Groundnut Breeding at ICRISAT

S. N. Nigam, S. L. Dwivedi, and R. W. Gibbons*

Breeding work on groundnuts started in mid-1976 after the acceptance of the detailed research proposal (Gibbons 1976) by the Governing Board of ICRISAT.

The main objective of the program is to produce high yielding breeding lines or populations with resistance to the main factors presently limiting production.

Much emphasis has been laid on disease resistance breeding — particularly for diseases such as leaf spots (*Cercospora arachidicola* and *Cercosporidium personation*) and rust (*Puccinia arachidis*), which are of international importance. Other priorities include breeding for earliness, high yield and quality. Since 1976, several more research projects have been started as and when necessary germplasm became available.

Groundnut growing environments vary greatly not only between but also within countries. In addition, there is considerable diversity in the uses to which the crop is put. Considering the diverse requirements, emphasis has been on supplying suitable early generation and advanced breeding material to cooperators in different countries of the Semi-Arid Tropics (SAT) for further selection in situ.

Program and Progress

Hybridization

The emasculation and pollination processes used at ICRISAT are basically the same as those described for Florida by Norden (1973). However at Hyderabad, emasculations can be made as early as 1.30 p.m compared with 5.00 p.m in Florida. Pollinations are carried from 7.00 a.m to 10.00 a.m in Florida, but the highest success rates are achieved at Hyderabad if they are made around 6.00 a.m.

The standard method of making crosses is to use large pots, containing single parental plants, which are placed on benches inside a glasshouse or screenhouse. However, it was realized that for the large numbers of crosses, which needed to be made for an international breeding program, there were severe limitations in using this method. In 1977 crossing was therefore extended to the field. Initial results were poor, but by improving insect control and using an irrigation system to maintain high humidity at the time of pollination, success rates of over 50% were obtained in the rainy season of 1979 and the postrainy season of 1979-80. During the current rainy season of 1980 the success rate averaged 67%, with some individuals achieving as high as 94%. During each of the two crop seasons some 30 000 pollinations are made in the field. As large number of crosses can now be carried out, specific combinations could be made for breeders in national programs who have limited facilities.

Initially the hybridization program mainly utilized germplasm lines but now after four years lines derived at ICRISAT are being used as parents to combine more desirable characters in breeding populations.

Rapid Generation Advance

The climatic conditions and the facilities at the ICRISAT Center provide opportunities to grow two full crops in a year. Many of the major pathogens and insect pests either occur, or can be induced, during both seasons and thus provide good opportunities for continuous screening.

The problem of postharvest dormancy in Virginia types (sub sp *hypogaea*) preventing immediate replanting in the second crop season, has been overcome. The seed is dressed with Ethephon, an experimental preparation in powder form of an ethylene-releasing com-

* Plant Breeders and Principal Plant Breeder, Groundnut Improvement Program, ICRISAT.

pound (Amchem Products Ina, USA), before planting. In the laboratory more than 90% of treated seeds germinate within 24 hours. Using this technique under field conditions, 75-80% emergence is obtained within a few days.

Evaluation

The advanced breeding populations are evaluated in two different environments at the ICRISAT Center. The rainfed crop is grown under low fertility conditions (20 kg P_2O_5) and is not protected against diseases and insect pests. The irrigated crop is grown at higher fertility levels (40 kg P_2O_5) and is protected. Early generation segregating material, when enough seed is available, is also grown in both environments. Very little material is discarded in early generations. Most of the material is bulked into uniform groups for evaluation and further selection at cooperating centers.

Stability of yield is important overyears and across sites. Currently the breeding material is evaluated on a limited scale in different agroclimatic zones in India. An international testing network will soon be set up after the establishment of outreach programs.

Research Projects

Breeding for Resistance to Foliar Pathogens

At present the work on foliar diseases at ICRISAT is restricted to rust and *Cercospora* leaf spots as they are worldwide in distribution and cause serious economic losses (Bunting et al. 1974; Hammons 1977; Subrahmanyam et al. 1979).

SOURCES OF RESISTANCE. Rust resistance breeding started in 1977 with two sources of resistance, PI 259747 and PI 298115. Since then several other sources of resistance have also been incorporated in the breeding program (Table 1).

High levels of resistance to leaf spots occur within the wild species (Abdou 1966; Abdou et al. 1974). Leaf spot resistant tetraploid progenies, resulting from interspecific hybridization, will soon become available from the Cytogenetics subprogram for utilization by the breeders (see Singh et al. in this volume).

Recently more intensive searches within the cultivated groundnut have shown some usable sources of resistance or tolerance to leaf spot fungi (Sowell et al. 1976; Hassan and Beute 1977; Melouk and Banks 1978; Subrahmanyam et al. 1980b). Many of the germplasm lines earlier selected for rust resistance have also shown resistance to late leaf spot at the ICRISAT Center (Table 2). Several rust-resistant FESR selections made at ICRISAT are also resistant to late leaf spot (Table 3). A few rosette-resistant cultivars, such as RMP 91 and RMP 12, have also some resistance to late leaf spot (Subrahmanyam et al. 1980b). For resistance to early leaf spot, NC 3033 (Beute et al. 1976) and P1109839 (Hammons et al. 1980) are being utilized in the breeding program.

CURRENT STATUS. The breeding material for rust resistance, other than FESR selections, has

Table 1. Sources of rust resistance.

Cultivar	Source	Type	Reference
PI 259747	Peru	Valencia	Mazzani and Hinojosa 1961
PI 298115	Introduction to Israel from USA	Virginia Bunch	Hammons 1977
NC Acc 17090	Peru	Valencia	Subrahmanyam et al. 1980a
EC 76446 (292)	Uganda	Valencia	Subrahmanyam et al. 1980a
NCAcc 17133 (RF)	S. America	Valencia	Subrahmanyam et al. 1980b
DHT 200	Peru	Valencia	Hammons 1977
FESR selections	USDA rust nursery, Puerto Rico	Variable	Bailey et al. 1973; Subrahmanyam et al. (unpublished data)

Table 2. Rust resistant sources also resistant to lata loaf spot.

Cultivar	Source	Type	Reference
PI 259747	Peru	Valencia	Filho and de Moraes 1977; Subrahmanyam et al. 1980b
EC 76446 (292)	Uganda	Valencia	Subrahmanyam et al. 1980b
NC Acc 17133 (RF)	S. America	Valencia	Subrahmanyam et al. 1980b
FESR selections	USDA rust nursery, Puerto Rico	Variable	Subrahmanyam et al. (unpublished data)

Table 3. Rust and late leaf spot reactions of soma FESR selections in field screening trials at ICRISAT Center, 1978-1980.

Selection	Mean disease score[a]	
	Rust	Leaf spot
FESR 5-P2-B1	2.0	3.0
FESR 5-P17-B1	2.0	3.0
FESR 7-P13-B1	2.0	3.0
FESR 9-P3-B1	2.0	3.0
FESR 9-P4-B1	2.0	4.3
FESR 9-P7-B1	2.7	3.3
FESR 9-P7-B2	2.7	4.3
FESR 9-P8-B2	2.0	3.0
FESR 9-P12-B1	2.0	2.7
FESR 11-P11-B2	2.3	2.7
FESR 12-P4-B1	2.0	2.0
FESR 12-P5-B1	2.0	2.7
FESR 12-P6-B1	2.7	3.7
FESR 12-P14-B1	2.0	3.3
FESR 13-P12-B1	2.0	2.7
TMV-2 (Check)	9.0	9.0

a. Mean score of three seasons on a 1-9 scale. where 1 - no disease and 9 = 50-100% foliage destroyed.

been advanced to the F_6 generation generally by following pedigree and bulk pedigree methods. Backcrossing has been adopted in a few cases. The material is screened in the field for both rust and leaf spot resistance using the infector-row technique developed by Subrahmanyam et al. (1980a). The plants are broadly classified into resistant and susceptible groups based on field scoring using a 1-9 scale (where 1=no disease, and 9=50-100% defoliation). Single plants or bulks classified as high yielding but susceptible to foliar pathogens are retained for further screening and use in other breeding projects.

FESR SELECTIONS. Fourteen F3-derived rust-resistant lines (FESR 1-14), from a natural cross between PI 298115 and an unknown pollen donor in the USDA rust nursery in Puerto Rico were received at ICRISAT in 1977 (Bailey et al. 1973). These lines segregated not only for morphological characters but also for reaction to rust at ICRISAT Center. All the lines were progeny-rowed in the next generation when they again segregated for reaction to rust. This indicated that resistance to rust, though recessive, may not be governed by duplicate loci as has been reported by Bromfield and Bailey (1972). Since then the material has been advanced to the F_8 generation. Fifteen hundred and forty-six selections are currently being finally assessed in the field for yield and rust resistance.

Some of the resistant FESR selections, evaluated under rainfed and low-fertility conditions, have yielded more than the released Indian cultivars, J-11 and Robut 33-1, and the rust-resistant parent, NC Acc 17090 (Table 4).

Breeding for Earliness

Groundnuts, which are earlier maturing than currently released cultivars and possess high yield potential together with good quality, will be extremely useful in areas of the SAT which have short growing seasons or where an early maturing crop may escape certain pests and diseases. There is also scope for fitting early maturing groundnuts into relay or sequential cropping systems, particularly in Southeast Asia by utilizing residual moisture after the harvest of the rice crop (Gibbons 1980).

Table 4. Performance of FESR selections under low-fertility and rainfed conditions (rainy seeson 1979).

Selections	Yield (kg/ha)
FESR 8-P12-B1-B1-B1	1301
FESR 5-P20-B1-B2-B1	1127
FESR 9-P5-B1-B1-B1	1076
FESR 8-P9-B1-B1-B1	1076
FESR 8-P11-B1-B2-B1	1003
FESR 8-P13-B1-B2-B1	1001
FESR 5-P19-B1-B2-B1	996
FESR 8-P3-B1-B2-B1	987
NC Acc 17090[a]	978
Robut 33-1*	816
J 11[b]	524
LSD (0.05)	282.7

a. Rust-resistant check.
b. Susceptible checks.

SOURCES OF EARUNESS. The following cultivars are presently being utilized in the breeding program:

Chico — a very early Spanish type, maturing in 75-80 days, commercially unacceptable because of extremely small pods; 91176 and 91776 —Spanish types, maturing in 80-85 days, bred in Tamil Nadu (India); and Robut 33-1 — a Virginia type, maturing in 100 days, released in Andhra Pradesh (India).

CURRENT STATUS. The breeding material has been advanced to the F_7 generation by pedigree or bulk pedigree methods.

Several early maturing (100-105 days) selections have been identified and are currently being evaluated for yield potential (Table 5). Some of the early flowering material identified in the current rainy season is presented in Table 6.

The cultivars Robut 33-1 and Chico have proved to be very good combiners for high yield in certain cases. Late maturing, high yielding selections from this project are being utilized in the high yield and quality project.

Breeding for High Yield and Quality

The purpose of this project is to generate base material with high yield potential for disease resistance programs, and for areas of the world where diseases are not prevalent or protective measures are routinely followed.

Table 5. Early maturing selections (postrainy season 1979—80).

F_4 generation	F_5 generation
Argentine x Chico	JH 89 x Chico
2-5 x Chico	JH 171 x Chico
28-206 x Chico	Dh 3-20 x Chico
SM 5 x Robut 33-1	NC Acc 2748 x Chico
Tifspan x Robut 33-1	TMV 7 x Chico
2-5 x Robut 33-1	Virginia 72R x Chico
Virginia 72R x Robut 33-1	Dh 3-20 x Robut 33-1

Table 6. Early flowering selections (rainy season 1980).

Generation	Selection (P_1 x P_2)	Days to 75% flowering P_1	Selection	P_2
F_1	Ah 330 x 91176	28	18	17
	Chico x Ah 330	18	17	28
	Mani Pinter x 91776	24	17	17
	Chico x NC Acc 344	18	23	29
	Robut 33-1 x Jacana	24	21	20
	91176 x NC Acc 2123	17	23	29
F_3	M 13 x 91176	25	21	17
	Chalimbana x 91176	26	23	17
	DM 1 x 91176	26	18	17
	RMP 91 x Chico	23	22	18
	Ah 114 x 91176	24	20	17

SOURCES. The following material is being utilized in the hybridization program: Cultivars and landraces from different geographical regions; high yielding and adapted varieties from different countries; and high yielding breeding lines developed at ICRISAT.

CURRENT STATUS. The breeding material has been advanced to F_7 generation using pedigree or bulk pedigree methods. Several promising selections are being evaluated for yield potential in different environments during the current rainy season.

Some of the promising selections made in the F_4 and F_5 generations, during the postrainy season of 1979-80, are listed in Table 7.

Table 7. High yielding selections (postrainy season 1979-80).

F_4 Generation	F_5 Generation
NC Acc 529 x Shulamit	Ah 8254 x JH 62
NC-Fla-14 x TG 1	G 37 x Spanhoma
Ah 6279 x Spancross	Faizpur 1-5 x NC Acc 316
Florigiant x SM 5	NC Acc 63 x TG 17
GAUG 1 x NC Acc 310	148-7-4-3-12-B x Manfredi
Starr x NC Acc 1107	NC Acc 2750 x Ah 8189
Tifspan x SM 5	NC Acc 316 x NC Acc 310
Virginia 72R x NC Acc 1107	USA 20 x TMV 10
X14-4-B19-B x SM 5	

Table 8. F_5 yield evaluation (postrainy season 1979-80).

Selection	Type	Days to maturity	Yield (kg/ha)
(Robut 33-1 x NC Acc 2821) F2-B3-B1-B2-B1	SB	121	3827
(Robut 33-1 x NC Acc 2698) F2-B2-B1-B1-B1	SB	118	3686
(Dh 3-20 x NC Acc 2608) F2-B3-B1-B1-B1	SB	112	3598
(2-5 x NC Acc 741) F2-B4-B1-B1-B1	VB	122	3576
Robut 33-1[a]	VB	121	2949
J 11[a]	SB	112	2915
LSD (0.05)			634.5

a. Standard checks.

Five hundred and twelve F_6 bulks were evaluated in an 8 x 8 x 8 cubic lattice design as well as in a systematic design, which was superimposed over the lattice, during the post-rainy season of 1979-80. The purpose of the trial was to compare the efficiency of these two designs in evaluation of breeding material. The results obtained from the cubic lattice analysis are presented in Table 8. Four breeding lines significantly outyielded the checks, Robut 33-1 and J-11, and 68 more breeding lines were equal in yield to Robut 33-1.

A yield trial consisting of progenies of several plant selections made in the Indian cultivar Robut 33-1 was carried out during the post-rainy season of 1979-80. Eight selections significantly outyielded the Robut 33-1 (Table 9). This cultivar was developed in Andhra Pradesh, India and originated as a selection from a mutant or chance out cross in an exotic introduction.

New Research Projects

During 1979 and 1980 thefollowing new breeding projects were initiated:

Breeding for Resistance to *Aspergillus Flavus*

Three breeding lines, with dry seed resistance to invasion by the fungus, are presently being utilized as parents in the hybridization program with a wide range of adapted but susceptible cultivars. The resistant germplasm lines are PI 337394F and PI 337409 (Mixon and Rogers 1973) and UF 71513 (Bartz et al. 1978).

Breeding for Resistance to Insect Pests

Two germplasm lines, NCAcc 2214 and NCAcc 2232, selected for resistance to thrips and jassids (Amin, unpublished data) are being used as parents in an attempt to incorporate resistance in commercially accepted cultivars.

Development of Cultivars for Vertisols

Groundnuts grown in Vertisols, or dark alluvial soils, often show symptoms of chlorosis due to lime induced iron chlorosis. Germplasm lines and advanced breeding populations are being screened for their reaction to iron, and other possible deficiency factors, in Vertisols at the ICRISAT Center.

Basic Studies

Some basic genetic studies are being conducted in cooperation with research workers in India and by postgraduate students at ICRISAT. Studies on breeding methods have shown high genetic divergence among Spanish and Valencia parents suggesting the utility of Spanish x Spanish, Spanish x Valencia and

Table 9. **Natural hybrid trial (postrainy season 1979-80).**

Selections from Robut 33-1	Type	Days to maturity	Yield (kg/ha)	Shelling (%)
11-7-B1-B1-B1	VB, SB, IB	119	2680	77
21-11-B1-B1-B1	SB	119	2683	66
10-3-B1-B1-B1	SB	119	2653	76
7-6-B1-B1-B1	VB, IB	119	2650	70
13-6-B1-B1-B1	VB, SB, IB	119	2628	71
12-10-B1-B1-B1	VB, IB	119	2620	75
50-1-B1-B1-B1	VB	119	2527	71
24-16-B1-B1-B1	SB	119	2488	72
Robut 33-1 (parent)	VB	119	2013	70
LSD (0.05)			389.4	

Valencia x Valencia crosses (Arunachalam et al. 1980).Similar results have been obtained in the USA by Wynne et al (1970).

Uniform non-nodulating lines of groundnuts have been developed through wide crosses and the genetics of non-nodulation has been determined (Nigam et al. 1980).

Some yield trials conducted during rainy and postrainy seasons at the ICRISAT Center have shown strong variety x season interactions. This suggests the need of identification of varieties for each season. This is particularly important for India where presently 8% of the total crop is grown under postrainy conditions.

Cooperation with National Programs

The breeding material, generated with desirable characteristics at ICRISAT, is freely distributed to breeders in national programs to enable them to carry out final selection under their local conditions. So far, 2792 selections have been supplied to breeders in 14 countries (Table 10). All the breeders, who received material, were able to make useful selections out of breeding populations supplied. Some selections have done exceedingly well in trials in Tamil Nadu (India). Another selection, maturing in 85 days, has been found suitable for summer cultivation in Maharashtra.

As the breeding program develops, a considerably greater volume of material will become available for distribution to any country which requests it.

Table 10. **Breeding material supplied to cooperators by ICRISAT, 1978-1980.**

Country	Number		
	High-yielding selections	Selections with earliness	Rust-resistant material
Bangladesh	6	14	
Benin	80	55	68
Burma	10	6	
China	8	2	40
Ghana	15		19
India	1121	858	288
Japan			3
Puerto Rico			14
Senegal	30	20	40
Sri Lanka	17	4	4
Tanzania	9	4	
Thailand	10	20	10
Upper Volta		5	6

References

ABDOU, Y. A-M. 1966. The source and nature of resistance in *Arachis* spp to *Mycosphaerella arachidicola* Jenk. and *M. berkeleyii* Jenk. and factors influencing sporulation of these fungi. Unpublished Ph.D. thesis, Department of Plant Pathology, North Carolina State University, Raleigh, North Carolina, USA. University Microfilms, Inc. Ann Arbor, Michigan, USA.

ASOOU, Y. A-M., GREGORY, W. C, and COOPER, W. E. 1974. Sources and nature of resistance to *Cercospora arachidicola* Hori and *Cercosporidium personatum* (Berk and Curtis) Deighton in *Arachis* species. Peanut Science 1: 6-11.

ARUNACHALAM, V., BANDYOPADHYAY, A., NIGAM, S. N., and GIBBONS, R. W. 1980. Some basic results of applied value in groundnut breeding. Pages 1-19 IN Proceedings of the National Seminar on the Application of Genetics to Improvement of Groundnut. 16-17 July, 1980. School of Genetics, Tamil Nadu Agricultural University, Coimbatore-641 003, India.

BAILEY, W. K., STONE, E., BROMFIELD, K. R., and GARREN, K. H. 1973. Notice of release of peanut germplasm with resistance to rust. Virginia Agricultural Experiment Station , Blacksburg, Virginia and USDA, Agricultural Research Service, Washington, D. C. 3 pp.

BARTZ, J. A., NOROEN, A. J., LAPRADE, J. C, and DEMUYNK, T. J. 1978. Seed tolerance in peanuts *(Arachis hypogaea* L.) to members of the *Aspergillus flaws* group of fungi. Peanut Science 5: 53-56.

BEUTE, *M.* K., WYNNE, J. C, and EMERY, D. A. 1976. Registration of NC 3033 peanut germplasm. Crop Science 16: 887.

BROMFIELD, K. R., and BAILEY, W. K. 1972. Inheritance to *Puccinia arachidls* in peanut. Phytopathology 62: 748 (Abstract)

BUNTING, A. H., G REGORY, W. C, MAUBOUSSIN, J. R., and RYAN, J. G. 1974. A proposal for research on groundnuts *(Arachis)* by ICRISAT. pp 1-38. ICRISAT, mlmeo.

FILHO, A. S., and de MORAES, S. A. 1977. Observacoes sobre a incidencia de Cercosporioses em cultivares de amendoim *(Arachis hypogaea* L.) Revista de Agriculture 52: 39-46.

GIBBONS, R. W. 1976. Groundnut Improvement Programme — Priorities and Strategies, pp 1-26. ICRISAT mimeo.

GIBBONS, R. W. 1980. Adaptation and utilization of groundnuts in different environments and farming system. Pages 483-493 *in* Advances in Legume Science, eds. Summerfield and Bunting 1980.

HAMMONS, R. O. 1977. Groundnut rust in the United States and the Caribbean. Pest Articles and News Summaries, 23: 300-304.

HAMMONS, R. O., SOWELL, G. Jr., and SMITH, D. H. 1980. Registration of *Cercospora arachidicola* resistant peanut germplasm. Crop Science 20: 292.

HASSAN, H. N., and BEUTE, M. K. 1977. Evaluation of resistance to *Cercospora* leaf spot in peanut germplasm potentially useful in a breeding program. Peanut Science 4: 78-83.

MAZZANI, B., and HINOJOSA, S. 1961. Diferencias varletales de susceptibllidad a la roya del mani en Venezuela. Agronomia Tropical 11: 41-45.

MELOUK, H. A., and BANKS, D. J. 1978. A method of screening peanut genotypes for resistance to *Cercospora* leaf spots. Peanut Science 5: 112-114.

MIXON, A. C, and ROGERS, K. *M.* 1973. Peanut accessions resistant to seed infection by *Aspergillus flavus.* Agronomy Journal 65: 560-562.

NIGAM, S. N., ARUNACHALAM, V., GIBBONS, R. W. BANDYOPADHYAY, A., and NAMBIAR, P. T. C. 1980. Genetics of non-nodulation in groundnut *(Arachis hypogaea* L). Oleagineux (In press).

NORDEN, A. J. 1973. Breeding of the cultivated groundnut *(Arachis hypogaea* L). Pages 182-184 *in* Peanuts-Culture and Uses. American Peanut Research and Education Association, Inc., USA.

SOWELL, G. Jr., SMITH, D. H. and HAMMONS, R. O. 1976. Resistance of peanut plant introductions to *Cercospora arachidicola.* Plant Disease Reporter 60: 494-498.

SUBRAHMANYAM, P., REDDY, D. V. R., GIBBONS, R. W., RAO, V. R., and GARREN, K. H. 1979. Current distribution of groundnut rust in India. Pest Articles and News Summaries. 25: 25-29.

SUBRAHMANYAM, P., GIBBONS, R. W., NIGAM, S. N., and RAO, V. R. 1980a. Screening methods and further sources of resistance to peanut rust. Peanut Science 7: 10-12.

SUBRAHMANYAM, P., MCDONALD, D., GIBBONS, R. W., NIGAM, S. N. and NEVILL, D. 1980b. Resistance to both rust and late leaf spot in some cultivars of *Arachis hypogaea* L. Proceedings, American Peanut Research and Education Association, USA. (In press).

WYNNE, J. C, EMERY, D. A., and RICE, P. W. 1970. Combing ability estimates in *Arachis hypogaea* L.II. Field performance of Fi hybrids. Crop Science 10: 713-715.