PROGRESS IN GROUNDNUT RESEARCH AT ICRISAT

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INTRODUCTION

Groundnut production in the semi-arid tropics (SAT) exceeds that of any other legume and comprises 70% of the world's production. With approximately 25% protein and 50% edible oil, groundnuts are an important source of food and cash to SAT farmers. The haulms remaining after the pods are removed constitute a valuable and nutritious animal feed. The average yield of groundnut for the SAT remains very low at around 800 kg/ha of dried pods, and yields fluctuate widely from unreliable rainfall. Disease and pest attacks also cause severe reductions in yield.

For the past 8 years we have been carrying out research into disease and pest problems, drought stress, and nutrient stress. Interactions between the various stress factors have also been studied. Considerable effort has gone into the development of high-yielding cultivars, particularly for stress-free situations. Our continuing management strategy is to use the genetic diversity in groundnut and its wild relatives to breed into the crop stable resistance or tolerance to the major yield reducers. This paper covers some of the ICRISAT groundnut research activities which are of relevance to the production and productivity of the groundnut crop in India.

FUNGAL DISEASES

Foliar fungal diseases : The most important foliar diseases causing severe yield losses on a worldwide basis are the 'early' and 'late' leafspots (Cercospora arachidicola and Cercosporidium personatum) which are together refered to as 'tikka' disease in India. Another foliar disease, rust, caused by Puccinia arachidis, has become increasingly important over the last decade. In India it causes severe damage, particularly, in the Southern states and is spreading to other areas as well. At ICRISAT Centre it has been shown that rust and late leafspot together can cause yield losses in susceptible cultivars as high as 70%, while each disease on its own is capable of causing up to 50% yield loss (Subrahmanyam et al, 1980; Proc. Int. Workshop on Groundnuts, ICRISAT, India p. 193). All released Indian cultivars are susceptible to both these diseases. From field screening of over 9,000 germplasm collections several genotypes with good resistance to both rust and leafspots have been identified (Table 1). In addition, 61 wild species accessions of Arachis have been screened for rust resistance. Most of them were found to be immune, 6 were highly resistant and 2 were susceptible to the pathogen (Subrahmanyam, Moss and Rao, 1983; Plant Disease 67(2): 209-212). Fourteen breeding lines with rust resistance have been jointly released by ICRISAT and USDA.

Stability of the resistance to rust and late leafspot has been checked by conducting an International Groundnut Foliar Diseases Nursery and these resistance appear to be stable (Subrahmanyam et al., 1983; Plant Disease 67(10): 1108-1111). The biology of the pathogens and the components of resistance have been investigated. The physiological implications of disease resistance are now being examined and the findings may influence breeding and disease control strategies.

Most of the rust and late leafspot resistant lines are unadapted and have undesirable pod and seed characters. A large scale hybridization program has been mounted to combine resistances with good agronomic characters and several high yielding rust resistant lines with moderate levels of resistance to late leafspot and with acceptable pod and kernel characters have now been developed. Several of these resistant lines have outyielded the popular Indian cultivars, Robut 33-1 and JL-24 (Table 2) and have given over 4000 kg/ha pod yields at ICRISAT Centre (Table 3).

In addition to the above lines developed by the utilization of resistant germplasm sources within the cultivated species, several stable interspecific derivatives involving A. cardenasii, A. batizocoi, and A. spegazzini with high lvels of resistance to rust and late leafspot have been developed. Some of these derivatives have given significantly higher yields than the check cultivars (Table 4).

At ICRISAT the early leafspot disease caused by C. arachidicola does not normally become severe enough to permit reliable field resistance screening. However, during the 1983 rainy season, in addition to the usual severe rust and late leafspot attacks, early leafspot attack was also severe thus permitting meaningful field evaluation of germplasm for resistance to this disease. None of the germplasm lines tested were resistant to early leafspot, including the lines NC 3033, PI 270806, PI 259747 and PI 350680 reported to be resistant' to this disease in the USA. However, three breeding lines showed very high resistance to early leafspot and rust (Table 5).

Early leafspot disease occurs in epidemic form at Chitedze Agricultural Research Station, Lilongwe, Malawi, where an ICRISAT Regional Groundnut Program was established in 1982, and both germplasm lines and segregating material are being screened there for resistance to the disease.

Pod rot diseases : Pod rot diseases caused by a complex of soil inhabiting fungi are responsible for serious reduction in both yield and quality of groundnuts in the SAT region. The extent of the damage caused is not always evident at harvest and it is likely that the incidence of pod rots and the yield losses attributed to them have been considerably

underestimated. Losses of over 20% have been recorded at ICRISAT for some genotypes. Field screening for resistance is complicated due to uneven disease incidence and special field screening techniques need to be devised. About 3500 lines have been screened and 11 genotypes showed consistently low percentage incidence of pod rot (Mehan et al., 1981; Amer. Peanut Res. Educ. Soc. 13: 91).

The various fungi involved in pod rotting at ICRISAT have been identified and the most important are Fusarium species, Macrophomina phaseolina and Rhizoctonia solani. Different fungi and varying combinations of fungi have been found associated with pod rots in different places and this variation may have implications for resistance screening and breeding.

The Aflatoxin problem : Aflatoxins - toxic secondary metabolites produced by strains of Aspergillus flavus when growing on groundnut seeds and products - are a serious quality problem in groundnut. Invasion of groundnut seeds by the toxigenic fungus is favoured by damage to the developing pods by pathogenic fungi, insects, drought stress and improper crop handling and storage methods. ICRISAT scientists are concentrating on finding genetic resistance to invasion of pods and seeds by the pathogen and/or resistance to the production of aflatoxin in the event of seeds becoming infected. In addition to confirming the testa resistance of some breeding lines to the invasion of rehydrated dried seeds, reported by Mixon and Rogers (1973) several more 'dry seed resistant' genotypes have been identified at ICRISAT. Interestingly, some of these genotypes such as J 11 and Ah 7223 were also found resistant to pod rot.

A number of germplasm lines have also been tested for resistance to aflatoxin production following invasion of seeds by the fungus. Although all the genotypes supported aflatoxin production, significant differences in the rate of accumulation and total toxin production were observed among the host genotypes (Mehan and McDonald, 1981; Proceedings, Intl. Symp. on Mycotoxins, Cairo, Egypt).

Attempts are being made to transfer 'dry seed resistance' and the low toxin production trait together with pod rot resistance into high yielding susceptible cultivars. A few high yielding breeding lines with good levels of dry seed resistance have been developed (Table 6).

In addition to concentrating on genetic resistance to the fungus we examined the effects of seed maturity and time of drying in the windrow on seed infection with A. flavus and contamination with aflatoxin. Four genotypes, J 11 (resistant to pod rot; resistant to seed invasion by A. flavus), EC 76446(292), M 13 and TMV 2, were sown in a replicated field trial. There were four harvest dates,

normal harvest time, 30 and 10 days before normal harvest and 10 days after normal harvest. Seeds were tested for infection with A. flavus and for aflatoxin content at time of lifting and after 2, 4 and 6 days of windrow drying for material lifted at normal harvest time and at 10 days later. The genotype J 11 had the least seed infection with A. flavus and the lowest levels of contamination with aflatoxin. Seed invasion by A.flavus increased with increasing maturity of the seeds.

Over the rainy seasons of 1979 to 1982 we recorded seed infection with A. flavus of immature, mature and over-mature seeds of several groundnut genotypes with varying levels of resistance to colonization of rehydrated dried stored seed by A. flavus. In general, genotypes with dried seeds' resistance to A. flavus showed lower levels of seed infection with the fungus at time of lifting than did the other genotypes. Infection with A.flavus increased with maturity of seeds (Table 7).

VIRUS DISEASES

Bud Necrosis Disease: Bud necrosis caused by tomato spotted wilt virus has been recognized as probably the most economically important virus disease in India. The virus is transmitted by the thrips, Frankliniella schultzei (major vector) and Scirtothrips dorsalis. Some 7000 genotypes have been screened for resistance and no resistant genotypes have yet been found among cultivated groundnuts. However, very large differences have been found between genotypes in field incidence of this disease. Results on the studies on the management of this virus is reported in the section dealing with Insect Pests.

Peanut Clump Virus Disease : Peanut clump, a soil-borne virus disease, has been found in Punjab, Gujarat, A.P. and Tamil Nadu State of India. We have identified five geographically separated isolates of peanut clump virus (PCV) which have different degrees of disease severity on groundnut and have differential reactions on diagnostic hosts. The isolates have been purified and antisera produced. Immunosorbent electron microscopy and das-ELISA tests indicate that three of the isolates are serologically related while two are distinct.

Transmission : The fungus Polymyxa graminis has been found in all PCV-infested soils examined, and several weed and crop plants growing on PCV-infested soils were found to contain both P. graminis and PCV. Groundnut plants grown in sterilized soil to which portions of PCV-infested wheat roots were added became infected with PCV.

Screening for resistance : In the 1983 rainy season we used naturally infested soils to screen for PCV resistance 1050 germplasm and 483 breeding lines at Bapatla, Andhra Pradesh

State, and 265 breeding lines at Ludhiana, Punjab State. None was resistant. Three germplasm lines selected for advanced screening in 1982 were rated as susceptible to PCV in the 1983 trials at Ludhiana and Bapatla.

In 1983 we also screened 18 wild Arachis spp. and 140 interspecific hybrid derivatives for resistance to PCV at Bapatla. All the interspecific derivatives were susceptible. Thirteen of the Arachis spp. did not become infected, and none of the 5 species which did become infected showed typical PCV symptoms.

Peanut Mottle Virus Disease : This disease is known to be present in all groundnut growing countries. Using a field mechanical inoculation method we screened 433 germplasm lines in the 1982/83 and 1983 season for resistance to peanut mottle virus (PMV). Four lines showed less than 5% yield loss from the disease and will be included in advanced screening trials in 1984.

In the 1982/83 postrainy season we tested 5 genotypes and two PMV-susceptible cultivars for yield loss following infection with PMV. The genotype NC Ac 2240 had no loss in yield, the other test entries had from 13 to 30% and the susceptible cultivars 43 and 55% losses in yield. In the 1983 rainy season a similar trial with the 4 best entries from the previous trial and one susceptible cultivar again showed that NC Ac 2240 suffered the least loss in yield from PMV (Table 8).

Forty-three wild Arachis spp. were screened for resistance to PMV by mechanical inoculation. The experiment was carried out in a screenhouse and plants of the PMV-susceptible groundnut cv. TMV-2 were included as controls. Thirty-seven species were found to be infected with PMV by ELISA test. Six species - Arachis spp. 30009, 30081 and 3501, A. chacoense, A. pusilla, and A. sp. manfredi were not infected despite repeated inoculation.

"Mild Mosaic" Virus Disease : A disease of groundnut characterized by mild mosaic symptoms on foliage was observed on groundnuts at ICRISAT Center in 1978. Incidence was low and the disease has not reappeared. Limited investigations have shown that the causal agent is a virus that is mechanically transmissible but is not transmitted by Aphis craccivora, Frankliniella schultzei or Bemisia tabaci insects. Electron microscopy of partially purified virus showed flexuous rods with distinct helical structure. Physical properties of the virus are being investigated.

INSECT PESTS

Over 300 insect and mite species have been recorded from groundnut but most are of limited distribution. Yield losses worldwide have been assessed at 17% and 6-10% from field and storage pests respectively. No storage work has been done at ICRISAT although there are indications of genetic resistance to some important insect pests. Research has concentrated on problems caused by aphids, jassids, thrips, the tobacco caterpillar, leafminers, bollworms and termites. Particular emphasis has been given to research on vectors of virus diseases.

Estimates of yield losses at ICRISAT Centre Trials were conducted in four postrainy seasons from 1979/80 to 1982/83 to determine losses caused by thrips, Scirtothrips dorsalis. The losses in pod yield caused by thrips were 800 kg/ha in 1979/80, 400 kg/ha in 1980/81, 200 kg/ha in 1981/82 and 350 kg/ha in 1982/83 valued at US $130. The total losses in haulm yield were 800 kg/ha in the 1981/82 trial and 1070 kg/ha in the 1982/83 trial valued at approximately US $ 45/ha. Most losses were caused during the period 15-60 days after sowing.

Similar results were obtained in a separate trial with cv Robut 33-1 in the 1982/83 postrainy season. Crops not protected throughout the growing season yielded 21% less than fully protected crops. Most of this loss occurred between 45-85 days after sowing. Major pests were thrips, Scirtothrips dorsalis.

Surveys: All major groundnut growing areas of India have been surveyed to identify pest problems and measure yield losses. The surveys have shown recent shifts in pest incidence, some insects becoming more damaging and others less so. The overall trend is towards increased pest damage, and one factor that may be responsible for this is the recent increase in cultivation of irrigated groundnuts in the postrainy season. In 1968 only four pests of the crop were considered to be important whereas in 1984 nine pests are considered to be of major importance (Table 9). Leafminers have become a serious problem wherever irrigated groundnuts are cultivated on a large scale (Figure 1). The value of groundnuts lost by pest damage each year in India is estimated at US $160 million.

Virus Vectors: Insect pests may be of importance because of the direct damage they do or because of their role in transmission of virus diseases. For instance, the groundnut aphid, Aphis craccivora, can cause severe damage to young plants, particularly when large populations build up during early season drought when their sap sucking activities may even cause death of the plants. However, their activity in spreading peanut mottle virus worldwide and groundnut rosette virus in Africa is of much greater economic importance than the direct damage they cause. Similarly, thrips are more important as vectors of tomato spotted wilt

virus causing bud necrosis disease in India than they are as direct foliage feeding pests.

At ICRISAT the entomology research emphasis has been to effectively combine cultural practices and host plant resistance to develop integrated pest management systems.

For management of bud necrosis disease it was necessary to understand the epidemiology of the disease. Factors influencing build up and migration of the vector thrips and associated spread of the disease were investigated. Frankliniella schultzei was identified as the major vector. It was found that by (1) early sowing, (2) close spacing of plants, (3) intercropping groundnuts with pearl millet and (4) use of the high yielding virus susceptible but "field resistant" cultivar Robut 33-1, the incidence of bud necrosis disease could be reduced by 90-95% and yields increased by 15-20 times (Table 10). Although Robut 33-1 shows 50-80% lower field incidence of bud necrosis disease compared with such commonly grown cultivars as TMV-2, it is equally susceptible to the virus. Even lower field incidence of the disease has been recorded for progeny of the cross Robut 33-1 x Nc Ac 2214 and this and similarly promising lines have been used in the resistance breeding program.

Field Pests: The effects of cultural practices on the incidence of other important pests are being studied and particular attention is being given to effects of intercropping. The high yielding and multiple pest resistant genotype NC Ac 343 has been used in developing a breeding line with good resistance to thrips, jassids and termites (Table 11).

Breeding for pest resistance: Breeding for pest resistance was started in 1980 with the objective to combine resistance to leafhoppers, thrips and termites into high yielidng genotypes. An extensive hybridization program has been initiated and a large number of single and multiple crosses have been made using NC Ac 2214, NC Ac 2232, NC Ac 2240, NC Ac 2242, NC Ac 2243, NC Ac 2230, NC Ac 1705, NC Ac 343, NC Ac 16940 and NC Ac 785 as sources of resistance to thrips, leafhoppers and termites. The materials from these crosses are in different generations and are subjected to natural/artificial infestation under field and laboratory conditions. The thrip populations are abundant in both rainy and postrainy seasons and the material is screened in both seasons under natural field conditions. However, the leafhopper population in the postrainy season is very low and screening for resistance to this insect is done mainly during the rainy season. If natural leafhopper populations are too low, laboratory-bred insects are released on the test material to ensure sufficient pest pressure. Based on the amount of damage to the leaf at the time of maximum infestation, progenies resistant/tolerant to thrips and

leafhoppers are selected for advancing. Through repeated testing and selection, several high yielding progenies have been developed which have good resistance to thrips and leafhoppers (Table 11). The segregating material from crosses involving lines such as NC Ac 343, NC Ac 2242, and NC Ac 1705 which are resistant to pod scarifying termites were screened for termite resistance in termite infested fields. Some termite resistant progenies have been identified and further tests are in progress to confirm their resistance.

It was observed that presence of trichomes, and thick leathery and waxy leaves are associated with leafhopper resistance in groundnut. The genetics of the different mechanisms of resistance is under investigation.

Since it is suspected that resistance to insects and high yield are negatively correlated, a two stage breeding strategy is being followed to overcome this undesirable linkage. In the first stage, high yielding lines with moderate levels of resistance are developed, then in the second stage these lines are intermated to increase the levels of resistance to various insects. Intermating of early generation selections made on the basis of pest damage and/or on the basis of morphological traits such as thick leathery and waxy leaves with or without trichomes will be made to increase the favourable genes for resistance.

PHYSIOLOGICAL RESEARCH

Drought research & physiology :

Drought research is conducted mainly in the postrainy season because of lack of water control the rainy season. Two simultaneous efforts have been made in the drought research. One has been to develop a screening method to apply to germplasm and breeders' lines, and to screen as much material as possible as the method has been developing. The second has concentrated on examining in detail the physiological responses of groundnuts to drought stress, the factors which determine the use of water, water use efficiency, and the physical and physiological basis for genetic differences in response to drought.

The Physiology Sub-Program has cooperated with other groups both within ICRISAT (FSRP) and outside ICRISAT (ODA unit at University of Nottingham). These collaborative efforts have been very fruitful and have materially speeded up progress in this area by bringing a very much expanded resource base to bear on the problems.

Drought Screening Achievements: Drought screening commenced in the 1980/81 postrainy season with a small range of treatments applied to 80 genotypes. Stress was varied to occur at different stages in crop development but only two

levels of stress were imposed - full irrigation for a control treatment and no-irrigation for a dry treatment. Lines with 'tolerance' to drought were identified and the hypothesis that time of stress x genotype interactions existed was confirmed. Variability was substantial and an unexpected aspect of drought added a confounding factor. At harvest the crop was irrigated to facilitate lifting and one replicate was harvested each day. On the second day of lifting pod rots were prominent and on the third day most pods had rotted. This observation is being exploited by the pathologists to improve their screening methods for pod rots resistance. Screening for drought resistance has been modified to overcome this factor.

In 1981/82 line source irrigation was utilized to create 6 levels of water application in each of 4 drought timings. Drought timings were selected with the intention of choosing the phases of crop growth for which the greatest amount of genetic variability existed and seeing if responses at these times could be related to drought responses in different phases of growth. These treatments also represented the most 'commonly' occurring droughts in the SAT. One set of treatments represented variations on mid-season drought, another set represented early drought, and another represented environments where rainfall is always less than potential evaporation.

Lines from this screening were tested at Anantapur, a site where drought commonly occurs, and two of them were found to be significantly better than the local check cultivars (TMV-2 and Robut 33-1). In a season with no rainfall for 63 days after sowing and a total during the crop's life of only 220 mm yields of 1.15 t/ha were achieved.

In 1982/83 500 lines were screened but with a change in the treatments applied. The long term stress and end of season stress patterns were retained but the midseason variations were replaced by a long term stress interrupted by irrigation on 20 occasions. This change was made because the preliminary analysis on the total dry matter of these treatments showed only small affects and the intercepted long stress was thought to present an opportunity to score for recovery from drought. These ideas were shown to be incorrect in the light of final analysis and a midseason stress has been re-introduced into the present drought screening exercise. In 1982/83 a drought screening evaluation was done on 25 lines selected from the previous drought screening using twelve patterns of drought stress each with 8 intensities of stress. These treatments were designed to examine the genetic variability and interactions of genotypes to multiple droughts, and variable durations and timings of drought. The trial provided 96 sites differing mainly in the water component of the environment. (temperature, photoperiod, and most other aspects of the

environment being constant). The results of this trial are still being analysed but preliminary analysis indicates that early stress definitely provides adaptive advantages in the event of a second drought at a later stage; long droughts with occasional short periods of being returned to good water relations do not change the nature of the basic response to that drought pattern.

From this series of drought screening trials lines which have consistently performed better than the mean of all varieties have been identified.

Drought Physiology Studies : These have been conducted to investigate the effects of time and intensity of drought, plant population effects on water used, and the development of drought and the effect of timing of stress on the drought recovery responses (1983/84 with ODA unit).

The research on the effects of timing of stress has shown that early stress can increase yield by 14 to 30% and that for Robut 33-1 late stress has a much greater impact on yield than mid-season stress. In terms of water management and water efficiency, it was found that irrigation management to withhold water early and apply evenly deficient amounts during pod growth was better that utilizing the available water early leaving no irrigation at later stages.

The investigations of population effects on water use and the development of drought stress have provided basic information on the development of root growth, leaf area development, stomatal resistances and the inter-relationships of these factors.

The detailed comparison of different genotypes in droughts utilized four contrasting genotypes identified in the drought screening. Differences in water use efficiency were demonstrated between drought tolerant and susceptible lines and major differences in reproductive development during the drought and subsequent to the release of stress were found to be the reasons for differential performance.

Gypsum and drought interactions: Previous research findings showing an interaction of cultivar x gypsum x drought were confirmed. In field experiment, six cultivars were fertilized with gypsum at 0 or 500 kg/ha. Irrigation was applied regularly in all treatments until 60 days after sowing after which irrigation was either continued to ensure no water stress or withheld until 90 days after sowing. The results confirmed our earlier finding that some cultivars benefited significantly when gypsum had been applied and a drought occurred during the seedfilling phase. This effect was not apparent in other cultivars.

The reasons for this interaction of cultivar, gypsum and drought have been investigated utilising three cultivars, where gypsum was applied in three concentrations and drought imposed by the lines source method. This experiment has shown that in droughts, gypsum has increased the pod number and development of subterranean pegs and this effect results in the yield benefits observed from gypsum when droughts have occurred in the later part of the season. However, if the stress is released the benefit of gypsum may be eliminated by compensation during subsequent growth. It was found that although pod numbers had been increased by gypsum in an initial drying cycle, subsequent pod growth was inversely related to pod numbers at the time that water stress was released.

Photoperiod Studies :

Photoperiod studies have been made possible by GTZ support to the University of Bonn who collaborate with the Physiology Sub-Program on this aspect of groundnut physiology.

The work was initiated because although photoperiod effects had been discounted as a major factor in the adaptation of groundnuts, phytotron studies at North Carolina State University showed (in unrealistic day lengths) that major changes in reproductive development could result from changes in day length.

The ICRISAT objective was to establish the significance of photoperiods to the yield of groundnuts within the range of day lengths which occur in actual cropping environments. After preliminary experiments to examine the light intensity necessary to induce photoperiod effects, experiments were conducted under field conditions. Six genotypes were studied in long days (16 hours) and short days (11-12 hours) and large changes in yield were observed for some cultivars. In some cultures yield could be decreased by 50% by having long days while in other cultivars long days resulted in slight yield increases. At present research is continuing in this field with a view to developing a reliable method of screening.

Nutrient Stress

Biological Nitrogen Fixation: Although most cultivated soils of the tropics contain large populations of Rhizobium bacteria capable of forming nodules with groundnut cultivars, and although the groundnut is an efficient fixer of nitrogen, it was decided that there was a good chance of increasing nitrogen fixation by manipulation of Rhizobium strain, host genotype and environment and their interactions.

[illegible] with [illegible] : There are several reports of

Rhizobium inoculation increasing groundnut yields in fields where the crop had not previously been grown. In trials at ICRISAT Center over the past seven years it has been shown that inoculation of groundnut genotypes with a very effective strain of Rhizobium could increase nitrogen fixation and pod yield when the crops were grown in fields well populated with effective strains of Rhizobium. (Table 12). The Rhizobium strain NC 92 was found to be very efficient, particularly when in symbiosis with cultivar Robut 33-1. Field inoculation trials at ICRISAT Center with this strain and cultivar resulted in yield increases of 18 to 34 percent while a similar trial at Dharwar in Karnataka State resulted in 40 percent yield increase. Strain NC 92 was also shown to be very effective in combination with several other genotypes.

Method of inoculum application was found to be important. Groundnut seeds are fragile; and direct application of Rhizobium inoculum to them can cause significant damage and actually lead to decrease in yields. It was found better to apply the inoculum directly to the soil, and this was done easily and cheaply by mixing the peat containing Rhizobium with water and pouring the resulting mixture into the furrow just before the seed was sown. This method is also effective in reducing problems arising from incompatibility of Rhizobium inoculum and fungicide seed protectants. An animal drawn seed planter has been modified for direct application of Rhizobium inoculum to the soil.

Studies of inoculum concentration indicated that a minimum of 10 rhizobia per seed was needed to obtain good nodulation. Studies with strain NC 92 have shown that inoculation for a few years may be sufficient to establish a good soil population of a desired Rhizobium strain. This work was made possible by the use of enzyme linked immunosorbent assay (ELISA) for identifying Rhizobium strains in nodules.

Improving Host Genotypes: Over the past five years many germplasm lines were screened for nitrogen fixing ability. In general, the Spanish types were found to fix less nitrogen than the Virginia types, however, one Spanish line, X-14-4-B-19-B, was found to possess high nitrogenase activity and will be used in the breeding program to increase the nitrogen fixation of Spanish types. The Virginia line, NC Ac 2821 was found to have high nitrogenase activity and some progenies of this line were found to be high yielding. This suggests that it may be possible to increase yield potential by incorporating high nitrogen fixing lines in the breeding program. Incidentally, this line was also found to possess high nitrogenase activity when tested in fields in North Carolina, USA (Wynne, J.C., per. commun.).

Nitrogen Fixation, as Affected by Agronomic Practices: In collaboration with the Cropping Systems Program the effects of intercropping on nodulation and nitrogen fixation of groundnut were studied. It was observed that groundnut, when intercropped with nitrogen fertilised millet, maize or sorghum fixed less nitrogen than as a the sole crop. This suggests that high nitrogen inputs on the cereal component reduces the advantage of the nitrogen fixing ability of groundnut.

Many farmers practice deep sowing to make use of residual moisture for germination. This results in the development of an elongated hypocotyl and poor nodulation and reduced nitrogen fixation especially in Spanish cultivars. It was observed that most Spanish types lack the ability to nodulate on the hypocotyl. Hypocotyl nodulation contributes substantially to the nitrogen fixation of the deep sown crop. For example, in a deep sown Virginia cultivar, Kadiri 71-1, hypocotyl nodules contributed around 50% of the nitrogenase activity at 70 days after planting. Hypocotyl nodulation in Spanish types could be beneficial where deep sowing is practiced.

Measurement of Nitrogen Fixation: Nitrogen fixation was measured by estimating nitrogenase activity assayed by acetylene reduction, by nitrogen balance methods using non-nodulating groundnut, and by an isotope dilution technique using 15 N labelled fertiliser.

There is a marked diurnal variation in nitrogenase activity of field-grown groundnuts. Soil moisture, temperature and light intensity also influence nitrogen fixation. Intercropping has a marked effect on groundnut nitrogen fixation.

During the 1978 rainy season it was observed that some F2 progenies in a rust screening nursery were segregating for non-nodulation. Some of these have been purified to obtain non-nodulating lines. Nitrogen fixation was estimated as the difference in nitrogen uptake of the parental lines and a non-nodulating line. Values ranged from 67 to 145 kg N/ha. The non-nodulating line is poor in taking up soil nitrogen, and the yield level even when supplied with 400 kg N/ha was not equivalent to that of the nodulating crop grown without nitrogen fertiliser.

The 'A' value method of Fried & Broeshart was used to estimate nitrogen fixation using 15 N labelled ammonium sulphate and non-nodulating groundnut as the non-fixing control. A cover crop of maize was grown in the previous season to deplete soil nitrogen and even out the levels of nitrogen available for the groundnut crop. Estimates of nitrogen fixation ranged from 153 kg N/ha in Robut 33-1 to 100 kg N/ha in J-11.

Calcium Nutrition Research : Calcium deficiency of groundnuts is a major limiting factor in many parts of the world and gypsum application has been recommended in most groundnut producing areas.

Research in the Physiology Sub-Program at ICRISAT was initiated to investigate reported genetic differences in calcium uptake 'efficiency' of pods of different genotypes. As the Radio Isotope Laboratory was not available when the work started, the approach was adjusted to concentrate on the interactions of drought, gypsum and genotype.

Consistent and significant genotype x drought x gypsum interactions were demonstrated in a series of 3 experiments. Gypsum applied at the rate of 500 kg/ha increased yields of groundnuts in droughts by as much at 30% in selected genotypes, presumably by enhancing early pod initiation and so providing (or inducing) a drought 'escape' mechanism.

PLANT IMPROVEMENT

Breeding for high yield and quality :

Although for stability of production over years and locations breeding for resistance to various constraints has the highest priority, breeding for yield per se is important, particularly for areas where constraints do not occur or where progressive farmers can afford inputs such as pesticides and fungicides. Also, high yielding lines are necessary for use in the constraint based breeding programs and to counteract the rising costs of cultivation.

Advanced breeding populations are evaluated in two different seasons at ICRISAT Center. In the rainy season they are evaluated under both high input (60 kg P2O5/ha with supplementary irrigation and insecticidal sprays when required) and low input (20 kg P2O5/ha rainfed with no insecticidal sprays) conditions, but in the postrainy season under high input only. Very mild selection for yield is practised in the early generations. In the later generations, in addition to yield, pod shape and seed size are used as selection criteria. Most of the material is bulked into uniform groups for further evaluation and selection by cooperators in national programs.

Several high yielding lines with acceptable pod and seed characteristics and good shelling percentage have been developed (Table 13). Based on the consistently good performance of advanced lines over years, 62 lines have been given ICGS numbers before entering in national trials in India.

In the early years of the program we observed that cultivars which yielded well in the rainy season did not necessarily yield well in the postrainy season and

vice versa, indicating a strong genotype X environment interaction. It was therefore decided to make selections in the postrainy season to develop cultivars suitable for postrainy season irrigated cultivation and several high yielding lines suitable for this purpose have now been developed. Lines ICGS 30, 21 and 37 have given pod yields of over 6500 kg/ha which compare well with the 5500 kg/ha of the check cultivars J 11 and Robut 33-1 (Table 14). Many ICGS lines have been entered in the AICORPO trials to test their adaptability in different agroecological zones.

High yielding lines suitable for rainy season use have also been developed. ICGS 50, 30, and 1 did well under both low input and high input conditions at ICRISAT Center (Table 15) and several are under test by AICORPO.

The research on quality has concentrated on oil content. The oil and protein contents of 35 ICGS lines ranged from 42 to 50% and 22 to 33% respectively. Several lines have higher oil and protein content than the standard check cultivars J 11 and Robut 33-1.

Breeding for earliness and limited seed dormancy

In the SAT growing seasons can be very short due to early cessation of rains. Earliness coupled with good seed size and yield would provide stability for production in poor rainfall years. Efforts are in progress to identify early maturing groundnuts and to breed for increase in their yield levels. Use of early maturing groundnuts increases the probability of rain falling on the crop at or after maturity, so it is necessary that the early maturing groundnuts should have fresh seed dormancy.

In the initial years of this research two early Spanish types (Chico, and 91176) and a mid-early Virginia line (Robut 33-1) were used in crossing work with other high yielding bunch and runner types. Recently L No.95A, TG 1E and TG 2E were identified as new sources of earliness and used extensively in crossing work. From several hundred crosses selections have been made for earliness and high yield in the segregating material and lines with uniform plant growth habit, maturity, pod and seed characters have been developed and yield tested. Useful material has been generated with high yield coupled with diverse characters in an early background. Results of a 1982 rainy season trial are presented in Table 16. Currently, 63 early progenies are undergoing yield testing in three different trials at ICRISAT Center. Twenty new early flowering lines have been identified from germplasm and will be involved in the crossing program.

Seed dormancy has been difficult to introduce because of its almost complete absence from Spanish bunch types. A program has been initiated to identify methods of screening for dormancy and, if possible, identify dormancy from within populations derived from early, nondormant types crossed with dormant long season types.

UTILIZATION OF WILD *ARACHIS* SPECIES

There are an unknown number of wild species of *Arachis*. Those that have been collected are maintained in major living collections in Brazil, USA, and at ICRISAT. There are about 100 accessions at ICRISAT, some are named species, others are collections whose identity and taxonomic status is not yet known.

All these accessions are screened for desirable characters as soon as possible after release from quarantine. Emphasis has been placed on disease resistance, especially resistance to leafspots and other diseases where resistance has not been found within *A.hypogaea* .

Not all resistances can be transferred. The most accessible genes are those in species closely related to *A.hypogaea*. These species are in the section *Arachis*, and can be crossed with *A.hypogaea* by conventional means, but the hybrids produced are partially or completely sterile. Species outside the section *Arachis* cannot be crossed with *A.hypogaea* by conventional means. Some intersectional hybrids have been produced in the USA, and their potential in bridge crosses explored, but with no success. All sections other than *Arachis* are therefore effectively isolated from *A.hypogaea*, but some accessions have characters, such as resistance to viruses, which are of prime importance in groundnut improvement.

The emphasis in the cytogenetics unit has therefore been on three fronts. Firstly to overcome the problems of gene transfer associated with sterility in section *Arachis* hybrids; secondly to overcome intersectional barriers; and thirdly to develop the basic knowledge of the genomic constitution of the genus and the relationship between groundnut and potential sources of genes.

The sterility in crosses within the section *Arachis* has been successfully overcome by ploidy manipulations. The initial hybrids were triploids; chromosome doubling produced hexaploids, but subsequent backcrossing produced an unacceptable range of plant types, many of which were sterile.

Doubling the chromosome number of the wild species, to produce autotetraploids or amphiploids, and then crossing with *A.hypogaea* at the tetraploid level, produces a wide range of segregants with disease resistance and acceptable

plant types. These segregants have arisen by backcrossing selections with A.hypogaea to allow chromosome segregation and meiotic recombination to take place; the latter is especially important for elimination of undesirable characters. Cytogenetic analyses of chromosome complements of the newest collections indicate the presence of new genomes in the section Arachis. These genomes may not recombine meiotically with A.hypogaea chromosomes (those from other sections almost certainly will not)and the elimination of undesirable characters will be impossible. In the meantime we have made progress in using some wild species as sources of desirable characters, and have selected A.hypogaea-like lines with disease resistance, acceptable plant characters and good yield (see Section on Fungal Diseases). This progress will be limited without radiation facilities to induce recombination between distant genomes, and without a deeper knowledge of the genomic constitution and relationships between species obtained through DNA studies. A radiation facility is essential to provide new and quick avenues for alien genetic introgression, as well as being useful for inducing mutations, whereas the basic knowledge on genomes can be obtained at any suitably equipped laboratory willing to undertake the work. High priority should be given to obtain a radiation source.

Considerable progress has been made in overcoming barriers to intersectional hybridization. The major advance has been in the use of a simple technique to apply growth hormones to the flower at the time of pollination and at intervals therafter. Careful attention to concentration, types, timing and sequence of application of hormones has enabled the development of ovules, which would otherwise degenerate, to the stage at which they can be successfully transferred to in vitro culture.

When the Cytogenetics Laboratory started tissue culture in 1979, there were no reports of reliable, repeatable culture of Arachis. It was therefor necessary not only to develop the laboratory to obtain the necessary equipment, but also to develop techniques and media for culture of Arachis. Most parts of the groundnut plant can now be cultured and it is possible to stimulate callus, root and shoot formation.

This tissue culture technology has been applied to the culture of young ovules from wide crosses. These grow successfully in culture, and develop roots and shoots but are difficult to transfer to soil. Most cultures have been of crosses between sections Arachis and Rhizomatosae. Other intersectional crosses have been transferred to culture and current emphasis is to investigate the cause for the difficulty in transfering cultures to soil: is it genetical, with some inherent weakness in the root system in wide crosses, if so, does it occur in all wide crosses, or

is it purely a technical difficulty?

The future for wide crosses is bright. It is possible to develop embryos following intersectional hybridization, but the nature of those embryos, and the amount of foreign DNA incorporated cannot be known until there are sufficient plants to study, and the equipment and skills for DNA studies.

Table 1. Rust, early leaf spot, and late leaf spot reactions of some groundnut genotypes in field screening trials at ICRISAT Center, rainy season 1983.

Genotypes	Disease scores		
	Rust	Early leaf spot	Late leaf spot
NC Ac 17090	2.7	8.7	5.7
PI 259747	2.7	7.3	3.0
PI 390593	2.7	8.0	4.7
PI 393646	2.7	8.7	6.3
PI 405132	2.7	7.0	3.0
PI 414332	2.7	8.0	6.0
EC 76446(292)	3.0	7.7	3.0
PI 350680	3.0	7.0	3.3
PI 314817	3.0	8.7	6.3
PI 315608	3.0	7.3	6.7
PI 341879	3.0	8.7	3.3
PI 381622	3.0	8.0	3.3
PI 393517	3.0	7.7	6.7
PI 393527-B	3.0	8.7	6.7
PI 393643	3.0	7.3	6.7
PI 407454	3.0	8.7	6.7
PI 414331	3.0	8.7	7.3
NC Ac 17133-RF	3.3	7.7	3.3
NC Ac 927	3.3	8.7	3.3
USA 63	3.3	8.0	3.0
PI 390595	3.3	8.0	3.3
PI 270806	3.7	7.3	3.3
PI 393526	3.7	8.3	5.7
PI 393531	3.7	8.3	6.7
PI 393641	3.7	7.7	4.7
PI 215696	3.7	8.0	3.3
NC Ac 17132	4.0	8.0	3.3
NC Ac 17135	4.0	7.3	3.7
NC Ac 17127	4.3	9.0	4.3
PI 298115	4.3	8.3	7.7
Krap.St.16	3.7	8.3	3.7
NC Ac 17129	4.7	9.0	4.3
PI 393516	4.7	8.3	3.3
NC Ac 17506	4.7	8.3	3.7
NC Ac 17142	5.0	8.0	4.3
C.No.45-23	6.3	8.3	5.3
NC Ac 17502	7.3	7.3	5.3
NC Ac 15989	8.3	7.0	3.7
RMP 12	8.3	6.7	4.0
NC 3033	9.0	9.0	9.0
EC 76446 Sp.	9.0	8.7	9.7
TMV 2 b	9.0	9.0	9.0

Cont....

J 11 b	9.0	9.0	9.0
JL 24 b	9.0	8.7	9.0
Robut 33-1 b	9.0	8.6	8.3
SE	± 0.24	± 0.36	± 0.27
CV(%)	9.14	7.71	9.11

a Mean of field disease scores on a 9-point scale; 1 = no disease and 9 = 50 to 100% foliage destroyed.
b Foliar diseases-susceptible released high-yielding cultivars.

Table 2. Summary of the foliar disease resistant advanced lines yield trials at ICRISAT Center, rainy season 1983

Trial	No. of resistant selections tested	Number of lines significantly outyielding					
		NC Ac 17090		Robut 33-1		JL 24	
		HI	LI	HI	LI	HI	LI
F6&F7 Trial	21	0	7	9	3	16	20
F8 Trial	35	1	3	25	3	14	30
F9 Trial	60	4	0	52	13	56	57
F10 Trial	37	0	4	10	6	8	31
F10 Trial - Rainfed selections	15	0	0	0	2	4	14
F11 Trial	22	0	0	7	1	13	13
F11 Trial - Rainfed selections	19	2	2	3	6	3	17
Multilocation trial	46	0	13	14	1	10	39
FDRVT	17	-	-	3	3	9	6

a. Rust resistant parent
b. Susceptible check cultivars
c. HI = High input (60 P O /ha with irrigation and insecticidal sprays)
d. LI = Low input (20 P O /ha rainfed and no insecticidal sprays)

Table 3. Performance of some rust resistant advanced lines at ICRISAT Center, rainy season 1983

Trial	Identity	Yield (kg/ha)		Rust Reaction
		HI	LI	
F6/7	(RMP-91 x Dht-200)-F6-B(S1)	4060	1970	3.2
	(RMP-91 x Dht-200)-F6-B(S2)	3730	2180	3.0
	(Robut 33-1 x PI 298115) F5-B	3650	2060	3.5
	NC Ac 17090 (Resistant check)	3890	1570	3.2
	Robut 33-1 (Susceptible check)	2810	1716	6.7
	JL 24 (Susceptible check)	2190	780	5.7
	SE	+ 142	+ 119	+ 0.4
	Trial mean	3640	1610	3.9
	CV (%)	8	13	19.5
F10 Selections from rainfed fields)	(NC-Fla-14 x NC Ac 17090)F9-B	3150	1790	3.7
	(Tifspan x NC Ac 17090) F9-B	3060	1320	3.0
	(Gang-1 x PI 259747) F9-B	2430	1930	4.0
	NC Ac 17090 (Resistant check)	3240	1750	3.2
	Robut 33-1 (Susceptible check)	2670	1490	7.2
	JL 24 (Susceptible check)	2290	840	7.0
	SE	+ 197	+ 94	+ 0.3
	Trial mean	2520	1430	4.0
	CV (%)	13	11	14.3
F9	(Ah-65 x NC Ac 17090) F8-B	4160	2200	3.3
	(NC Ac 2190 x NC Ac 17090) F8-B	4150	2020	3.2
	(JH 60 x NC Ac 17090) F8-B	3340	2240	3.2
	NC Ac 17090 (Resistant check)	3290	2040	2.8
	Robut 33-1 (Susceptible check)	2410	1620	8.3
	JL 24 (Susceptible check)	2280	1010	7.7
	SE	+ 165	+ 148	+ 0.4
	Trial mean	3160	1790	3.6
	CV (%)	9	14	20.8
F10	(NC Ac 1107 x NC Ac 17090) F9-B	4070	2080	2.8
	(JH 60 x PI 259747) F9-B	3850	2530	2.8
	(Ah 65 x NC Ac 17090) F9-B	2740	2470	3.0
	NC Ac 17090 (Resistant check)	3670	1820	3.0
	Robut 33-1 (Susceptible check)	2560	1740	4.7
	JL 24 (Susceptible check)	2710	1080	4.7
	SE	± 182	± 144	± 0.3
	Trial mean	2890	1830	3.1
	CV (%)	11	14	16.5

a. HI = See table 4 fn c
b. LI = See table 4 fn d
c. Recorded from rainfed trials on a 9 - point disease scale, see Table 1 fn 2

Table 4 : Disease reaction (1-9 scale) and yield (kg/ha) of selected wild species derivatives, ICRISAT Centre, 1982 Rainy season (8x8 triple lattice, plot size 16 m)

Entry	Rust Resistance	Leafspot Resistance	Pod Yield	Kernel Yield (Est.)	Oil Content (%)	Oil Yield (Est.)	Haulm Yield
CS 13	2.3	2.3	3150	1960	42	820	4570
CS 30	2.7	2.3	2640	1700	44	760	6540
CS 46	6.7	2.3	2540	1740	44	770	4490
CS 11	2.7	2.0	2520	1750	44	770	5620
CS 38	3.0	9.0	2440	1670	44	730	3810
CS 39	9.0	2.3	2130	1370	45	610	3270
Checks :							
Robut 33-1	9.0	6.3	1830	1320	41	510	1560
TMV 2	9.0	9.0	1240	850	41	350	1630
SE	0.42	0.6	134	87	0.67	39	350
Site Mean	4.2	5.5	1950	1280	43	550	4050
CV %	17	17	12	12	3	12	15

1. Results from trial at Bhavanisagar
2. Mean of 64 entries (ICRISAT Centre) 36 entries (Bhavanisagar)

Table 5. Rust, early leaf spot, and late leaf spot reactions of some breeding lines in field screening trials at ICRISAT Center, rainy season 1983.

Selections Pedigree	Disease scores		
	Rust	Early leaf spot	Late leaf spot
(Argentine x PI 259747)F2-P61-P2	3	3	8
(Argentine x PI 259747)F2-P152	2	7	3
(NC Ac 2750 x PI 259747)F2-P92	3	8	3
(x 14-x-x-1 x PI 259747)F2-B1-B1 B2-B1-B1	2	8	3
(JH 335 x EC 76446 (292)F2-B1-B2- B2-B1-B1	2	9	3
(TG 3 x EC 76446 (292)F2-B2-B1-B2- B3-B1-B1	2	2	2
(OG69-6-1 x NC AC 17090)F2-B1-B2- B2-B1-B1	2	2	5
(Variety 99-5 x PI 259747)F2-P108- P1-B1-B2-B1-B1-B1	2	8	3
(OG 71-3 x NC Ac 17090)F2-B2-B1-B1- B1	2	7	3
(NC Ac 1107 x NC AC 17090)F2-B1-B1- B1-B1-B1-B1	2	7	3
TMV 2 b	9	9	9
Robut 33-1 b	9	9	9

a Scored on a 9-point disease scale; (see Table 1 fn a)
b Foliar diseases-susceptible released high-yielding cultivars.

Table 6. Pod yields and percentage seed colonisation by *A. flavus* of selected breeding lines, postrainy season 1982/83

Pedigree	Pod yield (kg/ha)	% seed colonisation
(MH 2 x PI 337409)F3-B1-P21-B1-B1-(SB)-B1	5064	19.03
(MH 2 x PI 337394F)F3-B1-P53-B1-B1-(Var.)	5000	14.68
(PI 337409 x UF 71513-1)F2-B2-B1	5162	17.97
(UF 71513-1 x PI 337394F)F2-B2-B1	4796	19.74
(UF 71513-1 x PI 337409)F3-B3-B1	4432	17.45
Robut 33-1	4282	74.64
UF 71513-1	5069	19.86
J 11	4824	47.28
JL 24	4217	57.75
SE	291.7 ± 2.83	
Trial mean	4850	45.21
CV (%)	12.0	12.5

Table 7. Effects of seed maturity on seed infection by A.flavus; ICRISAT Center, Rainy seasons 1981 and 1982

Genotypes	Percentage of seeds infected by A.flavus					
	Immature crop		Mature crop		Over-mature crop	
	1981	1982	1981	1982	1981	1982
PI 337394F	0.3	0.3	0.7	0.3	2.0	2.3
PI 337409	0.0	-	1.0	-	2.3	-
UF 71513	0.0	0.0	0.7	0.7	1.3	3.0
J 11	0.0	0.3	0.3	0.7	1.6	3.3
Ah 7223	0.0	0.0	0.3	0.3	1.6	4.3
U 4-47-7	0.7	-	1.0	-	3.3	-
Var. 27	-	0.7	-	1.3	-	6.0
C 55-437	-	0.0	-	1.0	-	6.0
Faizpur	-	0.3	-	1.0	-	4.3
TMV 2	1.3	1.0	2.0	2.3	5.0	8.0
EC 76442(292)	1.3	2.3	2.0	4.3	6.0	11.7
Gangapuri	1.3	2.3	2.0	3.6	5.0	8.7
OG 43-4-1	2.0	-	2.0	-	4.0	-

	1981	1982
SE for comparison of crop maturity	+ 0.40	+ 0.75
SE for comparison of genotypes	+ 0.42	+ 0.82

a. Resistant or moderately resistant to seed colonization by A. flavus.
b. Susceptible check
c. Highly susceptible check

Table 8. Effect of infection with peanut mottle virus (PMV) on yield of selected genotypes at ICRISAT Center, rainy season 1983

Genotypes	Yield of pods (kg/ha)		Estimated yield loss (%)
	Not inoculated	Inoculated with PMV	
FSB-7-2 x EC 76446(292) F2B1B1B1B1B1	1930	1580	18
ICGS 35	2490	2030	14
NC Ac 2240	1090	1070	1
FDRS 4	2380	1850	22
Gangapuri a	1520	1020	32
SE	± 83.6		
CV(%)	17		

a. PMV-Susceptible released cultivar

Table 9 : Major field pests of groundnut in India

1/ 1968	1984	
Aphid Leafminer	Leafminer Thrips (vectors)	White grub Thrips (pests)
Hairy caterpillar	Aphid	Tobacco caterpillar
Termites	Jassid	Hairy caterpillar
	Termite	

1/ Rai, 1976

Table 10 : Integrated pest (vector) control practices reduce Bud necrosis Disease (BND) and increase yields

Management practice	Incidence of BND in crop at		Yield of pod kg/ha
	50 days	100 days	
1. Normal farmer's practice	71%	95%	64
2. Improved practice	3%	26%	1590

Table 11 : Some high yielding pest resistant breeding lines

High yielding pest resistant breeding lines	Yield of pods	
	High inpur	Low input
1. Manfredi 68 x NC Ac 343 (F7)	2604	1236
2. [(Gangapuri x MR 374) x (Robut 33-1 x NC Ac 2214)]-(F7)	2583	1212
3. Robut 33-1 x NC Ac 343 (F9)	2536	1500
4. 28-206 x NC Ac 10247 (F7)	2286	1361
5. Robut 33-1 x NC Ac 2214 (F7)	2286	1360
6. Robut 33-1 (Check)	2106	1149
7. NC Ac 343 (Check)	2020	1201
8. JL 24 (Check)	1552	531
9. J 11 (Check)	1627	430
SE ±	10.6	10.9
Mean (44 breeding lines)	1836	882
CV %	11.0	23.0

Table 12 : Summary of response of cv Robut 33-1 inoculated with Rhizobium strain NC 92

Season	POD YIELD (kg/ha)		
	Uninoculated	Inoculated	SE
Postrainy (1978/79)	3500	4500	± 291.2
Rainy (1979)[a]	970	1160	± 24.3
Postrainy (1979/80)[a]	4280	4400	± 104.7
Rainy (1980)[a]	1350	1640	± 77.4
Postrainy (1980/81)[a]	3210	3300	± 78.8
Rainy season (Site.1)(1981)	2350	2760	± 187.8
Rainy season (Site.2)(1981)	1100	1150	± 34.5
Rainy season (1981)	1530	2150	± 176.5
Mean	2274	2634	± 6.3

a Trial conducted at ICRISAT Center
b Trial conducted at Dharwar

Table 13 : Relative performance of high yielding groundnut selections in different trials at ICRISAT Center

Season	Environment	Number of lines better than standard check cultivars		
		Robut 33-1	J 11	JL 24
1980 R	HI[a]	8	225	11
	LI	19	230	-
1980-81 PR	HI	40	75	52
1981 R	HI	59	37	56
	LI	28	11	-
1981-82 PR	HI	116	22	150
1982 R	HI	20	90	12
	LI	17	55	30
1982-83 PR	HI	60	65	131

a. HI = High input (60 P2O5/ha with supplemental irrigatin and insecticide spray when required)

LI = Low input (20 P2O5/ha rainfed without insecticide spray)
R = Rainy season
PR = Postrainy season

Table 14 : Pod yields of some high yielding ICRISAT selections during postrainy season trials at ICRISAT Center

Entry	1981/82	1982/83
ICGS 30	6600	7340
ICGS 21	6500	7040
ICGS 26	6430	6280
ICGS 16	6420	6050
ICGS 25	6300	6950
ICGS 23	6240	6390
ICGS 37	6150	7130
ICGS 35	6060	5770
ICGS 44	6060	6860
J 11 (Check)	5440	5440
JL 24 (Check)	4760	3860
Robut 33-1 (Check)	5450	5180
SE	± 289	± 297
CV (%)	10	10

Table 15 : Pod yield of ten selected ICGS lines at ICRISAT Center, rainy season 1983

High input			Low input		
	Pod yield (kg/ha)	Shelling (%)		Pod yield (kg/ha)	Shelling (%)
ICGS 50	3800	71	ICGS 35	1685	60
" 30	3580	68	" 11	1623	76
" 1	3579	70	" 6	1617	68
" 33	3503	64	" 1	1567	76
" 12	3426	64	" 45	1555	68
" 27	3407	72	" 34	1543	64
" 58	3404	63	" 17	1543	56
" 11	3373	72	" 20	1530	90
" 32	3333	67	" 61	1524	64
" 61	3327	74	" 30	1512	68
JL 24*	3067	74	JL 24*	586	56
Robut 33-1*	2810	70	Robut 33-1*	1321	76
SE	± 180	-	SE	± 89	-
Trial mean	2925			1223	
CV (%)	10	-	CV (%)	12	-

* check cultivar

Table 16 : Performance of five best early-maturing groundnut selections, ICRISAT Center, 1982 rainy season

Entry	1982 rainy season		
	Days to flowering	Days to maturity	Pod yield (Kg/ha)
(Ah 330 x 91176) F5-B1	18	93	2440
(NC Ac 2748 x Chico)F10B1	22	101	2120
(72-R x Chico) F9B	23	104	2130
(JH 89 x Chico) F9B	23	92	2000
(Chico x NC 344) F5	19	91	1980
Chico	20	91	1780
J 11	27	104	1920
JL 24	27	108	2190
SE	±0.6	±1.4	±116
CV(%)	5	3	13

a Early maturity parent. b. National check cultivar.
c Local check cultivar.