7	3.6	4.8		66	63	66	
SE	±0.29	±0.37	±0.70		±1.0	±2.4	±2.3	
CV (%)	22	23	30		7.0	8.0	7.0	

disease pressure, even the shelling percentage of the susceptible cultivars was low compared to that of ICGs 12988 and 12991.

In on-farm trials conducted during the 1997 off-season at three locations in Karonga, Malawi, the mean pod yields of ICGs 12988 and 12991 were similar to that of JL 24 under no disease situation. However, both ICGs 12988 and 12991 had better shelling percentage (Table 3).

In farmer-participatory yield trials conducted at 45 locations in different agroecological zones of Malawi during the 1998/99 growing season, ICG 12988 and ICG 12991 gave an average yield advantage of over 6% and 7%, respectively. Rosette incidence during the season was negligible (<1%) at all locations.

Both ICG 12988 and ICG 12991 are high yielding and have an excellent potential for cultivation in production systems characterized by short rainy seasons and recurrent rosette epidemics in sub-Saharan Africa.

Seed availability

The Genetic Resources and Enhancement Program, ICR1SAT, PO Box 1096, Lilongwe, Malawi, maintains the breeder seed of ICG 12988 and ICG 12991. Limited quantities of seed are made available on request.

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Management of Collar Rot of Groundnut by *Pseudomonas fluorescens*

J Sheela and D Packiaraj (Agricultural Research Station, Tamil Nadu Agricultural University, Aliyarnagar 642 101, Tamil Nadu, India)

Collar rot caused by *Aspergillus niger* is a widespread disease in groundnut. *Aspergillus niger* causes rotting of seed, pre-emergence soft rot of the hypocotyls, and post-emergence collar rot of seedlings. Collar rot spreads through the spores adhering to the seeds and pods from one season to the other. Several workers have tried to manage this disease by seed dressing with different fungicides (Sidhu and Chohan 1971, Whitehead and Thirumalachar 1974). Application of fungicides to soil and plants can cause soil and air pollution, hazards for humans, animals, and beneficial rhizosphere microorganisms. Therefore, an alternative method of biological control of plant pathogens has been focused recently. The present study was conducted to find out the effective biocontrol agent against collar rot as an alternative to fungicide.

Experimental trials were conducted at the Agricultural Research Station, Aliyarnagar, Tamil Nadu, India for two years in 1997 and 1998 cropping seasons. Groundnut culti vars Co 2 [rainy season (kharif)] and VR14 [postrainy season (rabi)], susceptible to collar rot were sown in 3 x 5 m^2 plots in a randomized block design with three replications and eight treatments. The commercial product ofthe antagonists, viz., *Trichoderma viride* and *T. harzianum,* both at 4 g kg^{-1} of seed and *Pseudomonasfluorescens* at 10 g kg^{-1} were used for seed treatment (ST). The treated seeds were shade dried and sown. Carbendazim seed treatment (2 g kg^{1}) was also included as one of the treatments. Neem cake was applied to the respective plots at 160 kg ha^{-1} before sowing. Control plots were maintained without any soil application (SA).

Pre-emergence rotting was estimated by counting the number of germinated seeds at 10 days after sowing (DAS). Disease incidence was recorded 25 and 45 DAS by counting the infected plants.

Among the treatments, *P.fluorescens* (ST) + neem cake (SA) was found to be the best in reducing collar rot (6.63%) followed by *T. viride* (ST) + neem cake (SA) (7.89%), and *P.flourescens* (ST) (8.27%) as compared to 18.77% in control (Table 1). Treatments receiving *T. viride* (ST) + neem cake (SA) gave higher pod yield (1849.49 kg ha^{-1}) followed

Table 1. Effect of antagonists on collar rot incidence in groundnut during 1997-99, Aliyarnagar, Tamil Nadu, India[1].

Treatment[2]	Collar rot incidence[3] (%)				
	K 1997	R 1997/98	K 1998	R 1998/99	Mean
Trichoderma viride (ST)	11.88(20.13)	9.12 (17.56)	11.83 (20.09)	13.26 (11.39)	11.53(19.82)
T. harzianum (ST)	15.73 (23.34)	13.44 (21.47)	14.42 (22.30)	15.41 (23.11)	14.75 (22.63)
Pseudomonasfluorescens (ST)	8.99 (17.36)	6.45 (14.77)	8.24 (16.64)	9.39 (17.85)	8.27 (16.74)
T. viride (ST) + neem cake (SA)	8.49 (16.95)	6.36 (14.65)	7.32 (15.68)	9.39 (17.85)	7.89 (16.32)
T. harzianum (ST) + neem cake (SA)	12.51 (20.70)	10.30 (18.72)	10.22 (18.63)	11.19(19.55)	11.06 (19.46)
P.fluorescens (ST) + neem cake (SA)	6.66 (15.00)	5.73 (13.81)	6.46 (14.77)	7.66(16.11)	6.63 (14.89)
Carbendazim (ST)	3.30 (10.47)	2.27 (8.72)	3.46 (10.78)	3.20 (10.30)	3.06(10.14)
Control	20.60 (26.99)	17.79 (24.95)	19.07 (25.91)	17.61 (24.80)	18.77 (25.70)
CD (P = 0.05)	0.45	0.58	0.54	0.31	

1. Collar rot susceptible groundnut cultivars were tested; Co 2 in kharif (K) (rainy season) and VRI 4 in rabi (R) (postrainy season).
2. ST = Seed treatment; and SA = Soil application.
3. Figures in parentheses are transformed values.

Table 2. Effect of antagonists on dry pod yield of groundnut during 1997-99, Aliyarnagar, Tamil Nadu, India[1].

Treatment[2]	Pod yield (kg ha^{-1})				
	K 1997	R 1997/98	K 1998	R 1998/99	Mean
Trichoderma viride (ST)	861.50	2612.97	893.33	2420.00	1696.95
T. harzianum (ST)	933.75	2524.08	906.67	2349.99	1678.62
Pseudomonas fluorescens (ST)	933.75	2781.49	933.33	2553.53	1800.48
T. viride (ST) + neem cake (SA)	975.00	2829.64	1026.67	2566.67	1849.49
T. harzianum (ST) + neem cake (SA)	940.00	2601.85	919.99	2486.67	1737.13
P. fluorescens (ST) + neem cake (SA)	1035.00	2305.56	1066.67	2533.33	1735.14
Carbendazim (ST)	1078.85	3048.16	1093.33	2580.00	1950.00
Control	800.55	2468.53	813.34	2146.67	1557.14
CD (P = 0.05)	55.32	201.04	76.21	188.12	

1. Collar rot susceptible groundnut cultivars were tested; Co 2 in kharif (K) (rainy season) and VRI 4 in rabi (R) (postrainy season).
2. ST = Seed treatment; and SA = Soil application.

by *P. fluorescens* (ST) (1800.48 kg ha^{-1}) as compared to control (1557.14 kg ha^{-1}) (Table 2).

Lashin et al. (1989) reported that collar rot disease incidence was lower in groundnuts receiving soil treatments of *T. harzianum* at the seedling and vegetative growth stages.

Bioprotectants provide unique opportunities for crop protection. A bioprotectant applied as seed treatment can grow on the planted seed and the emerging root, and if the genetics of the bioprotectants are appropriate, colonize and protect the entire subterranean plant portions from infection. Seed treatment with bioprotectants is quite inexpensive and ecofriendly as compared to other methods of disease control and can be successfully exploited for the control of a wide range of seedborne as well as soilborne diseases.

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Management of Leaf Spots of Groundnut by Nutrition and Fungicide: An Integrated Approach

S S Bag, S K Raj, and S Das (Department of Plant Pathology, Bidhan Chandra Kxishi Viswavidyalaya, Mohanpur741 252,Nadia, West Bengal, India)

Groundnut is one of the major oilseed crops after mustard and grown throughout the year in West Bengal, India. Early leaf spot *(Cercospora arachidicola)* and late leaf spot (*Phaeoisariopsis personata)* cause serious damage to groundnut crop in many areas. The yield declined by 5.50-6.08 g plot^{-1} (4 m^2) for every 1% unit increase in disease severity (Das and Roy 1995). To minimize loss in pod yield various chemicals including systemic fungicides have been used from time to time (Lokhande et al. 1998). Staggered use of chemicals for the management of crop disease is often associated with problems such as pollution hazards and residual toxicity. Integrated disease management through alteration of cultural operations and breeding for elite, disease resistant cultivars is gaining importance in recent times (Gupta 1985, Ghewande et al. 1992, Waliyaretal. 1993).

An experiment was conducted to determine the effect of organic and inorganic nutrition and its combination with fungicide on the severity of leaf spots of groundnut. Groundnut cultivar Phule Pragati (JL 24) (susceptible to early and late leaf spots) was sown on 2 x 5 m plots during rainy season in 1997 and 1998. The experiment was conducted in a randomized block design with three replications. There were 8 treatments: (1) Nitrogen-phosphorus-potassium

(NPK) at 30:70:30 kg ha^{-1}; (2) Farmyard manure (FYM) at 131 ha^{-1} which contains 0.25% N, 0.50% P_2O_5, and 0.25% K_2O; (3) FYM + NPK at 6.5tha^{-1} + 15:35:15 kgha^{-1} respectively; (4) FYM + NPK + fungicide; (5) NPK + fungicide; (6) FYM + fungicide; (7) Fungicide (no FYM and NPK); and (8) Untreated control (no FYM, NPK, and fungicide) (Table 1). All the fertilizers and FYM were used as basal during sowing. The fungicide Dithane M-45 at 2 g L^{-1} of water was sprayed 4 times, 25 days after sowing at 15-day intervals. Disease severity on individual plants was rated, using 1-6 scale (Lewin et al. 1973), 10 days before harvest by using a schematic diagram and computed as:

$$\text{Severity index (\%)} = \frac{\text{Sum of all numerical ratings}}{\text{Total leaflets observed on total plants} \times \text{Maximum rating}} \times 100$$

Ten plants per plot per replication were selected randomly to assess the disease severity per plot (maximum rating = 6). All plants in a plot were harvested to compute the total yield.

Disease control (DC) (%) was calculated as:

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

The cost:benefit ratio was obtained by calculating actual cost of production including cost of fungicide, fertilizers, and manures and their application, and the actual market price of produce.

All the treatments significantly reduced the severity of leaf spots and increased the pod yield as compared with the untreated control. They also showed differential effects in controlling the leaf spots under field condition

Table 1. Disease severity of early and late leaf spots and pod yield of groundnut in different organic and inorganic nutrient and fungicide combinations in rainy season 1997 and 1998.

Treatment[1]	Disease severity[2] (%)			Disease control (%)	Pod yield (t ha^{-1})			Pod yield increase over control (%)	Cost: benefit
	1997	1998	Mean		1997	1998	Mean		
NPK	48.72 (44.26)	46.09 (42.74)	47.41 (43.49)	21.16 (27.31)	0.95	1.27	1.11	28.91	0.4
FYM	51.03 (45.59)	44.97 (42.11)	48.00 (43.85)	20.19 (26.67)	1.00	1.20	1.10	28.15	0.3
NPK + FYM	42.63 (40.76)	37.28 (37.62)	39.95 (39.19)	33.58 (35.41)	1.31	1.57	1.49	67.79	1.0
NPK + FYM + fungicide	29.68 (32.99)	24.66 (29.76)	27.17 (31.37)	54.77 (47.74)	1.77	1.83	1.80	109.30	1.5
NPK + fungicide	36.42 (37.13)	30.29 (33.39)	33.36 (35.26)	44.49 (41.84)	1.52	1.76	1.64	90.55	1.3
FYM + fungicide	44.96 (42.09)	40.67 (39.62)	42.81 (40.85)	28.78 (32.42)	1.00	1.23	1.12	29.94	0.6
Fungicide	30.00 (33.21)	27.39 (31.56)	28.69 (32.38)	52.33 (46.32)	0.84	0.94	0.89	3.25	0.1
Control (untreated)	63.39 (52.82)	56.98 (49.01)	60.18 (50.91)	-	0.73	1.00	0.86	-	-
SE	±1.06	±0.69	±0.61	0.76	±0.069	±0.077	±0.041	±5.11	
CD (P= 0.05)	2.30	1.50	1.33	1.69	0.150	0.168	0.089	11.38	
CV (%)	3.08	2.15	1.84	2.66	7.17	6.60	3.82	10.27	

1. See text for treatment details and calculation of disease control.
2. Figures in parentheses are average angular transformed values.

(Table 1). The plots which were treated with NPK + FYM + fungicide showed the least disease severity followed by fungicide alone and NPK + fungicide. The treatment NPK + FYM + fungicide was superior in reducing the disease severity followed by fungicide alone, NPK + fungicide, and NPK + FYM. These treatments also showed good performance in disease control (%) (Table 1). This trend was observed in both years. No significant difference was observed in reducing the disease severity when plots were treated with only NPK or FYM.

It was observed that decrease in disease severity increased pod yield. The pooled data of two years showed that the pod yield did not differ significantly in treatments in which NPK and FYM were applied separately. Similar result was also observed in the plots treated with FYM + fungicide. The treatments NPK + FYM + fungicide and NPK + fungicide gave higher pod yield than others. The lowest pod yield was observed in the test plots treated with fungicide alone followed by FYM and NPK application. Bharadwaj and Shyam (1993) reported that application of sulfex in combination with NPK resulted in reduction of powdery mildew of pea and increase in maximum pod yield. Salako (1990) also showed that fungicide mixtures such as tridemorph + maneb or tridemorph + benomyl were more effective in controlling leaf spots and rust of groundnut with increased P application of plots (at least up to 18 kg ha^{-1}). The cost:benefit ratio showed that application of NPK + FYM + fungicide gave the maximum profit followed by NPK + fungicide and NPK + FYM. Thus application of NPK at 15:35:15 kg ha^{-1} in combination with 6.51 ha^{-1} FYM and 4 sprays of Dithane M-45 at 2 g L^{-1} of water was good for controlling leaf spots and increasing pod yield of groundnut followed by NPK + fungicide and NPK + FYM treatments.

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Bio-efficacy of Carbendazim and Mancozeb-based Fungicide in Control of Early and Late Leaf Spots of Groundnut

M S Joshi, P G Borkar, and A M Mandokhot (Department of Plant Pathology, Konkan Krishi Vidyapeeth, Dapoli 415 712, Maharashtra, India)

Early and late leaf spots of groundnut, caused by *Cercospora arachidicola* and *Phaeoisariopsis personata* respectively are endemic diseases in both rainy and summer crop seasons under Konkan conditions in India. Besides causing quantitative losses, these diseases are responsible for reduction in protein content and oil recovery (Gupta et al. 1987). So far, there is no resistant or tolerant variety to these diseases which will suit agroclimatic conditions of the region. As a result, use of fungicides is the only alternative for effective management of these diseases. Though several fungicides are already recommended by different workers, it is necessary to test the efficacy of new fungicides against these leaf spots.

A new fungicide constituting carbendazim 12% and mancozeb 63% has been developed by M/s United Phosphorus Ltd., Mumbai, India. This fungicide was tested at three concentrations (0.025%, 0.05%, and 0.1 %) with the recommended concentrations of carbendazim,

Table 1. Intensity of early and late leaf spots of groundnut in plots sprayed with different fungicides, alone and in combination during 1996/97.

Fungicide treatment	Concentration (%)	Disease intensity[1] (%)		Mean
		Rainy season crop	Summer crop	
Carbendazim + mancozeb (12% + 63%)	0.025	47.78	14.16	30.97
Carbendazim + mancozeb (12% + 63%)	0.05	41.52	15.00	28.26
Carbendazim + mancozeb (12% + 63%)	0.1	26.27	4.70	15.49
Carbendazim (50%)	0.1	38.35	7.80	23.07
Mancozeb (75%)	0.25	31.39	14.30	22.84
Copper oxychloride (50%)	0.25	49.38	18.13	33.75
Control (no fungicide spray)	-	55.66	27.63	41.64
SE		±2.484	±1.99	±2.90
CD (5%)		7.65	6.16	7.94

1. Mean of three replications.

mancozeb, and copper oxychloride (Table 1). Field trials were conducted during 1996/97 rainy season and summer crop season. The popular but susceptible groundnut cultivar Konkan Gaurav was sown in randomized block design in three replications. Standard and recommended package of practices for tillage, spacing, manuring, and irrigation were followed. The first spray of fungicide was done when the initial symptoms of the diseases appeared in the plots. This was followed by two more sprays at fortnightly intervals. Disease intensity was recorded on ten randomly selected plants from each treatment at weekly intervals by using 0-9 scale (Mayee and Datar 1986) and the average disease intensity (%) was calculated by the formula used by Mc Kinney (1923).

Disease intensity was high (55.66%) during monsoon compared to the summer crop (27.63%). This may be due to prolonged favorable climate for disease development during the rainy season.

The comparison of pooled means indicate that carbendazim + mancozeb-based fungicide at all three concentrations, carbendazim at 0.1%, and mancozeb at 0.25% were significantly superior as compared to control. However, carbendazim + mancozeb fungicide at 0.1% concentration is the most effective fungicide and it is at par with 0.1% carbendazim and 0.25% mancozeb. This indicates that the fungicide containing carbendazim 12% and mancozeb 63% at 0.1% is as effective as carbendazim 50% at 0.1% or mancozeb 75% at 0.25% in controlling early and late leaf spots of groundnut.

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Induction of Phenols in Groundnut Rust Resistance

A L Rathna Kumar and P Balasubramanian (Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India)

Rust *(Puccinia arachidis)* is a serious disease of groundnut. It causes severe yield and haulm losses and affects the seed quality. Few chemicals have been reported to control the disease. However, exploitation of host resistance would be an ideal approach in the context of subsistence farming of resource-limited semi-arid tropical regions of the world. Before formulation of a suitable breeding strategy, understanding the basic mechanisms associated with resistance becomes necessary.

A great deal of work has been done on the expression and mechanisms of resistance at the site of infection or upon challenging virulent pathogen on the host in many leguminous crops (Deverall and Dann 1995). It is evident from these studies that phenols and their oxidation products are implicated in disease resistance. The anti-microbial properties of phenolics are due to rapid accumulation of their oxidized products in vital loci within the cell wall, which in turn brings about interference in the metabolism of the host as well as pathogen (Kuc 1964). However, studies pertaining to groundnut and rust are rather limited. Hence, an experiment was conducted on the induction of phenols (total and ortho-dihydroxy phenols) and their oxidative enzyme, polyphenol oxidase, in resistant and susceptible groundnut cultivars following rust infection.

The materials comprised of two well adapted, rust susceptible cultivars TMV 1 and VRI 2, and two proven resistant donors, ICG 1697 (NcAc 17090) and ICG 10053 (PI 476183). The seeds were sown in earthen pots filled with sterile soil in a glasshouse.

Uredospores were collected from infected plants from the field and inoculated on 50-day-old plants as per the procedure of Subrahmanyam et al. (1995). Control plants were sprayed with distilled water. Estimation of phenols and assay of enzyme was carried out as per standard procedure (Rao et al. 1988) at 1,2,3,5, and 7 days after inoculation (DAI).

It was observed that the total phenols increased in response to infection by the pathogen within a day after inoculation in both resistant and susceptible cultivars. The accumulation of phenols was at faster rate in the resistant cultivars than in the susceptible cultivars until 3 DAI (Table 1). Thereafter (5 DAI), a sudden decline in the contents of phenol was recorded in the resistant cultivars while in the susceptible cultivars the decline was gradual. The decrease in phenols observed in resistant cultivars may be due to channelization of phenols for lignin biosynthesis (Taylor and Zucker 1966).

Pattern of accumulation of ortho-dihydroxy phenols indicated sudden spurt in the levels among resistant cultivars within a day after inoculation and persisted until 7 DAI.

Table 1. Changes in total phenols in response to inoculation with *Puccinia arachidis* in groundnut genotypes.

Genotype	Treatment	Days after inoculation[1] 1	2	3	5	7
Susceptible						
TMV 1	Healthy	240 fg	310gh	340 g	210gh	220 fg
	Inoculated	278 de	438 de	484 de	322 e	280 e
		(15.8)	(41.3)	(42.3)	(34.8)	(27.3)
VRI 2	Healthy	220 gh	368 g	342 gh	228 g	214 gh
	Inoculated	268 ef	570 c	480 ef	298 f	248 ef
		(17.9)	(38.6)	(40.3)	(30.7)	(15.9)
Resistant						
ICG 1697	Healthy	300 c	435 ef	540 c	440 bc	420 a
	Inoculated	446 a	720 a	880 a	499 a	384 bc
		(48.7)	(65.5)	(63.0)	(13.4)	(-8.6)
ICG 10053	Healthy	286 cd	440 d	498 cd	402 cd	390 ab
	Inoculated	404 ab	697 ab	764 b	451 ab	341 cd
		(41.3)	(58.4)	(53.4)	(12.2)	(-12.6)

1. Data expressed as $\mu g\ g^{-1}$ fresh weight of tissue.
Figures followed by the same letters are not significantly different *(P* = 0.05) according to Fisher's least significant difference test. Figures in parentheses indicate increase/decrease (%) over healthy.

Table 2. Changes in ortho-dihydroxy phenols in groundnut leaves in response to inoculation with *Puccinia arachidis*.

Genotype	Treatment	Days after inoculation[1] 1	2	3	5	7
Susceptible						
TMV 1	Healthy	50 gh	53 gh	60 gh	58 gh	53 gh
	Inoculated	74 cd	79 d	99 cd	86 de	72 ef
		(48.0)	(49.1)	(65.0)	(48.2)	(35.8)
VRI 2	Healthy	60 fg	64 fg	67 g	64g	60 fg
	Inoculated	88 c	98 c	106 c	96 c	79 e
		(46.7)	(53.1)	(58.2)	(56.0)	(31.7)
Resistant						
ICG 1697	Healthy	65 de	78 de	83 e	90 cd	98 c
	Inoculated	109 a	137 a	150 a	168 a	190 a
		(67.7)	(75.6)	(80.7)	(86.6)	(93.9)
ICG 10053	Healthy	62 ef	72 ef	80 ef	84 ef	89 d
	Inoculated	103 ab	122 b	144 ab	156 ab	170 ab
		(66.1)	(69.4)	(80.0)	(85.7)	(91.0)

1. Data expressed as μg g^{-1} fresh weight of tissue.
Figures followed by the same letters are not significantly different (P = 0.05) according to Fisher's least significant difference test.
Figures in parentheses indicate increase (%) over healthy.

Table 3. Changes in polyphenol oxidase activity in groundnut leaves in response to inoculation with *Puccinia arachidis*.

Genotype	Treatment	Days after inoculation[1] 1	2	3	5	7
Susceptible						
TMV 1	Healthy	43 ef	39 e	36 de	33 e	31 d
	Inoculated	54 b	29 gh	22 fg	16 fg	12 fg
		(25.6)	(-25.6)	(-38.8)	(-51.5)	(-61.3)
VRl 2	Healthy	39 fg	34 ef	30 ef	27 ef	25 de
	Inoculated	50 bc	30 fg	22 fg	17 gh	14 ef
		(28.2)	(-13.3)	(-26.6)	(-37.0)	(-44.0)
Resistant						
ICG 1697	Healthy	49 cd	52 c	54 c	59 c	56 c
	Inoculated	80 a	88 a	96a	109 ab	102 a
		(63.3)	(69.2)	(77.7)	(84.7)	(82.1)
ICG 10053	Healthy	47 de	49 cd	52 cd	58 cd	56 c
	Inoculated	80 a	86 ab	92 ab	110a	104 ab
		(70.2)	(75.5)	(76.9)	(89.7)	(85.7)

1. Data expressed as optical density (OD) (units) of reaction mixture at 490 nm after 180s; OD of 0.001 - 1 unit.
Figures followed by the same letters are not significantly different (P = 0.0S) according to Fisher's least significant difference test.
Figures in parentheses indicate increase/decrease (%) over healthy.

On the contrary, in susceptible cultivars, although the levels of ortho-dihydroxy phenols were initially high it reduced progressively from 5 DAI (Table 2). It is reported that ortho-dihydroxy phenols are highly fungitoxic and accumulate rapidly in resistant cultivars following infection by the pathogen (Bhatia et al. 1972) as observed in the present study.

Activity of polyphenol oxidase (PPO) was higher in the infected leaves of resistant cultivars throughout the growth period than in the susceptible cultivars, which recorded a decline in the enzyme activity within 2 DAI (Table 3). Kosuge (1969) reported that phenols are oxidized to quinones by PPO and there exists direct correlation between the accumulation of phenols and the activity of PPO. This supports the present study.

Based on the above studies it is clear that phenols are induced following rust infection and play a major role in groundnut rust resistance. Such an induction may be a general defense response or a phytoalexin per se. Interestingly, it was observed that susceptible cultivars had shorter incubation period, greater infection frequency, and lesion diameter than the resistant cultivars (data not provided). Hence, it is probable that induction of phenols may be more of a phytoalexin response than the elicitation of general defense. Further studies should focus on identification of specific phenolic compound(s) associated with phytoalexin activity and understanding mechanism(s) of induction.

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Characterization of Isolates of *Trichoderma* for Biocontrol Potential Against *Aspergillus flavus* Infection in Groundnut

S Desai[1], R P Thakur[2], V P Rao[2], and V Anjaiah[2]
(1. National Research Centre for Groundnut (NRCG), Ivnagar Road, PB No. 5, Junagadh 362 001, Gujarat, India; 2. International Crops Research institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India)

Groundnuts are infected in the field, during processing, and in storage by *Aspergillus flavus* resulting in accumulation of aflatoxins in the seeds, thus rendering them unfit for consumption and trade. Aflatoxins have been reported to be immunosuppressive, carcinogenic, and teretogenic in nature. In the absence of acceptable levels of host plant resistance, use of biocontrol agents could be a promising alternative for the management of aflatoxin contamination. *Trichoderma* spp are well known for their biocontrol ability, especially against soilborne plant pathogens, and these have several modes of action. A systematic characterization and cataloging of isolates for different modes of biocontrol ability will help in deployment of a biocontrol agent for effectively managing plant pathogens. Preliminary observations have indicated that some isolates of *Trichoderma* are effective against *A. flavus*. We report the in vitro antagonistic characteristics of some *Trichoderma* isolates against *A. flavus*.

A total of 26 *Trichoderma* isolates, belonging to five species aggregates, *viride, hamatum, harzianum, auroviride,* and *longibrachiatum,* obtained from different sources were used in the study (Table 1). The *A. flavus* isolate Af 11-4, which is a highly aggressive seed colonizer

and is toxigenic was used as the test pathogen. The *Trichoderma* isolates were characterized for growth in broth culture, antagonism in dual culture, production of volatile and non-volatile substances that are inhibitory to *A. flavus*, and tolerance to commonly used seed dressing fungicides (carbendazim and thiram).

All *Trichoderma* isolates were grown on potato dextrose broth for seven days at 28 ± 1°C with a 12-h photoperiod. After the harvest, dry weight of mycelium of the various isolates was recorded. The isolates differed significantly in their growth. Maximum mycelial dry weight was produced by *T. viride* - NARDI (366 mg), followed by *T. harzianum* - APDRC 19 (353 mg), and the least growth was recorded for *T hamatum* - T049 (75 mg) (Table 1). This character would be useful for mass multiplication of the fungus for use in product formulation.

The ability of *Trichoderma* isolates to suppress the growth of *A. flavus* was tested in vitro by dual-culture method (Deacon 1976) and their effectiveness was scored on a numerical scale (Bell et al. 1982) with slight modifications as: 1 = *Trichoderma* overgrowing the colony of *A.flavus; 2* = *Trichoderma* covering 2/3rd of the plate and progressing

Table 1. In vitro growth of 26 isolates of *Trichoderma* spp as mycelial dry weight and influence of non-volatiles produced by *Trichoderma* isolates on growth of *Aspergillus flavus*.

Trichoderma species	Identity	Source[1]	Mycelial dry weight[2] (mg)	Colony diameter[3] (mm)
T. viride	T071	NRCG, India	191	22
T. viride	T219	NRCG, India	229	20
T. hamatum	T049	NRCG, India	75	19
T. hamatum	T166	Dornach, Switzerland	230	21
T. hamatum	354	Giessen, Germany	253	22
T. harzianum	043	NRCG, India	261	17
T, harzianum	126	NRCG, India	155	17
T. harzianum	127	NRCG, India	167	22
T. harzianum	144	NRCG, India	226	18
T. harzianum	250	NRCG, India	182	24
T. harzianum	295	NRCG, India	220	19
T. harzianum	390	ATCC, USA	277	22
T. harzianum	391	ATCC, USA	167	17
T. longibrachiatum	TL-3	RAU, India	152	18
T. viride	TV4	RAU, India	177	21
T. auroviride	TA-2	RAU, India	197	21
T. harzianum	TH-1	RAU, India	284	27
T. viride	APDRC3	PKV, India	255	21
T. harzianum	APDRC4	PKV, India	246	22
T. viride	APDRC 12	PKV, India	279	22
T. harzianum	APDRC 19	PKV, India	353	18
T. harzianum	OPTNAB	Philippines	172	23
T. viride	Bca6	ICRISAT, India	238	23
Trichoderma sp	MPH	ICRISAT, India	314	19
T. viride	NARDI	NARDI, India	366	17
Trichoderma sp	Ananthapur	ICRISAT, India	312	20
A. flavus (control)			-	85
SEm			±21.08	±13.3
LSD (P = 0.05)			59.9	38.4

1. NRCG - National Research Centre for Groundnut, Junagadh, Gujarat, India; ATCC - American Type Culture Collection, Maryland, USA; RAU = Rajasthan Agricultural University, College of Agriculture, Udaipur, Rajasthan, India; PKV = Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharshtra, India; ICRISAT = International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India; NARDI - Nagarjuna Agricultural Research and Development Institute, Hyderabad, Andhra Pradesh, India.
2. Mycelial growth from 7-day-old culture in potato dextrose broth at 28 ± 1°C; mean of three replications.
3. Colony diameter of *A. flavus* (Af 11-4) recorded 10 days after incubation at 28±1°C; mean of three replications.

towards *A. flavus;* and 3 = *Trichoderma* and *A. flavus* meeting at halfway of the petri dish and producing inhibition zone. Seven isolates were fast growing and were rated 1, 16 isolates were rated 2, and three isolates produced inhibition zone with *A. flavus* and were rated 3.

To test the ability of these isolates for the production of volatile and non-volatile chemicals that are inhibitory to *A. flavus* the method of Dennis and Webster (1971a, 1971b) was followed. While assessing the production of volatiles, colony diameters of *Trichoderma* and *A. flavus* were recorded daily, for seven days. None of the isolates of *Trichoderma* inhibited the growth of *A. flavus* by production of volatiles. While assessing the production of non-volatile chemicals, initially, there was very slow growth of *A. flavus*. Even after 10 days of incubation, a maximum of only 27 mm colony diameter of *A. flavus* was recorded with *T. harzianum* - TH-1 as compared with 85 mm in the control (Table 1) indicating the production of non-volatile chemicals inhibitory to *A. flavus* growth by all *Trichoderma* isolates.

All 26 *Trichoderma* isolates were tested for their tolerance to common seed dressing fungicides, thiram and carbendazim (Bavistin®) following poisoned food technique. Potato dextrose agar was amended with either carbendazim at 0.005, 0.05, 1, 2, and 10 µg mL^{-1} or thiram at 100, 200, 500, 1000, and 1500 µg mL^{-1}. All isolates were sensitive to the fungicides at all concentrations indicating that these isolates were not compatible with the fungicides, and thus cannot be used in combination with these seed dressing fungicides. Sensitivity of *Trichoderma* isolates to carbendazim has been reported by Desai and Schlosser (1993). Identification of *Trichoderma* isolates with proven biocontrol ability and tolerance to seed dressing fungicides would be desirable to utilize them to control *A. flavus* infestation. Selected *Trichoderma* isolates from this study are being used in greenhouse and field experiments to evaluate their biocontrol potential against aflatoxin contamination in groundnut.

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Mycotoxins from Groundnuts Marketed in Yemen

Saleha Al-Nahdi (Sana'a University, Republic of Yemen. Present address: World Bank Office, Sana'a, PO Box 18152, Republic of Yemen)

One of the most serious aspects of the invasion of grain by some fungi is the production of toxic secondary metabolites known as mycotoxins. Many agricultural commodities and their products including feed have been shown to be contaminated by them. Mycotoxins are highly toxic to humans and livestock. Different fungi produce different types of mycotoxins, e.g., *Aspergillus flavus* and *A. parasiticus* produce aflatoxin, and *A. ochraceous* and *Penicillium viridicatum* produce ochratoxin. Groundnuts are most susceptible to the fungi that produce aflatoxin.

Surveys from several countries have reported considerable contamination of groundnut seeds, groundnut cake, and its feed with aflatoxin, ochratoxin, citrinine, zearalenone, trichothecens, T-2 toxins, deoxynivalenol (DON), nivalenol, diacetoxyscirphenol, and penicillic acid. Most of these studies were conducted in the areas of outbreaks of mycotoxicoses in farm animals or humans, while other representative samples studied had obvious mold damage (Bhat 1989). Mycotoxin contamination in groundnut can occur in the field during pre-harvest, harvest, and during postharvest handling (Nahdi 1997). In many countries, they are able to control the entry of contaminated groundnut in food chain by following strict regulatory programs. The maximum permissible limit of these mycotoxins varies from 0 to 100 µg kg^{-1} depending on the country and foodstuff and also whether the commodity is for human or animal consumption. Most of the groundnut for local consumption in Yemen is imported. Unfortunately, there are no regulatory mechanisms established in Yemen to prevent the entry of contaminated groundnut in food chain. The quarantine laboratories in the country are neither equipped nor have trained staff to undertake mycotoxin analysis.

Table 1. Contamination of groundnut by fungi and mycotoxins in Yemen[1].

	Seed infection (%)						Mycotoxin level (µg kg^{-1})		
Region	AF	AS	F	P	UF	Total	AT	T-2	DON
Sana'a									
WSM (I)									
China	17	4	2	3	2	28	40	0	0
India	9	9	0	0	0	18	0	0	0
Sudan	3	1	1	2	2	9	0	0	0
WSM (L)	9	4	0	3	1	17	0	0	0
Storage (I)									
China	4	1	14	4	11	34	0	140	0
India	11	0	1	1	9	22	0	0	0
Sudan	3	1	10	4	6	24	0	0	10
Storage (L)	4	3	2	2	3	14	0	0	0
Consumer level (I)									
China	0	0	3	20	7	30	0	0	0
India	6	0	0	0	14	20	0	0	0
Sudan	7	0	7	5	7	26	0	0	0
Consumer level (L)	1	3	1	0	23	28	0	0	0
Aden									
WSM (1)									
China	27	4	2	8	9	50	140	0	0
India	1	0	6	4	11	22	0	0	0
Sudan	8	0	0	0	1	9	10	0	0
WSM (L)	9	2	3	4	0	18	+	0	0
Storage (I)									
China	9	2	1	1	5	18	0	0	0
India	2	3	19	2	5	31	0	0	20
Sudan	6	11	0	0	3	20	0	0	0
Storage (L)	12	6	4	9	3	34	60	0	0
Consumer level (I)									
China	10	2	1	1	9	23	60	0	0
India	1	7	1	0	0	9	0	0	0
Sudan	8	3	3	0	1	15	20	0	0
Consumer level (L)	0	2	21	7	2	32	0	20	0
Hodida									
WSM (I)									
China	41	0	2	9	8	60	160	0	0
India	11	0	4	2	4	21	20	0	0
Sudan	21	2	2	5	2	32	20	0	0
WSM (L)	10	1	1	1	2	15	40	0	0
Storage (I)								-	
China	6	2	3	3	3	17	0	0	0
India	15	2	5	0	11	33	20	0	+
Sudan	4	0	16	0	9	29	0	+	0
Storage (L)	2	0	7	3	6	18	0	0	0
Consumer level (I)									
China	24	2	13	2	5	46	40	40	0
India	16	3	2	1	4	26	40	0	0
Sudan	17	8	12	3	5	45	160	0	20
Consumer level (L)	13	0	4	3	8	28	0	0	0

1 AF - *Aspergillus flavus;* AS - *Aspergillus* spp; F = *Fusarium* spp; P = *Penicillium* spp; UF = Unidentified fungi; AT - Aflatoxin; T-2 = T-2 toxin; DON = Deoxynivalenol or vomitoxin; WSM = Wholesale market; I = Imported groundnut; L = Local groundnut; + = Trace.

The first systematic study to estimate mycotoxin contamination in grains in Yemen was undertaken in 1997 (Nahdi 1997). It showed that mycotoxin contamination of grains was a widespread problem in the country.

The main objective of this study was to conduct systematic survey of imported and local groundnut for fungi that produce mycotoxins, and for mycotoxin contamination in three major cities in Yemen.

Sample collection

Samples were collected during January-February 1998 from (1) the wholesale markets (shops), (2) storage (wholesale godowns), and (3) retail shops at consumers' level in Aden, Hodida, and Sana'a (Table 1). The former two are the major seaports of the country. Groundnut is traded mostly in the form of seeds in Yemen. About 80% of the samples were seeds and the remaining were pods.

Samples were collected using standard sampling techniques. In the wholesale market and storage, the area at each site was divided arbitrarily into three replications. In each replication, a sample of seeds or pods was collected from bags at different levels, and they were mixed to get a 2-kg representative sample for each replication. In the case of consumers' level, a 2-kg representative sample was collected from different bags at retail shops.

Sample analysis

Visual examination. Samples were examined visually for external damage (both physical and biological), presence of foreign material and insects, and immature, shriveled, and unhealthy seeds. They were scored for visual disorder/damage as follows: low 0-5%, moderate 5-7%, high 7-10%, and very high >10% seeds showing various types of damage.

Fungal contamination. The fungal contamination of seeds was estimated using agar plate technique. One hundred mature seeds from each sample were selected and surface sterilized with 10% Chlorox® (5.25% sodium hypochlorite). After three rinses with sterile distilled water, the seeds were plated aseptically on potato dextrose streptomycin agar medium in 9-cm diameter petri dishes. After incubation for 5-7 days at 25°C, the number of seeds colonized by fungi was recorded and the fungi identified.

Mycotoxin estimation. Enzyme-linked immunosorbent assay (ELISA) kits were procured from Neogen Corporation, USA and ICRISAT, India. The ICR1SAT method was used for aflatoxins (Devi et aL 1999), and for T-2 and D O N toxins the kits supplied by Neogen were used. The positive samples of aflatoxins were also tested by thin layer chromatography (TLC) method (Pons et al. 1966).

Results and discussion

The majority of samples (58%) showed visual disorder with 30% of the samples exceeding the maximum permissible limit (10%). Of the total samples with mycotoxin contamination, 44% were imported and 14% were from Yemen. Of those samples which exceeded permissible mycotoxin contamination limit, 24% were imported (11% from Sudan, 8% from China, and 5% from India) and 6% were from Yemen. Insects were found in 16% of the samples. Insects not only contaminate the seeds and its products by their excretions but also spread other infections as they move from infested seeds to healthy seeds with spores of fungi adhering to their body and mouthparts.

All samples recorded fungal contamination. The contamination level ranged from 9% to 60% (Table 1). The average infection level was highest in samples from Hodida (30.8%), followed by Aden (23.4%) and Sana'a (22.5%). Hodida and Aden are the main seaports in the country having high relative humidity, conducive for fungal growth. Samples from China showed a high level of contamination (17-60%), followed by samples from Sudan (9-45%), Yemen (14-34%), and India (9-33%).

Many fungi *(A. flavus, A. versicolor, Fusarium* spp, and *Pencillium* spp, and other unidentified species) were isolated from the samples. These fungi under suitable environmental conditions (such as seed moisture content >12%, temperature >27°C, and relative humidity 70-80%) can produce mycotoxins. Most of the mycotoxins are produced before the fungi can be visually detected. The dominant fungal species was *A. flavus,* which infected 37.4% of the samples, followed by other fungi (21.8% samples infected) and *Fusarium* spp (18.9% samples infected).

Mycotoxins were detected in 52% of the samples collected in the country. The level ranged from <10 ug kg^{-1} to as high as 160 µg kg^{-1} (Table 1). Mycotoxins were detected in 25% of the samples from Sana'a. All the samples were imported (16% from China and 9% from Sudan). In Aden, 58% of the samples were contaminated by mycotoxins. Among these, 41% were imported (17% each from China and Sudan and 7% from India) and 17% were of local origin. Mycotoxins were detected in 67% of the samples collected from Hodida. Of these, 58% of the samples were imported. Samples from all the three countries (25% samples of India

and 17% each of Sudan and China) were positive for mycotoxins.

Mycotoxins are very stable in nature. Boiling and roasting do not destroy them, if they are present in seeds. Groundnuts in Yemen are consumed in various forms: roasted nuts for extraction of oil and groundnut cake as animal feed. In rural areas, where oil is extracted following the traditional method, mycotoxins are present in unrefined oil. Because of seed contamination and presence of toxins in groundnut cake, which is used as animal feed, aflatoxins can enter into human food chain. Consumption of aflatoxin-contaminated food is suspected to be one of the reasons for increasing incidence of liver cancer in Yemen. It is very important that necessary human resource and infrastructure facilities are developed in the country to screen for mycotoxin-contamination of groundnuts in foods and feeds.

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Entomology

Survey of Groundnut Leaf Miner and its Natural Enemies in Tamil Nadu, India

C Muthiah and A Abdul Kareem (Coconut Research Station, Veppankulam 614 906, Thanjavur District, Tamil Nadu, India)

The groundnut leaf miner *Aproaerema modicella* is one of the most important and widely distributed foliage feeders of groundnut crop in Asia. It affects the growth and yield of the plants, especially in rainfed groundnut. Logiswaran and Mohanasundaram (1985) reported pod yield losses of >50% due to leaf miner.

In the present study, a survey was conducted in six major rainfed groundnut-growing districts of Tamil Nadu in India, viz., Villupuram, Tiruvannamalai, Chengalpet, Erode, Salem, and Dharmapuri. The survey was conducted during 1996 rainy season (kharif) at 40-60 days after sowing to assess the extent of leaf miner incidence, damage, and its natural enemies. The survey was conducted in 7 blocks in each district. The incidence was assessed on 10 randomly selected plants and mean larvae plant^{-1} was calculated. In each location 20 larvae were examined to work out the percent parasitism. The 95% confidence interval for mean and coefficient of variation (%) were calculated for the mean larvae plant^{1}, leaflet damage (%), and parasitism (%). The parasitized larvae were collected, observed for the emergence of natural enemies, and identified. Similarly the eggs of leaf miner were also collected and observed for the emergence of natural enemies.

The survey results showed that the occurrence of the pest and its parasitoids was maximum in Dharmapuri district (Table 1) with mean percent leaflet damage of 90.1 ± 5.0. The mean larvae plant^{-1} was 11.3 ± 2.7 while the mean percent parasitism was 28.1±5.0. The percentage of parasitism was more when the availability of host larvae was more. Similar results were reported earlier by Shekharappa and Patil (1990). The maximum of 100% leaflet damage and 17.0 larvae plant^{-1} was observed in Athanoor village of Indoor block in Dharmapuri district. This was followed by Thiruvannamalai district which recorded a mean leaflet damage of 64.5±8.0 and mean larvae plant^{-1} of 3.8 ± 1.5. The leaflet damage and larval population estimated earlier were 20-55% (Jai Rao and Sindagi 1974) and 0.08-0.8 larva plant^{1} respectively (Khan and Raodeo 1987).

The study also revealed that the larvae of *A. modicella* were parasitized by 11 species of hymenopterous parasitoids

(Table 2). These included three braconids, *Chelonus* sp, *Avga chaospes,* and *Apanteles* sp; two eulophids, *Stenomesius japonicus* and *Tetrastichus* sp; one ichneumonid, *Temelucha* sp; one eurytomid, *Eurytoma* sp, one pteromalid, *Pteromalus* sp; one eupelmid, *Eupelums* sp; one bethylid, *Goniozus indicus',* and one chalcid larval parasite, *Brachymeria wittei.* The eggs of *A. modicella* were parasitized by an egg parasitoid *Trichogramma* sp. Shanower et al. (1993) reported nine primary and seven secondary parasitoids as responsible to reduce 50% of the leaf miner larvae in one generation. Among the 12 parasitoids identified the activity of the pupal parasitoid *Chelonus* sp was maximum (26.0%) followed by parasitoids *B wittei* (20.0%), and *G indicus* (16.7%). Yadavetal.(1987) earlier reported that parasitism by *Apanteles* sp was 1.02 to 27.27%, *Goniozus* sp was 0.54 to 50.0%, and *Stenomesius* sp was 0.2 to 79.16% at Anand, Gujarat, India. From our study it is evident that the groundnut leaf miner damage ranged from 11.0% to 90.1% in major groundnut-growing districts of Tamil Nadu. The parasitoid complex of leaf miner include 10 larval parasitoids, one pupal parasitoid, and one egg parasitoid, which are active in the ground-nut-growing areas of Tamil Nadu. The role of parasitoids needs to be considered while making decisions on plant protection.

Table 1. Occurrence of leaf miner in major groundnut-growing districts of Tamil Nadu, India, rainy season 1996.

District	Mean leaflet damage (%)	Mean number of larvae plant^{-1}	Mean parasitiism (%)
Thiruvannamalai	64.5 ± 8.0	3.8 ± 1.5	18.0 ± 9.3
Dharmapuri	90.1 ± 5.0	11.3 ± 2.7	28.1 ± 5.0
Erode	11.0 ± 2.9	0.8 ± 0.3	1.3 ± 1.6
Salem	16.2 ± 0.4	0.8 ± 0.4	3.3 ± 3.1
Chengalpet	45.8 ± 9.6	3.5 ± 0.8	11.7 ± 2.1
Villupuram	54.9 ± 7.9	3.8 ± 1.0	13.0 ± 4.5

Table 2. Natural enemies of *Aproaerema modicella* Deventer identified in groundnut-growing regions of Tamil Nadu, India.

Family	Parasitoid	Parasitism (%)
Braconidae	*Chelonus* sp	26.0
	Avga chaospes Nixon	1.3
	Apanteles sp	1.3
Eulophidae	*Stenomesius japonicus* Ashmead.	4.0
	Tetrastichus sp	2.7
Ichneumonidae	*Temelucha* sp	3.7
Eurytomidae	*Eurytoma* sp	5.3
Pteromalidae	*Pteromalus* sp	4.3
Eupelmidae	*Eupelmus* sp	1.3
Bethylidae	*Goniozus indicus* Ashmead.	16.7
Chalcididae	*Brachymeria wittei* Schmitz.	20.0
Trichogramrnatidae	*Trichogramma*sp	10.3

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Groundnut Leaf Miner *Aproaerema modicella:* A New Pest in Eastern Districts of Uganda

W W Page[1], G Epieru[2], F M Kimmins[1], C Busolo-Bulafu[2], and P W Nalyongo[2] (1. Natural Resources Institute, Chatham, Kent ME4 4TB, UK; 2. Serere Agricultural and Animal Production Research Institute (SAARI), PO Box, Soroti, Uganda)

In the Teso farming system of eastern Uganda, groundnut is grown as a major food and cash crop. Recent needs assessment exercises and socioeconomic surveys from this region have indicated that the major pest/disease constraint of groundnut is groundnut rosette disease caused by groundnut rosette virus (GRV) which is transmitted by the aphid vector, *Aphis craccivora* Koch. Research on the deployment of virus and vector resistant varieties has been in progress since 1998 by the Serere Agricultural and Animal Production Research Institute (SAARI), Uganda in collaboration with the Natural Resources Institute (NRI), UK and ICRISAT, Malawi. During these studies, a new pest, a groundnut leaf miner, has been observed to cause significant damage to groundnuts and farmers in the region have reported that it can result in severe crop loss. This short report describes what is known so far about the new pest in the Teso system.

Specimens of the leaf miner collected in Soroti District of Uganda during September 1998 were recently identified by the British Museum (Natural History), as being *Aproaerema modicella* Deventcr (Lepidoptera: Gelechiidae). This species has only been reported to date in South and Southeast Asia and is regarded as the most serious pest of groundnut in India (Amin 1983, Shanower et al. 1993). As far as we can ascertain this is the first record of this species in Africa although there have been recent reports of the pest appearing in Malawi in April 2000 (J M Lenne, ICRISAT, personal communication). Therefore information on the appearance and perceived incidence of the leaf miner in the area from local farmers, agricultural officers, and scientists was collected to ascertain its first appearance and relative importance in the region.

Leaf miner damage was first seen and reported in Kumi District (Fig. 1) in the first planting season of 1997 (March-July) and was also reported later during the second season (September 1997-January 1998). It is uncertain yet how widespread the first outbreaks were but none were recorded in other districts. Everybody questioned in all the districts visited agree that the leaf miner was never seen before this date. An example is a farmer in Soroti District, Mr Obadia Okiring, who was an entomologist for 30 years at SAARI and had not seen the leaf miners before. In the first and second seasons of 1998 there were large outbreaks of leaf miners causing considerable damage and there was an increased use of insecticides (predominantly dimethoate) in an attempt to reduce the problem. The sprays were previously used to control the aphid vector of GRV or cotton pests. Many farmers had complete crop losses due to miner damage during this period. In 1998 leaf miner was reported from Kumi and Soroti Districts (full extent not known yet) and in the southeastern part of Katakwi District (4 subcounties but not elsewhere) and the northern part of Pallisa District, both of the latter areas being adjacent to Kumi District (Fig. 1). There were calls from farmers to find other ways of controlling the pest such as breeding for resistance. Isolated occurrences of leaf miner damage were reported in both seasons in the above districts during 1999 although the overall distribution is not known. In some cases the damage to fields was severe (W. W. Page, NRI, personal observation). Mbale District Agricultural Office had not come across the groundnut leaf miner although some subcounties have high groundnut production.

Surveys to collect groundnut leaf miner in Kumi and Soroti Districts during the first growing season of 2000 (May) showed a low incidence of larvae. This was probably because the oldest groundnut fields were only just flowering due to late planting in mid- to late April. This would be too early to find large numbers of leaf miners as high numbers are normally seen after flowering and when pegging has begun. Farmers have also reported that adult populations build up after a prolonged dry spell during the growing season. Between May and July, isolated occurrences of leaf miner have been reported from Katakwi and Kumi Districts and large numbers of moths have been caught in a pheromone trap at SAARI although there have been no serious outbreaks of the pest in the area.

The status of this pest is uncertain in other districts in Uganda (i.e., Tororo, Busia, Iganga Districts and further westwards). But experience of growing groundnut in these other areas suggests that the pest may not be present and certainly has not been recorded as causing problems.

The sudden appearance of groundnut leaf miner in the eastern districts of Uganda poses a number of questions: (1) Have groundnut leaf miners been present in low numbers within Uganda and changes in farming practices or weather encouraged these recent outbreaks or is the sudden appearance due to accidental introduction? (2) Will the leaf miner be able to maintain numbers to remain a pest? (3) The knowledge gathered so far on the distribution of the pest suggests that it may be confined at present to a

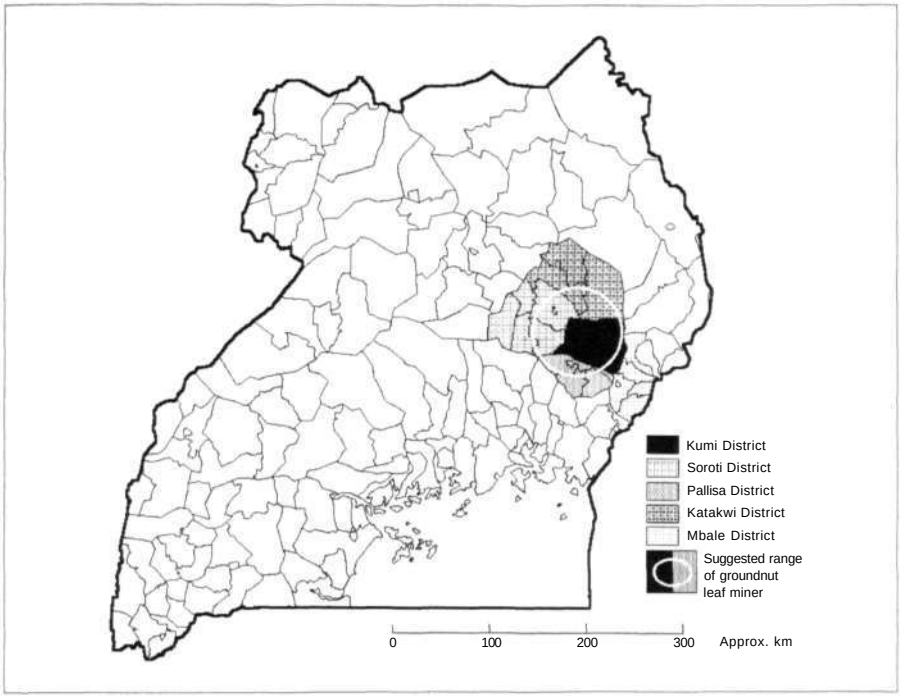

Figure 1. Map of Uganda showing the districts where information on groundnut leaf miner was gathered and an approximation of its range based on current knowledge.

particular area (suggested in Fig. 1). Is this correct? It is therefore important to identify more precisely the distribution using pheromone traps (Ranga Rao et al. 1993, Cork and Hall 1998), visual surveys, and farmer/agricultural office surveys both within the known area as well as elsewhere in Uganda. Once these answers have been established it may be possible to identify whether this pest has the potential to spread elsewhere and whether it can be controlled or eradicated in order to stop further spread.

One of the important features of introducing GRV and vector resistant varieties of groundnut into the Teso farming system was to release farmers from the costly and labor increasing work of spraying with insecticides to kill the aphid vectors (often four sprays in a season). The appearance of the leaf miner in the area now produces a new constraint which, at present, can only be controlled by individual farmers using insecticides. Many subsistence farmers in this farming system are unable to afford these chemicals and therefore the emergence of this pest may become an important factor in the sustainability of groundnut production for smallholder producers in the Teso system.

We would be grateful for any reports of groundnut leaf miner (*A. modicella)* being identified individually or causing damage in Africa so that the status of this pest can be determined.

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Occurrence of Groundnut Leaf Miner in Northern Malawi

P Subrahmanyam[1], A J Chiyembekeza[1], and G V Ranga Rao[2] (1. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), PO Box 1096, Lilongwe, Malawi; 2. ICRISAT, Patancheru 502324, Andhra Pradesh, India)

An outbreak of leaf miner (*Aproaerema modicella* Deventer) (Lepidoptera: Gelechiidae) on groundnut *(Arachis hypogaea)* was noticed in Karonga Agricultural Development Division (ADD) in northern Malawi in April 2000. Leaf miner infestation was observed in all 17 farmers' fields surveyed in Kasowa, Baka, Ipyana, and Lupembe areas; however, the pest was very severe and destructive (>5 mines per leaflet) only in Kasowa area. Affected groundnut fields showed a burnt appearance from a distance due to shriveling and desiccation of leaves (Fig. 1). Mild infestation was also observed on pigeonpea (*Cajanus cajan)* grown as mixed crop in groundnut fields. Leaf miner was not observed on other legumes such as common bean *(Phaseolus vulgaris),* bambara groundnut (*Vigna subterranea),* and cowpea (*Vigna mguiculata).* Infested groundnut plant samples were collected from farmers' fields in Kasowa and brought to the laboratory for investigation.

Examination of infested leaves revealed the presence of single shiny white eggs (0.5-0.7 mm long) on the lower side of the leaflets and on petioles. During the early stages of infestation, small blister-like mines were observed on the upper surface of the leaflets near the midrib due to feeding of mesophyll between upper and lower epidermis. When the mines were split opened, minute yellowish-green larvae with black head, usually one larva per mine, were seen inside. As the feeding advanced, the size of the mines increased and the leaflets became deep brown, rolled, and dried up prematurely (Fig. 2). Webbing of the leaflets was seen in advanced stages of infestation, but was not very severe. Matured larvae were 5-7 mm long and pupated within the webbed leaflets. Moths were grayish and small (7-9 mm long).

In Karonga ADD, groundnuts are cultivated both during the rainy season (from January to April, under rainfed conditions) and during the off-season [(from June to October/November, on residual moisture after lowland rice (*Oryza sativa),* supplemented by occasional showers] predominantly along the Songwe river bordering Tanzania, the Kyungu River Valley, and Kasantha Valley. The short-duration Spanish type Malimba (locally known as Kasawaya) is the most predominant groundnut variety grown in both crop seasons. The practice of continuous cultivation of groundnut has been implicated to contribute to survival and perpetuation of diseases such as rust (*Puccinia arachidis)* and rosette (Chiyembekeza and Subrahmanyam 1995). During the surveys conducted in Karonga ADD in the off-season of 1993 (by Subrahmanyam and Nyirenda) and in the rainy season of 1994 (Chiyembekeza and Subrahmanyam 1995) and in other parts of the country in 1986/87 (Wightman and Wightman 1994), a number of arthropod soil pests including white grubs (scarabeid larvae, predominantly *Schizonycha* spp and *Anomala* spp), termites (species of *Ancistrotermes, Hodotermes, Odontotermes, Macrotermes, Microtermes,* and *Pseudoacanthotermes),* wireworms (elaterids), false wireworms (tenebrionids), doryline ants (*Dorylus* sp), *Hilda patruelis* (Homoptera: Tettigometridae) and mealy bugs (Homoptera: Pseudococcidae), and foliage feeders such as aphids *{Aphis craccivora),* jassids (cicadellid), *Spodoptera* (probably *littoralis),* weevils (especially *Systoles* sp), and flea beetles have been recorded. Soil pests are more serious and economically important than foliage feeders in Malawi (Wightman and Wightman, 1994). It appears that there is no published record of the occurrence of groundnut leaf miner in Malawi. The practice of continuous cultivation of groundnut in Karonga ADD may be a contributing factor for the outbreak of leaf miner in these areas of Malawi. Further studies are required to determine the seasonal occurrence, distribution, host range, yield losses, and biology of groundnut leaf miner.

Figure 1. Extensive damage to groundnut foliage due to leaf miner infestation.

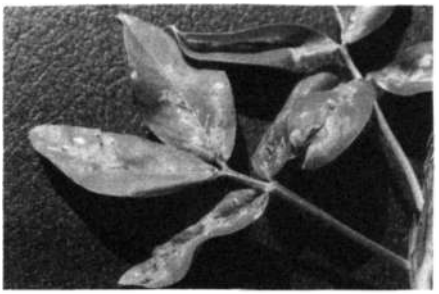

Figure 2. Mining of groundnut leaf surface due to leaf miner infestation.

Groundnut leaf miner has very limited host range in legumes. Soybean *(Glycine max),* groundnut, and pigeonpea are the most preferred hosts. Groundnut leaf miner has been reported in several countries in Asia (China, Indonesia, Kampuchea, Laos, Malaysia, Myanmar, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam). It is an important pest in eastern and southern Asia (Wightman and Ranga Rao 1994). In recent years, leaf miner was observed to cause considerable damage to groundnut crop in Uganda (P.J.A. van der Merwe and J.M. Lenne, ICRISAT, personal communication). However, we are not aware of any published report of the occurrence of groundnut leaf miner in Malawi and other parts of Africa. Groundnut leaf miner is believed to be a poor migratory pest and should be reduced from the primary foci of infestation. It would be useful to establish pheromone traps at all locations where it had been noticed.

Authors (PS and GVRR) would appreciate receiving information from scientists on the occurrence of groundnut leafminer in other parts of Africa.

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Screening of Promising Groundnut Genotypes for their Reaction to *Spodoptera litura*

P K Dharne and S K Patel (Oilseeds Research Station, Jalgaon 425 001, Maharashtra, India)

Groundnut is an important oilseed crop, occupying about 8 million ha which is about 46% of area under oilseed in India. Yield of groundnut in India is very low compared to that in China and USA. Several reasons could be ascribed to its low productivity of which tobacco caterpillar *(Spodoptera litura)* has become a limiting factor and reduces the yield to some extent (Amin 1988). Hence, an attempt has been made to determine the most stable sources of tolerance in groundnut. Screening techniques for groundnut germplasm against foliage pests are available (Vikram Singh 1979, Wightman et al. 1987). Mahadevan et al. (1988) reported that the variety 1CGS 50 is resistant against a foliage pest. The most promising entries having high degree of tolerance were identified as stable sources against some noxious pests. Control is aimed to be achieved through the development of tolerance against the major pests of groundnut.

Field experiments were conducted at the Oilseeds Research Station, Jalgaon, Maharashtra, India during 1995 to 1997 in the rainy season (kharif). Sowing of entries was undertaken in 5-m rows with interrow spacing of 30 cm and plant spacing of 10 cm in randomized block design with two replications. The observations were recorded on foliage eaten by the larvae on ten randomly selected plants. The percent damage rating was scored visually

and converted into arcsin values. In the present investigation efforts have been made to evaluate the comparative performance of groundnut genotypes for their reaction to *Spodoptera* larvae in the field.

Observations on *Spodoptera* defoliation on 32 genotypes revealed foliage damage of 5-30% (Table 1). However, the entries, viz., ICGVs 86156, 86400, 86528, 87128, 87141, 87290, 87411, and 91214 recorded lowest leaf damage (5%) whereas ICGVs 86393, 86402, 86513, 86699, 87453, 90228, 91166, 91168, 91180, 91183, 91187, 91200, and 91205 showed <10% leaf damage. In general, all the genotypes tested showed less defoliation during flowering to pegging stage by the early instar larvae which could be due to the hard and rough leaves of the genotypes.

Table 1. Screening of promising groundnut genotypes for their reaction to *Spodoptera litura* in Jalgaon, Maharashtra, India during rainy season in 1995-97.

	Foliage damage (%)				Aresin transformed values[1]			
Genotype	1991	1996	1997	Mean	1995	1996	1997	Mean
ICGV 86031	10	30	10	16.7	18.44	33.21	18.44	23.36 de
ICGV 86156	5	5	5	5	12.92	12.92	12.92	12.92 a
ICGV 86162	15	30	25	23.3	22.79	33.21	30	28.67 e
ICGV 86393	10	5	5	6.7	18.44	12.92	12.92	14.76 ab
ICGV 86402	10	5	5	6.7	18.44	12.92	12.92	14.76 ab
ICGV 86400	5	5	5	5	12.92	33.21	12.92	12.92 a
ICGV 86434	20	30	20	23.3	26.56	18.44	26.56	28.78 e
ICGV 86472	15	10	10	11.7	22.79	26.56	18.44	19.89 bcd
ICGV 86503	10	20	15	15	18.44	12.92	22.79	22.60 de
ICGV 86513	10	5	5	6.7	18.44	12.92	12.92	14.76 ab
ICGV 86528	5	5	5	5	12.92	18.44	12.92	12.92 a
ICGV 86699	5	10	5	6.7	12.92	12.92	12.92	14.76 ab
ICGV 87128	5	5	5	5	12.92	12.92	12.92	12.92 a
ICGV 87141	5	5	5	5	12.92	12.92	12.92	12.92 a
ICGV 87290	5	5	5	5	12.92	12.92	12.92	12.92 a
ICGV 87411	5	5	5	5	12.92	22.79	12.92	12.92 a
ICGV 87453	5	15	10	10	12.92	26.56	18.44	18.05 abcd
ICGV 88145	20	20	25	21.7	26.56	12.92	30	27.71e
ICGV 90228	15	5	5	8.3	22.76	18.44	12.92	16.21 abc
ICGV 91166	5	10	10	8.3	12.92	12.92	18.44	16.60 abc
ICGV 91168	10	5	5	6.7	18.44	26.56	12.92	14.76 ab
ICGV 91178	10	20	5	11.7	18.44	18.44	12.92	19.30 bcd
ICGV 91180	10	10	5	8.3	18.44	18.44	12.92	16.60 abc
ICGV 91183	10	5	5	6.7	18.44	12.92	12.92	14.76 ab
ICGV 91185	10	15	10	11.7	18.44	22.79	18.44	19.89 bcd
ICGV 91186	10	15	10	11.7	18.44	22.79	18.44	19.89 bcd
ICGV 91187	10	15	5	10	18.44	22.79	12.92	18.05 abcd
ICGV 91190	10	20	5	11.7	18.44	26.56	12.92	19.30 abcd
ICGV 91200	5	10	5	6.7	12.92	18.44	12.92	14.76 ab
ICGV 91205	5	15	10	10	12.92	22.79	18.44	18.05 abcd
ICGV91214	5	5	5	5	12.92	12.92	12.92	12.92 a
ICG 221[2]	25	30	30	28.3	30	33.21	33.21	32.14 f
Mean								17.87
SE								±2
CD (5%)								5.78
CV (%)								19.45

1. The percentages were transformed into arcsin values.
   Figures with same letters are not significantly different at *P* - 0.05%.
2. Susceptible check.

Further detailed studies are needed to determine types ofresistance exhibited by the cultivar and the larval feeding behavior and development. The promising entries should be considered in future breeding programs to strengthen future plant protection programs.

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Biochemical Basis of Resistance in Groundnut Against Leaf Miner

T Senguttuvan and K Sujatha (National Pulses Research Centre, Tamil Nadu Agricultural University, Vamban 622 303, Pudukkottai. Tamil Nadu, India)

The groundnut leaf miner *Aproaerema modicella* Deventer is the most important foliage feeding pest of groundnut in India, especially in southern states. It is a serious pest of groundnut and soybean in South and Southeast Asia (Wightman et al. 1990). It reduces groundnut yields by feeding on leaflets. More than 50% pod yield loss due to leaf miner was reported from Tamil Nadu, India (Logiswaran and Mohanasundaram 1985). Control of leaf miner much relied upon the use of insecticides, which leads to various deleterious effects. Thus, use of biocontrol agents and resistant varieties for control of the pest is inevitable. Resistance to leafminer in groundnut has been reported from ICRISAT, Patancheru, India in several genotypes (ICRISAT 1986). One variety ICGV 86031 has shown good tolerance to leaf miner. Visalakshi (1997) reported that both morphological and anatomical characters are the contributory factors for resistance in the genotypes ICGV 86031 and ICGV 87160. However, the biochemical basis of resistance in groundnut to the leaf miner is not known. Thus, this study was conducted to assess the differential amount of biochemical constituents in groundnut genotypes.

A total of 41 groundnut genotypes including 24 genotypes from ICRISAT, 16 high-yielding entries developed at the National Pulses Research Centre (NPRC), Vamban, Tamil Nadu, and the susceptible local check TMV 7 were screened under field conditions against leafminer. During field screening in all the seasons, each genotype was sown in single row of 5 m length (unreplicated) adopting a spacing of 39 x 10 cm alternated with the susceptible cultivar TMV 7. ICRISAT entries were tested during four seasons: kharif (rainy season) 1995, 1996, 1997, and rabi (postrainy season) 1995/96; NPRC entries were tested only during two seasons in kharif 1996 and 1997. Observations were made on top five leaves of 5 randomly selected plants for number of leaflets damaged and larvae, twice at peak incidence at 15-day intervals. The percentage of damaged leaflets and number of larvae per leaf were determined (Table 1). Five least susceptible genotypes were selected and raised again with the susceptible check (TMV 7) in the field during rabi 1997/98 and the leafarea damage was assessed graphically on 5 randomly selected leaflets twice at peak incidence at 15-day intervals. The second and third fully opened uninfested leaves (8 leaflets) from the

Table 1. Level of damage by groundnut leaf miner in less susceptible (LS) and susceptible (S) groundnut genotypes at Vamban, Tamil Nadu, India[1].

Genotype[2]	No. of larvae leaf^{-1}	Damaged leaflets (%)	Leaf area damage (mm^2)
NPRC			
VGN 52 (LS)	0.25	20.0	98.3
VGN 13 (LS)	0.05	18.0	89.5
ICRISAT			
ICG 2271 (LS)	0.53	25.5	18.7
ICGV 87141 (LS)	0.50	27.4	21.8
ICGV 87453 (LS)	0.55	31.8	26.2
Local check			
TMV 7 (S)	1.53	59.4	275.4

1. Data is mean of two replications.
2. Source: NPRC = National Pulses Research Centre; ICRISAT = International Crops Research Institute for the Semi-Arid Tropics.

Table 2. Biochemical constituents of less susceptible and susceptible groundnut genotypes.

Genotype[1]	Quantity[2] (mg g^{-1} of leaf sample)						
	Chlorophyll			Total phenol	Total protein	Total free amino acids	Total sugars
	a	b	Total				
NPRC							
VGN 52 (LS)	1.18	0.57	1.76	2.4	16.3	6.4	16.0
VGN 13 (LS)	0.85	0.38	1.22	2.4	25.6	7.3	16.0
ICRISAT							
ICG 2271 (LS)	1.18	0.56	1.74	2.6	24.4	6.6	18.0
ICGV 87141 (LS)	1.06	0.52	1.59	2.6	30.4	5.8	18.0
ICGV 87453 (LS)	1.15	0.58	1.73	2.5	45.8	5.9	27.0
Local check							
TMV 7 (S)	1.04	0.50	1.54	2.0	18.7	5.7	82.0

1. Source: NPRC = National Pulses Research Centre; ICRISAT = International Crops Research Institute for the Semi-Arid Tropics. Reaction to groundnut leaf miner: LS = Less susceptible; S = Susceptible.
2. Data is mean of two replications.

top were taken from the field at 50 days after sowing from two plants representing two replications. Laboratory analysis of the chemical constituents such as chlorlophyll (Witham et al. 1971), total phenol (Bray and Thorpe 1954), total soluble protein (Lowry et al. 1951), total free amino acids (Va Pin Lee and Takahashi 1966), and total sugars (Hedge and Hofreiter 1962) was done on the leaf samples of the entries.

Leafminer incidence was moderate to high during the study period. Among the 41 genotypes tested, five genotypes, ICGV 87141, ICGV 87453, ICG 2271, VGN 13, and VGN 52, were less susceptible to leafminer than the susceptible check TMV 7, with less larvae per leaf (0.05-0.55) and less leaflet damage (18.0-31.8%) (Table 1). Although the percentage of damaged leaflets was high in the less susceptible ICRISAT genotypes, the leaf area damaged was lower (18.7-26.2 mm^2) than that in NPRC genotypes (89.5-98.3 mm^2). The susceptible check TMV 7 recorded high leaf area damage of 275.4 mm^2.

The results of the biochemical analysis revealed that the less susceptible genotypes and susceptible check did not differ markedly in their content of chlorophyll a, chlrophyll b, total chlorophyll, total protein, and total free amino acids. Thus, these constituents might not have influenced the susceptibility of groundnut to leaf miner attack. However, there was marked difference between the less susceptible genotypes and susceptible check in the amount of total sugars. The amount of total sugars was high in susceptible TMV 7 (82.0 mg g^{-1}), while it was low in less susceptible genotypes (16.0-27.0 mg g^{-1}) (Table 2). The total phenol content was 2.0 mg g^{-1} of leaf sample in susceptible TMV 7, while it was 2.4-2.6 mg g^{-1} of leaf sample in the less susceptible genotypes.

Macfoy et al. (1983) recorded high concentrations of sugars and amino acids, and low amounts of phenols and crude fiber in cowpea cultivar Vita-1 susceptible to *Maruca testulalis.* Low amount of phenol content in pigeonpea flowers favored more flower damage by M *testulalis* (Ganapathy 1996). The results obtained in the present study also is in agreement with the above findings. This study concludes that less susceptibility of groundnut genotypes to leaf miner might be due to low amount of sugars and slightly higher amount of phenols. However, further studies are necessary for a better understanding.

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Morphological and Yield Attributes of Advanced Breeding Lines Susceptible and Resistant to *Spodoptera litura*

R P Vasanthi and K Padmavathamma (Regional Agricultural Research Station, Acharya N G Ranga Agricultural University, Tirupati 517 502, Andhra Pradesh. India)

Groundnut is an important oilseed crop in the state of Andhra Pradesh in India. Insect pests pose a serious problem for groundnut production. Among insect pests, the tobacco caterpillar *Spodoptera litura* is a serious pest in postrainy season (rabi) groundnut. Identification of resistant lines to *Spodoptera* would greatly help to increase groundnut productivity during the postrainy season. In the present study, advanced breeding lines developed through hybridization and selection using insect resistant genotypes were evaluated for their productivity, *Spodoptera* damage, morphological characters, and yield attributes.

Twenty-one breeding lines along with two check varieties, JL 24 and Tirupati 1, were laid out in a randomized block design with three replications during 1997/98 postrainy season at Tirupati, Andhra Pradesh. The lines were sown in two rows of 5 m length. An interrow spacing of 22.5 cm and plant spacing of 10 cm were adopted. The check variety JL 24 was sown after every three test genotypes. Observations were recorded on leaf color, shape, hairiness, and ashy nature, and stem hairiness after 60 days of sowing (DAS). The percentage of leaves damaged by *Spodoptera* was assessed 65 DAS by counting damaged leaves (>75% of the leaflet area eaten by caterpillars) and total number of leaves on 5 randomly chosen plants. Leaves with negligible damage of leaf area were not taken into account. Yield and yield attributes were recorded after harvest.

Significant differences were observed for pod yield plant^{-1} and percentage of leaves damaged by *Spodoptera*. The genotypes, TCGS-659 (24%), TCGS-636 (25%), and TCGS-667 (29%) had lower percentage of *Spodoptera* damage. All these genotypes had narrow leaves. The leaflets of genotypes TCGS-659 and 636 possess dense hairs with ashy coating. Seven genotypes, TCGS-636, 639, 646, 647, 648, 649, and 661, showed moderate percentage of *Spodoptera* damaged leaves (31-35%). Among these, except TCGS-647 and 661, the other five genotypes possessed narrow long leaflets with moderate to profuse hairiness and prominent ashy coating. In the genotypes TCGS-661 and 647 the leaflets were broad and short with moderate to profuse hairiness and prominent ashy coating (Table 1).

The genotypes TCGS-639 and 667 recorded significantly high mean pod yield plant^{-1} (14 g). These genotypes showed moderate percentage of *Spodoptera* damage. The genotypes TCGS-636, TCGS-644, and Tirupati 1 gave higher shelling out-turn (75%). The data did not reveal any relationship between percentage of *Spodoptera* damage and shelling percentage and 100-seed mass (Table 1). In susceptible genotypes, JL 24, Tirupati I, TCGS-644, 652, 653, 654, and 655, leaflets were broad or moderate and long; hairiness of stem and leaves was slight or moderate. In this study, leaf color did not show any relationship with *Spodoptera* damage.

From the results of this study, it can be inferred that the genotypes with narrow long leaflets and profuse hairiness of leaves and stem are less preferred by *Spodoptera* larvae for feeding compared to genotypes with broad long leaflets and slight hairiness on leaves and stem. Visalakshi (1997)

Table 1. Reaction of advanced groundnut breeding lines to *Spodoptera litura* and their morphological traits during 1997/98 postrainy season at Tirupati, Andhra Pradesh, India.

Entry	Pedigree	Pod yield plant^{-1} (g)	Percentage of leaves damaged	Special morphological features[1]					100-seed mass (g)	Shelling out-turn (%)
				LC	LS	LH	SH	Ashy coating		
TCGS-635	Tirupati 1 x 1CGV 86398	12	43	G	NS	S	S	Pr	39	69
TCGS-636	Tirupati 1 x 1CGV 86398	6	25	G	NL	P	S	Mo	46	75
TCGS-639	Tirupati 1 x 1CGV 86398	14	31	DG	NL	P	p	Pr	54	72
TCGS-644	JL 24 x 1CGV 86398	8	52	LG	BL	M	M	-	36	75
TCGS-646	JL 24 x ICGV 86398	8	33	DG	NL	P	P	Pr	41	71
TCGS-647	JL 24 x ICGV 86398	9	34	DG	BS	M	P	Pr	56	72
TCGS-648	JL 24 x ICGV 86398	8	33	DG	NL	M	M	-	35	70
TCGS-649	Tirupati 1 x ICGV 86031	8	33	DG	NL	P	M	Pr	34	70
TCGS-650	JL 24 x ICGV 86031	9	38	LG	BL	M	M	-	42	67
TCGS-652	JL 24 x ICGV 86031	7	53	DG	ML	M	M	-	38	66
TCGS-653	JL 24 x ICGV 86031	8	50	DG	ML	S	M	-	54	70
TCGS-654	JL 24 x ICGV 86031	8	62	DG	ML	M	S	-	40	72
TCGS-655	JL 24 x ICGV 86031	8	52	LG	BL	S	S	-	40	62
TCGS-658	JL 24 x ICG 5240	11	38	DG	BS	S	M	-	49	70
TCGS-659	TCGS-37 x NcAc 343	8	24	G	NL	P	S	Pr	34	61
TCGS-661	ICGV 86031 x TAG 24	10	35	DG	BS	P	S	Pr	36	60
TCGS-662	ICGV 86031 x TAG 24	12	41	DG	NS	P	S	Pr	39	68
TCGS-663	ICGV 86031 x TAG 24	13	40	DG	BS	M	S	Pr	42	62
TCGS-664	ICGV 86031 x JL 24	6	53	LG	BL	S	S	-	30	70
TCGS-665	ICGV 86031 x JL 24	8	36	DG	NS	S	S	-	36	70
TCGS-667	ICGV 86031 x TG 24	14	29	DG	NS	S	S	Pr	36	61
JL 24	EC 949493	10	63	DG	BL	S	S	-	48	68
Tirupati 1	EC 106983/3	9	52	LG	NL	S	S	Pr	35	75
CD (P = 0.05)		2.4	9.8							
CV (%)		15.0	15.0							

1. LC = Leaf color; LS = Leaf shape; LH = Leaf hairiness; SH = Stem hairiness; G = Green; DG = Dark green; LG = Light green; NS = Narrow short; NL = Narrow long; BS = Broad short; BL = Broad long; ML = Moderately long; P = Profusely hairy; M = Moderately hairy; S - Slightly hairy; Pr = Prominent; M = Moderate; - = Slight or absent.

reported that the resistant groundnut genotypes ICGVs 86031 and 87060 were less preferred by the leafminer for oviposition. Attributes such as trichomes in plant terminals and pedicels, surface waxes, okra leaf, and frego bract were shown to be associated with insect pest resistance in cotton (Narayanan 1995).

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Evaluation of Biological Control Potential of *Rhinocoris marginatus* on Four Groundnut Pests under Laboratory Conditions

K Sahayaraj (Crop Protection Research Unit, Department of Zoology, St. Xavier's College, Palayakottai 627 002, Tamil Nadu, India)

Rhinocoris marginatus Fab. is a widespread predator found in the cotton, soybean, groundnut agro-ecosystems of Tamil Nadu, India (Sahayaraj 1995). It has good searching ability, moderate degree of host specificity, shorter developmental period, and high reproductive capacity (Sahayaraj 1995, 1999). Field evaluation in groundnut ecosystem suggested that this predator could be used in the groundnut

biological control program. *Rhinocoris marginatus* feeds primarily on the young ones of Lepidoptera, Hemiptera, Coleoptera, and Isoptera, although it accepts prey from other insect orders (Kumaraswami 1991, Sahayaraj 1995, 1999). Prey and stage preference studies of fifth instars of *R. marginatus* suggested that it preferred fifth instars of *Aproaerema modicella* Deventer, *Helicoverpa armigera* Hubner, and *Spodoptera litura* Fab. and third instars of *Amsacta albistriga* Walk. (Sahayaraj 1999). Hence there is a need for further studies on the biological control potential evaluation of this predator.

Aproaerema modicella, A. albistriga, H. armigera, and *S. litura* are the most common defoliators of groundnut (Wightman and Rao 1993). Most of these pests are resistant to the commonly used pesticides. The feeding rate of an individual predator as a function of prey density is termed as functional response (Salomon 1949). Functional response reveals the predatory efficiency of a particular predator at different prey densities. Such knowledge is essential to understand the basic mechanism underlying the prey-predator interaction and to evolve strategies for mass rearing, large-scale release, and utilization of predators in biological control programs. The information on functional response of *R. marginatus* on these groundnut pests is not documented. Hence the present study is intended to estimate the biological control potential of this reduviid predator on these groundnut pests.

Table 1. Summary of calculations used in predicting the biological control potential of *Rhinocoris marginatus* on four groundnut pests.

Prey density (X)	Prey attacked (Y)	Attack ratio (Y/X)	Searching time (Ts) (days)	Handling time (b) (days)
Amsacta albistriga				
1	1.00	1.000	0.957	0.043
2	1.57	0.785	0.935	0.041
4	2.56	0.640	0.902	0.038
8	3.14	0.392	0.884	0.037
16	3.85	0.240	0.881	0.031
32	4.06	0.126	0.882	0.029
Aproaerema modicella				
1	1.00	1.000	0.972	0.028
2	2.00	1.000	0.948	0.026
4	4.00	1.000	0.916	0.021
8	6.53	0.816	0.875	0.019
16	13.46	0.841	0.784	0.016
32	18.37	0.574	0.724	0.015
Heliothis armigera				
1	1.00	1.000	0.961	0.039
2	2.00	1.000	0.930	0.035
4	3.45	0.862	0.890	0.032
8	6.78	0.847	0.800	0.029
16	12.08	0.755	0.698	0.025
32	16.93	0.529	0.611	0.023
Spodoptera litura				
1	1.00	1.000	0.962	0.038
2	2.00	1.000	0.938	0.031
4	3.30	0.825	0.917	0.025
8	6.05	0.756	0.861	0.023
16	11.75	0.734	0.753	0.031
32	16.12	0.503	0.694	0.019

Adults and nymphal stages of the predator R. *marginatus* were collected from the groundnut field in Trichy district, Tamil Nadu and were reared on groundnut pests under laboratory conditions (30±2°C, 75±5% relative humidity, and 11-12 h photoperiod) in 250 ml plastic containers. Newly emerged fifth instars of this predator were chosen for the experiment. The experimental predators were starved for 24 h prior to the test. Four groundnut pests, *A. albistriga, A. modicella, H. armigera, and S. litura,* were also collected from the same localities where the reduviid predators were collected. They were reared on groundnut leaves. The biological control potential of fifth instars of R. *marginatus* to third instars of *A. albistriga* and fifth instars of *A. modicella, H. armigera,* and *S. litura* was assessed separately at 6 different prey densities, viz., 1,2,4, 8, 16, and 32 prey per predator for 5 days continuously. Plants (45 days old) of the groundnut cultivar TMV 7 in pots covered with mesh cage (45 x 45 x 45 cm) were arranged for insect releases. Different larval numbers of the four pests were released on the upper surface of the plant and allowed to settle for 3 h. After 3 h, a fifth instar of *R. marginatus* was released into each cage. After every 24 h, the number of prey consumed or killed was counted and the prey number was maintained constant by replacing the dead prey throughout the experimental periods. The test was replicated 10 times for each pest with 10 different predators of both sexes separately. The functional response experiments were performed to determine the relationship between the prey density and the prey consumption or killed (Holling 1959).

Rhinocoris marginatus responded to the increasing prey density by killing higher number of prey than it killed at lower prey densities and exhibited type II of Holling's (1959) convex curve which is a typically density dependent function. The number of prey killed by the individual predator increased from 1 prey per predator to 32 prey per predator (Table 1). Such a kind of response can increase the probability of predator being an effective biological control agent. In general, the number of prey killed or consumed (Y) in a given time (Tt) did not differ significantly

from the numbers calculated (V) on the basis of Holling's 'disc' equation.

The highest attack ratio (Y/X) was observed at prey density (X) of one prey per predator which decreased as the prey density was increased (Table 1). The predator spent some time for searching its prey. The searching time (Ts) (days) was calculated by the following formula:

Ts = Tt - by

The time taken by the predator to feed the captured prey was observed as handling time or feeding time (b). Ts decreased with increased prey density. Hassell et al. (1977) stated that the attack rate decreased with increasing prey density in predators having type II functional response. Theoretically, each milligram of prey food required a constant amount of time 'B' for consumption. As observed for searching time, the handling time also decreased with increased prey density. This indicates that the predator subdued the prey more quickly and consumed them faster at higher prey density than at lower prey density. The handling time was minimum when the predator was provided with *A. modicella.* This might be due to the small size of this prey. Presence of hairs in *A. albistriga* may have caused stress during feeding and thus handling time was high. More time was taken by the predator to paralyze the single prey and to consume increased amount of food from the prey.

The maximum predation at the highest prey density is represented by the 'k' value. The k/Tt value was highest for *A. modicella* (18.37) followed by *H. armigera* (16.93), *S. litura* (16.12), and *A. albistriga* (4.06). Higher k/Tt in *A. modicella* was presumably due to small size of the prey, active searching and quicker paralyzing, and shorter intervals between successive attacks of the predator. However, the utilization of the predator for the control of *A. modicella* can only be determined through actual field trials. Lower predation in *A. albistriga* might be due to the presence of hairy body surface. The positive functional response observed in *R. marginatus* suggests its biocontrol potential. These studies and the previous observations (Sahayaraj 1999) where *R. marginatus* reduced 92.73% *H. armigera* and 94.91% *S. litura* confirms that it can be used in an integrated pest management (IPM) program.

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Natural Fungal Pathogencity on Groundnut Defoliator *Spodoptera litura*

S Venkatesan[1], S N Nigam[2], S E Naina Mohammed[1], and K N Ganesan[1] (1. Tamil Nadu Agricultural University, Regional Research Sation, Vridhachalam 606 001, Tamil Nadu, India; 2. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India)

Groundnut crop monitoring team of scientists constituted for Zone V Breeder Seed Plot visited ICRISAT, Patancheru, India on 23 September 1999. During the field visit mycoses (11%) among the larval population *of Spodoptera litura* was observed. The entomopathogenic fungus was identified as *Nomuraea rileyi* (Farlow) Samson (Moniliales: Moniliaceae). The dispersion and spread of this pathogenic fungus in rabi (postrainy season)-sown crop will naturally contain the *S. litura* larval population. Hence it

is the right time to exploit the pathogen under field conditions to strengthen the existing effective ecofriendly pest management strategies. Apart from this pathogen, use of botanicals, parasitoids, and predators to contain the defoliation by less than 10% damage in 60-day-old crop had no effect on the pod yield. Preliminary confined studies of the fungal pathogenicity against *S. litura* conducted at the Regional Research Station, Vridhachalam, Tamil Nadu, India revealed that the third instar larval mummification was due to the infection on the fifth day after spraying with *N. rileyi* at a concentration of 1 x 10^8 spores mL^{-1}. Assessment on the dynamics of conidial dispersal and density within the groundnut crop ecosystem at field level is in progress.

In future, studies at the field level on the utilization of naturally occurring fungal pathogens such as *Beauvaria bassiana* (white muscardine fungus) and *N. rileyi* (green muscardine fungus) to contain the groundnut defoliators without any reduction in pod yield will be an accessible ecofriendly pest management strategy for sustainable groundnut cultivation.

Impact of Some Plant Products on the Behavior of *Tribolium castaneum* in Groundnut Seed

K Sahayaraj and M G Paulraj (Plant Protection Research Unit, Department of Zoology, St. Xavier's College, Palayankottai 627 002, Tamil Nadu, India)

Groundnut (*Arachis hypogaea)* is stored both as pods and seeds. Both forms are susceptible during storage to attack by insects, which cause approximately 6-10% damage in stored seed (Srivastava 1970). The red flour beetle, *Tribolium castaneum* Hcrbst is one of the most important pests of stored groundnut seeds (Wightman and Ranga Rao 1993). As groundnut is used for human food, the use of insecticides against this stored product pest may represent a health hazard. Use of plant-derived pesticides to manage stored product pests is a traditional method that is environmentally safe and economically viable alternative method. *Azadirachta indica* (neem) has been found to affect more than 200 insect pests (Warthen 1989, National Research Council 1992) including several stored product pests (Jacobson 1988). In the present study, the leaf extracts of *A. indica, Vitex negundo, Calotropis gigantea,* and bulb extract *of Allium cepa* (onion) were evaluated for their repellent and insecticidal properties on the adults of *T. castaneum* in groundnut seeds.

The leaf extracts *of A. indica, V. negundo,* and *C. gigantea* and bulb extract of *A. cepa* were prepared according to Sahayaraj (1998). Ten grams each of the leaves and bulbs were macerated individually in pestle and mortar and extracted with 10 mL of water. The extract was passed through muslin cloth and the final volume made up to 100 mL to get 10% extracts. It was treated as a stock solution. From the stock solution 5 different concentrations, 0.5, 1.0, 2.0, 4.0, and 6.0% were made with required quantity of water. Groundnut seeds (5 g) were dipped in different concentrations separately for 15 min and air dried for 10 min.

In control, the groundnut seeds were dipped in water only. A glass olfactometer was used to find the repellent properties of the plant extracts against *T. castaneum.* An olfactometer consists of a middle glass chamber (60 mm diameter) from which 6 equally spaced tubes (20 cm length and 2.5 cm diameter) project outwards. The middle chamber has an opening of 2.5 cm diameter. The distal end of each arm is attached with a glass beaker (7 cm diameter and 9 cm height). The repellent property of the plants was tested by choice test. Ten-day-old *T. castaneum* adults were collected from the culture medium maintained in the laboratory and used for this study. Groundnut treated with different concentrations of the plant extracts were placed separately in the beaker attached in each arm. Then they were closed with muslin cloth. Sixty *T. castaneum* adults were introduced into the olfactometer through the opening present in the middle chamber and closed with muslin cloth and allowed for 3 h. After 3 h, the number of beetles present in each concentration was recorded. From the observed value the repellence was observed and defined in terms of excess proportion index (EPI) according to Sakuma and Fukami (1985). Each experiment was replicated six times with different insects and also groundnut seeds treated with plant extracts. The EPI is defined as follows:

$$EPI = NS - NC/NS + NC$$

where NS = number of animals in the sample side and NC = number of animals in the control side. In another experiment, ten adults were placed in a plastic container (250 ml capacity) and provided with 1 g of groundnut seed treated with different concentrations of each plant extract separately. Control categories were provided with water treated groundnut seeds. Mortality was recorded in all the categories for every 24 h up to 7 days. Six replications were maintained in each category.

EPI values ranged from +1 to - 1 . These terms simply express polarity of the directional choice. Positive and negative values indicated positive and negative approaches respectively. The results of the experiment are summarized

Table 1. Impact of plant products on the excess proportion index (EPI) behavior of *Tribolium castaneum*.

Plant	EPI				
	0.5[1]	1	2	4	6
Azadirachta indica	-0.616	-0.813	-0.881	-0.953	-1.000
Vitex negundo	-0.382	-0.601	-0.739	-0.893	-0.933
Allium cepa	-0.319	-0.470	-0.675	-0.783	-0.900
Calotropis gigantea	-0.084	-0.225	-0.406	-0.507	-0.628

1. Concentration (%) of plant product.

in Table 1 which shows that the insect avoided feeding on groundnut seed sprayed with *A. indica, V. negundo, A. cepa,* and *C. gigantea.* The results clearly indicated that *A. indica* was the most effective repellent for 71 *castaneum* followed by *V. negundo*, *A. cepa,* and *C. gigantea.* The EPI values for all the plant products used in this study showed negative values. Senguttuvan et al. (1995) reported that neem and *Vitex* leaf powders were most effective to control *Corcyra cephalonica* stainton in stored groundnuts.

In the present investigation, the repellence increased as the concentration increased. Sain and Meloan (1986) reported that powder of *Laurus nobilis* leaves acted as a repellent to *T. castaneum.* However, the mortality experiments indicated that all the four plants tested here did not cause any mortality on *T. castaneum* during the observed period. It is concluded that all the plants tested in this study have repellent property against *T. castaneum* and could be used to protect the stored groundnut seeds from *T. castaneum* damage.

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Field Evaluation of Plant Growth-promoting Rhizobacteria of Groundnut

R Dey, K K Pal, S M Chauhan, and D M Bhatt
(National Research Centre for Groundnut, Ivnagar Road, PB No. 5, Junagadh 362 001, Gujarat, India)

Direct use of microorganisms to promote plant growth and to control plant pests continues to be an area of rapidly expanding research. The ability of specific root colonizing bacteria or rhizobacteria to increase growth and yield of crop plants currently is attracting considerable attention. Beneficial free-living soil bacteria isolated from the rhizosphere, which have been shown to improve plant health or increase yield, are usually referred to as plant growth-promoting rhizobacteria (PGPR) (Kloepper and Schroth 1978), or by one group of workers in China as yield-increasing bacteria (YIB) (Tang 1994).

There has been, since the 1990s, a fast emerging trend to use the beneficial effect of these bacteria. Most of the reported work has been on other crops including oilseed crops such as canola (Kloepper et al. 1988). However, reports of PGPR in groundnut are scanty At the National Research Centre for Groundnut (NRCG), Junagadh, India, isolation of PGPR from groundnut rhizosphere was done by ACC (1-aminocyclopropane-1-carboxylate) deaminase activity using ACC (Sigma) as the sole source of nitrogen (N) (Jacobson et al. 1994). Using this approach, 233 isolates of PGPR were obtained from groundnut rhizosphere. Of these cultures, on the basis of germinating seed bioassay (Gerhardson et al. 1985) in water agar medium at 28±2°C for 7 days, nine cultures were selected which increased the root growth significantly. In the present study, an effort has been made to evaluate the effects of these PGPR in influencing the growth, yield, and nutrient uptake of groundnut under field conditions. A field trial was conducted during the rainy season of 1999 in 5 m x 5 m plots in a randomized complete block design with 10 treatments and four replications. The field soil was black calcareous having pH of 7.9, organic carbon content of 0.52%, available phosphorus (P) content of 10 (±1.2) kg ha^{-1}, and available potassium (K) of 240 (±14.6) kg ha^{-1} at the time of sowing. In the field, normal doses of fertilizers [20 kg N ha^{-1} in the form of ammonium sulphate and 40 kg P_2O,ha^{-1} in the form of single superphosphate (SSP)] were used. Groundnut cultivar, GG2, was used for field trials. Bacterial culture was applied as seed treatment using log phase cultures [48 h growth, optical density (OD) 1.2 at 600 nm, approximately 10^6 colony forming units (cfu) $seed^{-1}$]. Nodule dry mass of 10 plants sampled randomly from each replication was recorded at 45 days after sowing (DAS) and other parameters such as dry plant biomass (10 plants were randomly sampled from each replication), pod yield (measured per nr in each replication), and nutrient uptake were estimated at the time of harvest. The N and P contents in shoot and seed were determined from the same harvested materials sampled for plant biomass.

In the seedling bioassay, all the PGPR isolates significantly increased the root length (Table 1). All the cultures were identified as *Pseudomonas* spp. Bacterial cultures were identified by performing several morphological, physiological, and biochemical tests according to the description of the 9th edition of Bergey's Manual of Systematic Bacteriology (Krieg et al. 1984). Majority of them were *Pscudomonas fluoresceins.* Three of these cultures, PGPR 1, PGPR 2, and PGPR 4 (all fluorescent pseudomonads), were the best in producing siderophores [10 mm, 15.2 mm, and 24 mm of orange halos in Chromazole S (CAS) agar plates (Schwyn and Neilands 1987) after 72 h of growth], indole acetic acid (IAA) (Sarwar and Kremer 1995) (3.6, 7.8, and 9.3 mg L^{-1} respectively after 24 h), and solubilizing inorganic phosphate (Pikovskaya 1948, Gaur 1990) (48.52, 16.6, and 60 mg $100mL^{-1}$ broth respectively after 72 h) (Table 1). These isolates were also inhibitory in vitro to *Aspergillus flavus* [produced 14, 13.4, and 14 mm of inhibition zones respectively in King's B (King et al. 1954) after three days]. The field crop was harvested at 1 10 DAS when the crop was fully mature. After drying the pods under the sun, yield was recorded. Bacterization of groundnut with PGPR isolates PGPR 1, PGPR 2, PGPR 3, PGPR 4, PGPR 5, and PGPR 6 resulted in significantly higher pod yields (14.7% to 25.5%) while the three remaining treatments recorded yields at par with that of the control (Table 2). Plant biomass data showed a similar trend to that of the pod yield. Inoculation of PGPR 1, PGPR 2, and PGPR 4 gave significantly higher plant biomass as compared to that of the control while other treatments recorded biomass yield at par with that of control. All the inoculated treatments had better nodulation and significantly higher nodule dry mass as compared to the control. It was observed that inoculation with PGPR isolates resulted in enhanced N content in the shoots and seeds. There was significant increase in the N content of shoot and seed when inoculated with PGPR 1, PGPR 2, and PGPR 4 (Table 2). The other treatments were at par with that of the control. Treatment with PGPR isolates resulted in better mobilization and availability of P to the plants as depicted by the P content of shoot and

seed. The P content of shoot and seed gave significant increase over the control due to seed bacterization with PGPR 1, PGPR 2, and PGPR 4 (Table 2).

The experiment was conducted in a soil, deficient in P. Even applied P is fixed as tri-calcium phosphate. The pH (7.9) of the soil was suitable for excretion of siderophore by PGPR isolates. In the field, best result was obtained when inoculated with PGPR 1, PGPR 2, and PGPR 4. Solubilization of iron by microbial siderophores and P have been found to increase crop yield substantially (Brown 1974, Wani 1980, Kloepper et al. 1988, Glide 1995). Fluorescent pseudomonads having ACC deaminase

Table 1. Germinating groundnut seed bioassay and quantification of plant growth-promoting attributes of selected PGPR isolates[1].

Isolate	Root length of seedling (cm)	Siderophore diameter[2] (mm)	IAA-like substances[3] (mg L^{-1})	Phosphate solubilization[4] (mg 100mL^{-1} broth)	Inhibition zone (diameter) against *Aspergillus flavus* (mm)	Culture identification
Control	6.03	NR	NR	4.7	NR	NR
PGPR 1	8.40	10.0	3.6	48.5	14.0	*Pse udomonas fluorescens*
PGPR 2	9.10	15.2	7.8	16.6	13.4	*Pseudomonas fluorescens*
PGPR 3	7.90	-ve	-ve	-ve	-ve	*Pseudomonas* sp
PGPR 4	8.87	24.0	9.3	60.0	14.0	*Pseudomonas fluorescens*
PGPR 5	8.03	8.8	-ve	38.6	11.2	*Pseudomonas fluorescens*
PGPR 6	7.97	9.2	3.9	-ve	12.6	*Pseudomonas fluorescens*
PGPR 7	9.00	19.0	11.8	-ve	-ve	*Pseudomonas fluorescens*
PGPR 8	8.07	8.6	-ve	-ve	-ve	*Pseudomonas* sp
PGPR 9	7.6	9.0	-ve	23.8	-ve	*Pseudomonas* sp
CD (*P* = 0.05)	0.58	-	-	-	-	-

1. PGPR = Plant growth-promoting rhizobacteria; NR = Not relevant; -ve = the isolate(s) did not express the particular character. Data represent average of three replications repeated thrice.
2. Orange halo on Chromazole S (CAS) agar after 72 h of growth.
3. IAA = Indole acetic acid; data recorded after 24 h of growth.
4. After 72 h of growth.

Table 2. Effect of PGPR on the growth, yield, and nutrient uptake in groundnut cultivar GG2 during 1999 rainy season under field conditions[1].

Isolate	Pod yield (kg ha-')	Dry biomass (g plant^{-1})	Nodule dry mass (mg plant^{-1})	N content (%) at harvest		P content (%) at harvest	
				Shoot	Seed	Shoot	Seed
Control	1872	17.9	86.4	2.15	4.18	0.19	0.28
PGPR 1	2350	24.5	116.4	2.37	4.66	0.28	0.37
PGPR 2	2320	27.3	103.0	2.37	4.60	0.23	0.34
PGPR 3	2170	21.5	91.4	2.29	4.07	0.20	0.31
PGPR 4	2315	24.5	103.4	2.37	4.62	0.23	0.37
PGPR 5	2157	19.1	108.0	2.31	3.98	0.22	0.35
PGPR 6	2175	20.9	104.2	2.23	4.13	0.20	0.30
PGPR 7	2045	20.5	108.1	2.22	4.16	0.19	0.31
PGPR 8	1955	18.5	105.2	2.28	4.20	0.18	0.29
PGPR 9	1945	19.5	95.6	2.59	4.07	0.22	0.33
CD (P = 0.05)	258	4.7	5.15	0.21	0.35	0.03	0.05

1. PGPR = Plant growth-promoting rhizobacteria; N = Nitrogen; P = Phosphorus. Data represent average of four replications.

activity, phosphate solubilizing ability, and IAA and siderophore producing characters have been found to enhance groundnut growth under potted conditions (Pal et al. 1999). ACC deaminase activity of PGPR isolate *Pseudomonas putida* GR 12-2 has been reported to promote growth of canola seedling (Glick et al. 1995). If ACC deaminase activity alone was responsible for better root growth and yield in groundnut, all isolates would have produced similar results. But this did not happen though all the nine isolates had ACC deaminase activity. ACC deaminase activity might have produced better root growth in the initial stages of crop growth, but other attributes such as IAA, siderophore production, and phosphate solubilization by the PGPR isolates might have helped in better nutrient mobilization, availability, and thus uptake by the plants. However, all these parameters need to be measured in further studies. Synergistic effect was found between native *Bradyrhizobium* flora and PGPR as nodulation was enhanced due to inoculation of PGPR. Although, involvement of ACC deaminase activity in enhancing plant growth and yield of groundnut cannot be ruled out, coordinated expression of multiple plant growth-promoting traits could have been involved in the overall plant growth promotion of groundnut by these PGPR isolates. Mutational analyses of all these traits and subsequent evaluation only can unravel the exact mechanisms of these PGPR isolates in stimulating groundnut growth and yield. Work has been initiated in this direction in our laboratory.

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Performance of Groundnut Germplasm and Cultivars under Saline Water Irrigation in the Soils of Mundra in Gujarat, India

P C Nautiyal[1], A Bandyopadhyay[1], V G Koradia[1], and **Madhubhai Makad[2]** (1. National Research Centre for Groundnut, Ivnagar Road, PB No. 5, Junagadh 362 001 Gujarat, India; 2. Progressive Farmer, and Coordinator, Krishi Vigyan Kendra, Mundra 370 421, Gujarat, India)

In India about 7.1 million ha area is salt affected (Yadav et al. 1979), out of which 1.2 million ha comprise saline soils in the coastal tracts of Gujarat, where groundnut (*Arachis hypogaea)* is a major crop under cultivation. Information on tolerance of groundnut crop to various salinity levels is meager. Joshi et al. (1994) reported that the vegetative stage of groundnut crop can tolerate salinity level of ECe 8 dS m^{-1} [electrical conductivity (EC) of saturation extract). In the Kutch-Bhuj region of northern Gujarat, groundnut is the most preferred crop by the farmers and is cultivated in both summer and rainy seasons. The annual average rainfall in this region is very low (250-300 mm) and groundnut is cultivated, almost wholly, with irrigation. The major source of irrigation is the wells and due to extensive use of well-water for irrigation the salinity level of the well-water and soil is increasing at an alarming rate. The increasing salinity levels are rendering the cultivation of groundnut difficult. The National Research Centre for Groundnut (NRCG), Junagadh, Gujarat, therefore, took up the work on management of this problem and started screening groundnut germplasm and released cultivars for salinity tolerance. Experiments were conducted in collaboration with the Krishi Vigyan Kendra, Mundra, Gujarat.

During February 1997, 100 germplasm accessions were sown in a randomized block design (RBD) replicated twice, in two-row plots, each row 3 m in length with interrow spacing of 45 cm. Seed was sown in each row at 10 cm spacing. All recommended agronomical practices were followed to maintain a healthy crop. The crop was irrigated with saline water of EC 3.5 dS m^{-1} and pH 7.21. The well-water used for irrigation was analyzed before conducting the experiments (Table 1). However, the soil of the experimental site was analyzed after conducting the summer cropping season (February-June 1997) experiment. The crop received 12 irrigations from sowing till maturity. Observations on field emergence was recorded 30 days after sowing (DAS), whereas plant stand and pod yield were recorded at final harvest (130-140 DAS) and plant mortality was calculated by the following formula:

$$\text{Plant mortality (\%)} = \frac{\text{Field emergence (\%)} - \text{Plant stand at final harvest (\%)}}{\text{Field emergence (\%)}} \times 100$$

Twenty-nine genotypes having >5 mature pods at harvest were studied for the deficiency symptom, "hollow heart" of the cotyledons, due to salinity (boron or calcium or boron and calcium combined deficiency) as reported by Cox and Reid (1964) and Reid and Cox (1973). We observed symptoms similar to those reported by Cox and Reid (1964): the inner surface of the cotyledons were depressed and discolored and plumule was darkened. For recording the deficiency symptoms, three plants from the accessions having >5 pods were picked up and 5 pods from each plant were shelled immediately. Deficiency symptoms in the form of black spots on the cotyledons and darkened plumule were recorded. The data on deficiency symptoms were expressed on a scale of low, medium, and high deficiency (Table 2). Genotypes with <5 pods with cotyledons having black spots were classified as + (low deficiency), those with 6 to 10 such pods were classified as ++ (medium deficiency), and those with 11 to 15 such pods were classified as +++ (high deficiency).

Along with 28 released cultivars, 20 germplasm accessions having pod yield more than 1 g $plant^{-1}$ in the previous

Table 1. Chemical analysis of the well-water used for irrigation during the summer and rainy cropping seasons of 1997, in the experiment to screen groundnut for salinity tolerance conducted in farmers' fields at Mundra, Gujarat, India.

Character[1]	Concentration/unit	Remarks
pH	7.21	-
EC	3.5 dS m^{-1}	High
TDS	2240 mg L^{-1}	High
Calcium	700 meq L^{-1}	Medium
Magnesium	2.15 meq L^{-1}	Medium
Carbonate	-	Low
Bicarbonate	-	Medium
Chloride	24.2 meq L^{-1}	Medium
Sodium	26.11 meq L^{-1}	Medium
Sodium adsorption ratio	11.06	Medium
Residual sodium carbonate	1.15 meq L^{-1}	Satisfactory

1. EC = Electrical conductivity; TDS = Total dissolved salts.

Table 2. Plant mortality (%), pod yield, and deficiency symptoms on the cotyledons of some of the groundnut accessions screened for salinity tolerance under saline water irrigation at Mundra, Gujarat, India, summer and rainy cropping seasons of 1997.

Genotype	Plant mortality (%)		Pod yield (g m^{-2})		Deficiency symptoms rating[1]
	Summer	Rainy	Summer	Rainy	
ICG 1045	57.1	41.0	36.1	74.4	+ +
ICG 1467	40.0	52.3	50.0	47.0	+++
ICG 920	43.2	43.5	37.5	49.2	++
ICG 1017	24.2	46.1	27.7	58.5	+ +
ICG 1204	31.5	50.9	40.0	87.4	+++
ICG 881	23.6	30.0	50.0	55.0	+ +
ICG 1185	17.6	31.9	29.1	77.7	+++
ICG 1001	32.6	47.2	27.7	30.7	+
ICG 898	20.7	50.2	44.4	34.0	+ +
ICG 887	22.0	43.9	47.2	51.1	+ +
ICG 828	12.6	24.3	27.7	55.5	+ +
ICG 2106	53.3	69.2	27.7	40.7	+ +
ICG 1337	32.0	42.1	29.7	50.4	+
ICG 1273	32.7	47.6	27.7	72.5	+++
ICG 974	43.4	40.4	44.4	73.7	++
ICG 1673	54.5	62.1	27.7	27.3	+ +
ICG 1235	20.0	47.7	37.5	101.4	++
ICG 1237	42.8	39.4	30.5	82.9	++
ICG 967	57.9	51.5	37.5	55.1	+ +
ICG 1465	36.5	45.8	36.1	80.0	++
SE	±3.61	±3.11	±1.70	±6.18	

1. Deficiency of boron or calcium or combination of both recorded in summer cropping season: + = Low; ++ = Medium; +++ = High.

season experiment were also tested. The genotypes were sown in the rainy season of 1997 (July-November), in five rows, each 3 m in length, in the same plots where the previous season experiment was conducted. The same dataset, except the deficiency symptoms of cotyledons, was recorded.

The EC of irrigation water and total dissolved salts (TDS) were high (Table 1). Consequently after conducting the summer season experiment the soil EC_{125} was also quite high (0.65 dS nr^{1}). The observations on the 20 germplasm accessions which were tested during both the summer and rainy cropping seasons showed higher plant mortality in the rainy season (24.3-69.2%) than in the summer cropping season (12.6-57.9 %). However, the pod yield was higher (27-101.4 g m^{-2}) in the rainy season than in summer (27.7-50 g m^{-2}) (Table 2). In the summer crop pod yield was highest (50 g nr^{2}) in the genotypes ICG 1467 and ICG 881, whereas in the rainy season pod yield was highest in the genotype ICG 1235 (101.4 gm^{-2}), followed by ICG 1204 (87.4 g nr^{2}) and ICG 1237 (82.9 g m^{-2}). Thus the seasonal variation for pod yield in groundnut accessions was quite distinct. The deficiency symptoms rating of the cotyledons recorded in summer was low (+) in ICG 1001 and ICG 1337, while in most of the accessions tested it was medium (++) (Table 2).

In the experiment conducted during rainy season with 28 released cultivars, TAG 24 showed the highest mortality (91.8%) while M 145 showed (34.6%). Pod yield of different cultivars also varied significantly and ranged between 2.4 g m^{-2} (in TAG 24) and 145.4 g m^{-2} (in Karad 4-11). In general, pod yield was high in Virginia types (*Arachis hypogaea* subsp *hypogaea* var *hypogaea),* e.g., T 28 (121.7 g m^{-1}), RSB 87 (110.4 g m^{-2}), Punjab 1 (108.5 g m^{-2}), and Kadiri 2 (107.1 gm^{-2}) (Table 3).

This study showed large genotypic and seasonal variations for salinity tolerance in groundnut accessions and cultivars. However, further screening for salinity tolerance of the large gene pool of groundnut, and detailed studies on the tolerance mechanism are required to utilize genetic variability for salinity tolerance. Subsequent experiments conducted by NRCG on the amendments of saline soil by

Table 3. Plant mortality and pod yield of groundnut cultivars under saline water irrigation at Mundra, Gujarat, India during rainy season 1997.

Cultivar	Botanical type[1]	Plant mortality (%)	Pod yield (g m^{-2})
Karad 4-11	VR	39.9	145.4
Punjab 1	VR	42.9	108.5
RS 1	VR	38.9	103.8
Chitra	VR	47.2	102.3
Somnath	VR	50.9	90.0
M 335	VR	53.6	75.3
Kaushal	VR	41.7	62.1
UF-70-103	VR	62.8	57.4
DRG 17	VR	68.4	34.6
CSMG 84-1	VR	74.8	50.2
BG 2	VB	55.6	82.0
T 28	VB	45.6	121.7
RSB 87	VB	43.4	110.4
Kadiri 2	VB	37.1	107.1
TMV 10	VB	36.9	95.6
T 64	VB	50.6	92.0
BAU 13	VB	56.1	72.0
BG 3	VB	56.9	68.2
M 145	VB	34.6	82.9
ALR 1	VB	56.8	60.3
ICGS 76	VB	60.8	43.5
ICGV 86325	VB	64.7	30.1
Kadiri 3	VB	70.2	28.1
ICGS 5	VB	76.5	21.8
TG 26	SB	77.6	17.0
TAG 24	SB	91.8	2.4
TG 22	SB	50.5	46.2
TKG 19A	SB	55.8	72.3
SE	-	±1.82	±4.2

1. VR = Virginia runner; VB = Virginia bunch; and SB = Spanish bunch.

gypsum and potassium as nutrients showed encouraging results. Use of tolerant genotype coupled with soil amendments appears to be a feasible approach for cultivation of groundnut in the salt-affected costal regions.

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Yield Maximization of Postrainy Season Groundnut through Polythene Film Mulch Technology in Western Maharashtra, India

D K Kathmale, M S Ramble, J D Jadhav, and R C Patil
(Agricultural Research Station, K Digraj, Sangli 416 305, Maharashtra, India)

The average productivity of summer groundnut in Maharashtra state of India is 1.26 t ha^{-1}, while that in western Maharashtra plain zone is about 2.5 t ha^{-1}. The area under summer groundnut in the region is increasing. In this region summer groundnut is sown between 15 January and 15 February depending upon the prevailing temperatures. If the sowing is delayed, the crop is likely to be affected by pre-monsoon or early monsoon showers and if the crop is sown early the crop is affected due to low temperature. Use of polythene film mulch can increase the summer groundnut production by temperature regulation and moisture conservation.

In this study non-mulch groundnut (NMG), straw mulch groundnut (SMG), and polythene mulch groundnut (PMG) on flat bed (FB) as well as on broad-bed and furrow (BBF) systems were tested during summer in 1998 and 1999 at the Agricultural Research Station, K Digraj, Sangli, Maharashtra. The experiment was laid out in a split plot design with six treatment combinations, replicated four times. Groundnut variety ICGS 11 was sown in the first week of February with 25 kg nitrogen ha^{-1} + 50 kg P_2O_5 ha^{-1} as a basal application. Soybean straw at 5 t ha^{-1} (to treatment plots) was applied uniformly on the surface immediately after sowing. A transparent polythene film of 900 mm width and of 0.01 mm thickness was spread over the soil surface and before sowing secured on the sides of the

Table 1. Effect of seedbed forms and mulches on yield and yield attributes of summer groundnut (ICGS 11) in Vertisols of Maharashtra, India in 1998 and 1999.

Treatment[1]	Yield (t ha^{-1})			Days to maturity	Shelling (%)	100-seed mass (g)	SMS[2] (%)
	Pod	Haulm	Seed				
Seedbed forms							
BBF	3.62	6.88	2.60	120	71.7	43.0	94
FB	3.28	6.69	2.35	120	71.5	44.0	94
SE	±0.2	±0.05	±1.06	–	±0.3	±0.9	±0.4
CD (5%)	NS[3]	NS	NS	–	NS	NS	NS
Mulches							
NMG	2.86	6.39	2.03	120	70.5	41.1	93
SMG	3.43	6.70	2.46	116	71.9	43.5	94
PMG	4.06	7.27	2.93	112	72.4	45.9	95
SE	±0.12	±0.05	±0.08	–	±0.13	±1.0	±0.5
CD (5%)	0.48	0.20	0.32	–	0.42	3.1	1.7
CV (%)	7.06	5.04	6.57	–	1.30	6.6	2.7
Seedbed x mulch	NS	NS	NS	–	NS	NS	NS

1. BBF = Broad-bed and furrow; FB = Flat bed; NMG = Non-mulch groundnut; SMG = Straw mulch groundnut; PMG = Polythene mulch groundnut.
2. SMS = Sound mature seeds.
3. NS = Not significant

plot with soil. Sowing was done through the holes made in the film at 45 cm x 15 cm spacing. Two sprays of Monocrotophos® 36 EC at 0.05% for the control of *Spodoptera litura* and one spray of carbendazim at 0.05% for the control of leaf spots were given. During the crop growth period 10 irrigations were applied at 10- to 12-day intervals.

The results indicated that the yield of summer groundnut did not differ significantly due to FB and BBF systems (Table 1). However, higher net returns were recorded under BBF than FB systems (Table 2). PMG recorded significantly higher shelling percentage than NMG and SMG, higher sound mature seeds percentage than NMG, and greater 100-seed mass than NMG (Table 1). Choi and Chung (1977) reported 2.5-4% higher shelling percentage and seed mass in PMG than NMG in Korea.

PMG recorded maximum dry pod yield of 4.11 t ha^{-1} and dry haulm yield of 7.4 t ha^{-1} which is 41.9% and 13.8% higher than NMG and 19.8% and 4.8% higher than SMG, respectively. PMG also recorded 8 days early maturity than NMG. Hu et al. (1996) reported 20-50% higher yields in PMG over control in China. During 1998 groundnut trials of the All India Coordinated Research Project conducted at 9 locations recorded an average 22.6% and 21.6% higher dry pod yield in BBF and FB respectively in PMG than in control.

Table 2. Effect of seedbed forms and mulches on economics of groundnut in Vertisols of Maharashtra, India, during summer in 1998 and 1999.

Treatment[1]	Gross returns (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	Net returns (Rs ha^{-1})	Benefitxost ratio
Seedbed forms				
BBF	54096	11013	43083	4.91
FB	49312	10527	38785	4.68
Mulches				
NMG	43260	10091	33169	4.29
SMG	51335	10819	40516	4.75
PMG	60501	13894	46607	4.35

1. BBF = Broad-bed and furrow; FB = Flat bed; NMG = Non-mulch groundnut; SMG = Straw mulch groundnut; PMG = Polythene mulch groundnut.

Economic analysis revealed that greater gross returns, net returns, and benefitxost ratio were recorded in BBF than in FB systems. PMG recorded greater gross returns and net returns than SMG and NMG (Table 2). However, greater benefitxost ratio was observed in SMG followed by PMG.

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Efficacy of Polythene Mulch Technology in Improving Growth and Yield of Postrainy Season Groundnut in West Bengal, India

R C Samui and S B Ambhore (Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Krishiviswavidyalaya PO, Mohanpur, Nadia 741 252, West Bengal, India)

A field experiment was carried out at the instructional farm of the university [Bidhan Chandra Krishi Viswavidyalaya (BCKV)] located at Mohanpur in West Bengal during 1998/99 to study the effect of polythene film mulch on growth and yield of postrainy season (rabi) groundnut. Choi and Chung (1997) studied the effect of polythene mulching on growth and productivity of groundnut at Sawon in South Korea. They observed 44% higher pod yield and 56% higher seed yield in mulched over non-mulched plots. Beneficial effect of mulching has been reported by different workers (Devi Dayal et al. 1991, Gao 1993). In West Bengal, rabi groundnut is generally grown in riverbeds and rice fallows utilizing the residual moisture; however, low temperature during the postrainy season is a constraint for growth and development of the crop. So, polythene film mulch may be useful under such situations by increasing soil temperature and conserving soil moisture. The experiment was laid out in randomized block design with 6 replications. The soil of the experimental field was sandyloam having pH 6.9, 0.8% organic carbon, 0.058% total nitrogen (N), 39.8 kg ha^{-1} available P_2O_5, and 155 kg ha^{-1} available K_2O. Groundnut was fertilized with 20 kg N, 60 kg P_2O_5, and 40 kg K_2O ha^{-1} as basal application. Gypsum at 250 kg ha^{-1} was applied 50% as basal and remaining 50% as top dressing at 30 days after sowing (DAS). The treatments consisted: (1) Broad-bed and furrow (BBF) (60 cm bed with 15 cm furrow on both sides accommodating three rows of groundnut 30 cm apart) with polythene film mulch. The bed was covered with thin gauge polythene and the seeds were placed by piercing the polythene; (2) BBF without polythene film mulch; (3) Flat bed (FB) (with uniform rows, spacing of 30 cm) with polythene film mulch; (4) FB without polythene film mulch. The genotype used was ICGS 44. The sowing was done on 10 November 1998 and was harvested on 24 April 1999. In case of polythene mulching, the polythene mulch was applied to the whole field and it was kept until harvest of the crop. The plot size was 6 m x 5 m. The effect of polythene mulch on various growth and yield characters of groundnut is discussed.

Effect on emergence and plant stand

Polythene film mulching resulted in earlier emergence in both BBF and FB systems. Plant population improved due to polythene film mulch. The BBF method recorded higher plant population in mulched condition than in non-mulched condition.

Effect on growth characters

Shoot dry mass was significantly higher in mulched plots than in non-mulched plots at 30 and 60 DAS. Root dry mass was also significantly higher in mulched than in non-mulched plots at 60 DAS. Such increase in dry matter production due to mulching was earlier reported by Wang and Li (1987) and Mu et al. (1984). At 90 DAS shoot and root dry mass increased in mulched condition but the increase was statistically not significant (Table 1).

Number of nodules per plant was higher in mulched plots with both BBF and FB methods over their respective non-mulched treatments at 30 and 60 DAS; whereas the increase in number of nodules per plant at 90 DAS was statistically not significant. The BBF plot with mulch recorded 35.12% and 47.72% increase in number of nodules per plant and FB recorded 22.49% and 11.4% increase over their non-mulched conditions at 30 and 60 DAS. The increase in number of nodules per plant may be due to increased soil temperature by polythene film mulch. Mu et al. (1984) earlier have reported increased nodulations and N-fixing efficiency of *Rhizobium*,

Mulched plots in FB system recorded significantly higher number of branches per plant than in non-mulched plots (Table 1). At 30 DAS and 60 DAS both BBF and FB systems recorded significantly higher number of branches per plant compared to the non-mulched plots.

Effect on flowering

Flowering started 4 days earlier in mulched plots as compared to non-mulched plots. Non-mulched plots took 44 days to flower while the mulched plots took 40 days to flower. The

50% flowering and 75-100% flowering were also recorded 7 days earlier in mulched plots. The earlier emergence of the seedlings might be due to increasing soil temperature by mulching technique. Similar results were earlier reported by Ye et al. (1986) and Choi and Chung (1997).

Effect on pod development and yield

At 105 DAS, BBF method with mulch recorded significantly higher number of pods per plant compared to the non-mulched BBF but there was no significant difference between mulched and non-mulched FB plots. At 105 DAS, the mulched BBF system recorded 59.61% higher number of developed pods per plant compared to non-mulched BBF system whereas mulched FB system recorded 32.38% higher number of developed pods per plant. Similar results were earlier reported by Ye et al. (1986) and Choi and Chung (1997).

Polythene mulching resulted in higher pod dry mass than non-mulched plots in both BBF and FB systems at 75 DAS but not at 105 DAS. In both BBF and FB methods mulch treatments recorded significantly higher pod yields than non-mulched treatments (Table 2). Mulch treatment recorded 40.6% and 50.9% increase in pod dry mass in BBF and FB methods respectively over non-mulch treatment. Similar results were earlier recorded by Ye et al. (1986), Devi Dayal et al. (1991), and Gao (1993).

Effect on haulm yield

Both BBF and FB methods recorded higher dry haulm yield under mulched conditions than non-mulched conditions but the difference was not significant. Mulched conditions recorded 54% increase in dry haulm yield of groundnut over non-mulched condition in BBF method and 41.43% in FB method. Choi and Chung (1997) also had reported such increase in haulm yield of groundnut under mulched condition.

Effect on oil content, seed yield, and oil yield

Oil content in groundnut seeds in mulched treatments was significantly higher than non-mulched treatments (Table 2). The BBF system with mulch recorded highest seed and oil yield followed by FB with mulch and lowest yields were recorded on FB without mulch treatment. This increase in yield in mulch treatment might be due to higher shelling percentage, 100-seed mass, developed pods, and oil content in mulched plots than in non-mulched plots. The results corroborate the findings of Choi and Chung (1997) who reported higher yield of groundnut due to polyethylene mulch application.

Table 1. Effect of polythene film mulching on plant growth characters of groundnut genotype ICGS 44 grown at Mohanpur, India during 1998/99 postrainy season.

Treatment[1]	Shoot dry mass ($g\,m^{-2}$)			Root dry mass ($g\,m^{-2}$)			Nodules (number m^{-2})			Branches (number $plant^{-1}$)		
	30 DAS[2]	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
BBF with mulch	19.2	122.8	432.0	5.6	21.7	19.6	750	1382	2057	4.1	4.6	5.2
BBF without mulch	13.7	4.4	362.8	4.3	15.8	18.0	627	950	1890	4.0	3.5	4.8
FB with mulch	18.2	120.3	424.0	5.6	21.7	20.6	675	1062	1917	4.4	4.8	5.4
FB without mulch	12.7	61.7	420.7	4.4	17.2	18.1	550	935	2262	3.7	3.7	4.7
SEm	±1.51	±18.82	±23.16	±0.473	±1.24	±0.94	±38.5	±120	±154.5	±0.198	±0.254	±0.24
CD (0.05)	4.55	56.72	NS[3]	NS	3.73	NS	116.2	361.5	NS	0.577	0.77	NS
CV (%)	9	20	5	9	6	4	5	11	7	4	6	4

1. BBF = Broad-bed and furrow; FB = Flat bed.
2. DAS = Days after sowing.
3. NS = Not significant.

Table 2. Effect of polythene film mulching on yield attributes of groundnut genotype ICGS 44 at Mohanpur, India during 1998/99 postrainy season.

Treatment[1]	Developed pods[2] (number plant^{-1})	Dry mass of developed pods[2] (g m^{-2})	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Oil content (%)	Seed yield (kg ha^{-1})	Oil yield (kg ha^{-1})
BBF with mulch	21.4	396.7	2136	3688	45.6	1687	769
BBF without mulch	13.4	282.2	1518	2394	44.3	1139	504
FB with mulch	16.5	407.8	2038	4399	45.6	1590	725
FB without mulch	16.2	296.7	1351	3111	44.6	972	434
SEM	±2.44	±40.81	±198.1	±470.4	±0.319	±168	±72.9
CD (0.05)	7.39	NS	596.9	1417.6	0.961	507	219.7
CV (%)	10	11	11	13	0.7	12	11

1. BBF = Broad-bed and furrow; FB = Flat bed.
2. At 105 days after sowing.

Table 3. Economics of polythene film mulching in groundnut.

Treatment[1]	Gross return[2] (Rs)	Treatment cost[3] (Rs)	Cost of cultivation (Rs)	Net return (Rs)	Benefit: cost ratio
BBF with mulch	35693	6605	15105	20588	1.36
BBF without mulch	25254	5785	14285	10974	0.76
FB with mulch	34381	4805	13305	21076	1.58
FB without mulch	22861	3985	12485	10376	0.83

1. BBF = Broad-bed and furrow; FB = Flat bed.
2. Calculated based on data on pod yield and haulm yield given in Table 2. Value of 100 kg pod = Rs 1400.00; value of 100 kg haulm = Rs 200.00.
3. Includes the cost of polythene film and its placement as well as the cost of preparation of bed.

Economics of polythene film mulching

Polythene film mulch gave higher monetary return over respective non-mulch treatment (Table 3). The BBF and FB systems under mulched condition gave higher benefit: cost ratio than under non-mulched condition. It can be concluded from the experiment that polyethylene film mulching improves growth characters, yield attributes, and yield of groundnut and monetary return in both BBF and FB systems of groundnut cultivation; however, FB system with mulch was better than BBF system with mulch.

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Oil Recovery and Quality as Influenced by Foliar Diseases in Groundnut Genotypes

B N Motagi[1], M V C Gowda[1], and S N Nigam[2]
(1. Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad 580 005, Karnataka, India; 2. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India)

About 80% of total groundnut production in India is crushed for the extraction of oil. Hence, improvement in oil yield and quality is of interest to plant breeders and millers. However, the foliar diseases, late leaf spot (*Phaeoisariopsis personata*) and rust (*Puccinia arachidis*), which occur together worldwide can cause considerable loss in yield and quality. This study envisages to evaluate the groundnut genotypes with varying levels of resistance to foliar diseases for oil recovery and quality under rust and late leaf spot epidemics.

The genotypes in the study included one foliar diseases resistant mutant (28-2), two cross derivatives (D39d and B37c) in Spanish background, five foliar diseases susceptible cultivars (JL 24, TMV 2, TAG 24, Dh 8, and R 8808), one foliar diseases resistant cultivar (ICGV 86590), and a breeding line (GBFDS 272). They were assessed for oil content, oil yield, and oil quality [(oleic acid/linoleic acid ratio (O/L ratio)], under diseased and protected conditions. The crop was protected by spraying chlorothalonil at 0.2%. Each genotype was raised in five rows of 5 m in length in three replications. Oil content was determined by nuclear magnetic resonance (NMR) technique (Jambunathan et al. 1985). Fatty acid content was estimated following Mercer et al. (1990). From the fatty acid data, O/L ratio was computed. In each genotype, pod yield (t ha^{-1}) was multiplied by shelling out-turn (%) and oil content (%) to derive oil yield (t ha^{-1}).

A significant loss in oil yield but only marginal change in O/L ratio was observed due to foliar diseases (Table 1), which is in conformity with an earlier report (Dwivedi et al. 1993). However, genotypes under diseased condition differed significantly for oil yield, with susceptible cultivars recording very low values.

The foliar diseases resistant mutant and cross derivatives matured early and gave high oil yield as compared to

Table 1. Performance of groundnut genotypes for resistance to foliar diseases, and oil yield and quality at the University of Agricultural Sciences, Dharwad, India, 1998 rainy season[1].

Genotype	Days to maturity	FDS[2]		Oil yield (t ha^{-1})		Shelling out-turn (%)		Oil content (%)		O/L ratio (%)	
		LLS	Rust	P	UP	P	UP	P	UP	P	UP
Mutant	100-105	5	7	1.40ab	1.18b (17)	69.6b	69.1 bc	46.6b	44.9b	0.99f	0.96e
D39d	105-110	4	3	1.75a	1.49a (15)	79.0a	78.7a	48.5a	48.0a	1.75a	1.78a
B37c	110-115	4	3	1.62ab	1.22b (25)	76.5a	71.8b	45.0cd	43.1b	1.30c	1.34c
Dh 8	105-110	7	8	1.11bc	0.89bd (20)	68.1b	64.7c	42.7e	40.6c	1.50b	1.36c
R 8808	105-110	8	7	1.42ab	0.92bc (35)	68.7b	69.8bc	44.5cd	40.9c	0.88g	0.90e
JL 24	100-105	8	8	1.23bc	0.70cd (43)	69.8b	67.6bc	44.0cd	43.7b	0.96e	0.96e
TMV 2	100-105	9	9	1.30bc	0.62cd (52)	70.3b	66.3bc	40.4f	39.8cd	1.15d	1.10d
TAG 24	95-100	9	8	1.09bc	0.64cd(41)	70.4b	66.7bc	42.7e	38.3cd	1.07e	0.97e
1CGV 86590	110-115	8	3	1.15bc	0.71 cd (38)	59.8c	57.0d	45.2c	39.9cd	0.89g	0.92e
GBFDS 272	120-125	4	2	1.43ab	1.07bc(25)	62.2c	59.4d	46.5b	43.5b	1.50b	1.56b
Mean		-	-	1.35	0.94** (30)	69.5	67.0*	44.6	42.3**	1.20	L18[1]
CD (5%)		-	-	0.22	0.21	2.8	3.6	1.0	2.0	0.04	0.08
CV (%)		-	-	9.5	13.0	2.3	3.1	1.0	2.4	2.0	4.0

1. P = Protected; UP = Unprotected. Figures in parentheses indicate reduction (%).
   *, ** denote significance of difference between UP and P at 5% and 1% level of probability, respectively.
   Figures with same letters in a column do not differ significantly at 5% level of probability.
2. FDS - Field disease score (1-9 scale), where 1 - 0%, 2 = 1-5%, 3 = 6-10%, 4 = 11-20%, 5 = 21-30%, 6 = 31-40%, 7 = 41-60%, 8 = 61—80%, and 9 = 81-100% damage to foliage; LLS = Late leaf spot.
3. Not significant.

resistant breeding line GBFDS 272. The cross derivative, D 39d, recorded highest oil yield (1.75 t ha^{1}) with least reduction (15%) due to foliar diseases. Its oil was characterized by high O/L ratio (1.78), revealing better nutritional and keeping quality. Its high oil yield under diseased condition was especially due to high oil content (48%) and shelling out-turn (79%). This genotype could be widely tested for its suitability in commercial cultivation and/or profitably utilized in resistance breeding to improve Spanish bunch groundnuts.

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Utilization

Wild *Arachis* Species: A Possible Source of Legume Fodder in India

P K Ghosh[1] and S K Bera (National Research Centre for Groundnut, Ivnagar Road, PB No. 5, Junagadh 362 001, Gujarat, India; 1. Present address: Indian Institute of Soil Sciences, Nabibagh, Bhopal 462 038, Madhya Pradesh, India)

In India, an annual deficit of about 30% between availability and requirement of forage and fodder has been visualized. In reality, this deficit may be around 40% because forage though potentially available in the country may not be actually available to animals. This is possibly one of the reasons of low productivity of livestock in India. The diversion of other foods or commercial cropped area is not possible for forage cultivation because of preferential human food and other economic compulsions. Under such circumstances, one of the possible ways to bridge the wide gap between demand and supply is to ameliorate the forage resources through management of drylands and/or wastelands by introducing new fodder crops. Hence, the study was undertaken to find out the nutritive value of wild *Arachis* species, which may be introduced as a source of perennial fodder in dryland/wasteland areas.

The wild *Arachis* species have been maintained at the National Research Centre for Groundnut (NRCG), Junagadh, Gujarat, India in a small pasture since last five years. Five accessions of wild *Arachis* species, *A. hagenbeckii, A. prostrata, A. marginata,* and *A. glabrata,* along with three controls were tested in a completely randomized design with three replications. The controls included two cultivated species of groundnut (Spanish and Virginia types) and wheat. Cultivated groundnut was sown in the end of June 1997 with 1.25 g nitrogen and 2.5 g P_2O_5 m^{-2} and was harvested in the second fortnight of October. Wheat was sown on 19 November 1997 with 12 g nitrogen and 5 g P_2O_5 m^{-2} and was harvested on 7 March 1998. Five plant samples (whole plants) from each species were randomly cut from 5 cm above the ground level to study different nutritive characters as a fodder, viz., dry matter (DM), crude protein (CP), crude fiber (CF), ash, silica, phosphorus (P), potassium, and ether. Collected plant samples were air dried and then kept in an oven at 65±5°C till the samples attained a constant weight. Total dry matter was estimated by deducting dry weight from fresh weight and expressed in percent. Total phosphorus in the samples was determined by Vanadate-molybdate yellow method (Jackson 1973). Ether content was determined by Soxhlet method. The crude fiber, ash, and silica were estimated by treating the fat and mixture-free sample with sulfuric acid (1.25%) and then sodium hydroxide (1.25%). Potassium content in plant sample was determined following neutral 1N ammonium acetate method. Nitrogen content (%) in sample was analyzed by microKjeldahl method and then multiplied with 6.42 to obtain protein content in the samples.

In general, wild species had higher dry matter content than the cultivated species but the differences were not significant (Table 1). Among the wild species, *A. marginata* had the highest dry matter content which was significantly superior over cultivated species. Wild species, in general, had higher crude protein, higher crude fiber, and silica contents than cultivated groundnut. However, wheat straw had maximum crude fiber and silica contents. All the wild species contained low ash and ether as compared

Table 1. Nutritive quality (%) of cultivated and wild *Arachis* as fodder, Junagadh, Gujarat, India, 1997/98.

Genotype	Dry matter	Crude fiber	Ash	Silica	Phosphorus	Potassium	Ether extract	Crude protein
Wild species								
A. glabrata	32.37	25.83	9.42	0.91	0.29	0.61	2.38	14.51
A. prostrata	31.31	25.38	10.16	0.83	0.22	0.88	2.00	13.49
A. glabrata (IG 8966; PI 468363)	31.25	29.75	9.16	1.07	0.18	0.75	2.08	11.85
A. hagenbackii	32.27	27.75	10.28	1.58	0.22	0.89	2.48	13.81
A. marginata	33.25	26.58	10.02	1.06	0.29	0.73	1.89	15.26
Mean	32.09	27.06	9.80	1.10	0.24	0.77	2.17	13.78
Control								
Virginia type (cv Kadiri 3)	30.25	21.00	14.30	0.85	0.13	1.60	2.62	10.30
Spanish type (cv JL 24)	28.02	22.32	13.23	1.02	0.15	1.14	2.52	9.45
Wheat straw (cv Lok 1)	32.00	36.70	17.82	1.92	0.06	0.48	2.91	2.32
SE	±0.0428	±2.105	±0.771	±0.111	±0.025	±0.144	±0.110	±1.244

to the cultivated groundnut and wheat straw but had higher P and crude protein content than the three controls. *Arachis marginata* recorded significantly higher P and crude protein as compared to other wild species. The P and crude protein content in wheat straw was very low. Usually, nutritionally desirable fodder should have high dry matter, protein, and P contents with less crude fiber, ash, and silica content. *Arachis prostrata* maintained nutritionally desirable quality for fodder as is evident from Table 1. Moreover, since these wild species are known to have resistance to foliar diseases, better quality of fodder from wild species than that of cultivated groundnut is expected. Further study of detailed qualitative characters of the two wild species *A. marginata* and *A. prostrata* is needed so that these species can be put in long-term pasture development in dryland or wasteland areas to increase the availability of fodder.

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Socioeconomics

On-farm Participatory Evaluation of Groundnut Genotypes under Rainfed Conditions in Mahawite Governorate, Yemen

Saleha Al-Nahdi[1], C S Ward[1], Mehdi[2], and Al-Bushariy[2] (1. World Bank Office, Sana'a. PO Box 18152, Republic of Yemen; 2. Ministry of Agriculture and Irrigation, Republic of Yemen)

About 77% of the population in Yemen resides in the rural areas and is engaged in agriculture. In the last two decades, the contribution of agriculture to the national gross domestic product (GDP) has dropped from 75% to 18% in 1999. This decline in the GDP contribution has been caused by a number of factors such as migration of labor to other countries or to urban areas within the country, abandonment of the agricultural land and terraces, poor agricultural productivity, ecological factors (erratic and low rainfall, drought, floods, extensive soil and water erosion, removal of vegetative covers), and poor cultural practices (cultivation of monocrop, especially cereals, e.g., sorghum and millet, without crop rotation).

When more than three million workers returned home after the Gulf crisis in 1990, they had to fall back on agriculture

in these deteriorated lands. In order to survive, they continued to explore lands, even marginal lands, without any inputs, viz., fertilizers, organic manure, improved crop varieties, and proper application of pesticides and fungicides to control pests and diseases. These practices resulted in low yield and poor quality of produce and further deterioration of the land resources. This discouraging situation forces the farmers to leave their traditional homes and migrate to already overcrowded urban areas. The farmers are keen to cultivate cash crops due to low return from cereals. In the past, groundnut cultivation in small areas was concentrated in Tiham region. But it was abandoned later on due to termite problem. In recent years, farmers in other regions of the country have shown interest in growing groundnut.

The main objective of this on-farm evaluation of groundnut genotypes was to identify, in partnership with farmers, the most adapted genotype with stable performance and expose farmers to groundnut crop and its cultivation to enable them to make their choice of alternate cash crops.

Farmers in four pilot villages (Al -Hojoul, Al-Manak, Al-Hadan, and Al-Koran), where main occupation is agriculture, were approached to participate in the on-farm evaluation of groundnut genotypes in their fields. Many informal discussions were held with farmers to secure their participation under the following conditions:

1. The project will supply groundnut seed to farmers. They will carry out sowing and other day-to-day management operations under the guidance and supervision of project staff.
2. The project staff will monitor the trials and provide diseases and pest control materials, if needed.
3. The project will buy back the produce of groundnut from participating farmers to sell it to other farmers next year.
4. In the event of crop failure, the project will adequately compensate the participating farmers.

In 1998, four farmers in Al-Koran, three farmers in Al-Hojoul, and two farmers in Al-Hadan participated in on-farm trials. In 1999, nine farmers in Al-Koran, eight farmers each in Al-Manak and Al-Hojoul, and seven farmers in Al-Hadan participated in these trials. In all these villages, farmers grow one crop per year, mostly cereals (sorghum, millet, and maize), under rainfed conditions. The soils are clay silt or silt and the cultivation is either on terraces or in wadis.

Eleven improved varieties of groundnut were obtained from ICRISAT, Patancheru, India. These varieties had differing growth habit, crop duration, and reaction to diseases and insect pests. They were evaluated with local variety Baladi (Table 1). In both years, the fields were prepared in traditional way using buffaloes. The trials were hand sown in rows with interrow spacing of 80 cm; seed to seed distance within a row was 10 cm. They did not receive any organic manure, chemical fertilizers, or plant protection measures. Weeding was done manually when needed.

Table 1. Participatory on-farm evaluation of new groundnut genotypes in four pilot villages of Mahawite Governorate, Yemen, 1998 and 1999.

			Average pod yield (t ha^{-1})		
	Crop duration (days)		Yemen		
Genotype	Yemen	ICRISAT[1]	1998	1999	ICRISAT[1]
ICGV 86325	130-140	120-125	4.0	3.0	3.0
ICGS 76	130-140	120-125	2.5	1.5	3.0
ICGV 86590	130 -140	110 -115	2.0	1.0	1.5
ICGS44	130-140	120 -125	1.5	1.0	2.5
ICGS 1	120-125	110 -115	1.0	0.7	2.0
ICGS 11	130-140	120-125	1.0	0.5	2.0
ICGV 88409	130 -140	125-135	0.8	0.5	1.5
ICGV 94361	120-130	90-100	0.9	0.7	1.5
ICGV91123	110-120	90 -100	0.8	0.5	1.6
ICGV 86564	140 -150	130	0.6	0.5	3.0
ICGV 88409	140-150	130	0.6	0.4	3.5
Baladi (control)	140-150	-	0.9	0.7	

1. As reported in ICRISAT publications.

In 1998, sowing was completed during 14-20 May in Al-Koran and Al-Hojoul and on 6 June in Al-Hadan. The plot size varied from 2 liban (1 liban = 65 m^2) to 8 liban. In 1999, sowing started from 25 May in all the four villages and was completed by 30 June. The plot size varied from 0.25 liban to 20 liban. The produce of 1998 was used as seed for 1999.

About 600-800 mm rainfall is received during the rainy season (May-September). In both years, the crops experienced drought. In 1998, trials were under early drought stress for two months. Rainfall was scanty in June and in most part of July. Heavy rains started from the last week of July and caused severe damage. During early drought stress, most of the farmers lost their other crops but groundnut was able to withstand this drought spell.

In 1999, the crops faced both early and late season droughts (in June, August, September). Due to these droughts, most of the farmers lost their sorghum and other crops and had to undertake re-sowing. When these farmers saw groundnut still growing in their neighboring fields of participating farmers, they approached us for groundnut seed. We could not meet their requests as we had only limited quantity of seed.

Other than grasshoppers at Al-Hojoul and 'leaf yellowing' at Al-Koran during both years, no other diseases and pests were found on the crop. The 'leafyellowing' did not seem to affect pod yield. The trials were harvested during September and October. Pod yield data from each field were pooled to work out average yield for each year. The results obtained are summarized in Table 1.

Farmers were impressed with groundnut crop especially when they saw it withstanding early drought when other crops had failed. ICGV 86325 did well even in drought stressed conditions. Its pods were free from damage by soilborne insects or fungi. The farmers were not willing to sell the seed to us even though we offered double the price. Groundnut cultivation in Yemen is very profitable as it fetches 120-180 Yemeni Riyal (YR) kg^{-1} ofpods(1 US$ = 160 YR) compared to 30-50 YR kg^{-1} for sorghum and millets.

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Groundnut in Central Asia

Groundnut in Turkmenistan

A N Durdiyev (Ministry of Agriculture and Water Resources, Management of Turkmenistan, 63 Azadi Str., 744000 Ashgabat, Turkmenistan)

After recent surveys conducted in Turkmenistan, it was found that groundnut can be grown throughout the country on the salt-free irrigated areas. The varieties tested yielded 1.8-3.8 t ha^{-1}. Groundnut crop could easily be grown and was resistant to weeds and diseases. However, areas intended for this crop would have to be weed-free. The results of a study of 12-15 varieties showed that yields of Virginia, florunner, and starr varieties (all from USA) and one accession from India, K 1388, were the highest.

Some experiments on development of production technology have been performed in Turkmenistan on the variety Tashkent-1. Based on their results, some recommendations were developed regarding agrotechnique of this crop, and a technological map of activities was prepared.

Groundnut is used in Turkmenistan mainly for food purposes (as fried snack), and can be used in patisserie production by some factories that produce sweets, cakes etc. The major limiting factors for production of this crop are of socioeconomic nature, i.e., utilization of main areas under the basic crops such as wheat, cotton, alfalfa, and vegetables. Groundnut is not grown in *dekhkan* farms (newly established private farms), but mainly in small holdings and small farms.

No research activities relating to seed production have been done during the last 10 years in Turkmenistan. In fact, the germplasm available in the past have been lost, and only in private farms this crop is grown from the locally produced seed material, which has no specific name. A small collection of about 4 varieties exists at the Research Institute of Agriculture and Water Management in Turkmenistan.

Certain characters of groundnut crop such as comparatively higher yield potential, easy-growing techniques, and highly desirable taste and nutritive qualities are making this crop very attractive for agricultural production and for the processing industry in Turkmenistan.

Copies of titles are available from: Public Awareness Unit, Information Resource Management Program (IRMP), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India. (Email:imailist@cgiar.org).

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Virmani, S.M., and Shurpali, N.J. 1999. Climate prediction for sustainable production on rainfed groundnuts in SAT: crop establishment risks in groundnut production in the Anantapur region. Technical Manual no. 4. 50 pages. ISBN 92-9066-409-6. Order code TME 004. LDC $15.00. HDC $40.00. India Rs 530.00.

Nearly 80% of the area sown to groundnuts in India is rainfed and relies entirely on summer monsoon rainfall. The rainfall in most of the groundnut-growing regions is low and erratic. There is a high variability in the onset of monsoons, annual rainfall, and distribution of rainfall over the growing season. Moreover, such high variability in precipitation is generally associated with a high probability of an early season drought. Thus, rainfed agriculture in India is a risky proposition. One of the decision-making problems confronting the farmers at the onset of cropping season is choice of an optimum sowing window.

With the above in view, a research project was undertaken at ICRISAT to examine the trends in groundnut production in India over the past few decades in the global context, to characterize the groundnut production environment of the Anantapur region, and to provide a first approximation "decision support system" to the farmers of the Anantapur region in the state of Andhra Pradesh and thus aid them in deciding an optimum "time window" for sowing the groundnut crop.

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The following 1999 listings and publications have been generated from ICRISAT's electronic bibliographic

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Groundnut publications

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Information for I A N contributors

Publishing objectives

The *International* Arachis *Newsletter* (IAN) is published annually by the International Crops Research Institute for the Semi-Arid Tropics (1CRISAT), 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 arc 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.

Whattocontribute?(ICRISAT)

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

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

How to format contributions?

- Keep the items brief- remember, IAN is a newsletter and not a primary journal. About 600 words is the upper limit (no more than two double-spaced pages).
- If necessary, include one or two small tables (and no more). Supply only the essential information; round off the data-values to just one place of decimal whenever appropriate; choose suitable units to keep the values small (e.g., use tonnes instead of kg). Every table should fit within the normal type-written area of a standard upright page (not a 'landscape' page).
- Black-and-white photographs and drawings (prepared in dense black ink on a white card or a heavy-duty tracing paper) are welcome - photocopies, color photographs, and 35-mm slides are not. Please send disk-files (with all the data) whenever you submit computer-generated illustrations.
- Keep the list of references short - not more than five references, all of which should have been seen in the original by the author. Provide all the details including author/s, year, title of the article, full title of the journal, volume, issue, and page numbers (forjournal articles), and place of publication and publishers (for books and conference proceedings) for every reference.
- Express all the quantities only in SI units.
- Spell out in full every acronym you use.
- Give the correct Latin name of every crop, pest, or pathogen at the first mention.
- Type the entire text in double spacing. Please send a file, which should match the printout, on a double-sided/high density IBM-compatible disk using **Microsoft Applications.**
- Contact the Editors for detailed guidelines on how to format text and diskettes.
- **Include the full address with telephone, fax, and e-mail numbers of all authors.**

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

Contributions and requests for inclusion in the mailing list should be sent to:

Africa and Asia

IAN Scientific Editor
ICRISAT
Patancheru 502 324
Andhra Pradesh. India

Fax +9140 3241239
E-mail newsletter@cgiar.org
Tel +9140 3296161

Americas, Europe, and Oceania

IAN Scientific Editor
c/o Peanut CRSP
1109 Experiment Street
Griffin, GA 30223-1797.USA

Fax +770 229 3337
E-mail crspgrf@gaes.griffin.peachnet.edu
Tel +770 228 7312

Peanut CRSP

The Peanut Collaborative Research Support Program
The University of Georgia, College of Agricultural Environmental Sciences
1109 Experiment Street, Griffin, GA 30223-1797, USA

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
Patancheru 502 324, Andhra Pradesh, India

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