Status of Groundnut Research and Production in South Asia

P.S. Reddy[1], M.S. Basu[1], M.A. Khaleque[2], M.S. Hoque[2], Naazar Ali[3], Shah Nawaz Malik[3], Hla Than[4], Tin Soe[4], B. Regunathan[5], B. Mishra[6], T.G.K. Murthy[1], and S.N. Nigam[7]

Abstract

*South Asia, comprising Bangladesh, Bhutan, India, Myanmar, Nepal, Pakistan, and Sri Lanka, accounts for about 43.4% of the world groundnut (*Arachis hypogaea*) area (8.6 million ha) and 35.7% of production (8.1 million t). The period coinciding with the Southwest monsoon is the main growing season in the region although the crop is grown in more than one season in India, Myanmar, and Sri Lanka. The low average yields of groundnut in the region result from: raising the crop mostly under rainfed conditions on marginal and submarginal lands with low levels of inputs, use of varieties with long maturity periods, susceptibility of the crop to a plethora of insect pests and diseases, and nonavailability of efficient farm machinery and quality seed. All countries in the region made sustained efforts in the development of improved technology, including development of high-yielding varieties, improved agronomic practices, new and efficient strains of* Bradyrhizobium, *and efficient and economical plant protection schedules for the control of major insect pests and diseases. When tested in the farmers' fields, the technology indicated much unrealized yield potential. The future crop improvement research in the region aims to concentrate on the areas of crop duration, fresh seed dormancy, resistance/tolerance to major biotic stresses, seed quality and production, and design and development of efficient farm implements and machinery. To realize full impact of research on groundnut production in the region, it is important to ensure adequate support price and market to the crop. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has contributed substantially towards the development of improved cultivars as well as offering training facilities to accomplish better human resource development in the region.*

Résumé

Bilan de la recherche et de la production arachidière en Asie du Sud: *L'Asie du Sud, comprenant le Bangladesh, le Bhutan, l'Inde, le Myanmar, le Népal, le Pakistan et le Sri Lanka, représente environ 43,4 % de la superficie mondiale consacrée à la culture de l'arachide (*Arachis hypogaea*),*

1. Director, Project Coordinator (Groundnut), and Scientist, National Research Centre for Groundnut (NRCG)/ICAR, Ivnagar Road, P.O. Timbawadi 362 015, Dist. Junagadh, Gujarat, India.
2. Project Director (Oilseeds) and Senior Scientific Officer, Oilseed Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh.
3. Principal Scientific Officer (Oilseeds) and Scientific Officer, Barani Agricultural Research and Development (BARD), National Agricultural Research Center, P.O. NARC, Islamabad, Pakistan.
4. Head, Plant Pathology, and Head, Oilseed Crop, Central Agricultural Research Institute (CARI), Myanmar Agricultural Service, Yezin, Pyinmana, Myanmar.
5. Research Officer, Regional Agricultural Research Centre, Makandura, Gonawila, N.W.P., Sri Lanka
6. Assistant Agronomist, National Oilseeds Research Programme (NORP), Nawalpur, Sarlahi, Nepal.
7. Principal Groundnut Breeder, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

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soit 8, 6 millions d'hectares et 35,7 % de la production (8,1 millions de tonnes). La période coïncidant avec la mousson du sud-ouest est la principale campagne de la région, bien qu'on cultive l'arachide pendant plus d'une saison en Inde, au Myanmar, et au Sri Lanka. La faiblesse du rendement de l'arachide dans cette région résulte des causes suivantes: la culture se fait surtout dans des conditions pluviales, dans des terres marginales ou sub-marginales avec de faibles niveaux d'intrants, l'usage de variétés à long cycle, la sensibilité de cette culture à une multitude d'insectes nuisibles et de maladies, et la non disponibilité du machinisme agricole efficace et de semences de qualité. Tous les pays de la région ont fait des efforts acharnés pour développer une technologie améliorée, y compris la mise au point de variété à haut rendement, l'emploi de pratiques agronomiques améliorées, de sources nouvelles et plus efficaces de Bradyrhizobium, *et la programmation efficace et économique de protection des plantes pour la lutte contre les principaux insectes ravageurs et les maladies. La technologie, lorsqu'elle a été essayée dans les champs paysans, indiquait un grand potentiel de rendement. Les recherches futures sur l'amélioration de la culture dans cette région visent à se concentrer sur la durée de la culture, et la dormance des semences fraîches, la résistance/tolérance aux principaux stress biotiques, la qualité et la production des semences, la conception et l'élaboration de matériel et de machinisme agricoles efficaces. Pour tirer meilleur parti de la recherche sur la production arachidière de cette région, il est important de fournir un prix de soutien et le marché pour cette récolte. L'Institut international de recherche sur les cultures des zones tropicales semi-arides (ICRISAT) a contribué largement à mettre au point des cultivars améliorés et en même temps à offrir des possibilités de formation pour assurer une meilleure mobilisation des ressources humaines dans la région.*

South Asia, comprising Bangladesh, Bhutan, India, Myanmar, Nepal, Pakistan, and Sri Lanka accounts for 43.4% of the area (8.6 million ha) and 35.7% of the production (8.1 million t) of groundnut (*Arachis hypogaea*) in the world (FAO 1990, pp. 157–158). However, the average productivity in the region (940 kg ha^{-1}) remains below the world average. India is the leading groundnut producer in the region.

The Present Situation

Groundnut is the major oilseed crop in India and accounts for 45% of the area and 55% of the production of total oilseeds in the country. In other countries of the region, it ranks either second or third among the annual oilseed crops grown.

In India, groundnut is grown in three seasons, i.e., rainy (85% area), postrainy (10% area), and summer (5% area). The rainy season groundnut, which is grown during the Southwest monsoon period (June-November) is spread over the entire country and is generally rainfed. The postrainy season groundnut is confined to South India and is raised mostly in rice (*Oryza sativa*) fallows during October-March. The summer crop is restricted to the central Indian states of Gujarat, Maharashtra, and Madhya Pradesh, and is grown from January to May. The postrainy and summer crops are irrigated. During the last decade, the groundnut area has increased gradually from 7.4 million ha in 1981 to 8.0 million ha in 1990. However, the production fluctuated violently primarily because of erratic distribution of rainfall. The yield and production pattern of groundnut for three decades in India (1960–1990) are depicted in Figure 1. Groundnut yields fluctuated from 550 to 1100 kg ha^{-1} and consequently the total production also varied from 4.3 million t to 9.6 million t. The rise and fall in the yield and production coincided with the percentage deviation from the mean annual rainfall (DES 1990).

In Myanmar, groundnut is the second most important oilseed crop next to sesame (*Sesamum indicum*). Its area ranges between 0.53 million and 0.65 million ha depending on the weather conditions. The crop is grown in the winter (47%) and monsoon (53%) seasons. The monsoon crop is normally cultivated on upland areas of the dry zone tract, whereas the winter crop is mainly confined to riverside areas of central Myanmar and rice fields of delta areas. The monsoon season yield (760 kg ha^{-1}) is much lower than that of the winter season (1190 kg ha^{-1}).

In Pakistan, groundnut is an important cash crop in *Barani* (dry) areas of upper Punjab and parts of Northwest Frontier Province (NWFP). In Sind, it is grown under irrigated conditions. About 85% of the total groundnut area in Pakistan lies in the province of Punjab, 10% in NWFP, and 5% in Sind. Since groundnut cultivation was started in 1949, there has

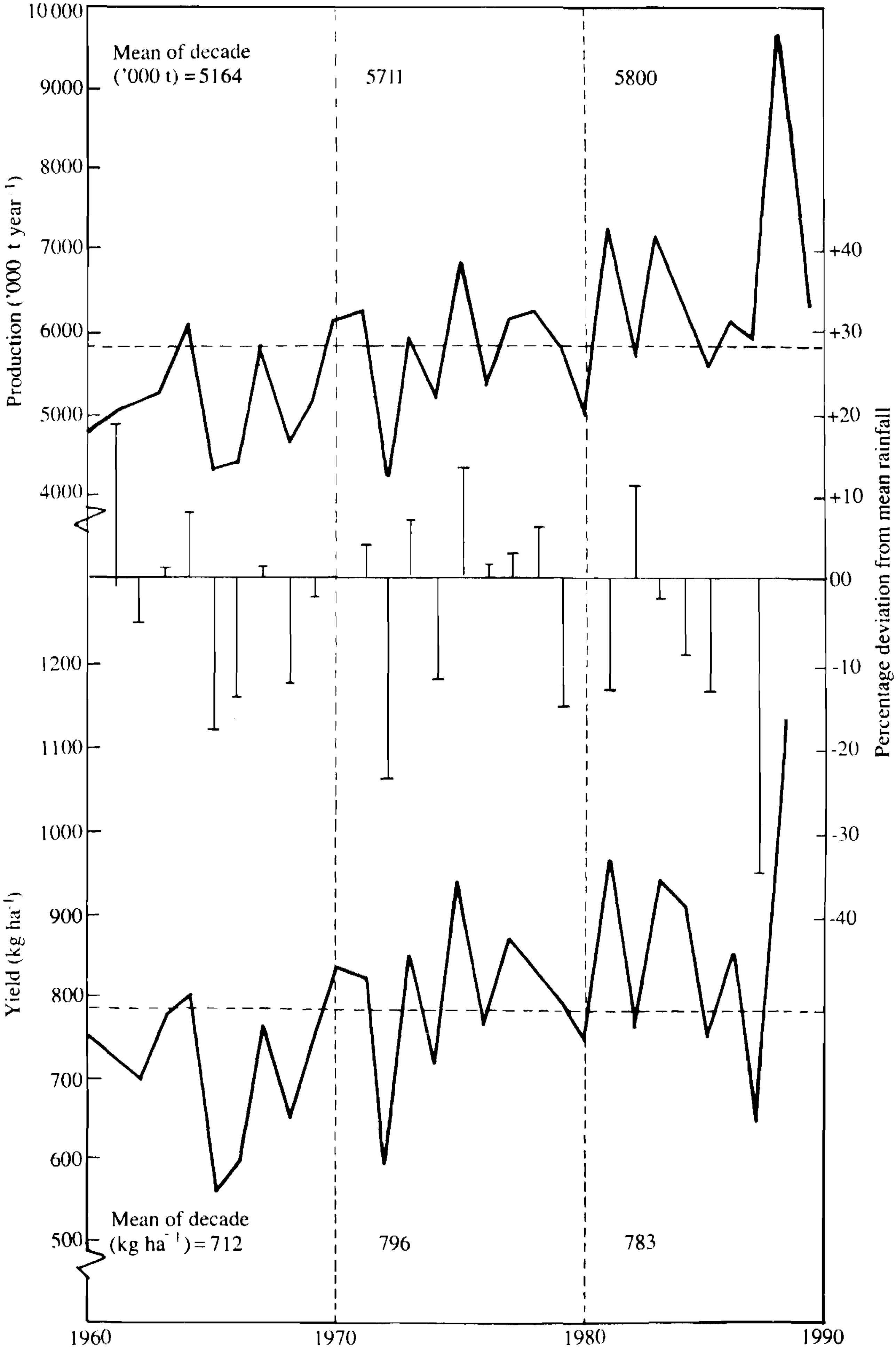

Figure 1. Yield and production pattern of groundnut in India. (Source: DES 1990.)

been a steady increase in area and production. During 1989/90, the total area under groundnut in Pakistan was 80 100 ha, with a production of 81 700 t of pods. The pod yield averaged 1019 kg ha^{-1}.

In Bangladesh, groundnut occupies the third largest area among the oilseed crops, next to rape seed/mustard (*Brassica* sp) and sesame. Currently, groundnut is grown in an area of about 32 000 ha with a production of 43 000 t. The pod yield averages 1230 kg ha^{-1}. It is mostly grown in *Char* area (low lying inundated area in the rainy season) or river basins during the winter season (November to March) without irrigation. A small crop is grown in the rainy season on highlands mainly to provide seed for the winter crop.

In Sri Lanka, groundnut is mainly confined to the dry zone. It is also grown to a limited extent under coconut (*Cocos nucifera*) plantations in the intermediate zones, particularly in the Kurunegala district. The two main growing seasons in Sri Lanka are *Maha*, the period of major rains (mid-September to January), and *Yala*, the period of minor rains (mid-March to July). On an average, about 80% of the crop is grown in the *Maha* season. In 1989/90, the crop was grown in 10 990 ha, which produced 11 120 t pods with average productivity of 1015 kg ha^{-1}.

In Nepal, groundnut is a minor oilseed crop, grown in an area of about 5000 ha. Its cultivation is mainly confined to the Terai and inter-Terai areas and to a limited extent on mid-hill areas. In Bhutan, the crop is grown in small pockets mainly for local consumption.

Low Productivity and Causes

The average yield of groundnut in South Asia is low. In 1990 the pod yield obtained was 940 kg ha^{-1} as compared with 2387 kg ha^{-1} in the USA and a world average of 1141 kg ha^{-1} (FAO 1990, pp. 157-158).

The causes for low yields in the region are:

- Cultivation of the crop on marginal and submarginal lands under rainfed conditions subjected to frequent droughts,
- Poor agronomic practices and low levels of inputs because the crop is cultivated mainly by resource poor farmers,
- Use of low-yielding and late-maturing cultivars,
- Insect pests and diseases, and
- Inadequate availability of high quality seed of improved varieties.

In addition to these factors, poor marketing facilities and the lack of a support price also work against the farmers' interests in many countries. As groundnut is a labor-intensive crop, a lack of proper farm machinery for small holdings also retards the development of improved groundnut production systems in the region.

Research Accomplishments

Except for the large groundnut research program in India, the research input into the crop from other countries is relatively small. This is indicative of the place of groundnut in the overall agricultural economy of the countries. Recently under the aegis of the South Asian Association for Regional Cooperation (SAARC), a cooperative varietal testing program was initiated among member countries. Groundnut research in the region received a further stimulus with the establishment of the Asian Grain Legumes Network (AGLN) at ICRISAT.

Crop Improvement

Introduction and reselection with the exception of India continues to be the main method of crop improvement in the region. In the past decade, the importance of hybridization has been realized in India and now a majority of new breeding lines/cultivars are the result of hybridization between selected parents. However in countries where the research program is small and the scientists are entrusted with more than one crop, dependence on introduction of improved germplasm from various sources is heavy. ICRISAT has played an important role in introducing improved germplasm into the countries of the region.

Prior to 1980, breeding efforts were directed mainly towards improving yield potential. With the identification of resistance sources to major diseases and insect pests at ICRISAT and in national programs, resistance breeding received a strong stimulus resulting in the release of varieties with multiple resistances in India. Characteristics of registered/released varieties in the past decade in India (Basu and Reddy 1987) and other countries of the region are given in Table 1. A genetic gain of 1.3–3.2% annually has been achieved during the 1980s under rainfed cultivation in India (Nigam et al. 1991).

In spite of the release of so many varieties, the area covered with improved varieties in the region is

Table 1. Characteristics of released/registered groundnut varieties in South Asia.

Variety	Growth habit[1]	Year of release	Attributes
Bangladesh			
DA 1	SB	–	High shelling percentage (75%), no seed dormancy
DG 2	VB	–	Tolerant to late leaf spot and rust, seed dormancy for 40–50 days, 2-seeded bold pods
DM 1	VL	–	Dwarf plant, suitable for spring season, good for intercrop with sugarcane and maize, tolerant to late leaf spot and rust
Acc 12	VL	–	Tolerant to drought, late leaf spot, and rust, more than 50% pods 3-seeded
India			
KRG 1	SB	1981	Medium-sized 2-seeded pods, suitable for rainy and summer seasons
TG 17	SB	1982	Bold podded, pinkish testa, high harvest index, fresh seed dormancy up to 30 days
GG 2	SB	1983	Suitable for both rainy and postrainy summer seasons, dark green leaves, reticulated 2-seeded pod, drought tolerant
Co 2	SB	1983	Medium 2-seeded plump pods
Dh 8	SB	1984	Dark-green leaves, compact plant, tolerant to late leaf spot, 2-seeded small pods
TG3	SB	1985	Suitable for both rainy and summer seasons, tolerant to pod borer
ICGS 11	SB	1986	High-yielding, tolerant to bud necrosis disease and end-of-season drought, adapted to rainy and postrainy seasons
VRI 1	SB	1986	High shelling, fresh seed dormancy for a week, long pods with deep constriction and prominent beak
Girnar 1	SB	1988	Early-maturing, multiple resistance to foliar diseases, aflatoxin, jassids and drought
ICGS 44	SB	1988	High-yielding, tolerant to bud necrosis disease and mid-season drought
RG 141	SB	1989	Dark-green foliage
VRI 2	SB	1989	Pods bold with medium constriction, suitable for both rainfed and irrigated conditions
ICGS 1	SB	1990	High-yielding, suitable for both spring and rainy seasons, tolerant to bud necrosis disease
ICGS 37	SB	1990	High-yielding, tolerant to bud necrosis disease and end-of-season drought, suitable for summer cultivation
ICG(FDRS) 10	SB	1990	Resistant to rust and tolerant to late leaf spot and bud necrosis disease
VRI 3	SB	1990	Pods and seeds are small with slight to moderate constriction, suitable for delayed sowing in the rainy season
RSHY 1	SB	1991	Suitable for residual moisture conditions
M 197	VB	1982	Pods with less prominent venation and bold seeds
Chitra	VB	1984	Testa variegated on rose background
Kaushal	VB	1984	Compact plant, dark-green leaves, 1–3 seeded pods
UF 70-103	VB	1984	Suitable for summer season
MA 16	VB	1986	Bold seeded, suitable for confectionery trade
BG 3	VB	1988	Early-maturing
ICGS 76	VB	1989	High-yielding, tolerant to bud necrosis disease and mid-season drought, high shelling (73%) and good oil quality
ICGV 86590	SB	1991	High-yielding with multiple disease and insect pest resistance
GG 11	VR	1984	Bold podded
M 335	VR	1986	Bold podded with prominent reticulation, 2-seeded with light brown testa

Continued

Table 1. *Continued.*

Variety	Growth habit[1]	Year of release	Attributes
Myanmar			
SP 121	SB	–	2-1 seeded small pods, early-maturity
M 10	SB	–	2-seeded small pods, high shelling (76%), high oil (54%), early maturity
M 11	SB	–	2-1 seeded small-medium pods, high oil content (55%)
M 12	SB	–	2-3 seeded medium-sized pods, high oil content (55%)
M 15	SB	–	2-3 seeded medium pods, high shelling (77%), and high oil content (54%), seed dormancy for 2 weeks
Kyaung Gone	VB	–	2-seeded pods, seed dormancy up to 2 months
MS 2	VR	–	2-3 seeded pods, seed dormancy up to 3 months
Pakistan			
Banki	VB	–	Medium-sized 2-3 seeded pods with stable yields
BARD 699	SB	1989	High shelling (70%), high oil content, medium maturity, a composite of ICGS 37 and ICGS 44, suitable for areas with 500 mm rainfall
BARD 479	VB	–	Widely adapted, large-sized pods (under release)
No. 334	VR	–	Medium-sized pods with stable yield and wide adaptability
BARI 89	VR	–	Higher yield than No. 334, medium pod and seed size, suitable for areas with < 500 mm rainfall (under release)
Sri Lanka			
MI 1	SB	–	Medium-sized 2-seeded pods with pink testa
Red spanish	VL	1961	Large 3-seeded pods with dark pink testa
No. 45	SB	1982	High shelling (75%), 2-seeded pods with pink testa
South China	SB	–	Medium-bold pods with pink testa

1. SB = Spanish bunch, VB = Virginia bunch, VL = Valencia, and VR = Virginia runner

not large. Nonavailability of high quality seed of improved varieties at an affordable price remains the biggest bottleneck in increasing groundnut production in the region.

Agronomic Research

Seed rate and spacing

Maintenance of an optimum plant population is important to the success of groundnut cultivation. The seed rate depends on the growth habit and 100-seed mass of the variety and the recommended spacing. The most common spacing recommended for spanish and valencia cultivars in India is 30 × 10 cm. In the case of virginia bunch and virginia runner types, the most common spacing recommended is 30 × 15 cm. The common spacing adopted for spanish cultivar in Bangladesh is 40 × 15 cm. In Nepal, a spacing of 40 × 20 cm is common. In Myanmar, the recommended plant population for spanish and valencia types is about 260 000 plants, whereas for virginia bunch and runner it ranges from 150 000–190 000 plants ha^{-1}. In Pakistan, virginia runners are sown with a spacing of 60 × 10 cm. In the case of virginia bunch varieties, the recommended spacing is 45 × 10 cm. In Sri Lanka, a spacing of 24 × 15 cm for spanish bunch and 24 × 30 cm for virginia bunch is common.

Sowing time

For rainy season groundnut in India, the optimum sowing time ranges from the second fortnight of June to the first week of July, depending upon the receipt of adequate monsoon rains. Advance sowing by 10 days before the recommended sowing date by giving one presowing irrigation increases the yield considerably. In Pakistan, mid-April is the optimum sowing time in rainfed fallow areas and mid-March in irrigated areas. The last week of June to the third week of

July is optimum for sowing in Nepal. In Sri Lanka, the recommended sowing time for *Maha* season is mid-October to the end of October and April for *Yala* season.

Fertilization

The NPK fertilizer doses recommended for the major groundnut growing states in India are 15 kg N, 40–60 kg P_2O_5, and 0–45 kg K_2O ha^{-1}. All the P_2O_5 and K_2O and half of the N should be incorporated in the soil before sowing. Single superphosphate and ammonium sulphate are the preferred fertilizers for the groundnut crop. Application of gypsum is recommended in the sandy loam soils at 500 kg ha^{-1} in two equal split doses, at the time of sowing and peak flowering stage.

No fertilizer recommendations for groundnut are reported from Bangladesh. In Myanmar, application of phosphate and potash fertilizer as a single preplant dose at the rate of 30–60 kg ha^{-1}, depending on the fertility level of the land, and 9000 kg farmyard manure ha^{-1} at the time of land preparation is recommended. Gypsum is recommended at 150–200 kg ha^{-1} for low calcium soils in the deltaic regions. For Nepal, a fertilizer dose of 20–40–20 kg NPK ha^{-1} was found to be optimum. From multilocational trials in Pakistan 20 kg N and 80 kg P_2O_5 ha^{-1} were found appropriate to produce high pod yields. In the case of sandy soils or in areas intensively cropped with all crop residues removed, application of 50 kg K ha^{-1} is also suggested. In addition, 500 kg gypsum ha^{-1} is also recommended at the pegging stage (BARD 1989). Recommended fertilizer doses in Sri Lanka include 30 kg N, 65 kg P_2O_5, and 45 kg K_2O ha^{-1} as basal application and 30 kg urea ha^{-1} as top dressing at the flowering stage. In noncalcic Latosols and Regosols, 100 kg ha^{-1} gypsum application is also recommended to avoid 'pops' (empty pods) in the produce. However, on-station trials have also indicated a beneficial effect of organic manure and coir dust on groundnut production.

Micronutrients

Micronutrients play an important role in increasing the productivity of groundnut in India. The soils in the states of Andhra Pradesh, Tamil Nadu, and Punjab are deficient in zinc. Presowing application of zinc sulfate to the soil at 25 kg ha^{-1} once in 3 years, has been recommended. When zinc deficiency is noticed in the standing crop, foliar application of 0.2% zinc sulfate is recommended. Soils in the states of Tamil Nadu and Maharashtra are deficient in boron. This deficiency can be corrected either by addition of boron to the soil at 5–10 kg ha^{-1} along with NP fertilizers or foliar spraying of boron at a 0.1% concentration. In Maharashtra State, spraying of 0.1 ppm boric acid (300 mg of boric acid in 500 L of water) at 30 days after sowing (DAS) resulted in 10% and at 50 DAS resulted in 15% increased pod yield.

Iron chlorosis in groundnut has been reported from the calcareous black soils of high pH in the states of Tamil Nadu, Gujarat, Karnataka, and Maharashtra. Spraying of 1% ferrous sulfate plus 0.1% ammonium citrate corrects the deficiency to some extent. The spanish bunch varieties JL 24, Girnar 1, and GG 2 are found to be tolerant to iron chlorosis.

Weed control and earthing-up operations

Weeds cause maximum reduction in pod yield up to 45 DAS. Later on they hinder other field operations including harvesting. When the row sowing is done by seed drill, the crop is intercultured with bullock-drawn implements in India; the interculture operations reduce weeds and create a soil mulch.

Application of herbicides followed by one or two hoeings controls the weeds effectively. The recommended herbicides for groundnut in India are alachlor at 1.0-1.5 kg ai ha^{-1} or butachlor at 0.5 kg ai ha^{-1} as preemergence sprays within 2 days of sowing, or fluchloralin at 1.5 kg ai ha^{-1} in 500 L of water as preplant soil incorporation (PPI) sprays. PPI application of fluchloralin at 1 kg ai ha^{-1} resulted in a yield increase of 71% and a postemergence herbicide fluazifop-p-butyl at 0.25 kg ai ha^{-1} gave an increase of 50% over the unweeded check. In Nepal also, application of alachlor at 1.8 kg ai ha^{-1} controlled grassy and broad leaf weeds significantly. A study conducted at the National Agricultural Research Centre (NARC) in Pakistan during 1988 using fluazifop-p-butyl revealed that two applications at low rates (0.125 kg ai ha^{-1}) were more effective than one application at a high rate (0.5 kg ai ha^{-1}) in reducing weed infestation and increasing pod yields. In Sri Lanka, application of alachlor at rates ranging between 1.4 and 2.4 kg ai ha^{-1} at sowing, followed by hand weeding at the 6-week stage was effective in controlling weeds.

In Myanmar, experimental results on earthing-up of the crop indicated a yield loss of 14.82%. As a result, in 1982, nonearthing-up technology was transferred to 20 locations of monsoon groundnut. In Sri

Lanka, no yield increase was observed when earthing-up was done at flowering in the red-yellow Latosol soils.

Irrigation

Groundnut crop requires on an average 400–450 mm of water. In the Indian subcontinent, rainy season groundnut is subjected to many weather aberrations. Water stress at the critical growth stage (55–75 DAS) diminishes the yield drastically. If there is a failure of a single rain at the pod development stage, yield is reduced by about 50%. Provision of protective irrigation during the critical stages increased pod yield to the extent of 63% in Gujarat and 33% in Punjab.

Experiments conducted in India on postrainy and summer groundnut indicated that 11–12 irrigations are optimum for realizing high pod yield. More than 12 irrigations reduced pod yield. Withholding irrigations at 30–50 days and 90–105 days did not result in much loss of yield and quality, but the reduction was drastic at the 50–80 day stage. Although the best surface method of irrigation is 'border strip', farmers find 'check-basin' more convenient to use. Poor-quality irrigation water can limit production and quality of produce.

In Bangladesh groundnut is cultivated without irrigation in *Char* lands, where adequate moisture is available during the growing season. However, in highland areas one to two irrigations at the podding stage increase pod yields considerably. The *Maha* season crop in Sri Lanka is rainfed, whereas the *Yala* season crop receives full irrigation. Irrigation at 50% moisture depletion in reddish-brown soils gave optimum pod yield and water-use efficiency. However, in red-yellow Latosols irrigation at 25% depletion gave a 29% increase in pod yield over that at 50%.

Intercropping

In India, the most important cereal intercrops grown with groundnut are pearl millet (*Pennisetum glaucum*) and sorghum (*Sorghum bicolor*). Other crops intercropped with groundnut are black gram (*Vigna mungo*), castor (*Ricinus communis*), cotton (*Gossypium* sp), pigeonpea (*Cajanus cajan*), and sunflower (*Helianthus annuus*). The ratio of groundnut to intercrop varies from 1:1 to 1:8 depending on the location and intercrop species.

In Nepal, intercropping of groundnut with maize (*Zea mays*) is widely practiced. In Pakistan, groundnut is intercropped with maize, pearl millet, and sorghum in small pockets. In Bangladesh, intercropping of groundnut with sugarcane (*Saccharum officinarum*) and maize is recommended. In Sri Lanka, groundnut is normally grown as a sole crop.

Harvest, drying, and storage

The crop is mainly harvested manually. Plants are pulled out by hand at the time of maturity. Occasionally hoes and bullock-drawn diggers are also used to dig plants out. In the case of small holdings, the pods are stripped off the plants soon after harvest and carried home for drying. In the case of large holdings, plants are either left in windrows or in small heaps for sun drying before stripping off pods by mechanical threshers. Proper drying of groundnut produce is very important. The moisture content in pods should be brought down to around 8% before storage since higher moisture levels in the produce are congenial for the production of aflatoxin by yellow mold (*Aspergillus flavus*). The produce from the postrainy/summer crop in India loses viability quickly if dried under direct sunlight because of high temperatures prevailing at the time of harvest. To avoid this, the following procedure is recommended (Basu and Reddy 1989).

1. Tie the harvested plants into small bundles and keep them in a single layer with pods upward under shade. In the summer season, due to the natural movement of hot air, pods dry quickly.
2. When the bundles are dried, the pods may be detached from the plants and spread in a thin layer under shade for further drying. The following simple tests help to determine the correct stage for storage: the well-dried pods rattle upon shaking; when a seed is pressed between thumb and index finger it easily splits into two cotyledons; and when the surface of the seed is rubbed hard a portion of the testa comes off.
3. When the pods are thoroughly dried, as indicated by the above tests, they should be stored in polythene-lined gunny bags along with commercial grade calcium chloride at 300 g for each 40 kg bag. The calcium chloride should be placed in a wide-mouthed plastic bottle with pores in its upper portion. The bottle is covered with thin muslin cloth and kept at the central portion of the bag containing the pods.

The above procedure maintains viability up to 80% for a period of 10 months.

Experimental results in Bangladesh revealed that seeds with 9% moisture packed in polythene bags and stored in gunny bags retain their viability up to 90% for a period of 7 months.

Development of a viable storage technique for deltaic farmers is one of the future research thrusts in Myanmar.

Microbiological Research

The major groundnut crop in the region is grown without *Bradyrhizobium* inoculation. However, in the rice-based cropping system, the nodulation observed is generally poor. The waterlogged conditions in the rice fields reduce the population of native *Bradyrhizobium* to very low levels resulting in the low productivity of groundnut in the rice-based cropping system.

The National Research Centre for Groundnut (NRCG), Junagadh, India, has identified two effective strains of *Bradyrhizobium*, namely, IGR 6 and IGR 40, for higher productivity of groundnut in the postrainy/summer season (Joshi et al. 1989). In on-farm tests in West Bengal the increase in pod yield due to inoculation ranged from 14 to 16% with IGR 6 and 8 to 14% with IGR 40. Additionally, these strains are tolerant to Thiram and Bavistin, fungicides commonly used in seed treatment. These strains are commercially produced in India.

Bradyrhizobium inoculation gave 39–72% pod yield increase in on-farm trials in Myanmar. At 28 kg ha^{-1} of triple superphosphate (TSP), the inoculated plot yielded 2347 kg pods ha^{-1} while the control yielded only 1688 kg ha^{-1} and the plot applied with urea at 56 kg ha^{-1} produced 1816 kg ha^{-1}. The yield was further increased when the TSP dose was increased from 28 to 56 kg ha^{-1}. The *Bradyrhizobium* strains recommended for groundnut in Myanmar are TAL 1000 and TAL 1371. Commercial production of these strains is undertaken at the Agricultural Research Institute (ARI), Yezin, Myanmar.

At ICRISAT, a large number of *Bradyrhizobium* strains have been collected and tested for nitrogen-fixing ability in combination with a range of cultivars and germplasm lines. Field trials in many parts of India have shown that it is possible to increase yields of groundnuts by inoculation with *Bradyrhizobium*, even in fields where groundnuts have been grown for many years. ICRISAT has published an information bulletin on 'Nitrogen nutrition of groundnut in Alfisols'. This bulletin by Nambiar (1990) covers aspects of demand and acquisition of nitrogen by groundnut, results of experiments conducted in Alfisols at ICRISAT Center to improve groundnut productivity with *Bradyrhizobium* inoculation and fertilizer N, together with those relating to host-cultivar specificity, and possible problems in applying this information to farmers' fields. More attention will now be given to nitrogen nutrition in irrigated groundnuts, especially in the rice-based cropping systems of the region.

Plant Protection Research

A wide range of pests and diseases attack groundnut and cause considerable losses in yield in South Asia. Research efforts designed to tackle these biotic stresses in a more systematic manner are under way by national programs in collaboration with ICRISAT. In addition, several vertebrate pests such as rats, wild boars, crows, and squirrels can cause extensive damage to the crop when groundnut holdings are small.

Insect pests

The groundnut crop in the region is attacked by a number of insect pests from sowing to storage. In spite of advances in technology, losses by pests have been increasing in recent years, possibly due to changing cropping patterns and overlapping cultivation seasons. The major pests include leaf miner (*Aproaerema modicella*), white grub (*Lachnosterna consanguinea*), red hairy caterpillar (*Amsacta albistriga*), termites, defoliators such as tobacco cutworm or armyworm (*Spodoptera litura*), gram caterpillar (*Helicoverpa armigera*), leaf webber (*Anarsia ephippias*), and sucking pests such as aphids, jassids, and thrips.

The main emphasis in the past has been on chemical control. Integrated pest management is now receiving more attention. At ICRISAT, research aims to effectively combine cultural practices and host-plant resistance to develop integrated pest management systems. The effects of cultural practices on the incidence of important pests are being studied and particular attention is being given to intercropping. In the recent past, genotypes have been screened for resistance to thrips, jassids, leaf miner, *Spodoptera*, and aphids. Breeders are incorporating these resistances into high-yielding commercially-acceptable cultivars, and several lines with good resistance to thrips and jassids have out-yielded control cultivars.

Aphids, jassids, and thrips. Spraying monocrotophos 0.05% or dimethoate 0.05% at several testing centers in India not only gave significantly greater yields but also resulted in the highest cost benefit ratio (CBR). The CBR for these chemical treatments ranged from 1:6.33 to 1:19.68.

Leafminer. Economic threshold studies indicated that chemical control should be adopted only when the number of mines reaches 61–70 per 100 leaflets. Carbaryl 50 WP 0.2% spray was most economical for controlling this pest, since the CBR obtained in the All India Coordinated Research Project on Oilseeds (AICORPO) trials ranged from 1:6.52 to 1:9.56.

Red hairy caterpillars. The pupae may be handpicked and destroyed in the field after summer plowing. Immediately after rainfall, light traps may be set up to attract and destroy the moths. The egg masses and larvae, which can easily be detected, may be collected and destroyed. Before the caterpillars develop hairs on their bodies they can be controlled effectively by spraying monocrotophos 40 EC at 1 L ha^{-1}. A biological control measure through the spray of nuclear polyhedrosis virus (NPV) at Tamil Nadu Agricultural University, Coimbatore, India, was found to be effective and economical. The virus may be sprayed twice against early instar larvae at 250 larva equivalent ha^{-1}.

Tobacco cutworm, gram caterpillar, and leaf webber. These pests can be controlled by spraying 0.05% quinalphos at 400 ml ha^{-1} (CBR: 1:6:2). Other insecticides like carbaryl 0.2%, endosulphan 0.04%, and parathion 0.05% are also effective. In the case of tobacco cutworm, the larvae are nocturnal in habit; hence, the control measures should be applied during the night time.

Whitegrub. Whitegrub is a major problem for groundnut in the sandy loam soils of North India and Pakistan. Due to whitegrub infestations, the area under groundnut has declined considerably during the last two decades in the states of Uttar Pradesh, Rajasthan, and Punjab in India. The following integrated control measures can help to keep the pest under check:

- The field should be plowed twice during May–June to expose beetles present in the soil.
- Wherever possible, the crop should be sown early (between 10 and 20 June) to reduce the damage.
- The adult beetles should be killed by spraying the preferred host trees with carbaryl 50 WP or 50 ml Folithion®/Sumithion® 50 EC in 100 L of water.
- The soil may be drilled with phorate or carbofuran or sevidol granules at 25 kg ha^{-1} at least 1 week before sowing.
- Wherever the incidence is moderate, a cheap method of seed treatment may be adopted by treating the seed with chloropyriphos at 1.25 L (100 kg $seed)^{-1}$.

Diseases

The important groundnut diseases in the region are early and late leaf spots (*Cercospora arachidicola* and *Phaeoisariopsis personata*), rust (*Puccinia arachidis*), *Aspergillus flavus*, collar rot, dry-root rot, stem rot (*Sclerotium rolfsii*), and bud necrosis disease (BND).

Some of these diseases can be controlled by using proper fungicides.

Leaf spots and rust. Bavistin® 0.05% + Dithane® M-45 0.2%, sprayed at 2–3 weeks interval, two or three times starting from 4–5 weeks after sowing can effectively control these foliar diseases. In AICORPO trials, this combination of fungicides resulted in the best control of both diseases and gave a CBR ranging from 1:14.8–24.4.

Collar rot and dry root rot. Seed treatment with 5 g thiram or 3 g of Dithane® M-45 or 2 g Bavistin® (kg of $seeds)^{-1}$ can minimize the incidence of these diseases in the field.

Stem rot. The seeds should be treated as described for collar rot. In the soils infected with stem rot causing fungi, frequent disturbances of plant and soil should be avoided to prevent the stems from coming to contact with the organism. In such soils, herbicides may be used to minimize the disturbance of the soil due to manual weeding.

Breeding for resistance to diseases has received more attention in the region, particularly in India. Significant progress has been made in developing cultivars resistant to rust, late leaf spot, and bud necrosis diseases.

Rust and late leaf spot

At ICRISAT, several *A. hypogaea* genotypes and interspecific derivatives with high levels of resistance to rust and late leaf spot have been identified. These resistant sources are in extensive use in the disease resistance breeding programs of the region. Cultivars Girnar 1, ICG(FDRS) 10, and ICGV 86590 with resistance to rust and tolerance to late leaf spot have been released for cultivation in India.

Information bulletins on rust (Subrahmanyam and McDonald 1983) and leaf spots (McDonald et al. 1985) have been published by ICRISAT. These provide advice on their management and a good basis for further research on these diseases.

Bud necrosis disease

The bud necrosis disease is a virus disease transmitted by thrips. Chemical control of the vector is not always effective. Cultural methods such as timely sowing, closer spacing, intercropping with cereals, and use of vector-tolerant varieties (Kadiri 3, ICGS 11, ICGS 44, and others) help in reducing the disease incidence in the field.

Meanwhile, breeding efforts at ICRISAT are directed towards combining resistance to the vector and the virus in the high yielding background. Sources of resistance to thrips have been known for some time, but genotypes with tolerance to the virus have only been recently identified. The status of research on bud necrosis disease was recently summarized in an information bulletin published by ICRISAT (Reddy et al. 1990).

Aflatoxin contamination

The *Aspergillus* group of fungi invade groundnuts in the field and during postharvest handling. These fungi produce aflatoxins that are carcinogenic to humans.

Several genotypes with resistance to in vitro seed colonization by *A. flavus* have been known in the past. However, this form of resistance is effective only when the seed coat remains intact. Recently, genotypes that resist fungus invasion in the field and production of aflatoxin after fungus invasion have been identified. Breeding efforts are underway at ICRISAT and NRCG, Junagadh, India, to combine these forms of resistance with high pod yield. Proceedings of an international workshop on aflatoxin contamination of groundnut, held at ICRISAT Center in 1987, summarize the status of aflatoxin management research in the region and elsewhere (ICRISAT 1989).

Operational Research

In India, the production technology generated at different AICORPO groundnut centers was demonstrated in the rainy season in 1-acre farmer plots for 4 years (1980 to 1983). The results indicated considerable yield increases in the demonstration plots receiving the improved package instead of the farmers' procedure. The mean increase over the 4-year period ranged from 26.8% in Tamil Nadu to 100.8% in Rajasthan. A rough estimate showed that adoption of improved technology could increase the rainy season groundnut production from the present level of 5.3 million t to 7.5 million t – an increase of 40%.

In 141 on-farm trials conducted jointly by the Ministry of Agriculture, Government of India, and ICRISAT during 1987–1990, the improved groundnut varieties alone had an average pod yield advantage of 26% over local varieties, and the improved package of practices alone with local varieties had an advantage of 20% over the local recommended package of practices. Improved varieties, when used together with the improved package of practices, showed an average advantage of 60% over local varieties and local recommended practices.

In Pakistan, on-farm trials were organized during the past 5 years under the Barani Agricultural Research and Development (BARD) Project to transfer the improved production technology to the farmers in Rawalpindi Division. The improved technology included: timely sowing in straight rows, maintenance of optimum plant population by using 100 kg seed ha^{-1}, two weedings at 70 and 90 DAS, control of rats, harvesting the crop at 75% pod maturity, and use of improved machinery in field operations. Results from the demonstration plots were very encouraging, showing an average pod yield of 2450 kg ha^{-1} compared with 1400 kg ha^{-1} in the plots where local practices were used. Results further indicated that 50% yield can be increased only by rodent and weed control.

Technology Mission on Oilseeds in India

The Government of India instituted a Technology Mission on Oilseeds (TMO) in May 1986 with the objective of promoting production and processing of oilseeds for accelerating self-reliance in edible oils in the country. The Mission set a goal of producing 18 million t of oilseeds by 1989–90; it was achieved 1 year earlier in 1988–89. Groundnut production, which was at 6.21 million t during the premission period, increased to 7.81 million t after the TMO came into existence. It accounts for an increase in production of 25.7%.

Until 1986, the improved technologies developed for oilseed crops could not be adopted by the farmers for a multitude of reasons, namely: 1) unfavorable pricing policy and fluctuations in oilseeds prices in space and time to the disadvantage of the farmers, 2) limited developmental support for oilseeds, 3) non-availability of quality seed of high-yielding varieties in sufficient quantities at the right time, 4) low investment capacity of the bulk of the oilseed farmers, and 5) predominant cultivation of oilseeds under rainfed (86%) and input-starved conditions.

Since 1987–88, the scenario for oilseed production in the country became highly favorable to farmers due to the following integrated and mutually synergistic policies and measures initiated by the TMO: 1) declaration of minimum support prices to oilseeds with assured market support and an intervention mechanism, 2) availability of easy credit and other farmer support services, 3) progressive phasing out of imports of vegetable oils, and 4) building up of buffer stocks for effective market intervention to prevent steep falls or rises in price below and beyond specific price bands stipulated for major oilseeds.

All these measures had a cumulative and favorable effect on the open market price of oilseeds, which always remained much above the minimum support prices declared by the Government of India from time to time.

Machinery Development

Groundnut is a labor-intensive crop in the South Asia region, as most of the operations are carried out manually.

In India, machines available for shelling, threshing, and digging are popular with groundnut farmers. But for undertaking operations such as sowing, wet threshing, and gleaning (in sandy soils) suitable machinery has yet to be developed. Research work to develop this machinery is being undertaken at the Central Institute for Agricultural Engineering (CIAE), Bhopal, and also by the engineering departments of various state agricultural universities. The groundnut planter developed by Tamil Nadu Agricultural University, Coimbatore, is reported to be ideally suited for sowing groundnut in sandy loam soils.

In Pakistan, the BARD Project, in collaboration with the Farm Machinery Institute, has developed groundnut production equipment that is available from private manufacturers. The machines include a modified Italian mouthseed planter, a groundnut digger, and a power-operated thresher. In addition to sowing groundnut, maize, chickpea, soybean, and sunflower, the modified Italian planter can also do side band placement of fertilizers simultaneously. A tractor-mounted digger that can dig groundnut at the rate of 1–1.5 acres h^{-1} is rapidly gaining wide acceptance among groundnut growers. Similarly a thresher powered by a tractor with a crop intake capacity of 1200 kg h^{-1} is being manufactured commercially. A manually operated sheller imported from India with output of 40 kg seed h^{-1} with only 5% seed breakage is being considered for commercial production.

The Engineering Division of the Bangladesh Agricultural Research Institute (BARI), Bangladesh, has developed a hand-operated sheller for quick shelling of nuts. In Myanmar, development of a suitable groundnut planter is one important priority in future programs.

Marketing and Utilization

Marketing

Among the South Asian countries, a well-organized marketing system for groundnut exists only in India. In India, groundnut is marketed within the country either as pods or seeds, but the export is mainly in the form of seeds and groundnut cake. The marketing season for the rainy season groundnut generally commences in October and is over by February. The farmers either take their produce to the nearest assembling market or sell it at the farm gate. The markets concerned with groundnut trade fall under three categories: primary, secondary, and terminal (Patel 1988). Primary markets are mainly periodical, also known as weekly bazaars, which besides buying groundnut from farmers figure in the small retail sale. *Mandies* or *Gunj* are secondary markets that provide a permanent place for the daily transactions to take place with some amenities for the benefit of the sellers and buyers. The terminal markets are urban centers often connected by rail. Their stocks come from the primary and secondary markets.

The vegetable oil wing of the National Dairy Development Board (NDDB) was authorized by the

Government of India in 1988 to undertake the Market Intervention Operation (MIO) to ensure a fair price to the producer and a fair deal to the consumer. Prior to the MIO, the usual price spread was about 100% and in some years as much as 300% during the selling period despite huge imports of edible oil. The MIO brought about price stabilization in edible oils with a reasonable degree of success. The price spread was reduced to 25% in 1988/89, 50% in 1989/90, and 33% in 1990/91, despite the deficits not being met entirely through imports (NDDB 1991).

The vegetable oil and oilseeds project of NDDB has set up processing facilities throughout the country, with capacities of 3220 t day^{-1} for crushing, 1910 t day^{-1} for solvent extraction, and 710 t day^{-1} for refining oil. A storage capacity of 170 000 t for oilseeds and 86 550 t for oil has also been built. A National Oil Grid is being established with storage capacities at strategic locations, packaging stations spread all over the country, and an economical transport system to move oil and oilseeds from surplus to deficit zones.

Utilization

In India, about 81% of the groundnut produce goes for oil extraction, 12% as seed, 6% for edible use, and 1% for export. Handpicked and selected (HPS) groundnuts often referred to as "table nuts" and the deoiled cake are the main items of export.

In Myanmar, 70% of the groundnut produce is processed for oil, 20% as seed, and the remaining 10% for direct consumption as roasted, fried, or boiled groundnuts. In Bangladesh, Bhutan, Pakistan, and Sri Lanka, and Nepal, groundnut is used mainly for direct consumption.

Future Scope of Expansion of Groundnut Area in South Asia

In addition to increasing productivity, there is a great scope for increasing the area under groundnut cultivation in South Asia.

In Bangladesh, there is a scope to increase groundnut area without affecting other major crops mainly in coastal areas and river banks with silted soils, where no other crops except sweet potato (*Ipomoea batatas*) and water melon can be grown. Groundnut can be a good substitute for these crops on those lands.

In India there is only a limited scope for expanding the rainy season groundnut area as a sole crop in the highlands of Orissa, northern Bihar, and tribal belts of Andhra Pradesh and Madhya Pradesh. But there is enormous scope for groundnut as an intercrop with the traditional rainy season crops. Groundnut can be intercropped: with cotton and sorghum in the medium-black soils of Maharashtra, Karanataka, and Andhra Pradesh; with sugarcane in Maharashtra and Gujarat; with tobacco in Gujarat; and with coconut and cassava (*Manihot esculenta*) in Tamil Nadu and Kerala.

The area under postrainy irrigated summer groundnut has nearly doubled in India in the last decade, from 0.8 million ha in 1980–81 to 1.5 million ha in 1988–89. It may not be unrealistic to expect further expansion of the postrainy summer area to 2 million ha by the turn of the century. The high yield levels normally obtained from summer crops and high water-use efficiency are the major attractions to growing this crop in larger areas.

On the basis of soil type, climate, and irrigation facilities, it has been estimated that there is 1.4 million ha potential area where groundnut can be grown in Pakistan. Under the crop diversification program in Mahaweli Command Project area, potential exists for increasing the area under groundnut in Sri Lanka. Due to competition with maize and sugarcane (*Saccharum officinarum*), the groundnut area in the rainy season in Nepal is unlikely to increase. However, spring cultivation (Feb-Jun) in rice fallows with irrigation offers a possibility of expansion of the groundnut area in the country.

Future Thrusts in Groundnut Research

The important thrust areas for future research to overcome the production constraints in South Asia are as follows:

- Development of early-maturing varieties suitable for areas where the growing season is short, end of season droughts are frequent, and the crop is grown in rice-based systems with residual moisture;
- Incorporation of 2–3 week fresh seed dormancy in spanish varieties;
- Development of varieties resistant or tolerant to abiotic stresses such as drought in Bangladesh, India, Pakistan, and Myanmar, cold in India, shade for intercropping in coconut plantations in South India and Sri Lanka, and acid soils in northeastern India and Nepal;

- Development of varieties resistant or tolerant to major diseases such as late leaf spot and rust (all South Asian countries), bud necrosis disease (India, Pakistan, and Sri Lanka) and major insect pests, such as leaf miner in India and Nepal, and sucking pests in all South Asian countries;
- Development of varieties resistant to *Aspergillus flavus* and aflatoxin contamination in all South Asian countries;
- Research on methods of ensuring seed viability especially in summer season crop in Bangladesh, India, and Pakistan; and
- Design and development of suitable implements for farm operations such as shelling (Pakistan and Sri Lanka), sowing (India, Pakistan, and Sri Lanka), digging (India, Nepal, Pakistan, and Sri Lanka), and threshing (Pakistan and Sri Lanka).

In addition to the above research areas, the developmental activities in the region will involve creation of infrastructure for seed production and marketing.

ICRISAT's Contribution to Groundnut Improvement in South Asia

Development and Release of Improved Varieties

In India, the following varieties were released from the ICRISAT-bred material tested under the AICORPO trials: ICGS 11 (1986), ICGS 44 (1988), ICGS 76(1989), ICGS 37 (1990), ICGS 1 (1990), ICG (FDRS) 10 (1990), ICGS 5 (1990), and ICGV 86590 (1991). In addition to these, five more varieties selected from ICRISAT-supplied segregating material were released in India during 1984–89, namely, Spring Groundnut 84, ALR 1, VRI 1, Girnar 1, and RG 141. In Pakistan, two new varieties, namely, BARD 699 (released) and BARD 479 (under release), were selected from ICRISAT's material. Pakistan has also identified short-duration lines ICGS (E) 52 and ICGS (E) 56, which are being considered for release in dry areas. In Nepal, the early-maturing varieties of ICRISAT, namely, ICGS 30, ICG 789, and ICGS (E) 52, recorded 15 to 18% higher yield over the check variety B-4. In Myanmar, two varieties introduced by ICRISAT, ICG 7827 and ICG 799, were released as Sinpadetha 2 and 3 during 1984–85. In Sri Lanka, the following ICRISAT breeding lines produced high yields at different centers: confectionery types, ICGV 86552 and 86558, yielded over 3 t ha^{-1} at *Maha* Illuppallama; ICGV 88367 and 88379 recorded 4 t ha^{-1} at Araganwila; ICGV 87140 showed tolerance to leaf spots and rust and yielded 4 t ha^{-1} at Kilinochchi; and ICGV 87151 produced record yield of 7 t ha^{-1} and ICGV 86028 produced 6 t ha^{-1} under supplemental irrigation at Girandurukotte.

Training

ICRISAT provided training to the technicians and scientists in the areas of groundnut research and production. There was a periodical exchange of visits by the groundnut scientists of ICRISAT and those of the South Asian countries for discussions on production constraints and to facilitate information transfer.

Technology Transfer

The groundnut production technology generated at ICRISAT is being transferred to the farmers in India under the Legumes On-farm Testing and Nursery (LEGOFTEN). The National Dairy Development Board (NDDB) popularized ICRISAT's technology in an area of 10 000 acres in 1990–91. On-farm trials are in progress in Sri Lanka and Nepal under the Asian Grain Legumes On-farm Research Project.

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