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Peanut CRSP
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ICRISAT
International Crops Research Institute for the Semi-Arid Tropics
(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, socioeconomic forces, postharvest processing, and utilization). Peanut CRSP also works to foster human resource development and the communication of research results.

The Peanut CRSP provides support for collaborative research, training, and exchange of information through grants to 14 universities in USA linked to 15 host countries in the developing world. Both host countries and USA are expected to benefit from the activities of Peanut CRSP. Peanut CRSP actively collaborates with other organizations with interest in advancing development through the application of science and technology.

About ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a nonprofit, non-political organization that does agricultural research and innovative capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 600 million people - the poorest of the poor - overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT belongs to the Future Harvest Alliance of Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

IAN Scientific Editor

SN Nigam

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News and Views

From the Editor

Dear Readers,

International *Arachis* Newsletter (IAN) was launched in 1987. Up to 1992, it was published twice a year. From 1993 onwards, only one issue was brought out each year due to paucity of funds and also fewer submissions made to the Newsletter. With this issue (no. 25), IAN completes 18 years. The support of Peanut CRSP has been vital in keeping the Newsletter alive. IAN recipients have overwhelmingly supported its continuation. We hope to meet their expectations.

IAN provides an important means of communication among the groundnut fraternity particularly those in developing countries. Presently, IAN accepts only short articles. However, we shall be happy to accept one or two full-length, scholarly papers that deal with new information from the next issue. We are in touch with other Future Harvest Centers to bring out an E-Journal on rainfed agriculture. If that materializes, accepted full-length papers would also find a place there. Let us all try to enhance the value of IAN to its readers. I seek more contributions to IAN not only from the scientists of Africa and the Americas but also from the private sector and farmers.

I would like to acknowledge R Aruna, PM Gaur, V Leela Prasad, BR Ntare, A Ramakrishna, GV Ranga Rao, BVS Reddy, KL Sahrawat, KK Sharma, P Singh, RP Thakur, V Vadez, F Waliyar (ICRISAT); RDVJ Prasada Rao (NBPGR, Hyderabad); and PV Reddy (ANGRAU, Regional Agricultural Research Station, Tirupati) who reviewed IAN articles and the JS Kanwar Library at ICRISAT for compiling SATCRIS listing.

Please complete the form inserted in this issue and return it to us if you wish to continue receiving IAN in future. Alternatively, you can also respond electronically to newsletter@cgiar.org.

Looking forward to your contributions and wishing you the best.

SN Nigam

News from West Africa

Second Regional Planning and Project Coordination Meeting of the Groundnut Seed Project

The Institut Sénégalais de Recherches Agricoles (ISRA) hosted a 2-day regional planning meeting from 17 to 18 February 2005 in Dakar, Senegal. The national coordinators, and the representatives of the PEA, Common Fund for Commodities (CFC), ISRA and CORAF/WECARD attended the meeting. The objective was to review the progress made in year 2 of the project and prepare work plan and budget for the third year.

A successful mid-term review conducted

An independent consultant successfully conducted a mid-term review of the groundnut seed project in West and Central Africa (WCA). It is heartening to report that most targets have been successfully met and farmers are aware of the benefits of improved varieties, good quality seed and production practices. A team of representatives of CFC, PEA and the respective country coordinators supported the consultant. The team visited Mali, Niger and Senegal.

Enhancing skills of rural entrepreneurs in small-scale seed business management and marketing

A 3-day intensive in-country training course in small-scale seed business management and marketing was conducted in Mali, Niger, Nigeria and Senegal. In each country 25 rural entrepreneurs including emerging small-scale groundnut seed producers attended the training. Local consultants were hired to conduct the course.

A study on groundnut supply seed systems in WCA: current practices, constraints and opportunities

The agricultural economist (Jupiter Ndjeunga) at ICRISAT, Mali and partner economists in Mali, Niger, Nigeria and Senegal conducted a regional survey of

groundnut supply and demand systems in the four countries. The study reveals a limited access to seed of modern varieties by farmers and the formal seed sector only supplies 5% of the seed needs. The private sector has shown little interest in the production of seed of crops such as groundnut due to a number of reasons including the low seed viability not allowing private investors to keep seed stocks beyond a year, low genetic deterioration and weak vertical integration between seed and product markets, limiting the demand for seed. The local village seed systems are filling the void created by the poor performance of the public sector and the low interest from the private sector. Farmers consistently obtain seed from their own harvests, family, friends or relatives or purchase seed from local village markets. Village seed systems offer a range of local and diverse varieties that are accessible and are of acceptable physical purity with flexible transactions. In addition, village seed systems offer a cheaper and more efficient way of delivering seed to farmers especially at low transaction costs.

The study also documents the major constraints limiting the uptake of modern varieties or performance of groundnut seed systems, which include:

- Limited access to seed of newly bred modern varieties
- Limited supply of breeder/foundation/certified and commercial seed of varieties preferred by farmers or required by the markets
- Seed production is not profitable for some seed classes
- Seed demand is uncertain and thin
- National variety release committees are missing, non-functional or meet irregularly
- Poor integration between seed and product markets
- Lack of enabling policy and institutional environments

The opportunities to improve the seed systems include:

- Information dissemination on seed supply and demand across the region
- A better interface between the formal seed sector and community-based systems and between producers and processors
- Contractual arrangements between processors and producers to motivate farmers to use modern inputs (varieties, fertilizers, etc) and therefore increase their crop productivity
- Sustainable arrangements that operate at low transaction costs such as the promotion of local village seed schemes especially for crops that are bulky

Methodological and technical guides available

Several methodological and technical guides focusing on groundnut seed production are available on the groundnut seed project website. These include:

- A monitoring and and evaluation system as project management tool
- A methodological note on the assessment of village seed systems
- A methodological guide on participatory varietal selection (PVS)
- A technical guide on seed production and variety maintenance
- A business plan for linking producers and processors
- A methodological guide on harvesting and drying procedures
- A note on evaluation of seed production costs
- A training manual on business skills for small-scale seed producers

Visit the project website at www.groundnutseedproject.org

Publication

Ntare BR, Waliyar F, Ramouch M, Masters E and **Ndjeunga J.** (eds.) **2005.** Market prospects for groundnut in West Africa. CFC Technical Paper No. 39. PO Box 74656,1070 BR Amsterdam, The Netherlands: Common Fund for Commodities; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 252 pp.

Contributed by: BR Ntare
lCRlSAT
Bamako, Mali

Current ICRISAT Groundnut Research and Integrated Projects

Investor	Project title	Project coordinator	Grant (US$ '000)	Duration
Australia/ACIAR	Improving yield and economic viability of peanut production in Papua New Guinea and Australia using integrated management and modeling approaches	HD Upadhyaya	14	Jul 2002-Dec 2005
Common Fund for Commodities	Development of sustainable groundnut seed systems in West Africa	F Waliyar B Ntare	2,153	Apr 2003-Mar 2007
CGIAR/lCARDA/CAC	Research activities on groundnut and on management of drought in chickpea, targeted to the Central Asia and the Caucasus (CAC) region	SN Nigam	24	2001-05
CGIAR Global Challenge Program - HarvestPlus	Genetic engineering of groundnut for enhanced β-carotene production to combat vitamin A deficiency in the semi-arid tropics	KK Sharma	75	Jun 2005-May 2006
GCIAR - Generation Challenge Program - ClMMYT/EMBRAPA	Unlocking the genetic diversity in peanut's wild relatives with genomic and genetic tools	V Vadez	276	2005-07
CGIAR/IFAR	Development/introduction of new groundnut varieties suitable for Uzbekistan and their seed multiplication in collaboration with ICRISAT	M Amanova SN Nigam	10	2005
International Fund for Agricultural Development (IF AD)	Farmer-participatory improvement of grain legumes in rainfed Asia	SN Nigam	1,300	Sep 2001-Jun 2006
India/Effem India Pvt Ltd	Assessment of aflatoxin contamination in maize production systems in Andhra Pradesh: A step towards developing aflatoxin-free maize production technologies	F Waliyar	22	Jul 2005-Feb 2006
Norway/Development Fund	Enhancing groundnut production in the non-traditional and dryland areas of Malawi for improved nutrition and poverty reduction	M Siambi	65	Jan-Dec 2005
Opec Fund	Improved rural livelihoods and better health: Promoting and improving groundnut for poor farmers in Asia	SN Nigam	100	Jul 2005-Jun 2006
Philippines	Enhancing adoption of ICRISAT legume varieties and technologies in the Philippines	CLL Gowda	54	2004-06
	Introduction, promotion and efficient seed support system of ICRISAT 'Asha' peanut variety in Region 2, Philippines	SN Nigam	36	Apr 2005-Apr 2007
PLAN International	Collaborative project on groundnut and pigeonpea in Malawi	RJ Jones M Siambi	155	2003-05
UK - DFID/CPP/NRIL	Safer and better groundnut production for Southern India	F Waliyar	96	Apr 2005-Jan 2006
	Promotion of farmers' participatory management of groundnut diseases for higher yield and nutritive value of crop residues (haulm) used for peri-urban dairy production on the Deccan Plateau in India	P Parthasarathy Rao	118	Apr 2005-Jan 2006
USA/Univ of Georgia (Peanut CRSP)	Support for regional workshop and publications	F Waliyar	61	2000-06
USAID/US Univ Linkages - Univ of Georgia	Quantifying yield gaps and abiotic stresses in soybean- and groundnut-based production systems	P Pathak	90	2001-06
USAID/US Univ Linkages - Univ of Georgia	Management of aflatoxin in peanut through the use of atoxigenic strains of *Aspergillus flavus*	RB Jones	60	Jan 2005-Dec 2006
USAID/US Univ Linkages - Univ of Wisonsin-Madison	Elucidation of the peanut/*Aspergillus* interaction	F Waliyar	60	Jan 2005-Dec 2006
USAID/NASFAM	Promoting growth in Malawi's groundnut and pigeonpea trade through technology and market improvement	M Siambi RB Jones	850	Jan 2004-Sep 2006
USAlD/ABSP II (Sathguru/Mahyco)	TSV resistant oilseeds - Bio-engineered sunflower and peanut genotypes with resistance to tabacco streak virus	KK Sharma	23	May 2004-Oct 2005
	Development of tabacco streak virus resistant sunflower and groundnut	KK Sharma	35	Apr 2005-Sep 2006

Research Reports

Genetic Resources and Enhancement

Identification of Water-use Efficient Groundnut Genotypes for Rainfed Situations through Leaf Morpho-physiological Traits

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Groundnut (*Arachis hypogaea*), the annual legume grown in more than 100 countries, is mainly cultivated in the tropical, subtropical and warm temperate regions of the world where availability of water is the most important yield limiting factor. India, which accounts for more than 30% of global groundnut area and 21% of production, has about 81% of the groundnut area under rain-dependent cultivation. The dependency on monsoon rain, which is characterized by uneven distribution and year-to-year variation in the semi-arid regions, explains the low productivity in India (937 kg ha^{-1}) as compared to the world average of 1367 kg ha^{-1}.

The productivity of irrigated groundnut is about 1500 kg ha^{-1} and is more stable. However, scope for bringing more area under irrigation appears unlikely, as maximum area has already been brought under assured irrigation and on the other hand the sources of irrigation are fast shrinking. There is, therefore, an increasing interest currently being directed towards the breeding of groundnut varieties that are capable of yielding well under limited water conditions. Improvement in water-use efficiency (WUE) of the cultivars is one such attribute that could potentially lead to high yield under limited water conditions. So, both for rainfed and irrigated situations, cultivars that are efficient in utilization of available water are very essential. Such a goal might be possible since several studies have indicated substantial genetic variation for seed yield determinants, namely water transpired, WUE and harvest index. Wright et al. (1994) showed the existence of genetic differences for transpiration efficiency (TE) in groundnut, which is defined as dry matter (g) produced per kg of water transpired. However, measurements of transpiration and/or root biomass are difficult and, therefore, are not practical for use in large-scale breeding programs for improved drought tolerance. Transpiration efficiency of a genotype could also be estimated by measuring the carbon isotope discrimination ($\Delta^{13}C$) in leaves (Farquhar et al. 1982).

Specific leaf area (SLA, leaf area per unit leaf dry weight) is another useful parameter highly correlated with $\Delta^{13}C$ in groundnut (Nageswara Rao and Wright 1994). It has been observed that SLA is closely and negatively correlated with WUE (Wright et al. 1988, 1994). These studies suggest that SLA could be used as a surrogate while selecting for high WUE in groundnut breeding programs. Nageswara Rao et al. (2001) evaluated the use of hand-held portable SPAD (Soil and Plant Analysis-Development) chlorophyll meter for rapidly assessing drought tolerance in groundnut and observed a significant negative correlation between chlorophyll content (SCMR, SPAD chlorophyll meter reading) and SLA, and suggested that SCMR could be used as a rapid and reliable measure to identify genotypes with low SLA, and hence high TE in groundnut.

Increase in WUE is normally achieved by reduction in transpiration rate. Therefore, it is essential to measure the variability in both WUE and rate of transpiration. Stable oxygen isotopes have generated considerable interest in plant carbon and water relations in recent years. The isotopic enrichment occurs during evaporation, and transpiration being an evaporative process would result in the enrichment of $H_2{}^{18}O$ in leaf sap. Since the ^{18}O signature of the leaf sap is progressively imprinted into the organic molecules (Sternberg et al. 1986), the quantum of ^{18}O in the biomass would integrate the diurnal and seasonal changes in leaf transpiration rates. Thus, the enrichment of oxygen isotopes ($\Delta^{18}O$) can be utilized as an integration of the transpiration rate over time. Total transpiration (T) is a function of transpiration rate and leaf area. Since T depends on the efficiency of water uptake associated with roots, the $\Delta^{18}O$ and leaf area together can be used as a rapid and accurate approach to estimate the root biomass.

This study was conducted to assess genetic variability for the morpho-physiological characters, namely $\Delta^{13}C$, $\Delta^{18}O$, SLA and SCMR that are known to influence WUE, besides a few yield component traits in groundnut.

Materials and methods

Thirty-two genotypes comprising 20 advanced breeding lines developed for high WUE, eight parental lines of these breeding lines and four check genotypes (Somnath, JL 220, SB XI and JL 24) were evaluated in a replicated trial during *kharif* (rainy season) 2003 at Junagadh, Gujarat, India. Of the 20 advanced breeding lines, 11 had ICGS 76, 10 had CSMG 84-1 and nine had ICGS 44 as one of the parents in their pedigree. Six advanced breeding lines were derived from the cross ICGS 76 x CSMG 84-1, and five were from ICGS 44 x ICGS 76.

At 45 days after sowing, second fully opened leaf from the apex of five randomly selected plants in each replication grown under rainfed situations was used to measure SCMR in the morning (08.00-09.30 hours) with the help of hand-held Minolta SPAD chlorophyll meter (Minolta Corp., Ramsey, New Jersey, USA). Same leaves were used to measure SLA ($cm^2 g^{-1}$) using a LI-3100 leaf area meter (Ll-COR Inc., Lincoln, Nebraska, USA). Analysis for the estimation of $\Delta^{13}C$ and $\Delta^{18}O$, both expressed in per mill (‰), was done at the National Facility for Stable Isotopes, University of Agricultural Sciences (UAS), Bangalore, India. Observations were also recorded on pod yield and its component traits. Standard statistical procedures were adopted to quantify the amount of genetic variation available for the traits and in the materials studied. Pearson's correlations and cluster analysis using Euclidean distances were also performed with the help of statistical software SYSTAT 10 (SPSS Inc., Chicago, Illinois, USA).

Results and discussion

Highly significant genotypic differences (P <0.01) were observed for $\Delta^{13}C$, $\Delta^{18}O$, SLA, SCMR, harvest index, shelling outturn, plant height, pod and seed yields and total dry matter production. This revealed the existence of considerable genetic variation for traits associated with WUE (leaf morpho-physiological characters), partitioning efficiency and the yielding ability among the genotypes studied.

The study confirmed the strong inverse relationship of SCMR with SLA (r = -0.626, P <0.01) as previously reported by Nageswara Rao et al. (2001). The SCMR also recorded strong inverse relationship with $\Delta^{13}C$ (r = -0.552, P <0.01) and positive association with pod yield (r = 0.505, P <0.01). Significant but weak correlations of SCMR

Table 1. Performance of top ten genotypes for pod yield, harvest index and leaf morpho-physiological characters contributing to water-use efficiency in groundnut.

Character[1]	Variability: Range[2]	Variability: Population mean	Top ten genotypes	Range of top ten genotypes
Pod yield (kg ha^{-1})	1331-3407	2459	GG 20, CSMG 84-1, JL 220, JL 24, ICR 10, ICGS 76, ICR 24, JUG 27, JAL 17 and JUG 28	2812-3407
Harvest index (%)	26-54	39.19	JAL 36, ICR 20, JAL 17, TAG 24, JL 220, ICR 40, JL 24, ICR 24, TIR 42 and TIR 47	43-54
SCMR	31.3-41.6	36.39	JUG 28, ICGS 76, ICR 27, JUG 15, JAL 03, ICR 24, ICR 10, GG 20, JUG 27 and ICR 11	38.4-41.6
SLA ($cm^2 g^{-1}$)	206-298	248.91	TIR 16,ICGV 86031, JUG 28, ICR 40, ICR 27, ICR 10, ICR 11, CSMG 84-1, JUG 27 and ICR 20	206.1-234.1
$\Delta^{13}C$ (‰)	21.06-22.32	21.63	Somnath, JAL 03, CSMG 84-1, GG 20, ICGS 44, JUG 27, JUG 28, JL 24, ICR 11 and JUG 15	21.06-21.41
$\Delta^{18}O$ (‰)	18.55-21.62	20.24	TIR 16, ICR 40, JUG 28, ICR 10, ICR 11, ICR 20, JUG 27, JL 220, ICR 24 and TIR 42	20.58-21.62

1. SCMR - SPAD chlorophyll meter reading; SLA = Specific leaf area; $\Delta^{13}C$ = Carbon isotope discrimination; and $\Delta^{18}O$ = Enrichment of oxygen isotopes.
2. For 32 genotypes tested.

were observed with seed yield (r = 0.384, P <0.05), haulm yield (r = 0.401, P <0.05) and total dry matter (r = 0.375, P <0.05). These relationships suggest that SCMR can be used as indirect measure for SLA and $\Delta^{13}C$.

The $\Delta^{3}O$ is hypothesized to be associated with higher mean transpiration rate and stomatal conductance (Udayakumar et al. 1998, Bindumadhava et al. 1999). In this study, $\Delta^{8}O$ was negatively associated with SLA (r = -0.582, P <0.01). Therefore, those genotypes with low SLA (high TE) would have high $\Delta^{18}O$. This relationship in turn indicates that genotypes with lower SLA (thicker leaves) will have higher transpiration rate, which will be a genotype specific trait. The association of $\Delta^{18}C$ with haulm yield (r = -0.617, P <0.01) and total dry matter (r = -0.522, P <0.01) was negative, suggesting that selection for low $\Delta^{18}C$ (high TE) might result in production of more dry matter.

Groundnut genotypes with low SLA and $\Delta^{3}C$, and high SCMR values are likely to possess high WUE. Superior genotypes (top ten) identified with respect to pod yield, harvest index and leaf morpho-physiological traits are given in Table 1. Highest pod yield was recorded in GG 20 followed by CSMG 84-1, JL 220 and JL 24 (all commercial varieties) whereas high harvest

Table 2. Euclidean distance between pairs of genotypes based on 11 quantitative traits.

Cluster containing genotypes A and B		Euclidean distance between genotypes A and B	No. of genotypes in new cluster
Genotype A	Genotype B		
ICR 11	JUG 28	7.09	2
JAL 03	JUG 15	10.47	2
ICR 11	ICR 43	11.72	3
JL 220	JL 24	12.43	2
TIR 16	JUG 33	13.76	2
ICR 10	ICR 24	13.89	2
ICR 10	ICGS 76	13.93	3
JAL 03	JAL 05	18.90	3
ICR 10	JAL 17	19.34	4
JAL 03	JAL 36	21.30	4
ICR 11	JUG 27	22.76	4
GG2	SB XI	25.70	2
JAL 03	ICR 20	26.24	5
TIR 47	ICGS 44	26.99	2
TIR 47	ICR 40	27.65	3
GG 2	TAG 24	30.50	3
ICR 11	ICR 10	31.17	8
TIR 47	ICR 12	31.33	4
Somnath	ICR 27	32.90	2
JAL 03	TIR 47	35.71	9
JAL 03	Somnath	38.75	11
GG2	TIR 42	40.70	4
JAL 03	TIR 16	49.24	13
K 134	ICGV 86031	55.39	2
K 134	GG2	55.82	6
ICR 11	JAL 03	57.37	21
CSMG 84-1	ICR 11	69.93	22
CSMG 84-1	JL 220	72.00	24
K 134	CSMG 84-1	75.60	30
JUG 13	K 134	116.29	31
GG 20	JUG 13	121.23	32

index was observed in the advanced line JAL 36 followed by ICR 20, JAL 17 and TAG 24 (commercial variety). The $\Delta^{13}C$ value was least in the commercial variety Somnath, followed by the genotype JAL 03. For SLA, the lowest value was recorded in TIR 16 followed by ICGV 86031. The SCMR values that essentially estimate the chlorophyll content in the leaves is a simple method that can be rapidly measured with the help of a hand-held SPAD meter. The genotypes JUG 28, ICGS 76, ICR 27, JUG 15 and JAL 03 were the top five for high SCMR values among the 32 tested genotypes. Of these, four genotypes (JUG 28, ICR 27, JUG 15 and JAL 03), though developed at different locations, were derived from a common cross ICGS 76 x CSMG 84-1. From the study it is evident that all the genotypes that involved ICGS 76 as one of the parents (second highest for SCMR) in their pedigree scored high SCMR values. Hence ICGS 76 or its derivatives were identified as important donors for this trait. ICGS 76 also had the highest haulm yield and total dry matter yield.

The cluster analysis carried out on the basis of eleven traits placed the 32 genotypes in many groups (Table 2). The genotypes ICR 11 and JUG 28 were the most closely related ones and GG 20 and JUG 13 were the least related genotypes. Meticulous examination of tabulated data revealed that 11 pairs of genotypes were joined at less than 25 Euclidean distances. Interestingly all the genotypes of these pairs had at least one common parent in their ancestry and in some cases both the parents were common. As the divergence between the member-genotypes of a pair increased, the genotypes involved in the parentage were different. However, ICR 11 and ICR 10 were grouped at 31.17 Euclidean distance and had common parentage.

This study could detect considerable genetic variation for the WUE traits as well as yield and related traits in the 32 genotypes tested. The study also confirmed the association among the leaf morpho-physiological traits and yield attributes, and the possibility of indirect selection for improved WUE through associated traits. The genotypes could be grouped into different classes based on the genetic similarity or variability in 11 traits studied and this can help in future breeding strategies where some of these cultivars may act as potential donor parents. The identified genotypes, which possess superiority for novel traits except a few, may further be improved following introgression breeding approaches.

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Promising Parental Lines for the Development of High Water-use Efficient Groundnut Varieties

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In a biological model (Passioura 1986), seed yield is explained to be a function of water transpired (T), water-use efficiency (WUE) and harvest index (HI). Water-use efficiency in groundnut can be measured indirectly through the negatively associated character, $\Delta^{13}C$ (carbon isotope discrimination) (Wright et al. 1994). Being expensive and impractical to be used in the large segregating populations, specific leaf area (SLA, leaf area per unit leaf dry weight) can be used as a surrogate for $\Delta^{13}C$ as it is positively correlated with $\Delta^{13}C$ (Nageswara Rao and Wright 1994). Significant negative correlation between the SPAD (Soil and Plant Analysis-Development) chlorophyll meter reading and SLA was reported by Nageswara Rao et al. (2001) who suggested that this meter could be used as a rapid and reliable measure to identify genotypes with low SLA. Oxygen isotope enrichment ($\Delta^{18}O$) that occurs during transpiration is also a potential tool for the measurement of stomatal conductance and transpiration rate (Sheshshayee et al. 2003).

Conventional diallel analysis helps in partitioning the total variation into general combining ability (GCA) of each genotype and specific combining ability (SCA) of each cross. Information on the nature of gene action for the characters like $\Delta^{13}C$, $\Delta^{18}O$, SLA, SPAD chlorophyll meter reading (SCMR), HI, total dry matter production (TDM) and fodder yield (FY) is scanty. There are only two published reports (Jayalakshmi et al. 1999, Nigam et al. 2001) suggesting the predominant role of additive gene action in the inheritance of SLA. Thus, the objective of this study was to determine the genetic control of the WUE associated traits.

Materials and methods

Six genotypes (Chico, CSMG 84-1, ICG 4747, ICGV 86031, TAG 24 and TMV 2 NLM) were crossed in a full diallel mating design (Griffing 1956) resulting in 15 F_1s and 15 reciprocals in the rainy season of 2003. The resulting thirty hybrids were evaluated along with their parents at the National Research Centre for Groundnut (NRCG), Junagadh, India during summer in 2004 in a randomized complete block design. Each genotype was grown in five rows of 3 m length per replication with a row-to-row distance of 60 cm. The genotypes were planted at 10 cm spacing.

Data were recorded on seven quantitative traits, viz, $\Delta^{13}C$, $\Delta^{18}O$, SLA, SCMR, HI, TDM and FY. Second fully expanded leaf from the apex (from ten randomly selected plants of each genotype in each replication) at 45 days after sowing was used to record the SCMR in the morning (08.00-09.30 hours) with the help of Minolta SPAD chlorophyll meter (Minolta Corp., Ramsey, New Jersey, USA). The same leaf samples were used to record the leaf area using a LI-3100 Area Meter (LI-COR Inc., Lincoln, Nebraska, USA). These leaves were then oven-dried at 60°C for 48 h to estimate SLA ($cm^2\ g^{-1}$). The leaves were ground into fine powder and subjected to analysis of $\Delta^{13}C$ (‰) and $\Delta^{18}O$ (‰) at the National Facility for Stable Isotopes, University of Agricultural Sciences, Bangalore, India. The selected ten plants were harvested individually in each plot at maturity and observations on FY and pod yield were recorded after drying. Total weight of fodder and pod accounted for TDM (g $plant^{-1}$). The HI was determined as ratio of pod weight to TDM.

Mean data of the traits showing significant genotypic differences were subjected to diallel analysis Method 2 and Model 1 (Griffing 1956) to partition the total variation into GCA of each parent and SCA of each cross.

Results and discussion

Substantial genetic variability existed among the parental lines and F_1s for traits studied. The mean squares for GCA were highly significant for all the characters studied. Significant values for SCA were also observed for all the characters except HI, indicating that this trait is predominantly under the influence of additive gene action. All the four leaf morpho-physiological characters (SPAD, SLA, $\Delta^{13}C$ and $\Delta^{18}O$) established highly significant reciprocal differences indicating the influence of maternal parents in the inheritance of these characters. The magnitude of GCA variance was higher for all the characters when compared with SCA variance signifying the preponderance of additive gene action in the inheritance of these characters. Similar results are in agreement with those of Jayalakshmi et al. (1999) and Nigam et al. (2001) for SLA, and Nigam et al. (2001) for HI. High ratio between GCA and SCA variance observed

for SCMR, SLA and HI (> 17) suggested that additive genes control these characters. Hence, selection for the improvement of these characters will be effective in early generations. The low ratios (1.17 to 2.78) between GCA and SCA variances observed for TDM, FY, $\Delta^{13}C$ and $\Delta^{18}O$ indicated the preponderance of non-additive gene action for these characters.

Good general combiners and specific combinations identified for the characters studied are presented in Table 1. TMV 2 NLM showed highly positive and significant GCA effects for SCMR and highly significant but negative values for SLA and $\Delta^{13}C$. The genotype ICGV 86031 exhibited significant and positive GCA effects for SCMR and $\Delta^{18}O$ but significant and negative values for SLA. CSMG 84-1 was also a good combiner for SLA. Jayalakshmi et al. (1999) also identified breeding lines TMV 2 NLM and ICGV 86031 as good general combiners for SLA. The varieties TAG 24 and Chico were the best general combiners for HI. The parental line ICG 4747 was a good combiner for TDM and FY as this line has recorded the highest GCA effects for both the characters.

High positive and significant SCA effects for SCMR were observed in the cross ICG 4747 x TMV 2 NLM followed by CSMG 84-1 x TAG 24 and ICG 4747 x TAG 24. Among the reciprocals, TMV 2 NLM x ICGS 4747 followed by ICGV 86031 x CSMG 84-1, TMV 2 NLM x ICGV 86031 and ICGV 86031 x Chico were found to be good specific combiners for this character. Highest negative and significant SCA effects for SLA were observed in the cross CSMG 84-1 x TAG 24 followed by ICGV 86031 x TAG 24. Three reciprocal crosses recorded negative and significant SCA effects for SLA. Only one cross, TAG 24 x TMV 2 NLM, recorded significant positive SCA effects for HI. Desirable negative and significant SCA effects for $\Delta^{13}C$ were observed in two reciprocal crosses, TAG 24 x Chico and TMV 2 NLM x Chico. Significant and positive SCA effects for $\Delta^{18}O$ were observed in two crosses, Chico x ICGV 86031 and CSMG 84-1 x TAG 24, whereas six reciprocal crosses were found to be good specific combiners for this character. The cross Chico x ICGV 86031 was observed to be a good cross combination both for TDM and FY.

The GCA effects of the parents involved in the superior specific cross combinations for all the characters studied revealed that SCA effects of the crosses were independent of the GCA effects of the parental lines involved. Two crosses, TMV 2 NLM x ICGV 86031 and ICGV 86031 x CSMG 84-1, identified as good specific combiners for SCMR and SLA, respectively, involved parents with high GCA suggesting an additive x additive type of gene action, which can be fixed in the early generations in the absence of repulsion phase linkages.

Table 1. Good general combiners and specific combinations for seven quantitative characters in groundnut.

Character[1]	Good general combiners	Good specific combinations
SCMR	TMV 2 NLM, ICGV 86031	ICG 4747 x TMV 2 NLM, CSMG 84-1 x TAG 24, ICG 4747 x TAG 24, TMV 2 NLM x ICGS 4747, ICGV 86031 x CSMG 84-1, TMV 2 NLM x ICGV 86031, ICGV 86031 x Chico
SLA	TMV 2 NLM, ICGV 86031, CSMG 84-1	CSMG 84-1 x TAG 24, ICGV 86031 x TAG 24, ICGV 86031 x CSMG 84-1, TAG 24 x Chico, TAG 24 x CSMG 84-1
HI	TAG 24, Chico	TAG 24 x TMV 2 NLM
$\Delta^{13}C$	TMV 2 NLM	TAG 24 x Chico, TMV 2 NLM x Chico
$\Delta^{18}O$	ICGV 86031	Chico x ICGV 86031, CSMG 84-1 x TAG 24, ICGS 4747 x Chico, ICGV 86031 x Chico, ICG 4747 x CSMG 84-1, ICGV 86031 x CSMG 84-1, TAG 24 x CSMG 84-1, ICGV 86031 x ICG 4747
TDM	ICG 4747	Chico x ICGV 86031
FY	ICG 4747	Chico x ICGV 86031

1. SCMR = SPAD chlorophyll meter reading; SLA = Specific leaf area; HI = Harvest index; $\Delta^{13}C$ = Carbon isotope discrimination; $\Delta^{18}O$ = Enrichment of oxygen isotopes; TDM = Total dry matter; FY = Fodder yield.

Conclusion

All the WUE related traits studied are mainly under the control of additive gene action, suggesting that they can be selected in early generations. Among the good general combiners identified for different WUE traits, TMV 2 NLM (for SCMR, SLA and $\Delta^{13}C$) and ICGV 86031 (for SCMR, SLA and $\Delta^{18}O$) accounted for all the major WUE associated traits. Hence these genotypes should be used in the future breeding programs aimed at improving WUE and yield in groundnut. The crosses identified with high SCA effects for these traits should be advanced further to retrieve transgressive segregants in later generations.

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Confectionery Groundnuts Resistant to Seed Colonization by *Aspergillus flavus*

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In recent times, groundnut (*Arachis hypogaea*) is losing its pre-eminence as a main oilseed crop due to competition from cheaper sources of edible oil. However, large-seeded confectionery groundnuts have a great demand as snack food in domestic as well as international market. Aflatoxin contamination and pesticide residues in the nuts are the major impediments for export of groundnuts. Management of aflatoxin contamination requires both preventive and curative approaches starting from sowing and harvesting to processing and storage. Genetic resistance to *Aspergillus flavus* is one of the most viable and economical approaches to reduce aflatoxin problem (Swindale 1989).

In this study, fifteen large-seeded confectionery grade groundnut genotypes having 100 seed mass >60 g along with J 11, a resistant check (Mehan et al. 1987) and a susceptible check, TMV 2 were screened through artificial inoculation procedure for resistance to in vitro seed colonization by *A. flavus* isolate, Af 11-4, a highly aggressive and toxigenic strain (Thakur et al. 2000). Sixty sound mature seeds from each of the 15 genotypes were surface sterilized with 0.1% aqueous solution of mercuric chloride for 2 min and washed in two to three changes of distilled sterilized water. Each seed was uniformly wounded by pricking with a sterile needle to facilitate invasion by fungal spores. Seeds were placed in sterile petri dishes of 9 cm diameter and inoculated with *A. flavus* spore suspension at 1 x 10^6 spores ml^{-1}. Petri dishes were shaken to roll the seeds allowing uniform distribution of inoculum. The experiment was conducted in two replications with 30 seeds per replication. The petri dishes were incubated at 25°C and relative humidity of 95% in dark for 10 days. Individual seeds were scored for extent of seed surface colonized by *A. flavus* spores using 1-4 seed colonization severity scale and the mean of two replications is expressed as colonization severity. In the severity scale, genotypes with <5% seed surface colonized with scanty mycelial growth and scanty sporulation were scored 1; genotypes with 5-25% seed surface colonized

Table 1. Performance of confectionery groundnuts for *Aspergillus flavus* seed colonization and productivity parameters.

Genotype	*A. flavus* seed colonization[1]			Yield (g plant^{-1})			Shelling outturn (%)			100-seed mass (g)		
	Postrainy season	Rainy season	Pooled	Postrainy season	Rainy season	Pooled	Postrainy season	Rainy season	Pooled	Postrainy season	Rainy season	Pooled
Mutant 110-14	2.99	3.04	3.02	23.9	17.6	20.8	70.1	73.6	71.8	63.1	59.9	61.5
Mutant 28-2[2]	2.88	2.78	2.83	19.3	18.2	18.8	63.9	72.9	68.4	64.0	67.8	65.9
Somnath[2]	3.07	3.11	3.09	18.5	20.1	19.3	66.5	70.3	68.4	61.9	58.2	60.0
TKG 19A[2]	2.67	2.89	2.78	18.8	16.6	17.7	60.5	64.9	62.7	62.6	58.2	60.4
TG 18	1.89	1.87	1.88	14.4	19.3	16.8	60.5	66.4	63.5	64.5	57.1	60.8
TG 18A	1.74	1.81	1.78	15.9	19.7	17.8	61.6	60.4	61.0	60.5	61.7	61.1
TG 19	1.05	1.03	1.04	15.5	19.0	17.2	62.3	64.9	63.6	73.2	62.1	67.6
TG 39	3.94	3.83	3.89	19.6	16.0	17.8	75.3	66.9	71.1	69.3	68.1	68.7
TG 40	3.91	3.99	3.95	15.7	15.8	15.8	71.8	70.4	71.1	72.6	71.8	72.2
TG 41[2]	3.18	3.25	3.22	21.7	20.9	21.3	71.1	70.5	70.8	66.4	69.7	68.0
TG 42	3.31	3.42	3.37	19.2	17.0	18.1	71.8	60.0	65.9	64.6	71.8	68.2
TG 49	1.79	1.71	1.75	15.8	16.5	16.1	73.3	70.6	72.0	67.5	69.0	68.2
TGLPS 3	3.15	3.20	3.18	18.5	16.5	17.5	76.7	66.3	71.5	67.4	58.9	63.1
TGLPS 4	3.07	3.22	3.15	17.4	19.9	18.6	70.2	66.8	68.5	61.0	62.0	61.5
TGLPS 7	3.23	3.09	3.16	22.0	17.9	20.0	69.2	68.3	68.7	65.4	58.7	62.0
J 11[3]	2.87	2.91	2.89	13.3	14.7	14.0	50.9	51.5	51.2	30.4	29.4	29.9
TMV 2[4]	4.00	4.00	4.00	15.4	15.5	15.4	61.1	61.7	61.4	46.5	44.2	45.4
CD at 5%	0.54	0.39	0.36	4.2	4.5	3.1	7.5	8.5	5.7	11.7	6.9	6.8
CV (%)	9.0	8.2	8.6	10.8	12.1	11.4	5.3	6.1	5.7	9.5	5.4	7.6

1. Severity scored on 1-4 rating scale (see text).
2. Varieties released for commercial cultivation.
3. Resistant check.
4. Susceptible check.

with good mycelial growth and scanty sporulation were scored 2; genotypes with 26-50% seed surface colonized with good mycelial growth and good sporulation were scored 3; and genotypes with >50% seed surface colonized with heavy sporulation were scored 4 (Thakur et al. 2000). All the entries were evaluated in the field during postrainy (2002) and rainy (2003) seasons for productivity parameters, viz, yield plant^{-1}, an indicator of yield potential, shelling outturn, which provides information on percentage of seed recovery, and 100-seed mass, one of the important considerations for confectionery use. All the genotypes were grown in 5-m rows, each in two replications and all the recommended package of practices were followed to raise a good crop.

Trombay groundnuts TG 19 (1.04), TG 49 (1.75), TG 18A (1.78) and TG 18 (1.88) showed high level of resistance with very low seed colonization by *A. flavus* compared to resistant check J 11 (2.89). Genotypes TKG 19A (2.78) and Mutant 28-2 (2.83) were comparable to J 11 (Table 1). TG 39 (3.89) and TG 40 (3.95) recorded high seed colonization and sporulation comparable to susceptible check TMV 2 (4.00).

The genotype TG 41, a confectionery variety released for cultivation all over India (Kale et al. 2004), has recorded highest yield followed by Mutant 110-14 and TGLPS 7 but all were susceptible to infection by *A. flavus*. The highly resistant lines TG 19, TG 18, TG 18A and TG 49 have shown significantly low yield than high-yielding genotypes. Generally, highly resistant lines have low yield potential while the high-yielding lines show susceptible reaction to invasion by *A. flavus* (Kiran Kalia et al. 1988). However, moderately resistant Mutant 28-2 and TKG 19A have shown yield potential comparable to high-yielding confectionery groundnut varieties. These findings indicate the possibility of combining resistance to *A. flavus* infection and high yield potential. Mutant 28-2 has been released as a bold-seeded variety suitable for cultivation in Karnataka, India (Gowda et al. 2002). TKG 19A is a confectionery groundnut variety released for cultivation in Maharashtra, India (Deshmukh 1997).

Though resistant lines in general had low shelling outturn, TG 49 (71.96 %) recorded highest seed recovery. The resistant TG 49 (68.24 g) and TG 19 (67.64 g) were also superior for 100-seed mass making them better candidates for confectionery purpose. This study indicates the possibility of combining high yield and *A. flavus* resistance in the confectionery background to avoid poor quality to tap potential export market for the Indian groundnuts. The resistant genotypes, especially TG 19, TG 49, TG 18A and TG 18 form a potential source for *A. flavus* resistance. The cost effectiveness and ease in screening makes in vitro seed colonization as the most commonly used method (Thakur et al. 2000). Though positive correlation has been observed between in vitro seed colonization and resistance to natural seed infection (Waliyar and Bockelee-Morvan 1989), there is a need to estimate aflatoxin content to assess their true worth for the improvement of confectionery groundnuts in the future breeding programs.

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Farmer Participatory Varietal Selection in Groundnut - A Success Story in Anantapur, Andhra Pradesh, India

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Anantapur is a drought-prone district in Andhra Pradesh, India. It falls in a rain-shadow area. The average annual rainfall is not only low (522 mm) but also highly variable and erratic in distribution. The district experiences prolonged dry spells of 45-50 days with an average of 36 rainy days in the rainy season. During the last 12 years (1993—2004), there were only four 'good' years with better rainfall distribution during the cropping season and eight were 'drought' years. The soils in the district are predominantly light textured, gravelly, shallow Alfisols with depths varying between 30 cm and 60 cm and are low in nutrients and water-holding capacity. Smallholdings (<3.0 ha) dominate (60%) the district. Despite frequent droughts, over 70% of the cultivated area of the district (1.04 million ha) is sown to groundnut *(Arachis hypogaea)* each year due to its ability to survive long dry spells and also for its cash value. Further, it provides valuable fodder for livestock during dry years or in case of crop failures. The groundnut yield during 'good' years averages between 800 and 900 kg ha^{-1} and during 'drought' years between 300 and 400 kg ha^{-1}. There are instances of farmers getting yields up to 1500 kg ha^{-1} in 'good' years.

Current cultivar options

Despite many improved groundnut varieties (ICGS 11, ICGS 44, ICGS 76, RSHY 1, Tirupati 2, K 134, DRG 12, Kadiri 4, JCC 88 and others) released for Andhra Pradesh during the last 20 years, the old varieties, TMV 2 (released in 1940, covers 75-80% area), JL 24 (released in 1978, covers 15-20% area) and Pollachi Red (a landrace) continue to dominate farmers' fields. Some of the factors responsible for limited area sown to new varieties are new varieties falling short of farmers' expectations, non-availability of their seeds, reluctance of groundnut processors and millers to adapt their machinery to new varieties and consequent price discrimination by the traders in the local markets.

The Anantapur farmers prefer the following traits in a groundnut variety: high pod yield, high shelling outturn, early maturity, small-medium seed size, high haulm yield and resistance to drought, peanut bud necrosis, peanut stem necrosis and foliar fungal diseases. New varieties should have substantial improvement in pod and haulm yields (about 30%) to ensure their high adoption by the farmers.

Farmer participatory varietal selection

Despite the State government promoting other dryland crops in the district, the farmers are unwilling to give up groundnut cultivation. From the past experience, they realize that groundnut can withstand long dry spells much better than the other crops and can revive itself even with little rains after the dry spells. Further, in case of complete crop failure, it still yields some fodder for livestock. Therefore, for better livelihoods of small and marginal farmers, it is essential to stabilize groundnut productivity and production in the district by introducing farmer-preferred improved varieties and low cost/cost-saving production technologies.

Under the aegis of the IFAD Technical Assistance Grant 532-ICRISAT project, an on-farm farmer participatory varietal selection (FPVS) program was launched in 2002 in Anantapur in collaboration with the Rural Development Trust [a non-governmental organization (NGO)] and Agricultural Research Station, Acharya NG Ranga Agricultural University (ANGRAU) and active participation of farmers in partner villages to find a replacement for the traditional groundnut variety TMV 2 (ICRISAT 2002-2004).

FPVS trials. Five FPVS trials, each with nine improved varieties (eight from ICRISAT and one from ANGRAU) and a local control, TMV 2, were conducted in the 2002 rainy season in two representative villages of the district, Dhanduvaripalli and Rekulakunta. The partner farmers managed the trials. Soon after sowing in the first week of August, a dry spell of 45 days followed. After a couple of good rains during mid-September, there was again a dry spell of 25 days. The total rainfall received during the year was less than 400 mm, which was far below the average of the district. The farmers and scientists together visited these trials at different crop growth stages to observe the performance of new varieties. None of the

new varieties gave significantly higher pod yield than TMV 2 in both the villages. However, the farmers were impressed with the new variety, ICGV 91114, which gave higher fodder yield (1460 kg ha^{-1} as compared with 1355 kg ha^{-1} of TMV 2) with more green leaves, and comparable pod yield (385 kg ha^{-1} as compared with 305 kg ha^{-1} of TMV 2) and larger seed size despite severe drought conditions in the cropping season. Another variety, ICGV 89104, also looked promising to them because of its comparable pod yield and better shelling outturn than TMV 2.

These two varieties along with TMV 2 were evaluated in the 2003 rainy season in larger plots (0.21 ha) in five farmer holdings in West Narsapuram (new partner village) and Rekulakunta. Only 227.1 mm rainfall was received in 23 rainy days during the year. Despite severe drought, ICGV 91114 produced significantly higher average pod yield (507 kg ha^{-1}) and haulm yield (1391 kg ha^{-1}) than TMV 2 (453 kg ha^{-1} and 1111 kg ha^{-1}, respectively). The new variety also recorded a higher average shelling outturn and number of pods $plant^{-1}$ than the latter; ie, 59% and 2.9 as compared with 55% and 2.4 of TMV 2, respectively. Impressed with the performance of ICGV 91114 during two drought years (2002 and 2003), a woman farmer of West Narsapuram village multiplied the seed of this variety on a 1.5-acre (0.63 ha) land during the 2003/04 postrainy season with irrigation and produced 1200 kg pods (1920 kg ha^{-1}). She sold the produce to other farmers in the village as seed for the 2004 rainy season.

In the 2004 rainy season, 26 farmers in West Narsapuram, 25 farmers in Shivapuram (new partner village) and 33 farmers in Rekulakunta sowed their on-farm trials/seed production plots of ICGV 91114 with the onset of sowing rains during 10-12 July. Soon after, there was a dry spell of 36 days (30 July-3 September). Of the total annual rainfall of 495 mm, the crop received only 302 mm. ICGV 91114 again performed better than TMV 2 for pod yield in all the three villages but the yield differences were significant only in West Narsapuram and Shivapuram. While the haulm yield of ICGV 91114 was significantly higher in West Narsapuram, it was similar in Shivapuram and significantly lower than TMV 2 in Rekulakunta (Table 1). The average 100-seed mass of ICGV 91114 was 41 g as compared with 36 g of TMV 2. The oil content in ICGV 91114 was comparable to that of TMV 2 across farmers' fields and seasons.

Seed production of ICGV 91114. Convinced of its better performance, 111 farmers in 23 villages (10 *mandate)* of Anantapur and one village each in adjacent Kurnool and Chittoor districts undertook seed production of ICGV 91114 in the 2004/05 postrainy season in 48.04 ha under irrigation.

Large-scale adoption of ICGV 91114. Considering the better performance of ICGV 91114 in three consecutive drought years (2002-04), the farmers of the partner and neighboring villages collectively decided to adopt ICGV 91114 on a large scale in the 2005 rainy season.

Table 1. Comparative performance of ICGV 91114 and TMV 2 in on-farm farmer participatory varietal selection trials in Anantapur, Andhra Pradesh, India, rainy season 2004.

Village/Variety	Average pod yield[1] (kg ha^{-1})	Average haulm yield[1] (kg ha^{-1})	Shelling outturn (%)
West Narsapuram			
ICGV 91114	1524	1557	75
TMV2	1336	1375	75
t-test	*	*	
Shivapuram			
ICGV 91114	1502	1691	73
TMV2	1313	1665	75
t-test	*	NS	
Rekulakunta			
ICGV 91114	1730	2666	74
TMV 2	1651	2907	73
t-test	NS	*	

1. * Significant at P = 0.05; NS = Not significant.

During these three years, not a single seed of ICGV 91114 was sold as commercial produce in the open market. The farmers saved their produce as seed for the next season and the excess produce was sold to other farmers only for seed purpose. The total area under ICGV 91114 in the 2005 rainy season in 41 villages (18 *mandals)* is estimated to be 285 ha. It is also being grown in one village in the neighboring state of Karnataka.

Farmers were also made aware of the results of controlled feeding trials of Deccani sheep at ICRISAT, Patancheru where ICGV 91114 gave higher live weight gain day^{-1} and nitrogen accretion indicating better digestibility of its haulm than the other varieties released for Andhra Pradesh (Vellaikumar et al. 2004).

The farmers in partner villages (West Narsapuram, Shivapuram and Rekulakunta) are now promoting ICGV 91114 in the district by sharing their produce with their relatives and neighbors. They have developed a sense of ownership over this variety. For large-scale adoption participation of farmers, NGOs, government agencies and traders will be essential.

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Seed Releases

New Groundnut Variety Pratap Mungphali 2 Released in Rajasthan, India

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Groundnut (*Arachis hypogaea*) is an important oilseed crop of Rajasthan, India, with an area of 0.24 million ha and production of 0.17 million t. Spanish groundnut (*A. hypogaea* subsp *fastigiata* var *vulgaris*) varieties currently occupy about 40% of the total groundnut area of the state. The remaining 60% area is covered by Virginia groundnut (*A. hypogaea* subsp *hypogaea* var *hypogaea*). The Spanish varieties such as JL 24 and GG 2, grown in the state, have low yields and are susceptible to diseases and insect pests.

Pratap Mungphali 2, a Spanish variety, was bred and developed from the cross ICGV 86055 x ICG (FDRS) 10 at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India. After preliminary evaluation at the Maharana Pratap University of Agriculture and Technology (MPUAT), Udaipur, Rajasthan as ICGV 92195, it was proposed in 2001 for evaluation in the All India Coordinated Varietal Trials as ICUG 92195, signifying a joint contribution from MPUAT and ICRISAT. The State Seed Sub-Committee for Agricultural Crops released it as Pratap Mungphali 2 in 2005 in Rajasthan. It is erect in growth habit and early in maturity (about 95 days). The leaves are green and elliptical. Pods are two-seeded with moderate reticulation, constriction and beak. Seeds are medium, spheroidal and pink in color. The oil content in Pratap Mungphali 2 (49.5%) is higher than that in JL 24 (48.8%).

In All India Coordinated Varietal Trials conducted at 10 locations in Udaipur, Pratapgarh, Durgapura (Jaipur) and Hanumangarh districts, Pratap Mungphali 2 produced a mean dry pod yield of 2494 kg ha^{-1} as compared with 2016 kg ha^{-1} of check JL 24, thereby exhibiting 23.7% pod yield superiority over the check. This variety also showed 25.9% superiority in seed yield over JL 24 (Table 1). In On Farm Trials conducted in Udaipur, Rajsamand,

Table 1. Comparative dry pod yield (kg ha^{-1}) and seed yield (kg ha^{-1}) of ICUG 92195 in All India Coordinated Varietal Trials conducted in Rajasthan, India during rainy season 2001–03.

Location	Trial[1]	ICUG 92195 (Proposed variety)		JL 24 (National check)		CD at 5%		CV (%)	
		Dry pod yield	Seed yield	Dry pod yield	Seed yield	Dry pod yield	Seed yield	Dry pod yield	Seed yield
Udaipur	2001 IVT-I (SB)	3233	2289	2366	1561	163.0	125.8	4.3	5.0
	2002 IVT-II (SB)	2833	2004	2616	1844	248.3	176.1	6.2	6.2
	2003 AVT (SB)	3475	2626	2495	1751	209.0	135.0	7.0	4.0
Pratapgarh	2001 IVT-I (SB)	2799	1883	2183	1370	154.5	110.6	4.4	5.0
	2002 IVT-II (SB)	3116	2189	2499	1737	127.4	109.6	3.2	3.95
	2003 AVT (SB)	3341	2379	2475	1678	130.0	87.0	4.0	9.0
Durgapura	2001 IVT-I (SB)	1042	440	984	424	NS[2]	NS	17.8	17.5
	2002 IVT-II (SB)	1389	719	1273	663	396.6	66.7	17.6	17.3
Hanumangarh	2001 IVT-I (SB)	2159	1221	1771	1114	338.3	66.3	11.5	11.4
	2002 IVT-II (SB)	1556	846	1500	1113	286.5	63.7	13.9	14.1
Mean (10 locations)		2494	1670	2016	1326				
Increase (%) over check		23.7	25.9						

1. IVT = Initial Varietal Trial; SB = Spanish bunch; AVT = Advanced Varietal Trial.
2. NS = Not significant.

Table 2. Performance of ICUG 92195 in Adaptive Trial Centre (ATC) and On Farm Trials (OFT) in Rajatthan, India during rainy season 2002-04.

	ATC		OFT				
			Dry pod yield (kg ha^{-1})				
Genotype	Dry pod yield (kg ha^{-1}) (2003)	Increase (%) over check	2002 (2 locations)	2003 (4 locations)	2004 (4 locations)	Mean	Increase (%) over check
ICUG 92195	1361		2600	2475	1860	2311	
JL 24 (National check)	1333	2.10	2200	2025	1700	1975	17.0
Local check			2000	1925	1650	1858	24.3

Chittorgarh and Bhilwara districts, Pratap Mungphali 2 produced mean pod yield of 2311 kg ha^{-1} as compared with 1975 kg ha^{-1} of check JL 24, resulting in 17.0% yield increase over the check (Table 2). Pratap Mungphali 2 is moderately resistant to early and late leaf spots and bud necrosis disease. It is also moderately resistant to *Spodoptera,* leaf miner and thrips.

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Phule Unap - A New Groundnut Variety for Western Maharashtra, India

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A new groundnut *(Arachis hypogaea)* variety Phule Unap (JL 286) was released in 2004 by the Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, Maharashtra, India for cultivation in 10 districts of western Maharashtra. This variety is suitable for *kharif* (rainy) and summer seasons. Phule Unap was recommended for pre-release during April 1998 and was recommended for release by the Research Review Committee on field crops in MPKV, Rahuri in 2004. It was released by Maharashtra Agricultural Universities Joint Agresco 2004. Phule Unap has longer flowering span of 40-45 days as against JL 24 with 22-25 days. It has medium seed size with 100-seed mass of 38 g and is tolerant to *Sclerotium rolfsii.* It is a derivative of cross JL 86 x NcAc 343-75. It gave higher (2493 kg ha^{-1}) dry pod yield than JL 24 (1883 kg ha^{-1}).

During the rainy season in 1998 and 1999 in All India Coordinated Research Project-Groundnut (AICRP-G) trials in zone III in Maharashtra, Phule Unap (JL 286) produced dry pod yield of 1329 kg ha^{-1} with superiority of 8.75% and 52.05% over national check JL 24 (1222 kg ha^{-1}) and zonal check TAG 24 (874 kg ha^{-1}), respectively (Table 1).

The overall performance of Phule Unap (JL 286) in various station, multinational and inter university trials since 1992 to 2003 during rainy season is encouraging (Table 2). The average dry pod yield was 2212.17 kg ha^{-1} with 12.72% increase over JL 24 (1963.46 kg ha^{-1}), 29.36% over TAG 24 (1710.76 kg ha^{-1}), 20.81% over TG 26 (1846.27 kg ha^{-1}) and 31.68% over SB-XI (1680.06 kg ha^{-1}). The farmers are impressed with the performance of

Table 1. Performance of Phule Unap (JL 286) in Initial Varietal Trials in three locations in zone III, Maharashtra, India during rainy season 1998 and 1999.

Entry	Dry pod yield (kg ha^{-1})			
	Akola	Jalgaon	Khargone	Mean
ISK-1-9811 (JL 286)	1495	1066	1163	1329
ISK-1-9814 (JL 24)	1450	1000	994	1222
ISK-1-9817 (TAG 24)	971	939	777	874
SE±	75.8	21.0	29.8	39.3
CD at 5%	213.8	59.2	84.2	108.5
CV (%)	15.6	6.2	8.2	13.3

Table 2. Overall performance of Phule Unap (JL 286) in various trials in Maharashtra, India during 1992 to 2003.

Trial[1]	Year	Location	Mean dry pod yield (kg ha^{-1})				
			JL 286	JL 24	TAG 24	TG 26	SB-XI
RRT	1992	Jalgaon	2493	1883	1583	–	–
SST	1993	Jalgaon	3563	3170	2741	–	2977
ST	1994	Jalgaon	1937	1354	1695	–	1039
MLT	1995 to 1999	5 locations	2287	2022	1783	1975	1728
Inter University	1996, 1997, 2003	8 locations	1979	1819	1700	1551	1665

1. RRT = Rod Row Trial; SST = Small Scale Trial; ST = Station Trial; MLT = Multilocation Varietal Trial.

Table 3. Performance of Phule Unap (JL 286) in Multilocation Varietal Trials during summer 2002 and 2003.

Entry	Pod yield (kg ha^{-1})						
	Jalgaon		Digraj		Rahuri	Padegaon	Pooled mean
	2002	2003	2002	2003	(2002)	(2002)	(kg ha^{-1})
JL 286	1776	1868	3260	3576	3385	3215	2847
TAG 24	1893	1974	3172	3889	3125	3020	2845
SB-XI	1776	1754	2500	4387	2604	1933	2492
SE±	4.2	124.8	9.7	166.7	9.5	218.5	
CD at 5%	11.60	334.9	26.80	46.06	26.25	603.8	
CV (%)	9.77	11.3	12.94	7.12	11.11	13.3	

Table 4. Overall performance of Phule Unap (JL 286) in various trials in Maharashtra, India.

Entry	Overall mean pod yield (kg ha^{-1}) (39 trials)	Shelling outturn (%)	Oil content (%)	Mean seed yield (kg ha-^{1})	Mean oil yield (kg ha^{-1})	Yield increase (%) of JL 286	
						Seed	Oil
JL 286	2213	67	50	1494	747		
Phule Pragati	1963	69	47	1353	636	10.42	17.45
TAG 24	1710	68	45	1193	537	25.23	39.11
TG 26	1916	67	48	1284	616	16.36	21.27
SB-XI	1680	71	48	1221	586	22.36	27.47

Phule Unap (JL 286) due to higher dry pod yield as well as haulm yield when compared with the varieties JL 24, TAG 24, TG 26 and SB - XI.

During summer 2002 and 2003 Phule Unap (JL 286) also performed well in multilocational trials. It had average pod yield of 2847 kg ha^{-1} with superiority of 14% over SB-XI (2492 kg ha^{-1}). (Table 3). In 39 various trials, Phule Unap (JL 286) showed an increase of 25.23% seed yield and 39.11% oil yield compared with TAG 24 (Table 4).

Phule Unap (JL 286) has an erect growth habit and is medium tall in height. It is Spanish bunch *(A. hypogaea* subsp *fastigiata* var *vulgaris)* type. The leaves are elliptical, elongated and green; flowering is sequential. Pods are bold with medium seeds, which are oblong and elongated. This variety has mainly two-seeded pods, rarely three-seeded pods having prominent beak, brick red in color, and shallow constriction. The oil content is 49-50%. The variety has no dormancy; hence the harvested produce can be used for immediate sowing.

Early-maturing, Large-seeded and High-yielding Groundnut Varieties ICGV 96466, ICGV 96468 and ICGV 96469

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Purpose of description

Large-seed size coupled with early-maturity and high-yield potential is a desirable combination in groundnut (*Arachis hypogaea*) as most of the early-maturing groundnut cultivars have small seeds and low yields. Three groundnut varieties (ICGV 96466, ICGV 96468 and ICGV 96469) possessing particularly the above three traits were developed through hybridization at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India, and were released by the Plant Materials Identification Committee of ICRISAT in 2004 for subsequent utilization in research and/or the development of groundnut

Origin and development

ICGV 96466, ICGV 96468 and ICGV 96469 were derived from three different crosses. The details of their pedigree and selection history are:

ICGV 96466: (ICGV 87882 x ICGV 87885)-F_2-P_8-P_1-B_1-B_1-B_1-B_1-B_1-B_1-B_1

ICGV 96468: (ICGV 87885 x Ll)- F_2-P_4-P_1-B_1-B_1-B_1

ICGV 96469: (ICGV 87885 x LI Duchoa)-F_2-P_5-B_2-B_1-B_1-B_1

(P refers to plant selection and B to bulk.)

The parental lines used in the above three crosses were: ICGV 87882, derived from a cross of ICGS 30 x Var. 28-206; ICGV 87885, derived from a cross of 91176 x TG 2; and ICGS 30, derived from a cross of Ah 2105x Chico.

Ah 2105 is a Viginia type (*A. hypogaea* subsp *hypogaea* var *hypogaea*) of Indian origin. It is of medium growth duration and has 100-seed mass of 40 g. Chico is an early-maturing, Spanish type (*A. hypogaea* subsp *fastigiata* var *vulgaris*) of germplasm from USA. Var. 28-206 is a Virginia type from Mali. It is of medium growth duration and has 100-seed mass of 45 g. Accession 91176 is an early-maturing Spanish type and has 100-seed mass of 38 g. Accession LI is a Spanish, erect type from Vietnam. It is of medium growth duration with 100-seed mass of 35 g.

Agronomic performance

Yield trials including the three groundnut breeding lines, ICGV 96466, ICGV 96468 and ICGV 96469 and two control cultivars, JL 24 (early-maturing) and Somnath (medium-maturing with large seed) were conducted at ICRISAT, Patancheru research farm during 1997-2001 in both rainy and postrainy seasons. Sowing was done on Alfisol fields, in triple lattice design, in 6 m^2 plots under broad-bed and furrow system. A fertilizer dose of 60 kg P_2O_5 and 400 kg gypsum ha^{-1} were applied and the crops were raised under full irrigation and plant protection care.

Four trials (three in rainy season and one in postrainy season) were harvested when the crop had accumulated 1470°Cd (equivalent to 90 days after planting in rainy season at ICRISAT, Patancheru). The other three trials

Table 1. Comparison of 100-seed mats (g) of groundnut varieties ICGV 96466, ICGV 96468 and ICGV 96469 with control cultivar JL 24 at 1470°Cd and 1605°Cd harvests during 1996 -2001 at ICRISAT, Patancheru, India.

Environment[1]	ICGV 96466	ICGV 96468	ICGV 96469	Control	
				JL 24	Somnath
1470°Cd harvest					
PR 1996/97	55	72	68	53	72
R 1997	50	56	50	43	49
R 1998	33	40	34	28	41
Mean	46	56	51	41	54
Increase (%) over JL 24	12	37	24		
1605°Cd harvest					
PR 1997/98	68	75	59	53	70
PR 1998/99	56	70	53	51	73
PR 1999/2000	48	52	41	42	55
PR 2000/01	42	51	41	35	50
Mean	54	62	49	45	62
Increase (%) over JL 24	20	38	9		

1. PR = Postrainy season; R = Rainy season.

Table 2. Pod yield of early-maturing large-seeded groundnut varieties at 1470°Cd in the rainy season (R) and po strainy season (PR) during 1996-99 at ICRISAT, Patancheru, India.

Variety	Pod yield (t ha^{-1})					Increase (%) over control	
	R 1997	R 1998	R 1999	PR 1996/97	Mean	JL 24	Somnath
ICGV 96466	2.41	1.55	2.00	3.94	2.48	8.3	21.6
ICGV 96468	2.17	1.80	1.47	4.08	2.38	3.9	16.7
ICGV 96469	2.66	2.07	2.39	3.76	2.72	18.8	33.3
JL 24 (control)	2.02	1.78	1.48	3.89	2.29		
Somnath (control)	1.81	1.67	1.37	3.33	2.04		
SE±	0.062	0.087	0.263	0.112			
Trial mean	2.12	1.71	1.23	3.79			
CV (%)	4.1	7.0	2.8	5.1			

Table 3. Pod yield of early-maturing large-seeded groundnut varieties at 1605°Cd in the postrainy season darin g 1997-2000 at ICRISAT, Patancheru, India.

Variety	Pod yield (t ha^{-1})				Increase (%) over control	
	1997/98	1998/99	1999/2000	Mean	JL 24	Somnath
ICGV 96466	3.83	3.55	2.71	3.36	-1.5	-14.1
ICGV 96468	4.01	4.21	2.79	3.67	7.6	-6.1
ICGV 96469	4.77	4.33	3.84	4.31	26.4	10.2
JL 24 (control)	4.06	3.30	2.87	3.41		
Somnath (control)	4.33	3.79	3.61	3.91		
SE±	0.084	0.120	0.177			
Trial mean	4.21	3.73	3.07			
CV (%)	2.8	4.5	5.7			

Table 4. Morphological, agronomical and seed quality traits of three high-yielding groundnut varieties.

Characteristics	ICGV 96466	ICGV 96468	ICGV 96469
Cultivar group	Spanish	Spanish	Spanish
Growth habit	Erect	Erect	Erect
Branching pattern	Sequential	Sequential	Sequential
Stem pigmentation	Absent	Absent	Absent
No. of primary branches[1]	4	5	6
No. of secondary branches[1]	0	0	0
Plant height and breadth[1] (cm)	19.8, 35.4	20.8, 38.6	23.0, 42.8
Leaf characters			
Size	Medium	Medium	Medium
Shape	Elliptic	Elliptic	Elliptic
Color	Light green	Light green	Light green
Flower color			
Standard	Orange	Orange	Orange
Crescent	Garnet	Garnet	Garnet
Crescent mark	Orange	Orange	Orange
Wing petal	Yellow	Yellow	Yellow
Pod characters			
Pod beak	Slight-moderate	Moderate-prominent	Absent
Pod constriction	Slight	Slight-moderate	Absent-slight
Pod reticulation	Moderate	Moderate	Slight
Pod ridge	Moderate	Moderate	Moderate
Pod length[2] (cm)	2.24	2.69	2.06
Pod breadth[2] (cm)	0.99	1.23	1.10
Seeds per pod	2-1	2-1	2-1
Shelling outturn[3] (%)	74	69	71
Seed characters			
Seed length[2] (cm)	1.11	1.31	1.09
Seed breadth[2] (cm)	0.62	0.68	0.72
100-seed mass[3] (g)	54	62	49
Seed color	Tan	Tan	Tan
Quality characters			
Oil[4] (%)	48.5	47.8	48.6
Protein[4] (%)	26.3	26.4	22.4
Maturity[5] (days)	100	100	100

1. Recorded on the postrainy season crop 2000/01 at 90 days after sowing at ICRISAT. Patancheru, India.
2. Recorded on the postrainy season crop 2000/01 at ICRISAT, Patancheru; average of 20 pods/seeds.
3. Average of four seasons at 1605°Cd.
4. Recorded in the postrainy season crop 2000/01.
5. Recorded on the rainy season crop at ICRISAT, Patancheru.

conducted in postrainy seasons were harvested when the crop had accumulated 1605°Cd (equivalent to 100 days after planting in the rainy season at ICRISAT, Patancheru). At 1470°Cd harvest, the 100-seed mass was 46 g for ICGV 96466, 56 g for ICGV 96468 and 51 g for ICGV 96469 compared to 41 g for JL 24 and 54 g for Somnath (Table 1). At 1605°Cd, the 100-seed mass was 54 g for ICGV 96466, 62 g for ICGV 96468 and 49 g for ICGV 96469 compared to 45 g for JL 24 and 62 g for Somnath. These three varieties had 12 to 37% greater 100-seed mass at 1470°Cd and 9 to 38% greater 100-seed mass at 1605°Cd compared to JL 24 (Table 1).

On comparing the pod yields at 1470°Cd harvests, the three new varieties out-yielded both the control cultivars and the gain was maximum in ICGV 96469, which showed 18.8 and 33.3% increase over the controls, JL 24 and Somnath, respectively (Table 2). At 1605°Cd harvests, the mean yields of the three new varieties were 3.36 (ICGV 96466), 3.67 (ICGV 96468) and 4.31 t ha^{-1} (ICGV 96469). ICGV 96469 out-yielded both the controls by 26.4% (JL 24) and 10.2% (Somnath) (Table 3).

The increase in pod yields of the three new varieties at 1470 to 1605°Cd ranged from 35.5 to 58.5% compared to 48.9% increase in JL 24 and 91.7% in Somnath. JL 24 is a representative early-maturing variety and therefore, the three new varieties could be considered of similar maturity duration.

Plant characters

The groundnut varieties ICGV 96466, ICGV 96468 and ICGV 96469 are distinct from each other. A detailed description of these varieties is given in Table 4.

Prospects

ICGV 96466, ICGV 96468 and ICGV 96469 arc large-seeded, early-maturing and high-yielding varieties. These can be used as parents in groundnut breeding. The varieties can also be evaluated for direct use as commercial cultivars, particularly in short groundnut cropping environments. Small quantity of seeds of these varieties for research purpose can be obtained from the genebank at ICRISAT, Patancheru.

Groundnut Cultivar Nyanda (ICGV 93437) Released in Zimbabwe

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Purpose of description

The government of Zimbabwe in 2000 released the groundnut (*Arachis hypogaea*) variety ICGV 93437 as Nyanda for commercial cultivation in the country. Cultivar Nyanda significantly out-yielded the popular cultivar Falcon by 13.5%. It matures earlier than Falcon by six days and is almost similar to Falcon in shelling outturn and seed size.

Origin and development

Cultivar Nyanda (ICGV 93437) is an early-maturing, high-yielding, Spanish (*A. hypogaea* subsp *fastigiata* var *vulgaris)* breeding line developed at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India during 1990s. It was derived from a cross between two early-maturing advanced breeding lines, ICGV 86063 and ICGV 86065, developed at ICRISAT, Patancheru. The full pedigree and selection history of ICGV 93437 is:

ICGV 86063 x ICGV 86065 F_2 -P_{30} - B_1 - B_1 -B_1
(P refers to plant selection and B to bulk.)

ICGV 86063 originated from Ah 65 x Chico cross and ICGV 86065 from Var. 2-5 x Robut 33-1 cross. Ah 65 and Chico are Spanish germplasm lines from USA, the latter being early-maturing (Bailey and Hammons 1975). Var. 2-5 and Robut 33-1 (also known as Kadiri 3) are Indian cultivars, the former being Spanish and the latter Virginia (*A. hypogaea* subsp *hypogaea* var *hypogaea*) bunch type.

Agronomic performance

Yield trials including the breeding line ICGV 93437 and two controls, JL 24, an early-maturing and high-yielding Indian cultivar, and Chico, an early-maturing germplasm line from USA were conducted at ICRISAT, Patancheru during 1993-96, in two rainy **and** two postrainy seasons.

The trials were sown in Alfisol fields, in triple lattice design, in 6 m^2 plots under broad-bed and furrow system. A fertilizer dose of 60 kg P_2O_5 and 400 kg gypsum ha^{-1} were applied and the crops were raised under full irrigation and plant protection care.

The trials were harvested when the crop accumulated 1240°Cd (degree days) [equivalent to 75 days after sowin g (DAS) at ICRISAT, Patancheru rainy season] and 1470°Cd (equivalent to 90 DAS at ICRISAT, Patancheru, rainy season]. At 1240°Cd harvest, ICGV 93437 produced 2.38 t ha^{-1} pod yield (Table 1). This represents 29.8% increase over JL 24 and 48.1% over Chico. Similarly at 1470°Cd harvest, ICGV 93437 produced 13.1% higher yield compared to JL 24 and 47.8% compared to Chico (Table 2).

On comparing the pod yield performance of the groundnut varieties under 1240°Cd and 1470°Cd harvests , gain was 26.11 % for ICGV 93437, 44.62% for JL 24 and 26.41% for Chico (Tables 1 and 2) indicating mat optimum growth period of ICGV 93437 is about 90 days at ICRISAT, Patancheru in the rainy season.

Table 1. Pod yield of groundnut cultivar ICGV 93437 under 1240°Cd crop duration in the rainy season (R) and p ostrainy season (PR) during 1993-96 at 1CRISAT, Patancheru, India.

	Pod yield (t ha^{-1})					Increase (%) over control	
Cultivar	R 1993	R 1995	PR 1993/94	PR 1995/96	Mean	JL 24	Chico
ICGV 93437	1.62	1.29	0.99	2.38	1.57	29.8	48.1
JL 24 (control)	1.31	0.77	0.50	2.27	1.21		
Chico (control)	0.71	0.76	0.36	2.40	1.06		
SE±	0.083	0.062	0.065	0.057			
Trial mean	1.20	1.09	0.95	2.52			
CV(%)	12	10	12	4			

Table 2. Pod yield of groundnut cultivar 1CGV 93437 under 1470°Cd crop duration in the rainy season (R) and pos trainy season (PR) during 1994-96 at 1CRISAT, Patancheru, India.

	Pod yield (t ha^{-1})					Increase (%) over control	
Cultivar	R 1994	R 1995	PR 1994/95	PR 1995/96	Mean	JL 24	Chico
ICGV 93437	1.26	1.62	2.07	2.97	1.98	13.1	47.8
JL 24 (control)	1.33	1.08	2.00	2.58	1.75		
Chico (control)	0.57	0.73	1.24	2.83	1.34		
SE±	0.058	0.064	0.069	0.087			
Trial mean	1.43	1.21	2.31	2.96			
CV (%)	7	9	5	5			

Table 3. Performance of ICGV 93437 and control cultivar Falcon in Zimbabwe, 1996-2001.

Cultivar	Days to maturity[1]	Pod yield[2] (t ha^{-1})	Increase (%) over Falcon	Shelling outturn[1] (%)	100-seed mass[1] (g)
ICGV 93437	115	1.76	13.5	73	28
Falcon	121	1.55		72	29

1. Mean based on 42 trials.
2. Mean based on 51 trials.

ICGV 93437 was tested in 51 yield trials in Zimbabwe during 1996-2001. It out-yielded the popular check cultivar Falcon by 13.5% (Table 3). On average, ICGV 93437 matured six days earlier compared to the control cultivar. ICGV 93437 had 73% shelling outturn and 100-seed mass of 28 g, which were almost similar to the cultivar Falcon.

Table 4. Morphological, agronomical and seed quality traits of groundnut cultivar ICGV 93437.

Trait	Description
Cultivar group	Spanish
Growth habit	Erect
Branching pattern	Sequential
Stem pigmentation	Green
Leaf characters	
Size	Large
Shape	Wide elliptic
Color	Green
Flower color	
Standard	Orange-yellow
Crescent	Yellow
Wing petal	Yellow
Pod characters	
Pod beak	Slight
Pod constriction	Slight
Pod reticulation	Slight
Pod ridge	Slight
Seeds per pod	2-1-3
Pod length[1] (mm)	25.1
Pod breadth[1] (mm)	12.1
Shelling outturn[2] (%)	71
Seed characters	
Seed length[1] (mm)	12.5
Seed breadth[1] (mm)	9.1
100-seed mass[2] (g)	33
Seed color	Tan
Seed quality characters	
Oil[2] (%)	45.7
Protein[3] (%)	23.5
Maturity[4] (days)	90

1. Kadoma Research Center, Zimbabwe, 1999/2000.
2. Average of 4 seasons at 1470°Cd at ICRISAT, Patancheru, India.
3. Average of 3 seasons at 1470°Cd at ICRISAT, Patancheru, India.
4. Recorded on rainy season crop at ICRISAT, Patancheru, India.

Plant characters

The cultivar Nyanda could be classified as Spanish type botanically. It has erect growth habit, sequential branching pattern and green plant color. More details of morphological, agronomical and seed quality traits are given in Table 4.

Availability of seeds

The breeder and foundation seeds of cultivar Nyanda are maintained by Seed Co Limited, Rattray Arnold Research Station, PO Box CH 142, Chisipite, Harare, Zimbabwe. Small quantity of seeds of this variety for research purpose can also be obtained from ICRISAT genebank, Patancheru, India under the 'Material Transfer Agreement'.

Reference

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SC Orion - A New Large-seeded Groundnut Variety Released in Zimbabwe

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Groundnut *(Arachis hypogaea)* is a very important component of snack foods such as roasted and salted peanuts and peanut butter. However, production in Zimbabwe of groundnut varieties suitable for confectionery use has dwindled, and local processors are having difficulty sourcing their processing requirements.

Although groundnuts are grown widely in Zimbabwe, the long-duration confectionery types are only successfully grown with irrigation and therefore are grown on a limited area. However, under these conditions, where input use and management levels are high, very high yields of acceptable confectionery quality can be produced.

Table 1. Relative performance of Flamingo and SC Orion in trials conducted during 2001/02-2003/04 in Zimbabwe.

Characteristic	Trials	Flamingo	SC Orion	SEm+	LSD (5%)	Significance of F - test[1]
Days to 50% flower	11	40.1	39.9	0.25	0.8	NS
Days to harvest	17	165.9	158.9	1.60	4.8	**
Defoliation at harvest (%)	15	84.5	90.5	1.00	3.1	***
Pod yield (t ha^{-1})	17	4.98	5.22	0.153	0.46	NS
Shelling outturn (%)	17	67.1	71.6	0.87	2.6	**
Seed yield (t ha^{-1})	17	3.39	3.75	0.128	0.38	NS
100 - seed mass (g)	17	53.3	81.1	1.72	5.17	***
Pod drop (%)	17	1.33	3.80	0.993	2.98	NS
Retention on 9.5 x 31.75 mm slotted screen (%)	17	19.0	55.2	1.39	4.2	***
Sound mature seeds (%)	17	49.2	41.3	3.37	10.1	NS
Seed appearance[2]	17	6.76	6.82	0.166	0.50	NS
Seed uniformity[2]	17	6.29	6.47	0.151	0.45	NS

1. NS = Not significant; ** = Significant at 1% level; *** = Significant at 0.1% level.
2. Scored on a 0-10 scale where 0 = poor and 10 = excellent.

One of the quality characteristics sought after by processors locally and abroad is large uniform seed size. An important objective of the groundnut breeding program of Seed Co Limited, Zimbabwe has been to develop varieties that have large seeds of uniform shape and size, and produce high yields when grown with irrigation.

Some progress has been made in achieving these objectives, although maintenance of uniformity of size and shape has proved difficult when approaching the larger seed sizes. A number of breeding lines have shown promise and Seed Co Limited proposed the release of one breeding line for this purpose. The variety was named SC Orion and the Variety Release Panel of the Ministry of Lands, Agriculture and Rural Resettlement, Zimbabwe approved its recognition and release on 26 November 2004.

SC Orion was selected from the cross (ICGV-SM 90710 x MGS 3) made in 1994. It was evaluated in 17 trials during the 2001/02 to 2003/04 crop seasons. Evaluation was conducted on research stations and commercial farms where the trials were planted early (usually in early October) with irrigation, and grown under high levels of management. A summary of relative performance of SC Orion and Flamingo (the only other commercially available variety of this type in Zimbabwe) in these trials is shown in Table 1.

SC Orion matures, on average, in about 159 days, with the range in the trials reported being 136 to 176 days. On average, SC Orion had a 5% pod yield superiority over Flamingo. It has considerably larger seed than Flamingo. Shelling outturn varied between 64.3 and 77.2% and 100-seed mass varied from 55 to 111 g depending on the location. The seeds of SC Orion are dark tan, rounded and uniform in size and shape. Some seeds have flat end surfaces.

SC Orion pods are typical of the Virginia cultivar group *(A. hypogaea* subsp *hypogaea* var *hypogaea)* being mainly two-seeded. Pods are characterized by a slight beak and medium constriction. One- and three-seeded pods do occur but not frequently. The pod length averages 46.5 mm and pod breadth averages 18.9 mm. Seed length averages 22.4 mm and seed breadth averages 13.2 mm. SC Orion can be distinguished from Flamingo by seed color, slightly shorter stature and greater susceptibility to foliar diseases, particularly cercospora leaf spot and web blotch.

Limited processing evaluation for market acceptability has been carried out by one of the local processing companies, and SC Orion was found to blanch and roast satisfactorily and has a satisfactory taste.

Huayu 22 - A High-yielding Large-seeded Groundnut Variety with Improved Seed Quality

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Huayu 22, a large-seeded groundnut (*Arachis hypogaea*) variety, suitable for export, was developed by Shandong Peanut Research Institute (SPRI) and released by the Shandong Provincial Crops Approval Committee in 2003 in China. Huayu 22 was derived from a cross between 8014 and Haihua 1 (dry seeds treated with ^{60}Co) following modified pedigree method.

In the new groundnut lines tests at SPRI from 1997 to 1999, Huayu 22 out-yielded the control Luhua 10 by 25.6% (Table 1). In the Shandong Provincial New Groundnut Variety Trials from 2000 to 2001, the dry pod yield of Huayu 22 averaged 4.95 t ha^{-1} in 22 locations, 7.6% higher than the control Luhua 11. In a field demonstration test at eight locations in 2002, Huayu 22 gave 5.58 t ha^{-1} pod yield, 8.8% higher than Luhua 11.

Huayu 22 has an erect growth habit, sequential flowering and dark green leaves. The main stem is about 40 cm tall. The plant has 7-8 primary branches. The pods are mostly two-seeded and cluster around the main taproot in the soil. The 100-pod mass is 250 g and 100-seed mass is 110 g. The shelling outturn is 72.5% and the seeds contain 49.2% oil and 24.3% protein. The oleic acid/linoleic acid (O/L) ratio is 1.71. The variety matures in 130 days in the spring season.

Huayu 22 is resistant not only to web blotch, early leaf spot and late leaf spot but also to drought and waterlogging (Table 2). Thus, it has wide adaptability in northern China. Huayu 22 is one of the groundnut varieties that has the best comprehensive characteristics in China.

Table 1. Pod and seed yield of Huayu 22 in different trials in China.

Trials	Year	No. of sites	Yield (t ha^{-1})		Increase (%) over control		Control
			Pod	Seed	Pod	Seed	
New lines tests	1997-99	9	5.18	3.78	17.7	17.4	8130
					25.5	25.6	Luhua 10
					7.5	7.2	Luhua 14
Provincial trials	2000-01	22	4.95	3.53	7.6	4.9	Luhua 11
Field demonstration test	2002	8	5.58	4.03	8.8	7.5	Luhua 11

Table 2. Reaction of Huayu 22 to biotic and abiotic stresses in China.

Variety	Score[1]				
	Web blotch	Early leaf spot	Late leaf spot	Drought	Waterlogging
Huayu 22	1	1	2	1	1
Luhua 11	4	4	2	2	2
Baisha 1016	7	5	1	5	4

1. Scored on a 0-9 scale where 0 = immunity, 1-2 = highly resistant, 3-5 = moderately resistant, 6-7 = susceptible and 8-9 = highly susceptible.

RAPD Polymorphism Among Groundnut Genotypes Differing in Disease Reaction to Late Leaf Spot and Rust

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Late leaf spot (LLS) and rust are two economically important diseases in groundnut *(Arachis hypogaea)* causing yield losses up to 50% (Subrahmanyam et al. 1980). Breeding for resistance to LLS and rust is a cost-effective and viable option. Several breeding lines/genetic stocks/ varieties resistant to these foliar diseases are reported (Subrahmanyam et al. 1995, Gowda et al. 2002a, 2002b). Resistance to rust is controlled by two recessive genes (Knauft 1987), whereas resistance to LLS is controlled by duplicate complementary recessive genes (Motagi et al. 2000). Identification of the resistant genotypes needs careful, repeated and thorough screening under ideal epiphytotic conditions, which is time consuming and laborious. Molecular markers associated with LLS and rust would hasten the process of identification of resistant genotypes. Information on such markers is lacking. Only seven out of 480 RAPD (random amplified polymorphic DNA) primers were polymorphic in 70 selected genotypes with wide variability (Subramanian et al. 2000). Phylogenetic relationships among cultivated groundnut and *Arachis* wild species could be established by using RAPD and ISSR (Inter simple sequence repeat) primers (Raina et al. 2001). Hopkins et al. (1999) developed six fluorescent SSR (simple sequence repeat) primer pairs, which discriminated 19 accessions into 17 unique genotypes. Subsequently, more number of SSR primers were developed and polymorphism among cultivated groundnut genotypes was reported (He et al. 2003, Ferguson et al. 2004, Moretzsohn et al. 2004). In groundnut, transcripts involved in resistance responses to LLS were recently identified (Luo et al. 2005). Our study was carried out to identify molecular polymorphism among the groundnut genotypes differing in disease reaction to LLS and/or rust.

Based on disease reaction, 19 genotypes (Table 1) were screened with RAPD primers Kit A, Kit J and Kit F from Integrated DNA Technologies (IDT), USA. Young leaves were collected from a single plant grown in the experimental fields at Trombay, Mumbai, India. DNA was isolated by following cetyltrimethylammonium bromide (CTAB) method (Saghai-Maroof et al. 1984) with minor modification. Phenolics activity was nullified by adding 1% 2-mercaptoethanol in extraction buffer. The polymerase chain reaction (PCR) was performed in Mastercycle gradient (Eppendorf, Germany) with an annealing temperature of 38°C. Reaction mixture for PCR (25 µL) consisted of IX *Taq* buffer A, 250 µM dNTP, 50 p moles of primer, 20 ng DNA and 1U of *Taq* polymerase (Bangalore Genei Pvt. Ltd., India). The reaction was carried out under the following temperature conditions: 94°C for 5 min initial denaturation with 35 cycles of 92°C for 30 s, 38°C for 1 min, 72°C for 2 min with a final extension at 72°C for 10 min. Amplified product was analyzed in 1% agarose gel with IX TBE buffer at 80 V for 2 h, stained with ethidium bromide and documented by gel documentation system (Syngene).

Table 1. Disease scores for rust and late leaf spot in groundnut genotypes during rainy season at Trombay, Mumbai, India.

	Rust		Late leaf spot	
Genotype	2002	2003	2002	2003
VG 9514	1	1	1	1
TFDRG 5	1	1	3	3
GPBD 4	1	1	1	1
GBFDS 272	-	-	-	-
NcAc 343	-	-	-	-
Mutant 28-2	3	3	1	1
DTG 27	2	2	2	2
DTG 57	1	2	1	2
DTG 58	1	1	1	3
DTG 60	2	2	2	2
TDG 56	2	3	2	3
TMV 2	8	9	9	8
SB XI	8	8	8	8
JL 24	7	8	8	8
TAG 24	8	8	8	8
TG37A	7	8	8	7
TG 39	8	7	8	8
TG 40	8	8	8	8
TPG 41	8	8	8	7

1. Scored on a 1-9 rating scale where 1 = no disease and 9 = severe incidence with 50-100% defoliation (Subrahmanyam et al. 1995).

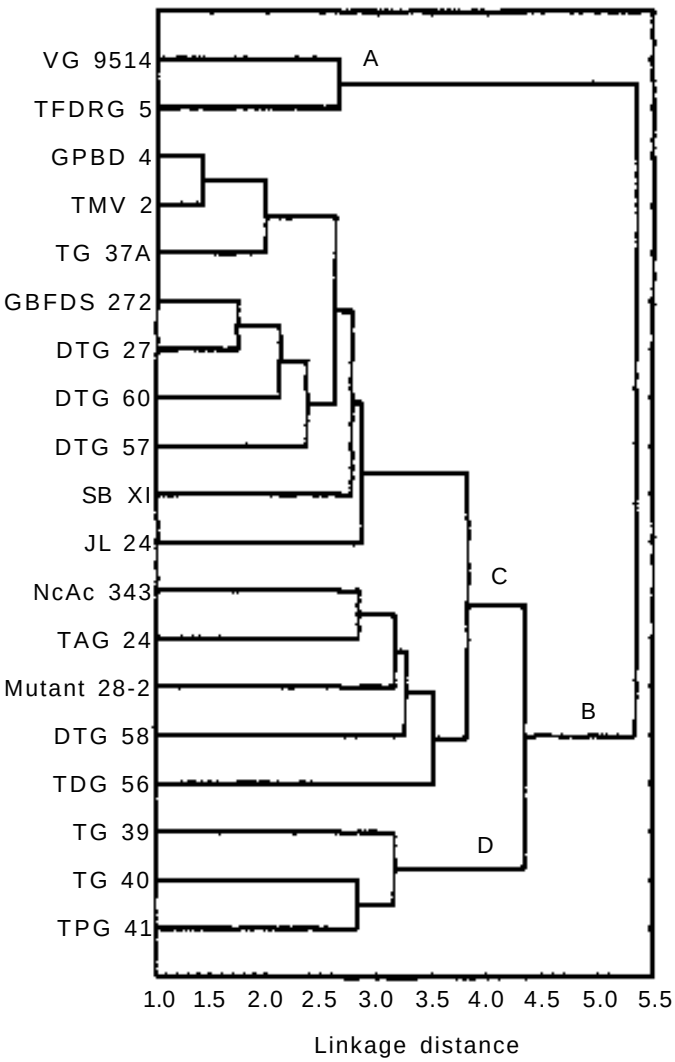

Figure 1. Dendrogram of 19 groundnut genotypes differing in disease reaction to late leaf spot and rust.

Amplified products were scored for presence and absence of a band by assigning the values 1 and 0 respectively. Polymorphism (%) for each primer was computed as $P = (N_p/N_a)*100$, where N_a is the total number of amplified fragments and N_p is the number of polymorphic fragments. Genetic distance was calculated based on Euclidean distance and dendrogram was constructed based on UPGMA (unweighted pair-group method of arithmetic average) using Statistica software (Statistica 1996).

Field disease reaction indicated that VG 9514, TFDRG 5, GPBD 4, DTG 27, DTG 57, DTG 58, DTG 60, TDG 56 and Mutant 28-2 are resistant while other test genotypes are susceptible to LLS and rust (Table 1). Of the 50 primers screened, 11 exhibited polymorphism among the 19 genotypes. The extent of polymorphism ranged from 12.5% to 76.9%, with an average of 37.5% (Table 2). Among the primers, Kit A19 revealed the highest polymorphism, followed by Kits J 17, A 3 and J 1. These results indicated that the cultivated groundnut has lower polymorphism at DNA level as reported earlier (Halward et al. 1991, Kochert et al. 1991, Raina et al. 2001). Based on Euclidean distance, the similarity matrix was made among 19 genotypes by analyzing 135 RAPD bands from the pooled data of all 11 primers. Genetic distance among the genotypes ranged from 1.41 to 6.40. The distances further revealed that TMV 2 and GPBD 4 were the nearest, whereas VG 9514 and DTG 57 were the farthest.

The dendrogram among the genotypes revealed two major clusters at a linkage distance (Euclidean distance) of around 5.3 (Fig. 1). TFDRG 5 and VG 9514 formed

Table 2. RAPD polymorphism among 19 groundnut genotypes.

Primer	Sequence	Number of total bands	Number of polymorphic bands	Polymorphism (%)
Kit A3	AGT CAG CCA C	8	5	62.5
Kit A8	GTGACGTAGG	14	6	42.8
Kit A19	CAA ACG TCG G	13	10	76.9
Kit J1	CCC GGC ATA A	19	10	52.6
Kit J4	CCG AAC ACG G	16	2	12.5
Kit J5	CTC CAT GGG G	11	2	18.2
Kit J6	TCG TTC CGC A	8	1	12.5
Kit J 12	GTC CCG TGG T	7	1	14.3
Kit J14	CAC CCG GAT G	13	3	23.1
Kit J 17	ACG CCA GTT C	14	9	64.3
Kit F10	GGA AGC TTG G	12	2	16.7
Total		135	51	
Average		12.3	4.6	37.5

separate cluster and are resistant to LLS and rust. VG 9514 was derived from CO 1 and *Arachis cardenasii* (Varman 1999). TFDRG 5 was a derivative from VG 9514 and TAG 24. The cluster B is subdivided into two sub-clusters C and D at a linkage distance of around 4.3. Among these, sub-cluster D comprised TG 39, TG 40 and TPG 41, which are susceptible to LLS and rust and incidentally these have large seeds. Further, sub-cluster C included both resistant and susceptible genotypes. Separation of VG 9514 and TFDRG 5 from rest of the genotypes could be due to their ancestry involving wild species. Similarly, it could be due to the large seed trait that TG 39, TG 40 and TPG 41 formed a distinct cluster. Current results could not associate any markers with resistance or susceptibility to rust and/or LLS. Similar absence of association between RAPD markers and resistance to LLS and rust was noticed earlier (Reddy et al. 2004).

This study is a beginning towards detection of polymorphism for resistance to LLS and/or rust. Further studies with other molecular markers for genotyping and tagging of resistance genes for these diseases will be undertaken.

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An Effective Method for Cloning of Partial MADS-box Genes Related to Flower Development in Groundnut

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The key genes in the developmental control of eukaryotes are often members of a very limited number of multigene families which encode transcription factors. Such homeobox genes have been thought to act as homeotic selector genes that are involved in differentiating different body regions from each other, probably by activating or repressing different sets of downstream genes in different parts of the body (Theissen et al. 2000). Recent studies have provided insight that inflorescence and flower development in higher eudicotyledonous flowering plants are determined by a network of regulatory genes which are organized in a hierarchical fashion (Theissen and Saedler 1998). In this, the late- and early-flowering genes are triggered by environmental factors such as day length, light quality and temperature.

The MADS-box is a highly conserved sequence motif found in the family of transcription factors. The conserved domain was recognized after the first four members of the family were identified as MCM1, AGAMOUS, DEFICIENS and SRF (serum response factor). The name MADS was constructed from the "initials" of these four "founder" proteins on which the definition of this gene family is based (Schwarz-Sommer et al. 1990). The MADS-box genes of plants are scattered throughout the entire plant genomes (Theissen et al. 2000) and by now, over a hundred MADS-box sequences have been found in species from all eukaryotics. MADS-domain proteins, like many other eukaryotic transcription factors, have a modular structural organization (Shore and Sharrocks 1995). The family of MADS-domain proteins has been subdivided into several distinct subfamilies. Most MADS-domain factors play important roles in plant developmental processes. Prominently, the MADS-box genes in flowering plants are the "molecular architects" of flower morphogenesis (Coen and Meyerowitz 1991, Angenent et al. 1995).

The MADS domain is by far the most highly conserved region of proteins (Purugganan et al. 1995). Based on the most conserved sequence region of the MADS box, a pair of degenerate primers were designed and used to amplify the genomic DNA of groundnut (*Arachis hypogaea*) in this study. The results indicate that an amplified fragment showed a high homology to the MADS-box protein of *Arabidopsis thaliana.* This study laid the foundation for obtaining the full length of MADS-box gene in groundnut.

Materials and methods

Seeds of groundnut cultivar JL 24 were planted in pots and maintained in the greenhouse. Genomic DNA was isolated from the young leaves by using the method described by Porebski et al. (1997) and Puchooa (2004).

Based on conserved amino acids found in the MADS domain of plant MADS-box genes, degenerate primers were designed to amplify the MADS-box gene homologues. The two forward primers used were MADSF1, 5'-ATGGG(ATCG)(AC)G(ATCG)GG(ATCG)AA(AG)AT(ACG)GA-3' and MADSF2,5'-(ATCG)TG(CT)GA(CT)GC(ATCG)GA(AG)GA(AG)GT(ATCG)GC-3' and the two reverse primers were MADSR1, 5'-GC(ATCG)AC(CT)TC(ATCG)GC(AG)TC(CT)AA-3' and MADSR2, 5'-GC(ATCG)AC(CT)TC(ATCG)GC(AG)TC(CT)CA(ATCG)AG-3'. A50μl PCR (polymerase chain reaction) contained 50 ng genomic DNA, 25 pmol

of each degenerate primer, 0.1 mM of each dNTP, and IX Reaction Buffer (including 2.0 mM MgS04). Touchdown PCR was used to amplify the expected fragment. The reaction was heated at 94°C for three min, then 1.5 unit of *Taq* DNA polymerase (New England BioLabs) was added to each reaction tube. Ten cycles of amplification were carried out, with denaturation at 94°C for 50 sec, annealing at 61°C to 50°C for 50 sec and extension at 72°C for 60 sec. The annealing temperature of the reaction was decreased 2°C every second cycle from 61°C to a "touchdown" at 50°C. Subsequently, all the reaction tubes underwent thirty cycles with the annealing temperature at 50°C, followed by a final extension at 72°C for 10 min. PCR products of the expected size were excised from agarose gels and cloned into pGEM-T easy vector (Promega). The clones were confirmed by PCR and restriction enzyme digestion prior to sequencing. The sequences were aligned with nucleotide sequences in Gene Bank by using MegaBlast search program (http://www.ncbi.nlm.nih.gov).

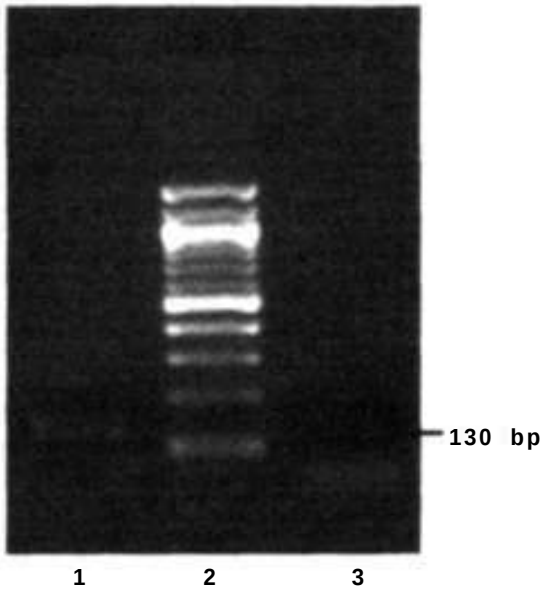

Figure 1. PCR amplification of fragment with expected size - Lane 1: JL 24; Lane 2: 100 bp DNA Ladder; Lane 3: Control (sterile distilled water).

Results and discussion

A 130 bp of the expected fragment named ApMADS1 was obtained by PCR amplification by using the primers MADSF1 and MADSR2 (Fig. 1). ApMADS1 was recovered from agarose gel and cloned into pGEM-T easy vector. Positive clones were confirmed by colony PCR and *Eco*Rl digestion (Fig. 2) and sequenced. Figure 3 shows the nucleotide sequences and deduced amino-acid sequences. When alignment was carried out using the GeneBank nucleotide database and Megablast search program, ApMADS1 was 79% homologous to MADS-box transcription factor HAM137 from sunflower

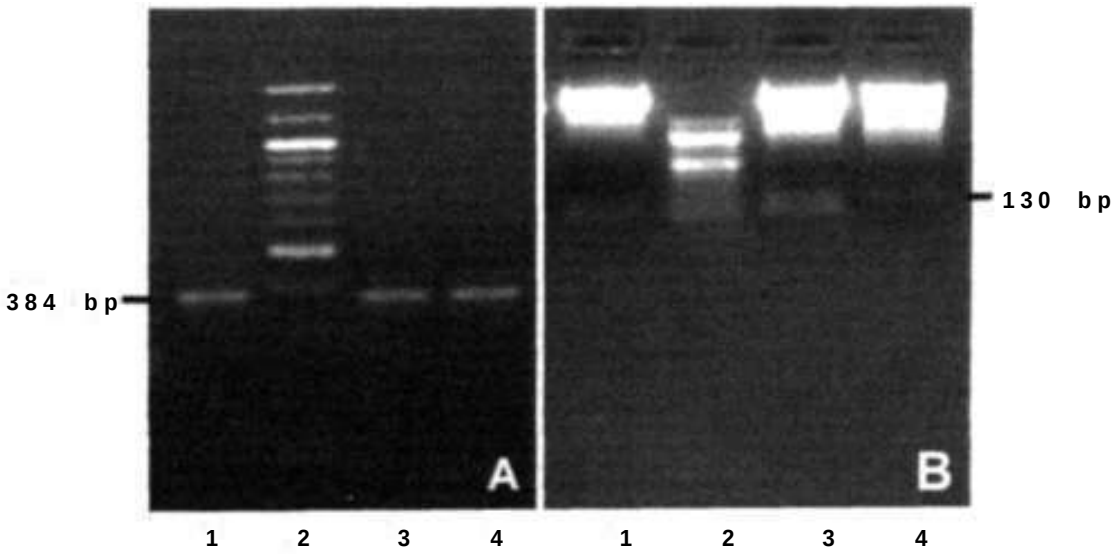

Figure 2. Clones confirmation by PCR amplification (A) using forward and reverse primer of M13 and *EcoR*1 digestion (B) - Lanes 1, 3, 4: Clone containing expected fragment; Lane 2: 100 bp DNA Ladder.

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ATGGGGCGTGGGAAGATAGAGATCAAGAGGATTGAGAACACTACAAATCGCCAAGTAACC
 M  G  R  G  K  I  E  I  K  R  I  E  T  T  N  R  Q  V  T
TTTTGCAAGCGCGGAAATGGTCTTCTCAAGAAAGCTTATGAGTTATCTGTGCTGTGTGACG
 F  C  K  R  G  N  G  L  L  K  K  A  Y  E  L  S  V  L  C  D
CCGAGGTGG
 A  E  V
```

Figure 3. Nucleotide sequences and deduced amino acid sequences (shaded regions indicate the position of forward and reverse primers).

(*Helianthus annum*). When discontiguous MegaBlast and Refseq_RNA were chosen, ApMADS1 showed identity ranging from 79% to 84% with 26 MADS-box mRNA. It can be concluded that ApMADS1 is a kind of MADS-box gene in groundnut.

Homology cloning method is effective and efficient, and used widely for gene cloning as confirmed by the result in this study. Compared with common homology cloning method, genomic DNA was used as the template for PCR amplification in this study. Therefore, this method is more simple and cheaper. Based on the sequence of ApMADS1, specific primers were designed and used for the amplification of 5' and 3' RACE. Some expected fragments from 5' and 3' RACE were obtained. Further work on the characterization of putative genes is currently ongoing. Our results indicated that the homology cloning method based on genomic DNA is feasible for MADS-box gene cloning in groundnut. The availability of such genes can be used to study the control of floral patterning thus providing an ideal genetic tool kit to study the diversification of flower architecture and its possible alteration through genetic engineering (Pavan Prakash and Kumar 2002).

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Pathology

A New Report on the Occurrence of Powdery Mildew of Groundnut in Maharashtra, India

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Although several groundnut (*Arachis hypogaea*) foliar diseases have been reported in India, early and late leaf spots and rust are the most widely distributed. Powdery mildew (*Oidium arachidis*), a very minor foliar disease of groundnut, has been reported in many countries, viz, Mauritius, Israel, Portugal, Tanganyika and India. The first incidence of powdery mildew on groundnut in India was reported on Spanish (*A. hypogaea* subsp *fastigiata* var *vulgaris)* varieties during *kharif* (*rainy* season) 1986 at the National Research Centre for Groundnut (NRCG), Junagadh, Gujarat by Ghewande and Reddy (1987). But so far this disease was not reported in the state of Maharashtra. During *rabi* (postrainy season) of 1999/ 2000, this disease was noticed on F_3 generation of a cross ICGV 86031 x TAG 24 at the Oilseeds Research Station, Jalgaon, Maharashtra (Figs. 1 and 2). The first record of this disease was noticed in February 2000 at the Oilseeds Research Station, when the rabi-sown crop was at pod maturity stage. Subsequently, powdery mildew was reported in February 2003 and 2004 in research fields as well as in farmers' fields in Jalgaon area (Table 1) (Anonymous 2004). The incidence of powdery mildew was moderate to severe in various *rabi / summer* seasons.

Figure 1. Powdery mildew of groundnut

Table 1. Distribution and severity of powdery mildew of groundnut during *rabi / summer* in Jalgaon, Maharashtra, India.

Year	Date of sowing	Date of first appearance of disease	Genotypes	Severity at maturity stage
1999-2000	First week, October 1999	18 February 2000	ICGV 86031 x TAG 24(F_3)	90% (Research farm)
2001-02	6 October 2001	15 February 2002	SB - XI	2% (Research farm)
2002-03	7 October 2002	Second week, February 2003	ICGS 76, 1CGV 86325, SB-XI, TAG 24	1-40% (Research farm)
2003-04	First fortnight, January 2004	Last week, February 2004	SB-XI	10-60% (6 farmers' fields)
2004-05	1 October 2004	5 February 2005	TAG 24 SB - XI	10-25% (Research farm) 5-60% (7 farmers' fields)

Figure 2. Powdery mildew on groundnut genotype JALW 41 (ICGV 86031 x TAG 24) in a field at the Oilseeds Research Station, MPKV, Jalgaon, Maharashtra, India.

The scientists of this research station jointly conducted the survey work of groundnut fields in Jalgaon district during 15-18 March 2005 and on 7 April 2005. During the survey, some groundnut fields in village Kasoda, taluka Erandol were moderately to severely affected by powdery mildew. The crop was sown in these fields during the first week of December 2004 to second week of January 2005. The variety SB-XI was sown by the farmers. The incidence of powdery mildew was 20 to 60% in various fields. Powdery mildew was also noticed in research trials on 16 April 2005 but the incidence was in traces and further spread was not observed. However, 10-25% incidence was observed on TAG 24 in breeder seed production plot at Jalgaon on 4 May 2005.

Ghewande and Reddy (1987) had recorded powdery mildew on groundnut when the crop was about 38 days old and average temperature and relative humidity were 27.2-29.2°C and 79.3-97.7%, respectively. The disease developed as white floury patches on the ventral surface of upper leaflets. These patches were found to originate as dull, minute, discolored specks from which a powdery mass radiated. The center of the spot later becomes brown and necrotic (Smith 1984). Microscopic examination showed similar description of oidia as recorded by Ghewande and Reddy 1987). The oidia were deciduous, elliptical, barrel-shaped, hyaline and unicellular. Their size varied from 34.2-50.96 µm x 17.1-24.51 µm. The conidiophores were produced vertically from the superficial hyphae on the upper leaflet surface. Each conidiophore had one or two oidia, but chains of three or four were also observed. Sub-spherical pyriform haustoria developed in epidermal cells.

It is clear that although this disease is of minor importance in Maharashtra today, it may cause an epidemic in future in *rabi* / summer-sown groundnut crop.

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In Vitro Testing of *Xenorhabdus* Metabolites Against Groundnut Collar Rot Fungus *Aspergillus niger*

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Entomopathogenic nematodes (EPN) and their symbiotic bacterial complex is known to give an effective and economic control of many insects as well as phytonematodes all over the world (Kaya et al. 1993, Smart 1995, Gaugler 2003). In recent years the metabolites produced by *Xenorhabdus* bacteria have been reported to have fungistatic effect against few plant pathogenic fungi also. Chen et al. (1994) have tested activity of two bacteria,

Table 1. In vitro antagonism of *Xenorhabdus* metabolites against *Aspergillus niger.*

	Inhibition (%) after time					
	24 h		48 h		72 h	
Bacterial isolate[1]	Undiluted	1:100	Undiluted	1:100	Undiluted	1:100
SrM	12	10	5	4	2	2
SA	24	14	18	8	14	4
Sc	32	19	19	13	13	5
St	26	21	19	13	13	6
OH	13	8	10	6	7	3
Control	0	0	0	0	0	0
SEm	0.9	0.9	0.8	1.0	0.9	0.6
CD at 5%	2.6	2.8	2.4	3.0	2.7	1.7
CV (%)	8.9	14.2	12.6	23.9	20.4	30.6

1. SrM = *Steinernema riobrave* Mogar isolate; SA = *Steinernema* sp Anand isolate; Sc = S. carpocapse; St = *S. thermophilum;* and OH = Ohio Standard.

Xenorhabdus and *Photorhabdus,* against plant pathogenic fungi in Canada, viz, *Botrytis cinerea, Ceratocystis ulmi, C. dryocoetidis, Mucor piriformis, Pythium coloratum, P. ultimum* and *Trichoderma pseudokingii* and reported complete inhibition of these fungi by phase one variants of the symbiotic bacteria, whereas the mycorrhizal fungus *Suillus pseudobrevipes* was not inhibited. Evaluation of the *Steinernema feltiae / Xenorhabdus bovienii* complex against the fungus *Phoma betae* on sugar beet (*Beta vulgaris)* seedlings showed that their extract exerted toxic effect on the development of *P. betae* mycelium (Lopez et al. 1997). In view of these, in vitro testing of EPN symbiotic bacteria, *Xenorhabdus* spp isolated from native *Steinernema riobrave* (Ganguly et al. 2002), *S. thermophilum* (Ganguly and Singh 2000) and 51 *carpocapse* (Gupta 2003) metabolites, against groundnut collar rot fungus *Aspergillus niger* was carried out in the laboratory during 2003-04.

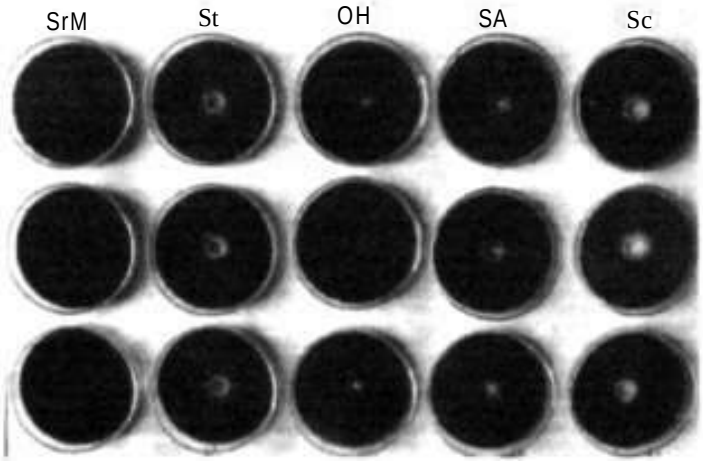

Figure 1. Fungistatic effect of exotoxins of *Xenorhabdus* spp against *Aspergillus niger* on potato dextrose agar at 72 h (SrM = *Steinernema riobrave* Mogar isolate; St = S. *thermophilum;* OH = Ohio Standard; SA = *Steinernema* sp Anand isolate; and Sc = *S. carpocapse).*

Potato dextrose agar (PDA) in petri dish of 7 cm diameter was used for optimum growth of the fungus. The petri dishes were inoculated with about 1.4 x 10^9 viable *A. niger* conidia $m1^{-1}$ using sterile micropipette. All the *Xenorhabdus* isolates were tested as undiluted exotoxic factors and 1:100 dilution. Wells of about 10 mm diameter were bored with sterile cork borer in the center of PDA plates and inoculated with exotoxic factors (0.1 ml) of respective cultures. The culture filtrates were prepared by growing *Xenorhabdus* cultures in minimal broth media with 10% dextrose without organic and protein ingredients, for optimum growth of bacteria and incubated at 23±2°C for 96 h in BOD incubator with stirring at 50 rpm. Proteins excreted by the bacteria were measured at a different absorption peak in the ultraviolet range at 260 nm and 280 nm in ultraviolet spectrophotometer. Individual optical density was counted and protein concentration (mg $m1^{-1}$) was calculated by the formula given by Kalckar (Jayaraman 1981). Besides this, direct impact of exotoxic factors was assayed by mixing undiluted culture filtrate (10% in PDA) before plating the petri dishes following inoculation of *A. niger* spores (poisoned food technique).

Table 2. Estimation of total proteins of Xenorhabdus spp.

Xenorhabdus culture[1]	Optical density		Protein concentration[2]
	260 nm	280 nm	(mg $m1^{-1}$)
Blank	100	100	–
SrM	0.031	0.040	0.038
SA	0.022	0.032	0.032
St	0.132	0.163	0.152
Sc	0.139	0.176	0.168
OH	0.020	0.025	0.023

1. SrM = *Steinernema riobrave* Mogar isolate; SA = *Steinernema* sp Anand isolate; St = S. *thermophilum;* Sc = 5. *carpocapse.*
2. Protein concentration (mg $m1^{-1}$) = (1.55 x OD_{200}) - (0.76 x OD_{260})

All the treatments were replicated three times. Plates were kept in the refrigerator for 30 min for diffusion of liquid and subsequently in BOD incubator at 27±2°C for incubation. Observations on inhibition zone were recorded at 24 h interval up to the optimum growth of fungus in each plate. Growth inhibition was calculated by the formula of Nene and Thapliyal (1979):

$$\text{Inhibition (\%)} = \frac{\text{Diameter of inhibition zone (cm)} \times 100}{\text{Diameter of petri dish (cm)}}$$

The results showed that up to 24 h of growth, fungus multiplication was lowered in all the treated plates compared to control. However, after 72 h, fungal growth was maximum covering whole plate except surrounding the wells in toxin inoculated plates. Bacterial symbionts of *S. carpocapse* and *S. thermophilum* had 32 and 26% inhibitory effect against *A. niger,* respectively at 24 h of inoculation compared to other cultures (Table 1). Bacterial isolates from *Steinernema* sp (Anand isolate) and *S. riobrave* (Mogar isolate) showed relatively low fungistatic effect with only 0.7 to 0.8 cm inhibition zones (Fig. 1); the effect was similar to that observed with *Xenorhabdus* (Ohio Standard). This may be due to low protein production by these three bacterial isolates as evident in the results on estimation of total proteins of *Xenorhabdus* spp. Quantitative analysis by ultraviolet absorption method of protein estimation indicated that total protein concentration present in *S. carpocapse* and *S. thermophilum* cultures was similar and good whereas the Ohio Standard culture, *S. riobrave* (Morgan isolate) and *Steinernema* sp (Anand isolate) exhibited low protein production (Table 2). Moreover, in another set, when culture filtrates were mixed in PDA and plated for assessment of toxic effect, *A. niger* spore germination was delayed by 24 h in treated plates compared to control. Later, mycelial growth was hampered till 96 h compared to control plates.

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Rate of Transmission of Indian Peanut Clump Virus to Groundnut by Mechanical Inoculation

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'Clump' is one of the major viral diseases of groundnut (*Arachis hypogaea*) caused by the Indian peanut clump virus (IPCV) in the Indian subcontinent (Nolt et al. 1988). A similar disease in Africa is caused by peanut clump virus (PCV) (Thouvenel and Fauquet 1981). Both PCV and IPCV belong to the genus *Pecluvirus*, and they have similar physical, biological and transmission properties, but their coat proteins are highly variable. Various isolates of IPCV and PCV occur in endemic regions (Nolt et al. 1988). IPCV and PCV are transmitted through seed and by a root endoparasite, *Polymyxa graminis*. Several serologically distinct isolates of PCV and IPCV were identified in Asia and Africa.

Clump disease occurs in patches in fields. The disease recurs when groundnut and certain IPCV-susceptible cereal hosts like pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) are grown regularly (Delfosse et al. 1999). Durable resistance to clump in groundnut germplasm is lacking. Although several thousand groundnut genotypes were screened for clump resistance in experimental sick plots, none of these were consistently resistant or tolerant to IPCV (Reddy et al. 1988). Genotypes that showed resistance (no infection) or low disease incidence in one trial showed severe infection in subsequent trials at the same location. The variation in resistance/tolerance reaction in genotypes in the sick plots was due to uneven distribution of virus inoculum in the fields, which depends on the germination of resting spores of *P. graminis* and environmental conditions (Reddy et al. 1988). A reliable virus inoculation procedure is essential to accurately evaluate groundnut genotypes for IPCV resistance. Although IPCV can be transmitted by mechanical sap inoculation, it seldom was used for resistance screening probably due to low

Table 1. Transmission of IPCV-H after mechanical inoculation with sap extracts prepared from virus-infected French bean.

	Groundnut cv JL 24					French bean cv Topcrop				
Date of inoculation	Incubation period[1]	Infected/ Tested[2]	Infection[3] (%)	Temperature[4] Max	Temperature[4] Min	Days to infection[1]	Infected/ Tested[2]	Infection[3] (%)	Temperature[4] Max	Temperature[4] Min
03/09/04	18	6/7	85	30.0	21.0	6	6/6	100	29.4	21.4
21/09/04	19	13/20	65	31.0	21.0	5	9/10	90	30.8	21.7
23/09/04	21	9/14	64	31.0	21.0	6	5/5	100	30.4	21.9
01/10/04	20	16/17	94	30.5	20.0	5	10/10	100	30.4	21.1
12/10/04	18	12/20	60	30.0	18.0	5	14/15	93	30.9	19.7
15/10/04	18	14/20	70	29.5	18.4	6	9/10	90	29.5	15.7
26/10/04	21	6/11	55	29.3	18.0	5	10/10	100	29.0	18.7
29/10/04	20	14/17	82	29.6	17.9	6	15/15	100	28.9	19.2
03/11/04	21	14/25	56	30.0	16.1	6	10/10	100	28.6	15.9
06/12/04	23	0/25	0	29.6	11.3	5	3/5	60	29.2	10.1
13/12/04	21	9/24	37	29.6	12.4	5	9/10	90	29.2	11.0
29/12/04	23	2/6	33	29.7	13.6	6	14/15	93	28.9	15.2
31/12/04	23	14/24	58	29.8	14.0	6	10/10	100	29.3	15.4
10/01/05	21	13/26	50	30.0	15.5	6	4/5	80	30.0	11.6
17/01/05	20	14/26	54	29.3	16.8	6	9/10	100	29.7	14.8
24/01/05	22	21/28	75	30.3	16.5	7	9/10	90	30.5	19.1
Mean	20.5	177/286	62	29.9	16.9	5.5	144/156	92	29.6	17.0

1. Maximum number of days at which all the virus-infected plants showed symptoms.
2. Number of plants.
3. Infection confirmed by DAS-ELISA.
4. Mean temperature (°C) recorded during days to infection.

infection rate achieved by this method. In this study, rate of IPCV [Hyderabad isolate (H)] transmission to groundnut by mechanical inoculation was assessed using the virus infected leaf sap and purified virus preparations as inoculum.

For the inoculum preparation, 0.05 M potassium phosphate buffer, pH 7 containing 0.1% (v/v) β-mercaptoethanol was used (referred as inoculation buffer). French bean (*Phaseolus vulgaris*) cultivar Topcrop at cotyledonous leaf stage and groundnut cultivar JL 24 at three-leaf stage were used for inoculation. Both these cultivars were highly susceptible to IPCV infection. Prior to inoculation test plants were kept in dark for 12-16 h. Test plants were dusted with carborandum (600 mesh) and freshly extracted inoculum was immediately applied onto the leaves with a double layer muslin-cloth pad. Inoculated leaves were washed with distilled water and covered with sheets of paper and kept in dark overnight. They were maintained in greenhouse chambers fitted with air-coolers to lower the day temperature (27-35°C, depending on the external temperature), which were operated during daytime only. Plants were regularly monitored for symptoms and tested for the virus in leaf samples (1:20 w/v) by DAS-ELISA (double antibody sandwich - enzyme-linked immunosorbent assay) using IPCV-H immunoglobulins as described by Nolt et al. (1988).

The IPCV-H infected groundnut seed stored at -70°C was used as initial virus inoculum source. In a pre-chilled mortar and pestle, seed material (1:10 w/v) was macerated in chilled inoculum buffer and immediately inoculated to French bean. Veinal necrosis symptoms, typical of IPCV infection, developed 4-7 days after infection. This was

Table 2. Transmission of IPCV-H to groundnut cultivar JL 24 using inoculum from virus-infected groundnut leaves.

Date of inoculation	Days to infection[3]	Infected/Tested[2]	Infection[3] (%)	Temperature[4]	
				Max	Min
18/11/04	21	5/20	25	29.2	11.5
19/12/04	23	9/26	35	29.7	13.5
04/02/05	19	19/20	95	33.2	15.4
11/02/05	18	17/24	71	34.4	16.7
Mean	21	50/90	55	31.6	14.2

1. Maximum number of days at which all the virus-infected plants showed symptoms.
2. Number of plants.
3. Infection confirmed by DAS-ELISA.
4. Mean temperature (°C) recorded during days to infection.

Table 3. Infection in groundnut cultivar JL 24 after inoculation with partially purified IPCV-H preparations.

Date of inoculation	Incubation period[1]	Dilution	Infected/Tested[2]	Infection[3] (%)	Temperature[4]	
					Max	Min
20/01/05	28	1:100	4/5	80	31.7	16.3
		1:1000	2/5	40		
		1:5000	1/5	20		
03/02/05	26	1:100	4/4	100	33.3	16.3
		1:1000	2/5	40		
		1:5000	1/5	20		
15/02/05	25	1:100	8/9	89	34.7	17.4
Mean	26		22/38	57	33.2	16.6

1. Maximum number of days at which all the virus-infected plants showed symptoms.
2. Number of plants.
2. Infection confirmed by DAS-ELISA.
3. Mean temperature (°C) recorded during days to infection.

used as the virus source for subsequent experiments. Leaf sap extract (1:10 w/v) prepared from 1PCV-H infected French bean was inoculated to 16 batches of French bean and groundnut plants raised in growth chambers on different dates from September 2004 to January 2005 (Table 1). Plants were monitored for symptoms up to 30 days after infection, and they were assayed for IPCV-H by DAS-ELlSA. French bean plants were readily infected with the virus in all these experiments. Infected plants showed typical symptoms within 5-7 days after infection. Except on one occasion, 80-100% of the inoculated plants were infected with the virus, with a mean infection of 92% for the entire experiment (Table 1). The sap inoculated groundnut plants took 18-23 days to develop symptoms; infection in most experiments was 50-75%, with a mean infection rate of 62% for the entire experiment (Table 1). When the groundnut plants were inoculated with sap extract prepared from the virus-infected groundnut leaves, 23-90% of the test plants were infected, and it took 18-23 days to develop symptoms (Table 2). Groundnut plants were also inoculated with partially purified IPCV-H preparations made from 100 g virus-infected French bean leaf tissue using the procedure described by Nolt et al. (1988). The partially purified virus pellets were dissolved in 5 ml of 0.02 M sodium borate, 0.03 M potassium phosphate buffer, pH 8.3, containing 0.3 M urea, and diluted to 1:100, 1:1000 and 1:5000 in inoculum buffer and applied onto the groundnut plants. Test plants inoculated with 1:100 dilution preparations showed 80-100% infection in three separate experiments, whereas those inoculated with 1:1000 and 1:5000 dilutions showed 20-40% infection (Table 3).

The night temperature seems to have an effect on IPCV-H infection in groundnut plants. Less than 40% of the inoculated groundnut plants showed infection when the night temperature was 12-14°C, and no infection resulted when the temperature was <12°C (Tabie 1). During the same period, there was no difference in percentage infection in French bean, but when the night temperature dropped below 11°C, only 60% infection resulted in the test plants (Table 1). Further studies are necessary to understand the effect of temperature on 1PCV infection in groundnut.

This study showed that using French bean as inoculum source, IPCV-H could be efficiently transmitted to groundnut by mechanical sap inoculation and the virus has about three weeks incubation period in groundnut. This method is convenient and allows reliable screening of elite groundnut germplasm for resistance to various IPCV and PCV isolates in relatively short period.

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Effectiveness of Neem Seed Kernel Extract in Combination with Selected Fungicides for Groundnut Rust Management

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Rust caused by *Puccinia arachidis* is an economically important disease of groundnut (*Arachis hypogaea*) in India. The disease is most severe in rainy season, causing yield losses of up to 40% in the state of Karnataka. Recently, up to 80% disease incidence of rust has been reported in Koppal and Raichur districts (NRCG 2002). Management of rust by application of chemical fungicides has been recommended, but this option is expensive and leads to environment pollution. Alternatively, neem seed kernel extract (NSKE) has been found to reduce the rust incidence to some extent in groundnut (Usman et al. 1991). Hence this study was undertaken to find out the

Table 1. Effect of neem seed kernel extract (NSKE) in combination with selected fungicides against severity of rust and pod yield of groundnut.

Treatment[1]	Concentration (%)	Disease severity (PDI)[2] 2002	2003	Pooled mean	Disease control (%)	Yield (t ha^{-1}) 2002	2003	Pooled mean	Yield increase (%)
C-C-C	0.2-0.2-0.2	45.93 (42.67)	48.52 (44.15)	47.23 (43.41)	45.58	1.35	1.39	1.37	25.68
N-N-N	5.0-5.0-5.0	61.48 (51.65)	64.22 (53.25)	62.85 (52.45)	27.59	1.20	1.17	1.19	9.17
H-H-H	0.1-0.1-0.1	30.37 (33.40)	33.48 (35.43)	31.93 (34.42)	63.21	1.67	1.67	1.67	53.21
P-P-P	0.1-0.1-0.1	35.12 (36.28)	37.89 (37.94)	36.51 (36.61)	57.93	1.49	1.46	1.48	35.77
D-D-D	0.1-0.1-0.1	30.85 (33.75)	33.74 (35.49)	32.30 (34.62)	62.78	1.62	1.65	1.64	50.45
C-N-C	0.2-5.0-0.2	55.93 (48.40)	53.33 (46.92)	54.63 (47.66)	37.06	1.30	1.30	1.30	19.26
H-N-H	0.1-5.0-0.1	40.26 (39.39)	39.70 (39.06)	39.98 (39.23)	53.93	1.40	1.49	1.45	33.02
P-N-P	0.1-5.0-0.1	42.22 (40.53)	40.44 (39.47)	41.33 (40.00)	52.37	1.33	1.35	1.34	22.93
D-N-D	0.1-5.0-0.1	41.80 (40.34)	38.86 (38.55)	40.35 (39.45)	53.53	1.32	1.52	1.42	30.27
N-C-N	5.0-0.2-5.0	60.55 (51.06)	63.70 (52.74)	62.13 (51.90)	28.41	1.21	1.21	1.21	11.00
N-H-N	5.0-0.1-5.0	46.57 (43.01)	44.70 (41.96)	45.64 (42.49)	47.41	1.25	1.23	1.24	23.76
N-P-N	5.0-0.1-5.0	46.67 (43.09)	52.67 (46.52)	49.67 (44.81)	42.76	1.30	1.21	1.26	15.59
N-D-N	5.0-0.1-5.0	45.93 (42.67)	51.57 (45.91)	48.75 (44.29)	43.82	1.26	1.24	1.25	14.67
Control	–	83.20 (66.19)	90.37 (71.30)	86.79 (68.74)	–	1.12	1.05	1.09	–
SEm±	–	0.84	0.87	0.91	–	0.06	0.05	0.05	–
CD at 5%	–	2.43	2.54	2.73	–	0.14	0.15	0.15	–

1. C = Chlorothalonil; N = NSKE; H = Hexaconazole; P = Propiconazole; D = Difenconazole.
   In each treatment, foliar application of fungicide or NSKE or a combination of both was given at 45, 55 and 65 days after sowing.
2. PDI = Per cent disease index.
   Figures in parentheses are angular transformation values.

suitable cost-effective integrated disease management spray schedule by integration of new fungicides and NSKE.

Field experiments were conducted in a randomized block design at the Regional Agricultural Research Station, Raichur, Karnataka for two years in 2002 and 2003 rainy seasons (June-October). Groundnut variety KRG-1, highly susceptible to rust, was sown in 3 m x 5 m plots with a spacing of 30 cm x 10 cm. All the recommended package of practices for tillage, manuring, irrigation, etc were followed. Fourteen treatments with three replications were evaluated for control of rust. These treatments included four fungicides, hexaconazole, propiconazole, difenconazole and chlorothalonil in different combinations with NSKE. The details of the treatment combinations are given below:

T_1: C-C-C (0.2% - 0.2% - 0.2%)
T_2: N-N-N (5.0% - 5.0% - 5.0%)
T_3: H-H-H (0.1% - 0.1% - 0.1%)
T_4: P-P-P (0.1% - 0.1% - 0.1%)
T_5: D-D-D (0.1% - 0.1% - 0.1%)
T_6: C-N-C (0.1% - 5.0% - 0.1%)
T_7: H-N-H (0.1% - 5.0% - 0.1%)
T_8: P-N-P (0.1% - 5.0% - 0.1%)
T_9: D-N-D (0.1% - 5.0% - 0.1%)
T_{10}: N-C-N (5.0% - 0.2% - 5.0%)
T_{11},: N-H-N (5.0% - 0.1 % - 5.0%)
T_{12}: N-P-N (5.0% - 0.1% - 5.0%)
T_{13}: N-D-N (5.0% - 0.1% - 5.0%)
T_{14}: No spray (without fungicides)

(In the above treatments, C refers to chlorothalonil, N to NSKE, H to hexaconazole, P to propiconazole and D to difenconazole.)

In all the treatments, these protective foliar sprays were applied. The first spray was given immediately after the appearance of rust pustules on lower leaves of the plant, ie, 45 days after sowing and two subsequent sprays were given at 10 days interval. The spray solution used per plot was 1, 1.5 and 2 L for the first, second and third sprays, respectively. The observations on disease intensity were recorded 10 days after the third spray at natural epidemic conditions. Ten plants were selected randomly from each plot and plants were rated for rust severity on a 1-9 scale (Subrahmanyam et al. 1995). Per cent disease index (PDI) was calculated using the following formula:

$$PDI = \frac{\text{Sum of all numerical ratings}}{\text{Total leaflets observed} \times \text{Maximum rating}} \times 100$$

The PDI values were transformed by angular transformation and analyzed statistically. Dry pod yield was also recorded. Disease control (%) and pod yield increase over control were calculated and data were analyzed statistically.

The comparison of pooled means indicate that all treatment combinations significantly reduced the severity of rust and also increased the pod yield as compared with untreated control (Table 1). However, they showed differential effects in controlling the disease. Among the treatment combinations, hexaconazole was significantly (P = 0.05) effective followed by difenconazole and propiconazole. Further, combination of hexaconazole with NSKE (H-N-H) showed better control (53.93%) than D-N-D (53.53%) and P-N-P (52.37%). These treatments were also effective in increasing the pod yield in the same pattern as they control the disease. Among them, H-N-H treatment was highly effective with more yields. The spray combination of H-N-H reduced one spray of hexaconazole without compromising on disease control. Also, NSKE and hexaconazole reduced the cost towards crop protection.

Jadeja et al. (1999) reported that among different triazoles tested best control of rust on groundnut was achieved with three sprays of hexaconazole and difenconazole with more pod yield. Usman et al. (1991) used different neem products and recorded lesser incidence of rust with higher benefit-cost ratio in NSKE-applied plots. By using a combination of hexaconazole and NSKE we observed further reduction in the quantity of fungicides required for effective disease control. Results of this study are also supported by Patil (1996) who suggested that rust of sunflower (*Helianthus annuns*) can be managed effectively with a spray schedule of propiconazole and NSKE (5%) with higher yields. The present findings are in agreement with Shivashankar and Kadam (1993) who reported that spraying of neem leaf extract in combination with recommended fungicides recorded numerical superiority in reducing rust incidence in groundnut.

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Agronomy/Physiology

Standardization of a Protocol to Screen for Salinity Tolerance in Groundnut

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Salinity is an ever-increasing problem, especially in areas where lands are irrigated with water containing salts. Worldwide, about 100 million ha of arable land is affected by salinity, which accounts for about 6-7% of the total arable land (Munns and James 2003). Salinity adversely affects plant growth at all stages and at seedling and reproductive stages in particular, dramatically reducing the crop yield (Munns et al. 2002).

Groundnut (*Arachis hypogaea*) is an important commodity in many developing countries, particularly in India where the nitrogen (N)-rich crop residues are also used as fodder. The production of groundnut in India needs to be increased from the current 8 million t to about 14 million t by 2020 to meet the increasing demand of the oil and confectionery industry (Girdhar 2004). This increase will have to be partially achieved by growing groundnut in lands considered so far as unsuitable for agriculture, like rice (*Oryza sativa*) fallow affected by salinity during the postrainy season.

Little is known about the salinity tolerance of groundnut and no attempt has been made to breed salinity tolerant groundnut varieties. A protocol is a prerequisite for understanding the response to salinity stress, assessing genetic variability and identifying surrogate traits and mechanisms contributing to tolerance. Therefore, the first step to this work is to standardize a screening protocol to use for the selection of tolerant materials. Although this protocol will be used to test large number of genotypes for their yield response under salinity, its standardization can be done on the basis of the vegetative biomass reduction under salt treatment.

In this article, we report the results of two experiments that were carried out to standardize a protocol to screen groundnut for salinity tolerance. Our objectives were: (i) to identify an optimum NaCl treatment; (ii) to explore the potential tolerance mechanisms; and (iii) to assess the genotypic variation for salinity tolerance in groundnut.

Materials and methods

Growth conditions and salt application. Two experiments were carried out in a glasshouse, with day/night temperature of 28/22°C. In both experiments, six genotypes belonging to different botanical types [ICG (FDRS) 10, ICGS 44, ICGS 76, ICGV 86031, JL 24 and TAG 24] were grown in 15-cm diameter pots filled with 2 kg of Alfisol, collected from the experimental station at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India. The soil was fertilized with diammonium phosphate (DAP) at 300 mg kg^{-1} soil, and also treated with carbofuran to prevent thrips infestation and thereby peanut bud and stem necrosis incidence. Four seeds were planted per pot and later thinned to two seedlings per pot. Five replicated pots per treatment and genotype were grown. In both the experiments, NaCl was applied at a fixed rate in g kg^{-1} of soil. The required salt was dissolved in water needed to saturate the soil to field capacity (23% w/w). Plants were grown for seven weeks in both the experiments and then harvested.

Experiment 1 (Exp 1). Four salt treatments were imposed, 0,0.67,1.34 and 2.02 g kg^{-1} of soil. They corresponded to a solution concentration of 0, 50, 100 and 150 mM NaCl, in the amount sufficient to saturate the soil at field capacity. In this experiment, salt was applied in three split doses, within the initial 10 days after sowing, to avoid a rapid build-up of salt in the soil. Plants were sown on 18 August and harvested on 6 October 2004. At harvest, the plants were separated into leaves, stems, roots, pods and nodules and dried to constant weight in a hot air oven at 70°C. Since pod weight was negligible in the different salt treatments, pod weight was not considered in the analysis.

Table 1. Ratio of biomass of groundnut under salinity to biomass under control in different NaCl treatments.

NaCl (mM) treatment	Exp 1[1]	Exp 2'
0	1	1
50	0.84+0.08	–
100	0.59+0.08	0.61 ± 0.09
125	–	0.39 + 0.07
150	0.33+0.04	0.25 + 0.02

1. Data are the average ratios of 6 groundnut genotypes (+SD). Mean biomass across genotypes in 0 mM treatment was 10.6 g $plant^{-1}$ in Exp 1 and 6.3 g plant $^{-1}$ in Exp 2.

Experiment 2 (Exp 2). Four salt treatments were imposed, 0, 1.34,1.68 and 2.02 g kg^{-1} soil, corresponding to an application of solution of 0, 100, 125 and 150 mM concentrations. Salt treatments were applied all in one dose at sowing. Plants were sown on 19 February and harvested on 13 April 2005. At harvest, leaves, stems and pods were separated and dried as in Exp 1.

Criteria to assess salt tolerance. Salt tolerance was assessed on the basis of total biomass (shoot + roots) in Exp 1 and on shoot biomass alone in Exp 2 as shoot biomass and total biomass in Exp 1 were found to be very closely associated (r^2 = 0.93, data not shown). The total biomass or shoot biomass is hereafter referred as biomass for brevity. Also the ratio between the biomass produced under salinity to that of control was used to assess salt tolerance (Krishnamurthy et al. 2003a, 2003b).

Measurement of plant traits. Leaf size: A few days before harvest, the two most fully expanded leaves in the main stem were collected for the leaf area measurement. The ratio of the replication-wise values under salinity divided by mean control value for each genotype and treatment gave an estimate of the relative reduction in leaf size due to salinity.

Stem/leaf ratio: After harvest, stems and leaves were separated and their ratio computed for each individual plant.

Nodulation: In Exp 1, at harvest, the nodule number and nodule dry mass were measured and their relative decreases under salinity were computed (replication-wise values under salinity divided by mean control value for each genotype and treatment).

SCMR: In Exp 2, the chlorophyll content of leaves at 49 days after sowing was assessed using the SPAD (Soil and Plant Analysis-Development) chlorophyll meter reading (SCMR). The SPAD readings were recorded on 4 leaflets of the top two most fully expanded leaves of the main stem, and averaged. The ratio of replication-wise values under salinity divided by mean control value for each genotype and treatment gave an estimate of the relative reduction in chlorophyll.

Na concentration in leaves: In Exp 1, 150 mg of finely ground leaf sample was digested in 4 ml of concentrated sulfuric acid with 0.5% selenium powder at 360°C for 75 min on a block digester and the digest was diluted to 75 ml. Using this digest K and Na were estimated (Sahrawat et al. 2002) using an atomic absorption spectrophotometer (Varion model 1200, Australia).

Results

Biomass response to salinity. In Exp 1, plants were little affected by 50 mM NaCl treatment, although there were significant genotypic differences (Fig. 1). Similarly, in both Exp 1 and Exp 2 the genotypic response for biomass production at 150 mM was minimal. In Exp 1, 100 mM NaCl appeared to induce large genotypic biomass differences, with genotypes ICGS 44, ICGS 76 and JL 24 having higher biomass than ICG (FDRS) 10, ICGV 86031 and TAG 24 (P = <0.001) (Fig. 1). In Exp 2, although the 100 mM concentration induced some differences between the genotypes, ie, ICGS 44 and ICGS 76 also had a high biomass compared to ICGV 86031 and TAG 24 (P = 0.042), the 125 mM concentration brought about larger contrast between genotypes, with ICGS 44 reaching the highest biomass whereas JL 24 and TAG 24 were the lowest (P = 0.003) (Fig. 1). Across experiments, it appeared that ICGS 44 achieved consistently the highest biomass at 100 mM whereas ICGV 86031 and TAG 24 had the lowest biomass.

While the ratio of biomass production under salinity to that of control was little affected at 50 mM concentration (0.84), the ratio decreased to a value as low as 0.59 and 0.61 at 100 mM concentration in Exp 1 and Exp 2, respectively (Table 1), and 0.39 at 125 mM in Exp 2. In both experiments, the ratio of biomass production was severely decreased at 150 mM NaCl (0.33 in Exp 1 and 0.25 in Exp 2). The consistent results across experiments clearly indicated significant genotypic differences. Therefore, we used the treatment from the two experiments giving the most genotypic contrast, ie, the 100mM treatment in Exp 1 and 125 mM treatment in Exp 2, to identify surrogate traits and mechanisms contributing to salinity tolerance.

Plant morphology and salinity tolerance. Leaf size reduction: In Exp 2, genotypes showing good growth under 125 mM treatment seemed to maintain leaf size close to that of control (Table 2). The regression of the relative leaf size reduction at 125 mM treatment on the ratio of shoot biomass under salinity revealed a significant association (r^2 = 0.45, P = <0.01), showing that tolerant plants were able to maintain the leaf size closer to that of control (data not shown).

Ratio of stem to leaves: Stem portion in groundnut represent a substantial part of the dry matter (Table 2). The ratio of stem to leaves dry weight and the ratio of shoot biomass under salinity were correlated with a highly significant relationship (r^2 = 0.56, P = <0.01) (data not shown). This shows that although Na accumulation in stems in relation to leaves was not measured, a larger stem proportion may serve as a Na sink and confer higher tolerance to salinity.

N status and salinity tolerance. Nodulation: Nitrogen fixation is very sensitive to salinity (Rao et al. 2002). In Exp 1 the number and dry mass of nodules reduced drastically with increasing salinity, especially at concentrations above 100 mM NaCl (Table 2). A highly significant positive relationship (r^2 = 0.40, P = <0.05) was found between the relative nodule biomass reduction and the ratio of shoot biomass under salinity, indicating that the more sensitive genotypes suffered a relatively larger decrease in nodulation compared to their respective controls (data not shown).

Ratio SCMR: Since nodulation was decreased in Exp 1, there was an interest to measure SCMR as an indirect measure of shoot N status. Although there was a trend to have plants with relatively less decrease in the SCMR values compared to control being also more tolerant (Table 2), this trend was not significant (r^2 = 0.24, P = 0.29). Several SCMR measurements recorded at various dates after sowing failed to show any significant trend (data not shown).

Na accumulation in leaves: In most plants, the accumulation of Na in shoot brings about deleterious effect, and the plant strategy is to limit the Na build-up in the shoot tissues. Although it was found that the Na concentration in shoot increased with the salt treatment (Table 2), there was no relationship between the shoot Na concentration and the relative sensitivity of plants to salt treatment (data not shown).

Discussion

We have shown that the 100-125 mM range of NaCl treatments was suitable to screen for salinity tolerance in groundnut. The material screened in this study was very limited, but large differences could be shown for response to salinity stress. So, there is a good scope for identifying genotypes with higher level of tolerance from larger screening of diverse sets of materials.

Certain aspects of the plant morphology, ie, the reduction in leaf size and the stem/leaves ratio in response to salinity stress provided interesting insights. The reduction in leaf area in sensitive plants under salinity stress indicated arrest of leaf expansion, which eventually limits the area available for photosynthesis. Further research

Table 2. Mean (±SE) values of nodule dry mass, Na concentration in leaves, ratio of stem/leaves, leaf area and SCMR in different NaCl treatments tested against six groundnut genotypes.

Genotype	Control	50 mM	100 mM	125 mM	150 mM
Nodule dry mass (g) (Exp 1)					
ICG (FDRS) 10	0.168 ± 0.010	0.096 + 0.008	0.075 + 0.023		0.018 + 0.003
1CGS 44	0.168 ± 0.023	0.134 + 0.015	0.132 + 0.020		0.056 + 0.003
ICGS 76	0.204 + 0.030	0.139 + 0.021	0.163 + 0.031		0.091 + 0.021
lCGV 86031	0.221 ± 0.013	0.136 + 0.023	0.084 + 0.013		0.036 + 0.000
JL 24	0.160 + 0.010	0.136 + 0.017	0.106 + 0.024		0.048 + 0.018
TAG 24	0.131 + 0.007	0.132 + 0.011	0.074 +0.015		0.041 + 0.006
Na concentration (%) (Exp 1)					
ICG (FDRS) 10	0.12 + 0.01	0.24 + 0.04	0.21 + 0.03		0.55 + 0.06
ICGS 44	0.13 + 0.02	0.20 + 0.04	0.23 + 0.04		0.73 + 0.13
ICGS 76	0.11 + 0.02	0.15 + 0.03	0.17 + 0.01		0.41 + 0.05
ICGV 86031	0.15 + 0.02	0.15 + 0.03	0.23 + 0.03		0.33+0.04
JL 24	0.12 + 0.01	0.14 + 0.02	0.28 + 0.05		0.80 + 0.22
TAG 24	0.19 + 0.03	0.28 + 0.04	0.27 + 0.05		0.57 + 0.08
Stem/leaves ratio (Exp 1)					
ICG (FDRS) 10	0.84 + 0.04	0.96 + 0.04	0.83 + 0.08		0.86 + 0.05
ICGS 44	0.99 + 0.04	1.08 + 0.07	1.08 + 0.04		0.80 + 0.04
ICGS 76	0.98 + 0.04	0.94 + 0.01	0.98 + 0.05		0.84 + 0.08
ICGV 8603 1	0.87 + 0.07	0.83 + 0.06	0.83 + 0.08		0.99 + 0.01
JL 24	0.86 + 0.05	0.87 + 0.06	0.97 + 0.08		0.86 + 0.05
TAG 24	0.82 + 0.11	0.90 + 0.10	0.88 + 10.12		0.88 + 0.03
Stem/leaves ratio (Exp 2)					
ICG (FDRS) 10	0.78 + 0.07		0.73 ± 0.04	0.62 + 0.03	0.61 + 0.02
ICGS 44	0.83 + 0.05		1.06 + 0.27	0.84+0.08	0.69 + 0.02
ICGS 76	0.72 + 0.03		0.62 ± 0.04	0.64 + 0.06	0.59 + 0.04
ICGV 86031	0.65 + 0.03		0.77 + 0.17	0.59 + 0.04	0.58 + 0.03
JL 24	0.68 + 0.02		0.59 + 0.04	0.56 + 0.05	0.56 + 0.03
TAG 24	0.70 + 0.04		0.81 + 0.05	0.73 + 0.04	0.69 + 0.02
Leaf area (of 8 leaflets) (cm^2) (Exp 2)					
ICG (FDRS) 10	47.4 + 3.3		38.7 + 2.9	33.2 + 3.8	26.2 + 2.4
ICGS 44	25.7 + 2.8		24.5 + 2.0	21.3 + 1.6	16.7 + 1.4
ICGS 76	30.1 + 2.8		24.9 + 3.0	20.1 + 1.8	14.9 + 1.4
ICGV 86031	40.0 + 3.7		25.3 + 2.3	24.1 + 1.8	19.3 + 2.0
JL 24	47.9 + 6.2		37.7 + 2.9	28.3 + 2.3	26.2 + 3.0
TAG 24	18.8 + 1.5		17.1 + 2.1	13.9 + 0.9	11.2 + 1.2
SCMR[1] (Exp 2)					
ICG (FDRS) 10	39.4 + 0.6		41.4 + 1.3	35.0 + 3.6	32.6 + 4.1
ICGS 44	46.5 + 2.4		36.9 + 1.4	40.3 + 2.0	36.8 + 1.3
ICGS 76	50.1 + 2.5		45.2 + 2.4	43.7 ± 2.8	42.6 + 2.9
ICGV 86031	46.0 + 5.2		40.1 + 2.3	33.8 + 1.1	32.1 + 1.2
JL 24	42.3 + 3.3		39.6 + 2.2	30.7 + 1.9	33.1+ 1.4
TAG 24	39.5 + 1.8		38.6 + 0.8	33.1 + 2.0	31.2 + 2.3

1. SCMR = SPAD chlorophyll meter reading.

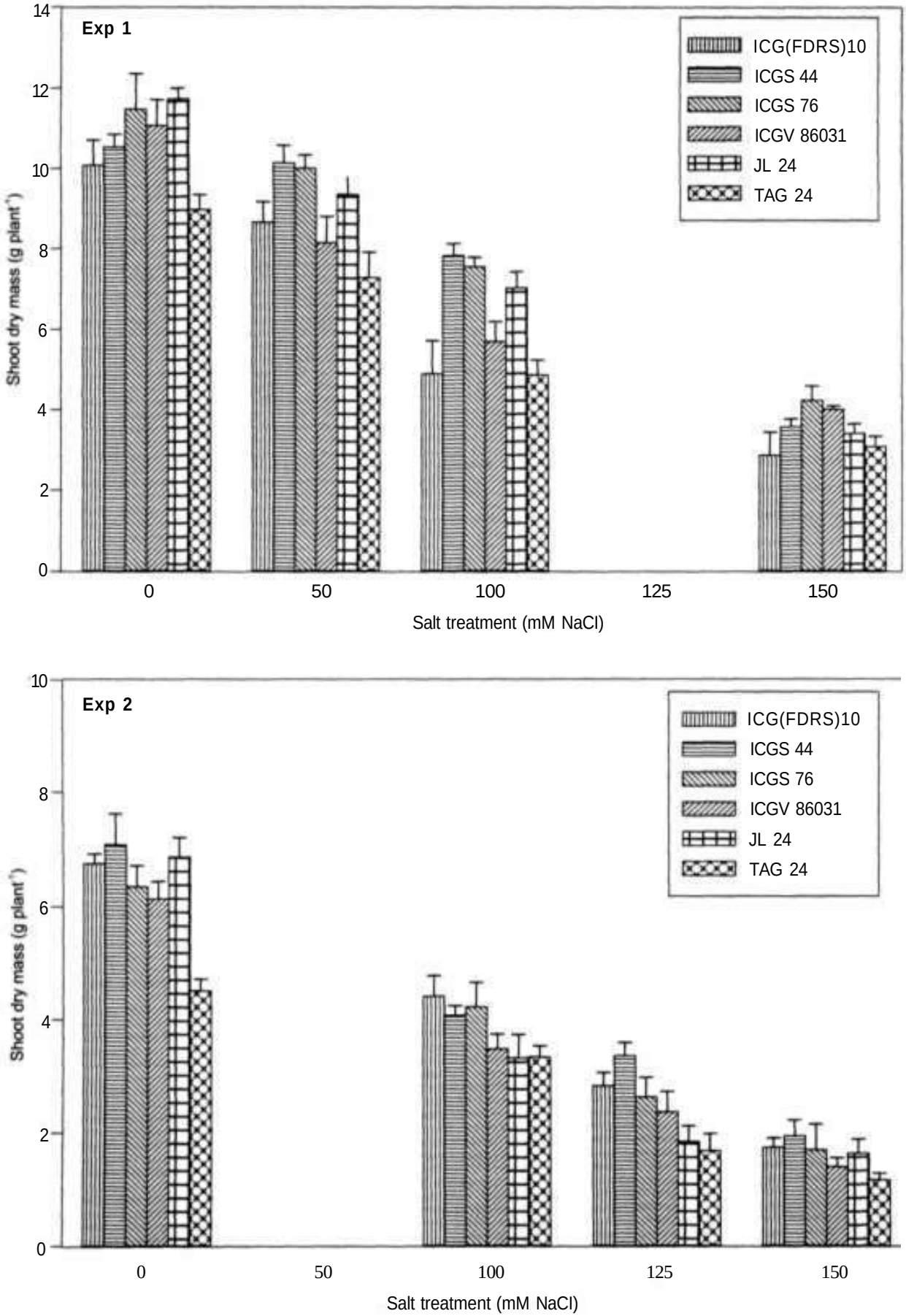

Figure 1. Shoot dry mass of groundnut under different salt treatments in Exp 1 and Exp 2. (Note: Data are means of five replicated plants per genotype and treatment and the vertical bars denote SE.)

is therefore needed to compare the leaf expansion of tolerant and sensitive genotypes under salinity stress and to assess the potential role played by abscisic acid. The ratio of stem/leaves was also an interesting aspect related to the possible storage of Na. It has been found in sorghum (*Sorghum bicolor*) that plants under salinity store a large amount of Na in the stem, as compared to leaves and young leaves (Netondo et al. 2004). We found in sorghum that there was a highly significant correlation between the salinity tolerance and the stem/leaves ratio (our on-going unpublished work in sorghum). The same turned out to be true in groundnut, where stems could be used as Na storage. Further investigation is needed to dissect the precise localization of Na in the shoot parts of tolerant and sensitive groundnut genotypes.

The N status of plants under salinity appeared to be severely affected along with a drastic reduction in leaf size. It is too early to conclude that nodulation reduction was the cause for the reduced production of biomass under salinity in sensitive genotypes, as nodulation is an endogenous variable (nodulation affects shoot growth but shoot growth in turn also affects nodulation). Further work would be needed to explore whether the N_2-fixation process is the most sensitive physiological mechanism in groundnut exposed to salinity.

Now that this protocol is set up, further work is needed to investigate the range of yield response to 100-125 mM NaCI treatment, using a large range of genotypes.

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Assessment of Efficient Groundnut Cropping Zone in Gujarat, India

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Groundnut (*Arachis hypogaea*) is the most important oilseed crop in Gujarat, India and occupies an area of 1.91 million ha with a production of 1.47 million t. This crop is grown in almost all the eight agroclimatic zones of the state irrespective of soil, climate and rainfall patterns. Crop production and productivity in agriculture is dependent on climate in general and weather in particular. The total production of any crop depends on the actual acreage under cultivation and the weather conditions during the crop life period whereas the productivity of the crop depends on both the soil characteristics and weather conditions during the season (Venkataraman and Krishnan 1992). The studies on long-term effect of sowing time and rainfall distribution revealed that the rainfall amount and distribution during the growth period significantly affected the groundnut production and productivity at Junagadh, Gujarat (Sahu et al. 2004). Veeraputhiran et al. (2003) have assessed and identified the efficient cropping zones for rice (*Oryza sativa*) and groundnut in Tamil Nadu, India.

Though generally crop area is increasing every year in some regions, the production and productivity are declining due to many obvious constraints. Rainfall is the most vital factor affecting dryland *kharif* (rainy season) crops. Hence the assessment of efficient groundnut areas for maximum and stabilized production and productivity is essential. Junagadh district is the most efficient and stable zone for groundnut. The total area under groundnut in Saurashtra region is 1.6 million ha but the productivity is 708 kg ha^{-1}, which is considerably lower than the other regions of the state of Gujarat. The yield potential of groundnut is higher in other regions of the state than the Saurashtra region.

Materials and methods

The district and state level data related to area, production and productivity of groundnut and rainfall were collected for 43 years (1960-2002) from the publications of the Department of Agriculture, Gujarat. The collected data were used to compute relative yield index (RYI) as given by Kanwar (1972) for each year and for each district separately and finally averaged over the years. The statistical parameters like mean, standard deviation (SD), coefficient of variation (CV) and correlation coefficient were calculated to interpret the results and determine the efficient cropping zones. The following formula was used to calculate RYI:

RYI = (Average yield of the district / Average yield of the state) x 100

Three categories of cropping zones were classified as most efficient (>125), efficient (100-125) and not efficient (<100) by using RYI values. Considering the CV values for RYI, the cropping zones were classified as most stable (<25%), stable (25-50%) and unstable (>50%). All the districts were grouped in five regions, viz, Kutch, Saurashtra, North Gujarat, Middle Gujarat and South Gujarat.

Results and discussion

The district-wise annual rainfall, area, production and productivity of groundnut in Gujarat and the correlation coefficient between rainfall and productivity are presented in Table 1.

Rainfall distribution in Gujarat. The annual rainfall of Gujarat is 851 mm with a variability of 31 %. The rainfall varied from as low as 330 mm with the highest annual variability of 69% in Kutch district to as high as 2088 mm with the lowest variability of 29% in Dangs district of South Gujarat region. Junagadh district has a peculiar rainfall characteristic of high rainfall as in a humid area and a high variability like an arid climate. Kheda district in Middle Gujarat with 941 mm rainfall has 47% variability but Junagadh district in Saurashtra region with 992 mm rainfall has 54% variability. Except Dangs and Valsad the rainfall is highly erratic in all the districts. Khambete and Biswas (1978) observed that more than 95% of annual rainfall in Gujarat occurs during the southwest monsoon season and neither the annual nor the seasonal rainfall distribution shows skewness.

Area, production and yield of groundnut in Gujarat. The groundnut area in Gujarat varied from 2.34 million ha in 1962 to 1.05 million ha in 1987-88 with an average of 1.91 million ha and year-to-year variability of only 11%. The production varied from 2.87 million t in 1988-89

Table 1. District-wise annual rainfall, area, production and productivity of groundnut in Gujarat, India.

Region/District	Rainfall (RF) (mm)			Area ('00 ha)			Production ('00 t)			Yield (Y) (kg ha^{-1})			Correlation coefficient[1] (Y × RF)
	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)	
Kutch	330	229	69	627	250	40	645	457	71	932	481	52	0.394*
Saurashtra													
Amreli	569	290	51	2623	322	12	1937	1011	52	719	361	50	0.675**
Bhavnagar	567	257	45	1982	384	19	1421	856	60	704	397	56	0.579**
Jamnagar	544	338	62	3533	566	16	2034	1680	83	569	444	78	0.596**
Junagadh	992	540	54	3708	575	16	3900	1914	49	1024	445	43	0.436*
Rajkot	572	264	46	3876	438	11	2245	1607	72	602	430	71	0.717**
Surendranagar	494	227	46	377	227	60	231	107	46	631	370	59	0.381*
Total				16099			11768						
Mean	623	183	29							708	165	23	
North Gujarat													
Ahmedabad	760	300	39	120	184	153	87	96	144	779	357	46	0.313
Gandhinagar	644	338	52	9	12	130	6	5	95	920	585	64	0.369*
Mehsana	565	323	57	134	149	111	104	178	170	774	368	48	0.548**
Banaskantha	601	278	46	35	27	78	23	15	64	828	419	51	0.741**
Sabarkantha	738	328	44	698	321	46	532	263	49	811	301	37	0.622**
Total				996			752						
Mean	662	85	13							822	59	7	
Middle Gujarat													
Kheda	941	446	47	229	146	64	238	168	71	1167	539	46	0.192
Baroda	825	333	40	185	93	50	140	67	48	848	369	43	0.431*
Panchmahal	856	356	42	355	233	66	261	154	59	849	356	42	0.483**
Total				769			639						
Mean	874	60	7							955	184	19	
South Gujarat													
Bharuch	896	425	47	105	63	60	81	48	59	840	333	40	0.195
Surat	1194	472	39	296	93	31	259	73	28	987	294	30	0.175
Valsad	1911	547	29	22	14	62	17	10	57	900	314	35	0.161
Dangs	2088	605	29	16	15	94	13	17	128	750	381	51	0.487**
Total				439			370						
Mean	1522	569	37							869	100	11	
State Mean/Total	851	264	31	19121	2158	11	14701	6655	45	765	349	46	0.813**

1. * = Significant at 5% level; ** = Significant at 1% level.

Table 2. District-wise efficiency and stability of groundnut production in Gujarat, India.

Region/District	Relative yield index (RYI)			Efficiency	Stability
	Mean	SD	CV (%)		
Kutch	144	111	77	Most efficient	Unstable
Saurashtra					
Amreli	94	23	24	Not efficient	Most stable
Bhavnagar	91	35	39	Not efficient	Stable
Jamnagar	67	35	53	Not efficient	Unstable
Junagadh	141	30	21	Most efficient	Most stable
Rajkot	73	32	43	Not efficient	Stable
Surendranagar	94	58	62	Not efficient	Unstable
North Gujarat					
Ahmedabad	129	116	90	Most efficient	Unstable
Gandhinagar	127	87	69	Most efficient	Unstable
Mehsana	109	37	34	Efficient	Stable
Banaskantha	113	33	29	Efficient	Stable
Sabarkantha	123	58	47	Efficient	Stable
Middle Gujarat					
Kheda	199	193	97	Most efficient	Unstable
Vadodara	130	73	56	Most efficient	Unstable
Panchmahal	134	80	60	Most efficient	Unstable
South Gujarat					
Bharuch	137	92	67	Most efficient	Unstable
Surat	171	146	86	Most efficient	Unstable
Valsad	142	86	60	Most efficient	Unstable
Dangs	87	45	52	Not efficient	Unstable

to 0.14 million t in 1987-88 with an average production of 1.47 million t in the past 43 years. The productivity varied from 1577 kg ha^{-1} in 1988-89 to 133 kg ha^{-1} in 1987-88, the disastrous drought year. Among districts Rajkot has the highest average area (0.39 million ha) followed by Junagadh (0.37 million ha), Jamnagar (0.35 million ha) and Amreli (0.26 million ha). Junagadh district ranks first in total production (0.39 million t) followed by Rajkot (0.22 million t), Jamnagar (0.20 million t) and Amreli (0.19 million t). Kheda district ranks first in productivity with 1167 kg ha^{-1}, followed by Junagadh (1024 kg ha^{1}), Surat (987 kg ha^{-1}), Kutch (932 kg ha^{-1}) and Gandhinagar (920 kg ha^{-1}).

The relationship between district-wise rainfall and productivity of groundnut was found to be strong and significant for Rajkot and Banaskantha whereas it was highly significant for Amreli, Bhavnagar, Jamnagar, Mehsana, Sabarkantha and Panchmahal districts. However, the relationship was not significant for Ahmedabad, Kheda, Valsad, Surat and Bharuch districts that are high rainfall areas (Table 1).

Efficient cropping zones. The district-wise average RYI is presented in Table 2. The results reveal that out of 19 districts in Gujarat only 10 districts were under most efficient cropping zone for groundnut. Considering the high RYI values, the most efficient districts for groundnut cultivation are Junagadh, Kutch, Ahmedabad, Gandhinagar, Kheda, Vadodara, Panchmahal, Valsad, Surat and Bharuch which fall under different agroclimatic regions. Among the ten districts only two districts, Junagadh and Amreli, exhibited the most stabilized RYI; five districts, Bhavnagar, Rajkot, Mehsana, Banaskantha and Sabarkantha, exhibited a stabilized RYI. Jamnagar, Surendranagar and Dangs districts were classified "not efficient" cropping zones for groundnut because RYI was very low and unstable.

Conclusions

From the above study the following conclusions are drawn:

- Junagadh district is the most efficient and most stable cropping zone for groundnut.
- Amreli, Rajkot and Bhavnagar districts have more area and stable yields but the productivity is very low.
- The districts of North Gujarat region such as Mehsana, Sabarkantha and Banaskantha are efficient zones with stable yield for groundnut but the spread is very low.
- Kutch, Ahmedabad, Gandhinagar, Kheda, Baroda, Panchmahal and South Gujarat districts are most efficient zones for groundnut but the productivity is very unstable and the spread is very poor may be due to low or high rainfall in these districts.
- Although the yield potential of groundnut is good in Middle Gujarat and North Gujarat regions, the spread is very low. Hence efforts should be targeted to increase the area of the crop in these districts to enhance the groundnut production in the state.
- The area under the crop in the districts of Saurashtra region is very high but the productivity is low.
- This study suggests that with relatively lower RYI in Amreli, Bhavnagar, Jamnagar and Rajkot the crop is grown extensively but with higher RYI in Kutch, Ahmedabad, Gandhinagar, Anand, Vadodara, Panchmahal, Surat, Bharuch and Valsad the area under the crop is most negligible. Hence efforts should be made to increase the area under the crop in other regions of the state to enhance the groundnut production in the state as a whole.

As the study was done at district level to identify the most efficient cropping zones for the crop, in-depth study should be undertaken at taluka and village levels of the concerned districts to have micro-level crop planning and delineation of most effective and efficient cropping zones.

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Food-Fodder Traits in Groundnut

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Groundnut (*Arachis hypogaea*) is one of the key crops of the semi-arid tropics. It is commonly cultivated as a food-feed crop that provides pods for human food and haulms for livestock feeding (Larbi et al. 1999, Omokanye et al. 2001). From farmer participatory studies in the Deccan plateau of India, Rama Devi et al. (2000) concluded that food from grain/pods and fodder from the crop residues almost equally contribute to livelihoods in mixed-crop livestock systems. It was because of this important dual-purpose usage of groundnut that the groundnut improvement group of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and livestock nutrition group of the International Livestock Research Institute (ILRI), Patancheru, India started to explore collaboratively the potential for improving pod yield and haulm quantity and quality. Successful inclusion of haulm fodder traits into groundnut improvement has three prerequisites:

1. Livestock-nutritionally important genotypic variation in haulm value (quantity and quality);
2. Laboratory infrastructure that can predict fodder quality in a large number of plant entries; and
3. No serious trade-off between pod and haulm traits.

The work reported here investigated haulms from 860 breeding lines and cultivars of groundnut considering these three prerequisites.

Materials and methods

Groundnut breeding lines and cultivars used. The groundnut genotypes, 860 in all, were grown during the postrainy season 2001/02 at ICRISAT, Patancheru, using established ICRISAT protocols. The genotypes came from diverse spectra of groundnut improvement: medium duration, confectionery type, rust and late leaf spot resistant and aflatoxin resistant materials. Twelve cultivars (checks) were repeated in the 2002/03 postrainy season for the initial assessment of year-to-year effects.

Haulm quality analysis. Haulms were analyzed by a combination of conventional laboratory techniques and Near Infrared Spectroscopy (NIRS). The NIRS instrument used was a FOSS Forage Analyzer 5000 with software package WinISI II. From 860 haulm samples, 180 representative samples were selected based on their NIRS spectra for conventional analyses of haulm nitrogen content by Kjeldahl method and haulm in vitro organic matter digestibility (OMD) and metabolizable energy content as described by Menke and Steingass (1988). The selected set of 180 haulm samples was randomly divided into 2 subsets of 90 samples each, one for development of the NIRS calibration equations and the other for validation procedures after blind-predicting haulm nitrogen, in vitro OMD and metabolizable energy content. Relationships between blind-predicted and conventionally analyzed variables were described by R^2 and standard error of prediction (SEP).

Results and discussion

Haulm quality characteristics predictions by NIRS. The statistical comparison of nitrogen content, in vitro OMD and metabolizable energy content of 90 haulm samples as blind-predicted by NIRS and as analyzed by conventional laboratory analysis is presented in Table 1.

There was very good agreement between NIRS predicted and measured values (Table 1). The R^2 for the

Table 1. Comparisons of NIRS blind-predicted nitrogen, in vitro organic matter digestibility (OMD) and metabolizable energy (ME) content with actually analyzed values in haulms of 90 groundnut genotypes.

NIRS blind-predicted trait	Agreement between NIRS predicted (y) and analyzed value (x)
Haulm nitrogen	$y = 0.18 + 0.9x$; $R^2 = 0.94$; SEP[1] = 0.06
Haulm in vitro OMD	$y = 8.2 + 0.85x$; $R^2 = 0.92$; SEP = 0.88
Haulm in vitro ME	$y = 0.5 + 0.93x$; $R^2 = 0.93$; SEP = 0.13

1. For assessments of standard error of prediction (SEP), see also mean and range in Table 2.

Table 2. Means and ranges of nitrogen content, in vitro organic matter digestibility (OMD) and metabolizable energy (ME) content and their least significant difference (LSD) and probability values *(P)* for haulms of 860 groundnut genotypes.

Haulm trait	Mean	Range	LSD	*P*
Nitrogen (%)	1.7	1.2-2.3	0.16	<0.0001
In vitro OMD (%)	56.3	51.7-61.1	1.9	<0.0001
In vitro ME (MJ kg^{-1})	7.9	6.9-8.9	0.4	<0.0001

Table 3. Relationships between haulm and pod traits in groundnut.

Trait comparisons[1]	n	Relationship
Haulm N (x) versus pod yield (y)	860	y = 1427 + 1303x; r = 0.28; *P* <0.0001
Haulm N (x) versus haulm yield (y)	839	y = -2911 + 3569x; r = 0.26; *P* <0.0001
Haulm in vitro OMD (x) versus pod yield (y)	860	y = 2163 + 25.7x; r = 0.05; *P* = 0.13
Haulm in vitro OMD (x) versus haulm yield (y)	839	y = -617 + 173.9x; r = 0.23; *P*<0.0001
Haulm in vitro ME (x) versus pod yield (y)	860	y = 734 + 365x; r = 0.13; *P* <0.0001
Haulm in vitro ME (x) versus haulm yield (y)	839	y = -5816+ 1129x; r = 0.27; *P* <0.0001
Haulm yield (x) versus pod yield (y)	839	y =2671 +0.31x; r = 0.46: *P*<0.0001
Digestible haulm yield (x) versus pod yield (y)	839	y = 2708 + 0.52x; r = 0.45; *P* <0.0001

1. N = Nitrogen; OMD = Organic matter digestibility; ME = Metabolizable energy.

relationships were well above 0.90, which is considered excellent particularly for biological methods like determination of in vitro OMD and metabolizable energy content assessed on the basis of inoculation of substrate with rumen microorganism. NIRS analysis is much quicker and cheaper than conventional analysis and is easy to integrate into routine crop improvement work, while conventional analysis is not. Establishment of accurate NIRS equations for predictions of groundnut haulms quality is, therefore, an important step towards implementing groundnut improvement for haulms fodder quality.

Variations amongst genotypes for haulm fodder quality traits. Highly significant differences amongst genotypes were found for nitrogen content, in vitro OMD and metabolizable energy content of the haulms (Table 2). Further, the range in these traits was large enough to have important relevance for livestock feeding. For example, low nitrogen content is often considered the most limiting factor in utilization of crop residues as fodder. Rumen microbes require a minimum of 1 to 1.2% nitrogen (or 6.25 to 7.5% protein, since protein is calculated as N x 6.25) in the fodder to effectively degrade it. Nitrogen content below this threshold results in low voluntary feed intakes and therefore low livestock productivity (Van Soest 1994). Nitrogen content of haulms among genotypes varied by almost 100% (Table 2), ranging from 1.2 to 2.3% (or 7.5 to 14.4% protein content) with a mean value of 1.7%. Thus, haulms even from genotypes relatively low in nitrogen will supply minimum microbial nitrogen requirement resulting in acceptable levels of intake and therefore livestock productivity (see also Blümmel et al. 2005). Similarly, a range of about 10 units in in vitro OMD (Table 2) will have important effects on livestock productivity. As shown recently (Blümmel et al. 2005), the differences amongst genotypes for haulm digestibility of 7.1% (in vivo) and 7.5% (in vitro) were associated with differences in live weight gain in sheep of about 100 g day^{-1}.

The range in metabolizable energy content amongst genotypes was proportionally slightly higher than the range in in vitro OMD, confirming the important differences amongst genotypes for haulm quality. Briefly, metabolizable energy content is potentially a more precise estimate of fodder quality than digestibility because losses in urinary and methane energy are taken into account, and metabolizable energy values can be directly used to predict milk yield and meat production.

Broad sense heritability for fodder traits estimated in 12 cultivars (that served as checks in the two consecutive growing seasons) grown in 2001/02 and 2002/03 postrainy seasons was 0.72 for nitrogen content, 0.72 for in vitro OMD and 0.67 for metabolizable energy content.

Relationship between pod yields and haulm quantity and quality. The relationships between haulm fodder quality traits and pod and haulm yield in 860 genotypes are reported in Table 3. It is encouraging to note that haulm fodder quality traits and pod and haulm yields were not inversely related. Even though highly significant, the relationships were generally weak (Table 3). The strongest relationship (R^2 = 0.21) was observed between pod and haulm yield, but even in this relationship most of the variation (79%) remained unaccounted for. The latter finding suggests that haulm yields should be recorded in its own right in groundnut improvement since a considerable degree of independence seems to exist between pod and haulm yields and high pod yield is not automatically associated with high haulm yield. To summarize, the relationships presented in Table 3 show that high pod yield and superior haulm quality and quantity are compatible traits.

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Preliminary Observations on Livestock Productivity in Sheep Fed Exclusively on Haulms from Eleven Cultivars of Groundnut

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Groundnut (*Arachis hypogaea*) haulms provide important fodder resources for livestock feeding in mixed crop-livestock systems in developing countries (Larbi et al. 1999, Rama Devi et al. 2000, Omokanye et al. 2001). In these systems fodder shortage is considered one of the major constraints to high livestock productivity and its corollary, high income from the marketing of livestock products. Shrinking common property resources and the little or no scope to expand arable land are further limiting the availability of fodder resources in the rainfed semi-arid tropics. These factors are increasing the value of groundnut as a food-feed crop for which both pod and haulm yields and quality traits are important. Improving the productivity of groundnut can address pod as well as haulm traits, but there is a lack of information on the variability amongst cultivars for the fodder quality of their haulms. This work reported here investigated the variability in cultivar-dependent fodder quality of groundnut haulms through measurement of productivity parameters of young sheep.

Materials and methods

Haulms from improved germplasm/released groundnut cultivars (ICGV 89104, ICGV 91114, TMV 2, ICGV 92093, ICGV 92020, ICGV 86325, ICGS 76, ICGS 11, ICGS 44, DRG 12 and ICGV 86590) were harvested at full pod maturity from seed multiplication trials at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India. Four of the cultivars (DRG 12, ICGS 11, ICGS 44 and ICGV 86325) were harvested and fed in two different years. Haulms were fed ad libitum as sole feed to growing Deccani sheep which had a mean initial live weight of about 18 kg. Ad libitum feed intake was adjusted by allowing less than 10% of refused feed. The haulm of a cultivar was fed to six sheep kept in metabolic cages. The sheep were adapted to a cultivar for 3 weeks, following which feces were collected for 10 days. The sheep were weighed before the start of the trial and before and after the 10-day collection period on two consecutive days for which mean weights were calculated. The groundnut haulms were analyzed in the laboratory for nitrogen content by Kjeldahl method and for neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and for in vitro true organic matter digestibility (OMD) as described by Goering and Van Soest (1970).

Results and discussion

Significant differences amongst cultivars were observed for OMD, organic matter intake (OMI), digestible organic matter intake (DOMI) and live weight gains (LWG) in sheep (Table 1). Greatest differences amongst cultivars were observed for daily LWG. Live weight gains in the four cultivars (DRG 12, ICGS 11, ICGS 44 and ICGV 86325) that were harvested and fed in two different years did not differ significantly ($P > 0.05$) between the years. Therefore mean values over the two years are reported in Table 1. When fed haulms of cultivar ICGV 89104, sheep gained daily more than 150 g live weight, which was probably close to the growth potential of Deccani sheep (N Krishna, formerly at ANGRAU, Hyderabad, India, personal communication) while sheep gained only about 50 g on haulms of cultivar ICGV 86590. The cultivar-dependent variation in LWG varied by almost threefold. These observations confirm that groundnut haulms are excellent fodder for ruminant livestock, probably as good or better than most of the planted forages in the semi-arid tropics, and that livestock productivity can be increased through choice of groundnut cultivars.

The indirect haulm quality estimates, OMD, OMI and DOMI accounted for 0.71 ($P = 0.001$), 0.34 ($P = 0.06$) and 0.76 ($P = 0.0004$) of the variation in daily LWG, respectively. The strong positive relationship between OMI and LWG is encouraging because OMI can be estimated by simple laboratory techniques based on rumen microorganisms, ie, in vitro OMD. Established relationships between laboratory haulm quality traits and the productivity of livestock when fed the haulms are essential if haulm quality is to be effectively targeted in multidimensional crop improvement, since animal experimentation is unsuitable for routine screening work in crop improvement work.

Table 1. Organic matter digestibility (OMD), organic matter intake (OMI), digestible organic matter intake (DOMI) and live weight gain (LWG) estimated when haulms from 11 groundnut cultivars were fed to sheep.

Cultivar	OMD (%)	OMI ($g/kg^{0.75}$)[1]	DOMI ($g/kg^{0.75}$)[1]	LWG ($g\ day^{-1}$)
ICGV 89104	72.7	92.9	67.5	151
ICGV 91114	72.6	93.4	67.9	135
TMV 2	71.4	98.1	70.0	122
ICGV 92093	71.9	93.7	67.4	119
ICGV 92020	69.7	94.3	65.7	105
ICGV 86325	67.3	94.4	63.5	94
ICGS 76	66.4	100.1	66.4	100
ICGS 11	67.4	85.6	57.7	74
DRG 12	68.6	86.2	59.1	68
ICGS 44	65.6	87.7	57.5	69
ICGV 86590	67.0	89.9	60.0	51
LSD	2.2	11.3	8.9	41.4

1. Live weight was expressed as metabolic live weight, which is live weight to the power of 0.75 to account for possible absolute difference in live weight between groups.

Table 2. Content of nitrogen (N), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and in vitro organic matter digestibility (OMD) in haulms from 11 groundnut cultivars.

Cultivar	N (%)	NDF (%)	ADF (%)	ADL (%)	In vitro OMD (%)
ICGV 89104	1.8	42.1	25.0	3.8	88.0
ICGV 91114	1.8	38.5	25.6	3.9	87.9
TMV 2	1.8	43.7	29.8	5.2	83.5
ICGV 92093	3.1	33.0	25.6	5.3	86.0
ICGV 92020	2.6	36.6	27.0	5.1	80.5
ICGV 86325	2.4	39.2	25.9	5.1	80.5
ICGS 76	1.6	42.4	27.6	5.2	83.0
ICGS 11	2.0	39.6	25.7	5.8	82.9
DRG 12	2.2	37.8	26.6	5.7	82.2
ICGS 44	2.2	40.7	26.7	5.6	83.7
ICGV 86590	2.1	40.1	28.5	5.1	80.7

Table 2 presents laboratory fodder quality traits, content of nitrogen (N x 6.25 is an estimate of crude protein content), NDF, ADF, ADL and in vitro OMD, which are often employed in roughage and forage analysis. From the perspective of ruminant nutrition, un-supplemented fodder should contain a minimum of 1.2% of nitrogen (Van Soest 1994) required as a critical basal nutrient for the rumen microbes to digest fodder efficiently. The results in Table 2 show that all haulms had nitrogen content well above this threshold level. Neutral detergent fiber is an approximation of total cell wall content (cellulose + hemicellulose + lignin) and the digestibility of NDF by rumen microbes depends on the chemical structure of NDF, particularly the degree of lignification. On the other hand cell contents (100 - NDF) are thought to be almost completely digestible and all haulms investigated consisted of more than 50% of cell content (Table 2). In vitro OMD varied amongst cultivars by 7.5 units, which is of similar magnitude to the range in OMD observed in sheep (7.1 percentage units, see Table 1). Mean in vitro OMD was 83.5% compared to 69.1% in sheep, which agrees well with the theoretical difference of 12.9 percentage units (Van Soest 1994) expected for the particular in vitro digestibility method employed, which was a "true" digestibility measurement, rather than the "apparent" digestibility measurement obtained in sheep.

The relationships between laboratory haulm quality estimates and digestibility, intake and LWG measurements in sheep fed on the haulms are reported in Table 3. Significant inverse relationships were observed between ADL and OMD, DOMI and LWG in sheep. Significant positive relationships were observed between in vitro OMD and OMD and LWG in sheep. Generally, the laboratory measurements accounted for approximately 50 to 58% of the variation in the measurements in sheep.

To conclude, substantial variation in fodder quality of groundnut haulm from this sample of cultivars was observed, such that the variability could be exploited through crop improvement for higher livestock productivity. From the laboratory measurements in vitro OMD and lignin content seem to be suitable for use in the initial screening of germplasm but further development of the laboratory quality traits is required.

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Table 3. Relationships between laboratory haulms quality measurements (as in Table 2) and digestibility, intake and live weight gain (LWG) measurement in sheep fed haulms from 11 cultivars of groundnut[1].

Variable	OMD	OMI	DOMI	LWG
Nitrogen	0.06 (P = 0.86)	-0.18 (P = 0.57)	-0.09 (P = 0.80)	-0.11 (P = 0.75)
NDF	-0.17 (P = 0.62)	0.25 (P = 0.45)	0.08 (P = 0.81)	0.04 (P = 0.90)
ADF	-0.22 (P = 0.52)	0.35 (P = 0.29)	0.12 (P = 0.72)	-0.29 (P - 0.40)
ADL	-0.70 (P = 0.02)	-0.36 (P = 0.27)	-0.62 (P = 0.04)	-0.76 (P - 0.007)
In vitro OMD	0.72 (P = 0.01)	0.10 (P = 0.77)	0.45 (P = 0.17)	0.74 (P = 0.01)

1. OMD = Organic matter digestibility; OMI = Organic matter intake; DOMI = Digestible organic matter intake; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; ADL = Acid detergent lignin.

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Groundnut publications

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Information for IAN contributors

Publishing objectives

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

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

What to contribute?

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 1000 words is the upper limit (no more than four double-spaced pages). In exceptional cases, longer articles may be accepted.
- 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 (eg, use tons instead of kg). Every table should fit within the normal type-written area of a standard upright page (not a 'landscape' page). Do not use the table-making feature of the word processing package; use simple tab set to prepare tables.
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About ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a nonprofit, non-political organization that does agricultural research and innovative capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 600 million people - the poorest of the poor - overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT belongs to the Future Harvest Alliance of Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

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