An Update on Groundnut Breeding Activities at ICRISAT Center with Particular Reference to Breeding and Selection for Improved Quality

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Abstract

Groundnut breeding activities at ICRISAT Center are organized into six project areas. Having already made reasonable progress with incorporating resistance/tolerance to single-stress factors, a high priority is now attached to develop genotypes with resistance/tolerance to multiple-stress factors. A brief update on progress in this direction is presented. The groundnut varieties resulting from different project activities are currently organized into five international trials for distribution internationally. Groundnut varieties derived from ICRISAT Center activities have been released or are in various stages of release to farmers for general cultivation in different national programs. Progress in breeding at ICRISAT Center for improved quality traits is described.

Sumário

Uma Actualização das Actividades do Melhoramento do Amendoim no Centro ICRISAT com Particular Referência ao Melhoramento e Selecção para o Aumento da Qualidade. As actividades de melhoramento do amendoim no Centro ICRISAT estão organizadas em seis áreas de projecto. Depois de se ter conseguido um razoável progresso na incorporação da resistência/tolerância a factores de "stress" simples, alta prioridade foi dada ao desenvolvimento de genótipos com resistência/tolerância a factores de "stress" multiplos. Uma breve atualização sobre o progresso nesta direção é apresentado. As variedades de amendoim resultantes das diferentes actividades dos projectos, estão actualmente organizadas em cinco ensaios internacionais para serem distribuidos internacionalmente. As variedades de amendoim derivadas de actividades do Centro ICRISAT, foram libertadas, ou estão em vários estádios de libertação para os agricultores, para o cultivo em diferentes programas nacionais. Progresso no melhoramento para o aumento dos factores de qualidade, feito no Centro ICRISAT, é apresentado em detalhe.

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Introduction

The groundnut section of the Legumes Program at ICRISAT Center is organized into the following 15 broad-based projects:

1. Biology and management of foliar diseases of groundnut.
2. Biology and management of aflatoxin contamination of groundnut.
3. Biology and management of groundnut diseases caused by soil fungi, bacteria, and nematodes.
4. Biology and management of groundnut diseases caused by viruses, prokaryotes, and viroids.
5. Adaptation to specific environments and requirements.
6. Drought stress effects on groundnut.
7. Investigations on nutrient stresses and exploitation of *Rhizobium* and mycorrhizae to increase groundnut production.
8. Exploitation of *Arachis* species to improve the cultivated groundnut.
9. Identification and utilization of host plant resistance to insect pests and associated organisms.
10. Biology and management of pests of stored groundnuts.
11. Integrated pest management with emphasis on *Spodoptera litura* and groundnut leaf miner.
12. Termite control in groundnuts.
13. Evaluation of nutritional and food quality of groundnut.
14. Photoperiod effects in groundnut.
15. International cooperation.

These projects were formulated in 1985 by merging several interrelated, independent projects and were reviewed at the Institute level in 1987. These are multidisciplinary and demand active collaboration and cooperation of all groundnut scientists working at the Center. Genetic exploitation and improvement, although a very significant component of the management, is considered as one of many approaches that need to be integrated into one management package so that returns to the farmer are maximized from each unit of money spent.

The Breeding Unit at the Center is actively involved in project numbers 1, 2, 4, 5, 8, 9, 13, and 15. In each project, we have a prioritized list of stress factors, where amelioration through genetic means is being attempted.

In 1987, the direction of thrust of breeding activities changed. Having made reasonable progress in incorporating resistance/tolerance to single-stress factors, we now attach a high priority to developing genotypes with resistance/tolerance to multiple-stress factors. We have recently begun the zonalization of groundnut-growing environments, based on both biotic and abiotic stress factors. This will help us to determine the most appropriate combination of different stress factors operating in a region.

The following breeding activities are currently being pursued under different projects:

Project	Priority stress factor	Breeding activity
1	Late leaf spot Rust Early leaf spot	Breeding for resistance to foliar diseases.
2	Aflatoxin contamination	Breeding for resistance to *Aspergillus flavus*.
4	Tomato spotted wilt virus Peanut mottle virus (PMV) Peanut stripe virus (PStV)	Breeding for resistance to bud necrosis disease. Screening advanced breeding lines for PMV tolerance. Screening germplasm lines for tolerance/resistance to PStV.
5	No stress Single biotic or abiotic stresses Multiple stresses	Breeding for adaptation to specific environments and requirements.
9	Thrips, Jassids, Aphids *Spodoptera* Groundnut leaf miner	Breeding for resistance to insect pests.
15	-	Regional and international varietal trials. Supply of seed material.

The progress made with these areas and the future direction of research in each is briefly reviewed.

Breeding for Resistance to Foliar Diseases

There are now several identified or confirmed resistant sources to groundnut rust disease at ICRISAT Center. Most of the rust and late leaf spot material have been evaluated at several other places, and they have, in general, maintained their resistance. Most of the rust and late leaf spot resistant material belong to subspecies *fastigiata* and have commercially unacceptable pod shape. Through hybridization and selection, we have been able to transfer rust and late leaf spot resistance to commercially acceptable and agronomically superior genetic backgrounds. Some of the most promising foliar disease resistant selections, which may be released for general cultivation in India in the near future, include ICG(FDRS) 4, ICG(FDRS) 10, and ICGS(FDRS)43. However, we have not been able to identify sources of resistance to early leaf spot.

Breeding for resistance to *Aspergillus flavus*

Aflatoxin contamination is a complex problem and it can occur at preharvest, harvest, or postharvest stages in the field and also during storage at the processor/consumer level. Genetic improvement in the resistance level is considered as one of several approaches to resolve this problem. Genetic resistance, together with better crop management practices and optimal storage conditions, can significantly reduce contamination.

Seven lines, which are sources of dry seed resistance to *A. flavus*, have been identified and used in the breeding program. The resulting derivatives have been tested for level and stability of resistance to *A. flavus* and for yield potential in multilocational trials. Our success has been limited: we have neither been able to improve upon level of resistance nor yield potential already available in some of the resistant sources, which are commercial varieties. We have, however, been able to transfer stable resistance into different genetic backgrounds and some of these lines outyielded local control varieties at certain locations.

Breeding for Resistance to Virus Diseases

At present, our breeding program involves developing resistant/tolerant varieties to bud necrosis disease (BND) and peanut mottle virus (PMV). Some preliminary screening is also being conducted to identify resistance/tolerance to peanut clump virus (PCV).

Bud necrosis disease, caused by tomato spotted wilt virus and transmitted by thrips, occurs in serious proportions in India and is becoming increasingly important in many other countries. By breeding for vector resistance, we have been able to reduce considerably BND incidence. Recent studies on virus tolerance have shown that virus multiplication is less in some of these lines (ICRISAT 1988, p. 234). Currently we are using both vector-resistant and virus-tolerant lines to improve the level of BND resistance. Most of the vector-resistant sources that we have used are unattractive plant types, are poor yielding, late maturing, and possess runner-growth habit. The only exception appears to be ICG 2271. We have now developed agronomically desirable bud necrosis tolerant lines, such as ICGV 86029, ICGV 86030, ICGV 86031, and ICGV 86032, which possess higher yield potential.

Some rust and late leaf spot resistant source lines, used in our foliar diseases resistant breeding [EC 76446(292) and NC Ac 17133(RF)], do not transmit PMV through seed. Other resistant sources (e.g., NC Ac 2240, an insect-pest resistant source) show tolerance of PMV and with yield losses lower than susceptible varieties. Breeding lines, involving these sources as parents, have been screened for nonseed transmission and tolerance of PMV. Eight of these showed no yield loss due to PMV.

Recently, in collaboration with Australian and Indonesian scientists, we have started screening germplasm lines for resistance to peanut stripe virus (PStV) in Indonesia.

Breeding for Adaptation to Specific Environments and Requirements

This is our major breeding project in which we hope to develop material for varying requirements, from no-stress to multiple-stress situations. In our zonalization exercise, we are attempting to identify complexes of important factors that operate in different environments to target our breeding efforts towards these. Most progress so far has been for no-stress situations or where stresses could be overcome by management means. Using this and other improved breeding lines with resistance/tolerance to single-stress factors, we are now aiming to develop lines with multiple resistances. Progress made for no-stress situation in different maturity groups is described below.

Early-maturity group. Early-maturing varieties are advantageous in areas where the growing season is short, or the crop is grown in a residual-moisture situation and can also be useful in multiple-cropping situations. However, maturity period for the same variety varies from location to location depending upon the temperature regime, solar radiation, moisture availability, and other factors. This problem can be partially overcome by using cumulative heat units (degree days) to determine harvesting dates. This system uses accumulated daily average temperature units above the base temperature for groundnut taken as 10°C over the cropping duration $[(T_{max} + T_{min})/2 - T_{base}]$. At ICRISAT Center, a crop duration of 75 days in the rainy season corresponds to 105 ± 6 days in the postrainy season, while a crop duration of 90 days in the rainy season corresponds to 120 ± 6 days in the postrainy season. Based on 14-year daily temperature records, 1240 degree days are accumulated in 75 days in the rainy season, and 1475 degree days in 90 days in the postrainy season. Accordingly, we harvest our crop whenever these many heat units are accumulated, irrespective of seasons. A comparison of the shelling percentage of these early-maturing breeding lines and the normal-maturity types indicate that the former varieties mature earlier than normal varieties. We also estimated oil content of some of these early-maturing varieties in staggered harvests, and found that sound mature seeds in early harvests had normal oil content.

Medium- and late-maturing group. Our success in the medium- and late-maturing group has been satisfying: ICGS 11 (ICGV 87123) in central and peninsular India, and ICGS 44 (ICGV 87128) in western India have been released for postrainy season cultivation. Other varieties awaiting release for the rainy season cultivation are ICGS 1 (ICGV 87119), ICGS 5 (ICGV 87121), and ICGS 11 (ICGV 87123) in northern India, and ICG(FDRS) 4 (ICGV 87157), and ICG(FDRS) 10 (ICGV 87160) in peninsular India. Two other varieties are in prerelease testing stages [ICGS 44-1 (ICGV 87784) and ICGS 37 (ICGV 87187)]. In addition, there are 45 lines for rainy season and 13 for postrainy-season evaluation in the All India Coordinated Oilseed Research Programme.

Tolerance of Drought

Reddy et al. (1985) summarized the work at ICRISAT Center on drought resistance in groundnut. Earlier, we have relied solely on screening advanced breeding lines emanating from other breeding activities. We identified nine lines among foliar-diseases resistant selections, which showed tolerance to drought. All the nine included NC Ac 17090 in their parentage. This parent line is drought tolerant and is more efficient than others in extracting water from surface layers of soil. As we have now devised screening techniques and have enough information on sources of drought resistance, we have initiated breeding for drought resistance, using five resistant lines in our first cycle of crossing.

Tolerance of Multiple Stresses

We monitor all advanced breeding lines for tolerance/resistance to multiple-stress factors. This helps us identify additional merits or weaknesses, if any, of advanced lines. Table 1 lists some of the multiple-stresses tolerant lines from the foliar diseases resistance group. The current crossing programs generally involve parents with multiple resistances.

Breeding for Resistance to Insect Pests

We have made satisfactory progress in identifying sources of resistance to thrips and jassids. Work is being done to incorporate this resistance into high-yielding background material. We now attach greater emphasis to *Spodoptera* and leaf miner, which are of increasing importance. Our entomologists are screening germplasm/breeding lines to locate useful levels of resistance to these pests.

Table 1. Performance of some multiple disease- and pest-resistant groundnut lines at ICRISAT Center, rainy seasons 1986 and 1987 and postrainy season 1986/87.

Variety	Pod yield (t ha^{-1})			Reaction to			
	1986 rainy season	1986/87 postrainy season	1987 rainy season	Rust[1]	Late leaf spot[1]	Jassids (%)[2]	Leaf miner[3]
ICGV 87333	2.7	6.3	1.6	3.0	7.5	3.3	7.5
ICGV 87334	2.4	6.0	1.4	3.0	7.5	2.7	5.6
ICGV 87335	2.4	5.6	1.0	2.6	5.8	5.0	6.5
ICGV 87167	2.3	4.4	0.8	2.8	7.6	4.3	7.0
ICGV 86606	2.7	6.2	1.6	3.0	8.0	4.3	5.6
ICGV 87183	2.8	5.3	1.4	3.3	7.6	3.3	6.5
Controls							
Robut 33-1	1.5	-	-	9.0	9.0	22.7	8.0
JL 24	1.4	5.0	1.8	9.0	9.0	-	8.3
SE	±0.17	±0.34	±0.09				
CV (%)	13.2	10.9	12.3				

1. Scored on 1-9 scale, where 1 = No disease, and 9 = 50-100% foliage destroyed during rainy season.
2. Scored as percentage of yellowed foliage during 1984.
3. Scored on a 1-9 scale, where 1 = No insect, and 9 = 90-100% foliage damaged during rainy season 1987.

International Cooperation

We reorganized the various international trials and observation nurseries into five trials:

Trial	Number of entries
International Early Groundnut Varietal Trial (IEGVT)	24+1[1]
International Medium and Late Groundnut Varietal Trial (IMLGVT)	34+2
International Confectionery Groundnut Varietal Trial (ICGVT)	23+2
International Foliar Diseases Resistant Groundnut Varietal Trial (IFDEGVT)	35+1
International Insect Pest Resistant Groundnut Varietal Trial (IIPRGVT)	14+2
International Drought Nursery (IDN)	16+2

1. Local control(s).

We intend to continue distributing these trials for at least two seasons at each location before revising them. The Center program caters for the requirements of Asia, East and Central Africa, and other areas not covered by the regional programs. In the geographic areas of the regional programs, it operates through the newly developed material at the Center being fed into regional programs as preliminary trials.

So far we have sent IEGVT to 20 locations, IMLGVT to 16 locations, ICGVT to 13 locations, IFDRGVT to 10 locations, IPRGVT to 5 locations, and IDN to 2 locations. These include 14 countries in Africa, 6 in Asia, and 2 each in Mesoamerica and Australia. Results of some of these are presented in Table 2.

Breeding for Confectionery Groundnut

Groundnut quality includes economic and sensory quality characteristics. Economic quality character-

Table 2. Performance of high-yielding ICRISAT groundnut breeding lines in four International Trials, with reference to local cultivars in selected countries.

Trial	Country	ICGV no.	Pod yield (t ha^{-1})	Improvement over local cultivar (%)
Confectionery	Burundi	86027	3.6	80
	Cyprus	86733	8.3	23
	Korea	86979	3.6	89
	Nepal	86959	2.8	47
	Pakistan	86564	3.1	63
	Zambia	86979	3.5	52
Early Maturity	Bangladesh	86015	3.2	60
	Burkina Faso	86065	3.0	23
	Haiti	86061	4.1	37
	Mali	86047	3.1	25
	Philippines	86015	3.0	50
	Thailand	86015	2.7	42
Medium and Late Maturity	Egypt	86234	6.8	183
	Pakistan	87778	3.8	80
	Philippines	87131	1.9	280
Foliar Diseases Resistance	Bangladesh	87183	3.6	125
	Swaziland	87157	4.7	42
	Thailand	87358	3.9	77

istics refer to "grade factors" that are well defined and influence the monetary value: in pre-1980 literature, groundnut quality was synonymous with grade factors. Sensory quality is the summation of all physical and chemical characteristics of edible groundnut seed or their product that influence human senses. Sensory quality traits tend to be subordinated by the grade factors particularly at moisture levels less than 10%, perhaps because of lack of in-depth research on sensory factors. Quality maintenance is a continuous process. Any breakdown in the system from planting to consumption may reduce quality, which cannot be restored once lost.

Sufficient information is available on curing, handling, and storage. Of equal importance is the effect of maturity on quality. After maturity and curing, economic and sensory qualities are established. During handling and storage, maintenance of quality and prevention of deterioration of quality should be ensured.

Current challenges for edible groundnut

Aflatoxin. Aflatoxin contamination is the major factor reducing the quality of groundnut. The tolerance level in USA is 20 ppb; in Canada, 15 ppb; in most EEC countries, 5 ppb or lower.

Chemical residues. The presence of chemical residues in groundnut seed reduces its edible value, and this is becoming an important issue. We must find alternatives to the use of chemicals, or develop safer chemicals.

Fat content. Groundnut has a relatively high fat content and with the increasing emphasis on use of low-caloric food, it is important that edible groundnuts should have a low but balanced fat content to satisfy the demand of a health-conscious population.

Quality issues for the manufacturer

The manufacturers' and importers' concerns are excessive foreign material, uniformity in seed size, and the need to provide a reliable and consistent product. A plant breeder can develop varieties, which have uniformity in seed size.

Quality issues for the marketeer

The marketing groups seek improved and specific flavor characteristics; maintenance of a good flavor and aroma throughout processing and on the shelf; maintenance of a reasonable shelf life; improved appearance; and product distinctiveness. Shelf life and flavor lend themselves to genetic manipulations but require great effort.

Quality factors of edible-groundnut seed

Various physical, sensory, chemical and nutritional factors determine the quality of edible-groundnut seed.

Physical factors

- **Intact testa.** Many varieties possess the genetic defect of a split testa. Such varieties are prone to *A. flavus* attack and should not be selected for edible use.
- **Seed size.** Groundnut seeds are graded into different categories before their economic value is determined. The groundnut grades followed by the US National Peanut Council are given in Table 3.

Table 3. The groundnut grades followed by U.S. Peanut Council[1].

Grade	Counts/ Ounce[2]	Seed shape
Pod		
Virginia Jumbo inshell	9/11	-
Virginia Fancy inshell	11/13	-
Seed		
Virginia Extra-large	28/32	Elongated
Virginia Medium	38/42	Elongated
Virginia no. 1	45/55	Elongated
Virginia no. 2	Splits	-
Runner Jumbo	38/42	Round
Runner Medium	40/50	Round/elongated
Runner no. 1	60/70	Round
Runner splits	-	-
Spanish Jumbo	60/70	Elongated
Spanish no. 1	70/80	Round/elongated
Spanish splits	-	-

1. Source: National Peanut Council of America (1986).
2. 1g = 0.03527 ounces.

- **Seed shape.** Seeds of regular and uniform shape with tapering ends are highly valued. Tapering ends also facilitate blanching. Two-seeded pods with a moderate constriction generally ensure tapering seed ends.
- **Ease of blanching.** Manufacturers and processors find it costly to process varieties that are difficult to blanch.
- **Resistance to seed splitting and damage.** Varieties prone to seed splitting and damage during and after processing are less acceptable. The tendency to split is commonly associated with low-moisture content of seed.
- **Moisture content.** A moisture content in the range of 5.5-7% is normally acceptable. A moisture content above 7% encourages mold growth and leads to an unacceptable loss in weight on processing.

Sensory factors

- **Seed color.** Pink or light b [illegible] preferred: seeds having variegated or dark-red skins are not liked. Variegated seeds result in nonuniform color development during roasting, whereas seeds with dark-red skin appear difficult to blanch. Color of the raw groundnut seed is attributed to both the testa and the oil. Tannins and catechols are responsible for testa color. The color of the oil is mainly because of the presence of carotenoids. The characteristic color of roasted groundnut is primarily because of sugar and amino-acid reactions, with subsequent production of melanins.
- **Texture.** A firm and crisp texture is preferred for roasted nuts. Soft or mushy roasted groundnuts will be rejected by the consumer even though they exhibit an attractive color and good flavor.
- **Flavor.** Consumption of groundnut as nuts and in the manufacture of peanut butter is based on the use of roasted groundnut seed. Amino acids and carbohydrates are precursors of the roasted flavor. Aspartic acid, glutamic acid, glutamine, aspargine, histidine, and phenylalanine give the nut its typical roasted flavor. Degree of roasting and roasting time exert a significant influence on the strength of odor and flavor of roasted nuts. Pattee et al. (1982) reported improvement in flavor score with increase in seed size (seed diameter) provided the crop was harvested at full maturity and the recommended curing and storage practices were followed (Table 4).
- **Wholesomeness.** Raw and roasted groundnuts

Table 4. Effect of seed size on flavor scores of peanut butter[1].

	Seed size (mm)			
	5.95	6.35	6.74	7.14
Flavor score[2,3,4]	4.8	5.1	5.3	5.3
Flavor score[5]	1	1	2	3

1. Source: Pattee et al. (1982).
2. Scores are an average of three location replications. A 10-point scale was used: 10 = Excellent; 1 = Very poor.
3. Indicates significantly different at $P < 0.01$.
4. Consumer taste panel (40 members).
5. Professional taste panel (6 members).

should be free from foreign material, unadulterated with toxic or noxious substances (pesticides, mycotoxins, etc.), not infested with insects or rodents, free of spoilage and pathogenic microorganisms.

- **Chemical and nutritional factors.** Groundnut seeds contain relatively large quantities of proteins (25-34%) and oil (44-56%) and have an average high energy value of 564 cal (100 g seed)$^{-1}$.
- **Protein.** Currently little attention is paid to protein quality in groundnut. With increasing demand for more protein supplies and balanced dietary sources of protein, it may become an important consideration. The limited amino acids of blanched but unroasted groundnut and roasted groundnut protein are lysine, threonine, and methionine. Other amino acids that could be limiting are isoleucine and valine.
- **Oil.** As many as 12 fatty acids have been reported in groundnut oil, only three are present in amounts exceeding 5%-palmitic, oleic, and linoleic (Ahmed and Young 1982). Groundnut oil contains about 80% unsaturated acids with more oleic acid (47%) than linoleic acid (33.7%) as reported by Carpenter et al. (1974). There is a conflict between the keeping quality and nutritional quality requirements. There is a negative correlation between linoleic-acid content and oil stability (Holley and Hammons 1968). The wider ratio of oleic acid to linoleic acid in groundnut oil was considered as an indicator of more stable oil (Brown et al. 1975). For improved nutrition, high linoleic-acid content is desirable because the acid, in addition to being an essential fatty acid, has a hipochole-sterolennic effect. Variation in fatty acid composition is present in groundnut germplasm. It is possible to improve the fatty acid composition through breeding efforts.
- **Carbohydrates.** The cotyledons of groundnut seed contain about 18% carbohydrates. Sucrose is the most abundant saccharide in groundnut seed and is involved in the browning reaction responsible for principal changes occurring in color and flavor during roasting.
- **Minerals and vitamins.** Some of the inorganic minerals and vitamins may be deficient in groundnut seed from the dietary standpoint.

Most of the factors associated with physical, sensory, and chemical and nutritional quality are highly influenced by genotype, location, growing-season conditions, crop management, harvesting, curing, and storage. Failure to meet optimum requirements of any one of these aspects will result in decrease in quality.

Quality factors of in-shell groundnut. In addition to the factors already discussed for edible groundnut seed, the following factors are important when in-shell groundnut is marketed for edible purpose: pod color and type, pod size and shape, pod texture, pod cleanliness and freedom from damage, absence of blind nuts (pops).

Bright cream-colored pods, which are free of dirt and damage, are most attractive to the eye. Large, elongated, and constricted two-seeded virginia pods are generally preferred for roasting and eating in shell. Thick-shelled pods are desirable for roasting, as they can be roasted without disintegration. Strongly striated pods carry much soil with them after harvest, which is an undesirable feature in roasted groundnuts. Presence of blind nuts in the stock lowers the quality of the produce. The 3–4 seeded, small valencia types are preferred for consumption as freshly boiled groundnuts.

Breeding for confectionery types at ICRISAT Center

Development of groundnut cultivars with large seed mass (virginia market type) is an important activity in groundnut breeding at ICRISAT Center. Promising lines, derived from crosses between large-seeded germplasm lines and high-yielding adapted varieties, are selected by pod yield, shape, size, and texture and higher seed mass [>80 g (100 seeds)$^{-1}$] with desirable seed characteristics, such as seed shape and color. Performance of some of the selected lines at

Table 5. Performance of some high-yielding confectionery groundnut varieties under high-input conditions, ICRISAT Center, postrainy season 1986/87.

Variety	Branching habit[1]	Pod yield (t ha-1)	Shelling percentage	Percentage of extra-large seeds	100-seed mass (g)	Oil content (%)	Protein content (%)
ICGV 86563	A	5.97	66	40	70	46.6	26.4
ICGV 86576	S	5.78	63	75	78	49.6	25.2
ICGV 86565	S	5.66	62	71	70	49.6	26.2
ICGV 86580	S	5.49	71	90	116	43.1	29.3
ICGV 86583	S	5.17	62	72	70	49.5	26.3
ICGV 86571	S	5.05	55	84	60	47.3	24.9
ICGV 86026	S	5.03	66	72	90	49.2	29.7
ICGV 86581	S	4.79	67	88	106	45.0	28.7
ICGV 86577	S	4.76	76	87	119	46.6	28.8
ICGV 86579	S	4.04	75	93	108	46.4	29.8
ICGV 86564	A	3.69	64	53	90	51.0	26.5
Controls							
M 13	A	2.83	55	10	67	45.6	24.0
Chandra	A	2.30	52	26	76	47.3	23.6
SE		±0.301					
CV (%)		10					

1. A = Alternate branching, ssp *hypogaea*; S = Sequential branching, ssp *fastigiata*.

ICRISAT Center is given in Table 5. After replicated evaluation at ICRISAT Center and cooperative research stations, the selected lines are channeled to the national programs through international trials. Results obtained from the 1986 International Confectionery Groundnut Varietal Trial are summarized in Table 2. Most of these varieties have been bred for their high-yielding ability under no-stress conditions and we are now trying to incorporate stress resistances in these and other new confectionery varieties.

Issues involved in a breeding program for quality

Different market types are used in different end products. It is important to choose the right market type to work on, depending on the local agroecological conditions and the market demand. It will be difficult for the national programs of many developing countries to have the necessary facilities to monitor most of the sensory, chemical, and nutritional factors. In such cases, "grade factors" are easy to monitor under field conditions. Proper monitoring of grade factors can ensure, to some extent, adherence to reasonable sensory quality factors, such as wholesomeness and flavor.

Stability of seed mass

The experience of groundnut breeders who have participated in the International Confectionery Groundnut Varietal Trial indicates that the seed mass is generally not maintained across locations. Similarly, when bold-seeded lines from USA and Malawi were grown at ICRISAT Center they did not maintain their seed mass. Data on 100-seed mass obtained from the International Confectionery Groundnut Varietal Trial conducted at 10 locations were analyzed for stability following Finlay and Wilkinson (1963). This study indicated significant genotype × environment interactions. To overcome this problem, it is imperative that the breeder should have access to diverse testing locations to select stable germplasm lines for crossing and to develop breeding lines with stable seed mass.

Shelf life versus nutritional requirement

There appears to be no easy answer to this dilemma. Genetic variation in fatty-acid composition is present in germplasm for exploitation in either direction.

Crop duration and seed mass

Most of our present day, bold-seeded cultivars are of longer duration and may not be appropriate in regions where the growing season is short. In such cases, where possible, either the growing season should be lengthened or the crop duration be reduced through management. Early-maturing cultivars generally have low seed mass. What then should be the minimum crop duration that will not adversely affect the grade quality?

Aflatoxin contamination

The problem can at best be overcome or reduced through better crop management, proper curing and drying, and storage. Failure in any one of these steps could result in the aflatoxin contamination of the produce and products. Genetic manipulation alone cannot help to eliminate this problem.

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Discussion

Reuben: How can you develop a variety with all the objectives you have mentioned to meet quality issues for the manufacturers, such as sensory factors, quality factors of groundnut in shell, etc., and still meet the yield requirements? Can you develop a perfect variety?

Nigam: It is not entirely impossible to develop a perfect variety. Not only at ICRISAT but at many other breeding programs, particularly in USA, breeders have been successful to combine desirable characteristics in a single variety. However, it is difficult, time consuming, and requires many sophisticated analyses, which many national programs in the developing world may not be able to afford. Since confectionary groundnuts are meant for export to developed countries where processors, buyers, and consumers are quality conscious, it is important that we give due considerations to these requirements if we want to stay in the market.

Some studies have indicated positive association between flavor score and seed size. It is likely that by improving seed size we might also improve flavor of groundnut.

Kannaiyan: How stable are your newly developed large seed size varieties across locations in your international nursery?

Nigam: In general, we find reduction in seed mass in large seeded confectionery lines when they are grown away from home environment. This holds true for most of the confectionery material, whether it originates from USA, Malawi, or ICRISAT Center. From our international trials, we have been able to identify lines that are more stable for seed mass as well as pod yield, when compared to others.