International Institute of Tropical Agriculture

# CROP IMPROVEMENT DIVISION

## Grain Legume Improvement Program

## Part I. Cowpea Breeding

## Archival Report (1988–1992)

# CROP IMPROVEMENT DIVISION

## Grain Legume Improvement Program

# Archival Report (1988–1992)

International Institute of Tropical Agriculture

October 1993

# Acknowledgement

B. B. Singh is the author of the Cowpea Breeding section of the Archival Report (1988–1992) of the Grain Legume Improvement Program.

## Contents

# 1. INTRODUCTION

Since its inception in 1967 until 1985, the International Institute of Tropical Agriculture (IITA) made considerable progress in improving cowpea varieties. It developed and distributed a range of improved breeding lines combining multiple disease and insect resistance with early maturity and preferred seed types to over 60 countries. About 45 countries have systematically evaluated the improved materials received from IITA, identified superior lines and released them for general cultivation. However, all of these lines require 2-3 sprays of insecticides to protect against flower thrips, pod borer (*Maruca*) and pod sucking bugs (PSB). This is due to lack of availability of germplasm lines with high levels of resistance to these pests. Most of the traditional farmers do not use chemical protection due to socio-economic and infrastructural constraints even though the new varieties, when sprayed, can yield between 1 to 2 MT/ha and give high economic returns. They continue growing cowpeas as an intercrop with millet and sorghum in the traditional manner without insecticide. Therefore, during the strategic planning review of IITA's research program in 1986, it was suggested that the cowpea breeding objectives should be diversified. The revised aims included systematic improvement of traditionally cultivated local varieties as well as development of a range of new improved cowpea varieties which would produce higher grain as well as fodder yields in the traditional intercropping systems which are so widely prevalent in the Central and West African Savanna and also in parts of East and Southern Africa. This revision led to: (1) The re-orientation of cowpea breeding objectives onwards from 1989 and (2) The establishment of IITA Kano Station in 1989. The major focus of the program has been to study traditional cropping systems, identify cowpea production constraints and, in collaboration with national programs, develop improved cowpea varieties combining disease and insect resistance with better adaptation and high yield potential under intercropping systems of savanna ecologies where soils are poor and moisture is limited. This report describes the different aspects of research undertaken during the last five years.

## 2. STUDY OF CROPPING SYSTEMS

The cropping systems are diverse and not only differ from region to region but also from farmer to farmer within the same region. It is essential, therefore, to understand the systems and identify major constraints that limit cowpea yields in these systems so that a breeding strategy could be developed for improving cowpea varieties specifically suitable for traditional intercropping. A general survey of cropping systems in the West and Central African Savanna was done in 1988, 1989 and 1990 covering Nigeria, Benin Republic, Niger Republic, Togo, Cameroon and Burkina Faso where cowpea is widely grown. A list of major cropping systems in different ecological zones cutting across these countries is presented in **Table 1.** In the forest and southern Guinea Savanna zone, cowpea is intercropped primarily with maize, cassava and yam and the major constraints are several diseases, and insect pests as well as poor seed quality. Cowpea is intercropped with groundnut, and/or sorghum in the Northern Guinea Savanna and major constraints are several diseases, insect pests and *Alectra*. In Sudan Savanna, cowpea is intercropped with millet and sorghum with or without groundnut. The key constraints are bacterial blight, *Striga*, *Alectra* and insects such as aphid, bruchid, thrips, *Maruca* and PSB. Millet-cowpea intercropping is the only system prevalent in the Sahelian region and the main yield reducing factors of cowpea are ashy-stem blight, bacterial blight, aphid, thrips, bruchid, PSB and *Striga* as well as moisture stress and poor fertility.

The broad observations of 1988-90 needed quantitative assessment of the most important cropping systems. In 1991 this major study was initiated by the technical staff of the cowpea breeding group. The study covered 14 farmers' fields in Minjibir and Gezawa local Government Areas of Kano State (Nigeria) which is the heart of cowpea growing region in West and Central Africa. A 20 m x 20 m block was studied in each field and detailed notes were taken on field history, land preparations, crops and varieties planted, dates of planting, planting patterns, diseases, insects, maturity, harvesting and yields of grain and fodder. This gave a quantitative description of different systems and their constraints which will help to sharpen research focus. Preliminary results show that farmers intercrop two types of cowpea varieties in alternate rows with millet and/or sorghum in the same field - one for grain and the other for fodder. Both varieties are photosensitive, spreading types but the grain type is earlier in maturity and planted earlier than the fodder type. Millet is planted first at the onset of rains (May-June) in wide rows (1.5-3m apart) with 1m hill to hill distance within the rows reaching about 4000 to 6000 hills per hectare. Early cowpea varieties are planted between millet rows at a hill to hill distance of 1m when the rains are more stable towards June end. Fodder type cowpea is planted later in mid-July between the remaining alternate millet rows. Sorghum and groundnut can either replace or supplement millet and early cowpea rows giving a more complex mixture. However, the most predominant practice in the study area was millet- early cowpea for grain - millet - late cowpea for fodder as shown in **Fig. 1**. The yield estimate of different crops for each farmer's plot are presented in **Table 2**. The yield of early cowpea ranged from 23-173 kg/ha except for the plot which recorded 405 kg/ha due to insecticide application but the late cowpea did not yield any grain. The millet yield ranged from 693-1858 kg/ha, sorghum yield ranged from 105-2150 kg/ha and groundnut from 38-270 kg/ha. However, as mentioned earlier not all crops were present in each field. Thus, the average grain yield of cowpea was 110 kg/ha with about 1200 kg/ha of millet or 937 kg/ha of sorghum and with a great variability in the fodder yield. The total biomass ranged from 2.35 t/ha to 1452 t/ha (thickly planted late sorghum). Principal constraints for cowpea production were insects primarly *Maruca*, low population and comptetition with cereals. Even though the findings of a study of this type may differ from year to year due to variation in weather, pests and other factors, the preliminary data indicate that the average cowpea grain yield under traditional intercropping systems is about 100 kg/ha in the Kano area. This provides a crude base line for establishing target yields of improved cowpea varieties under intercropping.

Building on the 1991 results, and with a multidisçiplinary team covering agronomy, entomology and pathology a very detailed study of 36 farmers' field was conducted in 1992. The results were similar to 1991 except that cowpea yields were very low due to heavy *Maruca* damage ranging from 0-40 kg/ha.

## 3. BREEDING AIMS AND STRATEGY

### 3.1 Aims

Based on the survey of cropping systems, it was apparent that cowpea breeding should include the following aims:

(1) Develop grain, fodder and dual purpose varieties
(2) Develop varieties for intercrop as well as pure crop
(3) Combine resistance to aphid, bruchid, thrips, *Maruca*, PSB, *Striga*, *Alectra*, bacterial blight, nematodes, false smut, *Septoria*, scab and brown blotch in a range of varieties and plant types to fit in different croppings systems of savanna ecologies
(4) Combine drought, heat and shade tolerance in improved varieties for Northern Guinea and Sudan Savannas and the Sahelian Region
(5) Develop cowpea varieties with inherent capacity to make normal growth under low concentrations of nutrients in the poor soils of the Sahelian Region

### 3.2 Strategy

In view of the long list of aims listed above the following strategy was developed to make maximum progress within a short time.
(1) Collect and evaluate local varieties to select the best recurrent parents for the hybridization and backcrossing programs
(2) Use the best multiple disease and insect resistant breeding lines already available from the on-going breeding program as donor parents
(3) Screen additional germplasm lines to identify sources of resistance and other desirable traits not available in the two sets of parents mentioned above
(4) Conduct basic genetic studies to elucidate nature of inheritance of desirable traits
(5) Use a combination of backcross and pedigree methods to combine desirable traits in traditional varieties
(6) screen new breeding lines in pure crop with 2-3 sprays, pure crop with no sprays and intercrop with no spray to select improved lines with high yield potential

(7) Evaluate promising breeding lines in different cropping systems and different locations to study genotype x cropping system x location interaction
(8) Develop suitable breeding methods for improving varieties for intercropping
(9) Use farmers participatory evaluation for selection of promising breeding lines for low input technology
(10) Involve lead national program scientists for testing improved breeding lines in different ecologies
(11) Distribute elite breeding lines to national programs in the form of Cowpea International Trials

### 3.3 Evaluation of genetic diversity amongst local varieties

In order to select suitable parents for hybridization, a systematic program was initiated in 1987-88 to visit farmers fields in northern Nigeria covering from Sokoto to Maiduguri via Katsina and Kano and select the best varieties/plants from farmers fields. Invariably all the fields had mixtures in respect of plant types, seed type and maturity. Therefore, individual plants were harvested. In some cases, a bulk sample was brought to the laboratory and different type of seeds were separated as sub-set of the original samples. These were planted in single progeny rows and evaluated for different characters. In 1987-88 over 50 individual plant progenies were evaluated and out of these 5 progenies were resistant to bruchid and were therefore used in the crossing program. Individual plants/progenies from farmers fields during 1989 to 1992 number over 500 and these are currently at different stages of testing.

### 3.4 Hybridization and handling of segregating populations

Crosses are made among selected parents in the screenhouse at IITA Kano station and F1's are also raised in the screenhouse. The F2 and F3 populations are planted in the field at Kano and selected for plant type, maturity seed type and for resistance to *Striga/Alectra* and bacterial blight. The selected F4 progenies are then tested at Ibadan both in the field (dry season with irrigation) and in the laboratory for resistance to aphids, bruchid, viruses, *Cercospora* and photosensitivity. The F5 progenies are again screened at Kano and the promising lines are bulked for multilocation testing at Mallam Madori, Maiduguri, Niamey and Maradi for drought, heat, *Striga* and *Alectra* and bacterial blight; at Kano for intercropping and pure cropping as well as *Striga* and bacterial blight; at Samaru for *Septoria* and scab as well as for adaptation to the Northern Guinea Savanna. These locations are indicated in **Fig. 2**. The bulking of the lines is not always done at F5, but at F6 or F7 stage depending upon the uniformity of the progenies for various characters. By using a combination of screenhouse and irrigation facilities, at least three generations are advanced each year which permits a multiple cycle of crosses among selected segregates enabling pyramiding of desirable genes in improved breeding lines.

# 4. VARIETAL TESTING

## 4.1 Varietal testing On-Station

### 4.1.1 Procedures

The F5/F6/F7 bulk progenies are grouped according to maturity, seed type etc and first tested in an Intial Evaluation Trial (IET). Promising lines are then tested in succession through Preliminary Variety Trial (PVT), Advanced Trial (AVT) and Cowpea International Trial (CIT). The details about these trials are given in **Table 3**. The trials are planted in 4 row-plots which are 4m long and 75cm apart and 20cm hill to hill expect for photosensitive, late maturing varieties which are evaluated in 4 row-plots which are 9m long and 1m apart with 40cm hill to hill distance. IET's are evaluated in an augumented design with one replication along with frequent checks. The number and types of variety trials conducted from 1988 to 1992 are listed in **Table 4**. IET's normally include a large number of lines ranging from 30 to over 100 but PVT and AVT invariably have 20 entries including the check (s). For pure crop spray, a maximum of three insecticide applications is made but normally two are sufficient.

### 4.1.2 Varietal evaluation in pure crop

The grain yield figures of best two to four varieties included in advanced trials from 1988 to 1992 are presented in **Tables 5-9**. Each advanced trial included similar groups of varieties with respect to maturity and seed color. The grain yields show a great range and differ from variety to variety and year to year (**Table 10**). However, on average, the improved early and medium maturing varieties have a grain yield potential of upto 2MT/ha with 2-3 sprays. Most of these varieties combine multiple disease resistance and some also have resistance to thrips, aphid and bruchid either separately or combined. Thus, a good range of choice of varieties for pure crop cowpea cultivation is available from the work done during the last five years. However, efforts are being made to stabilize their yield potential by combining in them resistance to *Striga*, *Alectra* and bacterial blight.

The yield potential of photosensitive early and late varieties (**refer Tables 7, 8 and 9**) is lower than that of photo-insensitive early and medium maturing varieties, even when the crop is protected by insecticides. This is mainly because photosensitive varieties are the spreading type and have greater interplant competition. Therefore, these should not be grown as pure crop.

4.1.3 Varietal evaluation as an intercrop

Most of the preliminary and advanced trials were planted at Kano in three systems:

(1) Pure crop with 2-3 sprays
(2) Pure crop without sprays
(3) Intercrop with millet and without sprays

For intercropping, millet is first planted in 2m wide rows with 1m hill to hill distance within the rows. About 2-3 weeks later cowpea varieties were planted in between two rows of millet in single row plots with 2 replications. The individual rows were 9m long. The hill to hill distance was kept at 20m for early and medium maturing cowpea varieties and was 40cm for photosensitive late maturing varieties . No insecticide was applied but the fields were kept clean of weeds. Cowpea and millet yields were recorded. The initial screening of cowpea varieties started in 1988 and the promising lines were further screened in the following years. The yield of cowpea ranged from 0-500 kg/ha and most of the varieties yielded less than 100 kg/ha. The coefficient of variability was often very high because of the uneven incidence of disease, pests, shading and lodging of millet in the experimental area. However, some of the varieties consistently yielded better than others. A summary of results obtained in 1991 is presented in **Table 11**. Each trial listed in this table consisted of 20 cowpea varieties. The results show the variability in the performance of cowpea genotypes under intercropping. The lowest cowpea grain yield was 5kg/ha and the highest was 448 kg/ha. Fodder yields varied from 62 kg/ha to 3062 kg/ha with considerable variability from trial to trial. The mean millet yield ranged from 386-885 kg/ha. The three highest yielding varieties for each trial are listed in **Table 12.** These data indicate that with 1:1 ratio for intercropping of cowpea and millet using the best cowpea varieties, grain yields of 150-200 kg/ha of cowpea (together with about 600 kg/ha of millet grain) can be obtained. This is 50-100% better than the average yield estimated at the farmers' fields during 1991 survey of cropping systems. The best varieties for intercropping were IT89KD-381, IT89KD-451, IT88Dm-400, IT89KD-1075, IT89KD-355, IT89KD-391 and IT88DM-363. These along with others were tested at various locations in 1992. A summary of data is presented in **Table 13**.

## 4.2 Variety Testing On-Farm

### 4.2.1 Farmers participatory evaluation

Screening varieties for intercropping at an experiment station has major limitations because sites are not representative of the diverse cropping systems and ranges of soil types and fertility levels at which farmers practice intercropping. To reproduce all these conditions at an experimental station is not feasible. Therefore, nine elite grain type varieties were given to a total of 36 farmers (one variety to 4 farmers) in 1992 for evaluation by them following their own systems. This enlarged the test environment and was undertaken in collaboration with Kano Agricultural and Rural Development Authority (KNARDA). The crop was planted by farmers in their traditional system and totally managed by them. However, the yield estimates were done by technical staff using a 10m x 10m sample plot on each farm. The results are summarised in **Table 14.** Inspite of the great variability from field to field, these data suggest definite genetic variability among varieties and indicate that farmers participation in variety evaluation should be pursued. However, more replications would further increase confidence in varietal differences. IT89KD-374-57, IT89KD-319 and IT88DM-867-11 appeared consistently better than other test varieties and Dan Ila, the local variety. Farmers were very happy with these varieties and wanted to participate in the trial next year.

## 4.3 Breeding Cowpea Varieties for Intercropping

### 4.3.1 Background

The study of traditional cropping systems in the West and Central African savanna indicates that farmers grow two types of cowpea varieties - an early maturing type for grain purpose and a late maturing type for fodder, often in the same field planted in alternate rows as intercrops in millet and/or sorghum. Both types of varieties are photosensitive but different in maturity. The apparent limitations in currently grown local varieties are their susceptibility to many insects and diseases and very late maturity of fodder type varieties. This gives rise to premature drying if the rains stop early in September. The early maturing grain type varieties like Dan Ila, Dan Wuri and Jan Wake are normally planted by June end and mature by the first week of September, whereas late fodder type varieites such as Kananado and IAR 1696 are planted in mid to late July and they flower in October. In case there are late rains, these varieties will produce some grains otherwise they will be harvested green and rolled into bales for fodder as soon as they show signs of wilting. Interestingly, most of the early grain type varieties are susceptible to leaf diseases and they disintegrate in the field and are seldom harvested for fodder. The average yield of grain type varieties ranges from 0-150 kg/ha depending upon insect pressure, cropping system and variety. Results of varietial screening in intercropping suggest that indeterminate and spreading type growth habit is essential for good performance since this minimizes insect damage and also permits cowpea plants to avoid competition for light. Therefore, even though a range of varieties are being tested under intercropping, the breeding efforts are being concentrated on improving photosensitive spreading type varieties for intercropping.

4.3.2 Variety development

Two approaches are being followed for variety development:

(1) Defect elimination. The improvenent of selected local varieties by incorporating resistance to aphid, thrips, bruchid, *Striga*, *Alectra*, and relevant diseases by backcrossing

(2) New varieties. Development of completely new photosensitive spreading type varieties by standard methods using relevant parents

4.3.3 Outputs

Dan Ila (Kano), Jan Wake (TN 5-78, Maradi) and Kananado selection (Kano) were crossed with IT84S-2246-4 and backcrossed to local parents. IT84S-2246-4 is the most promising multiple disease and insect resistant variety developed by IITA which has been formally released in Nigeria. It combines resistance to aphid, bruchid, thrips and several diseases. Therefore, this variety is being used as a donor parent for many desirable genes. From the above backcross populations, promising lines have been developed which look like local varieties but combine aphid, thrips, and some have bruchid resistance also. The most promising among these are:

IT88D-867-11 This is derived from the cross IT84S-2246-4 x Jan Wake$^2$. It looks very similar to Janwake but combines aphid and thrips resistance, Its performance has been very good in the drier regions like Niamey, Maradi and Gumel where Jan Wake (TN5-78) comes from. It has brown rough seed, is early maturing photosensitive and suitable for grain.

IT89KD-374-57 This is derived from the cross Dan Ila$^2$ x IT84S-2246-4. It is similar to Dan-Ila but combines resistance to aphid and thrips as well as several diseases. Its performance has been very good at several locations in the northern savanna. It has white seeds, is early maturing photo-sensitive and suitable for grain.

IT89KD-319 This is derived from the cross Kaokin local$^2$ x IT84S-2246-4. This looks very similar to Kaokin Local but combines resistance to aphid and thrips and several diseases. It has done very well in the northern savanna. It has white seeds, medium maturity, is non-photosensitive and suitable for grain.

IT89KD-245 It is derived from the cross IT87F-1772-2$^2$ (Kananado selection) x IT84S-2246-4. It is very similar to Kananado but combines resistance to aphid, bruchid, thrips and also is about two weeks earlier than Kananado. It has done well as a dual purpose variety.

IT89KD-288 It is also derived from the cross IT87F-1772$^2$ (Kananado selection) x IT84S-2246-4 but is as late as Kananado. It combines resistance to aphid, bruchid and thrips and does better than Kanannado both for fodder and grain.

Efforts are under way to incorporate resistance to bruchid, *Striga* and *Alectra* in these varieties. Results for dual purpose variety evaluations in 1990 are shown **Table 15.**

4.3.4 Target yield

When the cowpea breeding program for intercropping was initiated in 1988/89, there were apprehensions as to whether any progress in yield could be made over what farmers already obtain. The quantitative surveys of traditional cropping systems conducted in 1991 and 1992 found an average cowpea grain yield of 50-100 kg/ha. At the same time the best available improved varieties have yielded about 250 kg/ha at the experiment station and 100-150 kg/ha on farmers' field which indicates a definite possibility for genetic improvement of yield potential. But what should be the target yield for the breeding program? An experiment was conducted in 1992 to partly answer this question. The most promising varieties were grown in pure crop, strip crop and intercrop with millet in large plots and all possible care was taken to control weeds and insects so that the true genetic potential for yield would be expressed. Three insecticide sprays were sufficient to control insects. The strip crop had 4 rows of cowpea flanked by one millet row on both sides (80:20) and the intercrop had cowpea and millet in alternate rows (50:50). The yield data for selected varieties are presented in **Table 16**. IT90k-284-2, IT87D-941-1 and IT90K-59 are early maturing and have erect growth habit suitable for pure crop. IT86D-719 and IT86D-715 are medium maturing with semi-determinate growth suitable for pure crop; and IT89KD-349, and Dan Ila are early maturing, photosensitive with spreading growth habit suitable for intercropping. IT89KD-355 is medium maturing non-photosensitive with spreading growth habit suitable for intercropping in northern savannas. The early erect type cowpea varieties gave the highest yield and had less adverse effect on millet irrespective of the cropping systems followed by medium maturing varieties. The traditional type photosensitive varieties gave poor yields in all systems indicating their inherent low yield potential. However, as discussed earlier, under no insecticide protection, most of the erect type varieties yield less than spreading types under intercrop as well as pure crop. The data for the intercrop treatment in **Table 16** indicate that if insects can be controlled, grain yields level of 400-600 kg/ha are possible for cowpea with about 1500 kg/ha of millet grain. This is very close to theoretical expectations. Therefore, the target grain yield for intercrop breeding is about 400 kg/ha of cowpea with at least 1500 kg/ha of millet grain.

4.3.5 Evaluation of the intercropping breeding method

In order to develop improved cowpea varieties for intercropping should the segregating population be grown under intercrop and selection made there or can they be grown and selected in pure crop up to F5-F6 generation before testing under intercropping? An experiment was initiated in 1990 to answer this question. Two specific crosses were made in 1990 which combined a number of desirable characteristics. Sufficient F2 seeds were obtained and divided into two - half of the F2 seeds were planted out in 1991 under intercrop with millet and other half planted as pure crop, adjacent to each other. At maturity, the best individual plants were selected and harvested separately. F3 progenes were again planted in 1992 under intercrop and pure crop respectively. The individual plants were selected and F4 progenies have been again planted in 1993 following the same method as 1992. This will continue until the lines become homogenous and homozygous (F5 or F6) and then these will be tested in both intercrop and pure crop to ascertain which method is more effective.

## 5. BREEDING FOR INSECT AND DISEASE RESISTANCE

### 5.1 Strategy for insect resistance breeding

Five insects viz: aphid, thrips, *Maruca*, PSB and bruchids are the major pests of cowpea and cause up to 100% yield loss and seed damage when infestation is severe. High levels of genetic resistance to aphid and bruchid and moderate level of resistance to thrips were identified and incorporated into promising lines. However, inspite of large germplasm screening, good sources of resistance to *Maruca* and PSB have not been identified yet. This necessitates 2-3 sprays during the flowering and pod development stages which becomes a bottleneck for the small scale farmer. Therefore, three mutually compatible approaches are followed to develop cowpea varieties which can give reasonable grain yields (500-1000 kg/ha) without spraying:

(1) High Level of Resistance. To incorporate available resistances to aphid, thrips, and bruchid in all new breeding lines. This is a very important aspect of the on-going breeding program. Promising breeding lines with resistance to these pests are listed in **Table 17** and these are being used as parents in further crosses.

(2) Low Level of Resistanc. To screen breeding lines as well as germplasm lines for field resistance/tolerance to *Maruca* and PSB and initiate a recurrent selection program to build up the low level of resistance in improved lines. Genetic male sterile lines will be used for this population improvement program.

(3) Insect Escape. To breed for very early maturing varieties with good growth and acceptable seed type which can escape insect damage.

### 5.2 Progress in insect resistance breeding

As mentioned in Section 2.4.1, all the advanced trials and preliminary trials (if seed is available) are evaluated in pure crop without insecticide application so that lines with even low levels of resistance/tolerance to *Maruca* and PSB can be identified. This work started in 1989 and, over the years, a number of breeding lines have been selected which suffer less damage than others. This may be due to a low level of resistance or less preference by the insects. A few promising lines are listed in **Table 18**. The *Maruca* pressure in 1990 was very high and prolonged which caused low yields but in 1989 and

1991 *Maruca* pressure was much less and only for 3-4 weeks which permitted selection for a low level of resistance. Most of the varieties listed in **Table 18** have moderate levels of thrips resistance Thus, they all produce peduncles and flowers. If *Maruca* damages the flowers, these peduncles produce another flush of flowers, by which time *Maruca* pressure has lessened and reasonable yields are achieved. Also, if the angle between pods is more, *Maruca* attack is less. The best examples of varieties which have some tolerance of *Maruca* are IT86D-721, IT86D-715 and IT89KD-457. These varieties involve Kambosine Local and TVu946-2E as parents which were earlier identified as resistant to *Maruca*. In case a variety is susceptible to thrips, it does not produce peduncles and flowers and so remains vegetative with zero yield. It is imperative, therefore, to incorporate aphid and thrips resistance before screening for *Maruca* resistance under no spray conditions. This work is a major part of the breeding program. The above named varieties, as well as those identified to be moderately resistant from germplasm lines by the PHMD Entomologist, are used as parents.

In parts of Nigeria, Benin Republic, Togo, and Burkina Faso extra early maturing, small seeded cowpea varieties with semi-wild characteristics are grown at the onset of rains and harvested within 50-60 days before insect pressure becomes heavy. These varieties have small smooth seeds with various colour such as black, red, brown, mottled and the 100 seed weight ranges from 4-10g. These have very little market appeal and are mostly used for home consumption. In Nigeria, these varieties are called "Achishiru" (meaning "eat and keep quiet") and are extensively grown between Jos and Kaduna with Kafanchan as the centre. These "Achishiru" cowpea are planted in April-May with the onset of rains and harvested in July. Being small seeded and early maturing, pods develop very quickly and become fibrous which makes them less attractive to *Maruca* larvae. Thus, they escape insect damage. In addition, *Maruca* pressure is less during that time.

A large number of field samples of 'Achishiru' cowpea were collected from 1988 to 1991 and tested for field resistance at Kano. When planted at the normal time, most of these were as susceptible as other varieties and had to be sprayed to produce seeds. However, the lines IT88DM-345 and IT89KD-445 were earliest of all and have consistently escaped insects at Kano (**Table 18**). IT91K-180 was evaluated in 1992. This may even have some level of resistance to thrips, *Maruca* and PSB. Seeds have been given to the PHMD Entomologist for testing. In the meantime, these three lines have been crossed with several large seeded improved breeding lines and segregating populations are being screened to select very early maturing large seeded lines without insecticide protection.

It is expected that with a combination of the above three approaches, it would be possible to create cowpea genotypes which will produce reasonable grain yield both in pure crop and intercrop without any insecticide protection.

## 5.3 Bacterial and fungal diseases

There are several inportant diseases in the savanna but their incidence and severity vary with latitude which is related to rainfall pattern. Thus, *Septoria*, scab, brown blotch ,bacterial blight and *Cercospora* are more important in the Guinea Savanna; bacterial blight, *Protomycopsis* (black spot), *Cercospora* and *Macrophomina* (ashy-stem blight) are important in the Sudan Savanna whereas bacterial blight and ashy-stem blight are important in the Sahel. Most of advanced breeding lines are resistant to brown blotch and *Cercospora*. Therefore, major efforts are being made to combine resistance to relevant diseases for different ecologies.

A number of breeding lines have been identified which are immune or have high levels of resistance to these diseases. Some of the promising lines are listed in **Table 19.** These have been crossed to several improved breeding lines and F2, F3 populations are being screened.

In 1992, an additional 1600 germplasm lines were screened at Samaru, as a joint project with GRU and the PHMD Pathologist, for resistance to *Septoria* and scab. Over 100 lines were found to be resistant. These will be tested again at Samaru in replicated plots to confirm further their resistance before they are used in the breeding program.

## 5.4 Viruses

Cowpea aphid borne mosaic is a severe a problem throughout savanna ecologies and different strains are prevalent. Therefore, concerted efforts underway made in collaboration with the PHMD virologists to develop cowpea varieties resistant to different viruses. All the advanced breeding lines are routinely screened by artificial inoculation each year. Some of the promising lines are listed in **Table 20** and of these, IT90K-59 combines resistance to aphid, bruchid, thrips, *Striga* and *Alectra*. A number of these lines are being used in the breeding program. Tvu 401 to be resistant to several viruses and therefore this line was crossed with several improved breeding lines.

# 6. BREEDING FOR RESISTANCE TO *STRIGA* AND *ALECTRA*

## 6.1 Background

Two parasitic weeds, *Striga gesnerioides* (Wild.) Vatke, and *Alectra vogelii* (Benth.) of the family Scrophulaceae cause considerable damage to cowpea in the semi-arid regions of Africa. Presently *Striga* is more prevalent in Sudano-Sahelian belt and *Alectra* is more serious in the Guinea Savanna, but both are rapidly spreading beyond these limits. *Striga* incidence has been noticed in the coastal savanna of Benin Republic and *Alectra* is becoming a serious threat in several East and Southern African countries paticularly Kenya, Zambia, Zimbabwe and Botswana. Total yield loss is observed in heavily infested fields. These parasites are difficult to control by chemical and/or cultural methods due to the large amount of seeds which they produce and their adaptation/dormancy mechanisms which permit seeds to stay alive in the soil for several years. Therefore, a major component of a long lasting control package for these parasitic weeds should be genetic control through host plant resistance. Initial screening for *Striga* resistance was done by IITA scientists based at Kamboinse, Burkina Faso in 1981 where a total of 54 cowpea lines were planted in a heavily infested field. Subsequently a pot culture technique was developed for *Striga* and *Alectra* and used for controlled studies. A combination of field and pot culture screening has led to identification of several resistant sources and also permitted genetic studies leading towards identification of the genes responsible for resistance to *Striga* and *Alectra* and the allelic relationship among different genes.

## 6.2 Screening procedures

6.2.1 Field/screening

Most of the experimental fields at IITA Kano Station are infested with *Striga* and *Alectra*. One of these fields (0.5 ha) was selected and developed as the *Striga* sick plot by evenly spreading 20 bags of matured *Striga* plants and 10 bags of matured *Alectra* plants in it and incorporating them in the soil by repeated harrowing about 3 weeks before planting. This is used for field screening. More inoculum is added each year. In addition, plots at Kano Airport are heavily infested with *Striga* and *Alectra* and these are also used for field screening. Sick plots have also been developed/identified in Burkina Faso, Niger Republic, Nigeria and Benin Republic in collaboration with the national programs. The test lines are planted in these plots along with known susceptible varieties and data on number of emerged *Striga/Alectra* plants are taken, beginning 5-6 weeks after planting. The days taken to first emergence of *Striga/Alectra* in each line is recorded and then weekly counts are made to study the pattern of *Striga/Alectra* emergence. Seed of lines free from the parasitic weeds and those showing delayed and less emergence in the field are further tested using a pot culture technique in the screenhouse.

6.2.2 Pot culture screening

Plastic pots of 13cm diameter and 13cm depth are used for screening. Each pot contains about 1 litre of unsterilized sieved sand and top soil (sandy loam) mixture (1:1 v/v) previously inoculated uniformly with about 800 seeds of *Striga* or *Alectra*. The pots are kept on benches in a screenhouse and planted with test cowpea populations with two plants per pot. The pots are watered daily and weeds other *Striga* and *Alectra* are removed. Emergence of *Striga* and *Alectra* plants in pots containing susceptible plants normally begins from 6 weeks after planting. The experiments are terminated 10 weeks after planting when the differences between resistant and susceptible plants become quite marked. The levels of *Striga* and *Alectra* infection are determined by observing the attachments of *Striga* and/or *Alectra* on the roots of each cowpea plant. The soil is washed off the plant roots after submerging each pot in a 20l bucket of water for about 5 minutes. The roots of each plant are gently separated from the other and the numbers of *Striga* and/or *Alectra* attached to each plant is counted. Plants permitting attachment and healthy development of these parasitic weeds are classified as susceptible and those free of infection or showing only minute *Striga/Alectra* plants are grouped as resistant.

## 6.3 Sources of resistance

The initial lead on cowpea *Striga* resistance came from the work done by the IITA scientists based at Kamboinse, Burkina Faso working under the IITA/IDRC/Burkina Faso and IITA/SAFGRAD (Semi-Arid Food Grain and Development, Organisation of African Unity) projects. Field screening of 54 cowpea varieties at Kamboinse in 1981 indicated two that varieties, 'Gorom Local' from Burkina Faso and '58-57' from Senegal were resistant to *Striga*. These two varieties showed little or no *Striga* emergence compared with a large number of emerged *Striga* on other varieties. These resistant varieties along with other breeding lines were then evaluated by the IITA/SAFGRAD project at many locations in Burkina Faso, Mali, Republic of Niger, Cameroon and Nigeria during the years 1983-86 to ascertain the stability of *Striga* resistance across the West African savanna. 'Gorom local' and '58-57' showed a high level of resistance to *Striga* only in Burkina Faso. The susceptibility in other countries indicated the persence of different strains. Therefore, the search for additional sources of resistance continued and two new resistant sources, B 301 and IT82D-849, were identified in 1987 through collaborative work of IITA/SAFGRAD Project with Long Ashton Research Station, UK and various national programs. They showed stable resistance to *Striga* across Burkina Faso, Mali, Republic of Niger and Nigeria. B 301, a local germplasm line from Botswana was initially identified to be resistant to *Alectra* in Botswana. In addition to these two lines, a number of lines have also been identified which have lower numbers of *Striga* as well as showing delayed emergence of *Striga*. Some of these lines are listed in **Table 21**. IT86D-534, IT86D-371 and IT84D-666 are moderately resistant to *Striga* and highly resistant to *Alectra* whereas B 301 is completely resistant to both. IT82D-849 is completely resistant to *Striga* but susceptible to *Alectra*. Suvita-2, which is resistant to *Striga* in Burkina Faso, is moderately susceptible to *Striga* in Nigeria and highly susceptible to *Alectra*. Among the lines highly susceptible to *Striga*, some are also susceptible to *Alectra*. These data (**Table 21**) show the scale of yield loss due to parasitic weeds and demonstrate that breeding for *Striga* resistance alone in cowpea is not enough. *Alectra* can also cause damage as is evident in the yield performance of IT82D-849 and Suvita-2. Therefore, resistance to both parasitic weeds must be incorporated in improved varieties.

### 6.4 Mechanism and genetics resistance in different cowpea varieties

6.4.1 Manifestation of resistance

Field and pot culture studies have revealed major differences in the expression of resistance in different varieties. Lack of emergence or delayed and less emergence are noticed in resistant and moderately resistant lines compared to severe infestation of susceptible lines. In the pot culture test of B 301, at the two and four week root washings, we observed that this line stimulates germination of *Striga* as well as *Alectra* seeds and permits attachment. However, haustorial formation and further growth are inhibited and the parasite primodia subsquently die and distintegrate so that B 301 roots look apparently free of infection. This indicates a hypersensitive type reaction. The expression of resistance to *Striga* in IT82D-849 is a bit different from B 301.

This line also stimulates *Striga* seed germination and attachment and inhibits haustorial development like B 301. However about 10% of the plants show some haustorial development and support limited *Striga* growth with occassional emergencee of one or two *Striga* plants which are very weak and die before reproductive maturity. Unlike B 301, IT82D-849 is highly susceptible to *Alectra* permitting normal attachment and growth of *Alectra* plants. The variety IT81D-994 is moderately resistant to *Striga* and *Alectra*. It permits establishment of a few *Striga* and *Alectra* (3-5/plant) but delays their emergence. Any *Alectra* that emerge are weak and seldom reach maturity. In contrast the few emerged *Striga* plants reach maturity but cause little damage to the plants. The reactions of Suvita-2 to *Striga* from Burkina Faso and *Alectra* are similar to that of IT82D-849, but it is susceptible to the *Striga* strain from Nigeria.

6.4.2 Genetics of resistance

Good progress has been made in elucidating the genetics of resistance to *Striga* and *Alectra* in cowpea. Systematic genetic studies have a revealed single dominant gene for *Striga* and duplicate dominant genes for *Alectra* resistance in B 301. Further studies have showed that resistance in IT82D-849 to *Striga* is also controlled by a single dominant gene but it is different from that in B 301. Also, the single dominant gene possessed by Suvita-2 against the *Striga* strain from Burkina Faso is non-allelic to the single dominant genes in B 301 and IT82D-849. The dominant duplicate genes in B 301 against *Alectra* are non-allelic to a single gene in IT81D-994. Screening the parents of IT82D-849 and an allelic test revealed that its source of *Striga* resistance is from Emma 60. Gene symbols $Rsg_1$, $Rsg_2$ and $Rsg_3$ are proposed for resistance to *Striga gesnerioides* in B 301, IT82D-849 and Suvita-2 respectively and gene symbols $Rav_1$, $Rav_2$ and $Rav_3$ are proposed for resistance to *Alectra vogelii* in B 301 and IT81D-994. Most of these data have already been published.

6.4.3 Resistance mechanisms

Two factors play important role in the response of cowpea to infection by parasitic weeds:

(1) Production of active stimulant
(2) The defense mechanism of the host plant

In the situation where both factors act simultaneously, the resultant effect is the hypersensitive reaction leading to germination but death of the parasite as shown by B 301. It is proposed that the balance between stimultant production and defense mechanism changes due to different genotypes of the host plant, thus resulting in the threshold effects exhibited by IT82D-849, Emma 60 and SUVITA-2. IT81D-994 permits a lesser number of *Striga* plants to attach and develop thus showing a moderate level of resistance. The emerged *Alectra* plants on IT81D-994 are slow growing and rarely reach maturity On the other hand, if the host plant produces an active stimulant but does not have a good defence mechanism, it gets attacked as in IT84S-2246-4. The mechanisms of resistance shown by these resistant cowpea lines have the potential of reducing the number of parasite seeds in the soil over time.

## 6.5 Development of resistant varieties

A systematic breeding program for resistance to *Striga* and *Alectra* using B 301 as resistant source began in 1987. This is a land race from Botswana which has very small seeds and prostrate growth habit with late maturity. It is, therefore, an unacceptable variety for West Africa. This resistant line was crossed to a susceptible variety, IT84S-2246-4 which is otherwise a high yield variety with resistance to aphid, bruchid, thrips, and several diseases. The F1 was backcrossed to IT84S-2246-4 and the resistant BC1 F1 plants were grown in the greenhouse to maturity in 1988. The BC1 F2 families were planted at Ibadan in the off season and a large number of agronomically desirable plants were selected at maturity and threshed individually. The selected BC1 F3 progenies were then screened for resistance in 1989 at Kano in a field heavily infested with *Striga* and *Alectra*. Individual plants were selected based on resistance as well as on agronomic characters and the selected BC1 F4 plant progenies were then multiplied at Ibadan in the off seasen. Individual F4 plants were selected based on agronomic characters. The selected BC1 F5 progenies were then screened in 1990 at kano in the field as well as at Samaru in pot culture. The remanent seeds of selected F4 and F5 lines were tested for resistance to aphids and bruchids. A number of F6 breeding lones were then selected which were very similar to IT84S-2246-4 and had combined resistance to aphid, bruchid, thrips, *Striga* and *Alectra* and several diseases. These have been evaluated for yield and other characters in replicated trials in the 1991 and 1992 crop seasons and have done well (**Table 22**). The *Striga* resistant breeding lines are much superior in yield compared to IT84S-2246-4 which was used as a genetic base for improvement. These lines have been distributed to various national programs in Africa. These same lines are used as parents in the crossing program involving local varieties and other selected parents in order to develop a range of varieties including local varieties differing in plant type, maturity and seed characteristic to suit different cropping systems and regional preferences.

## 6.6 New sources of resistance

In view of the fact that strain diversity exists in *Striga*, it is desirable to have genetically diverse sources of resistance so that stable resistance can be bred in new improved cowpea varieties. Therefore, 1600 cowpea germplasm lines were screened in 1992 in the field at IITA Kano station. Each line was planted in *Striga* sick plot in 3m long rows which were 1.5m apart. Two plants per hill were maintained within the rows with a hill to hill distance of 20cm. The days taken to first *Striga* emergence and the number of emerged *Striga* per plot was recorded each week started 5 weeks after planting. At maturity 104 lines remained free from *Striga*. These lines were further tested in the screenhouse using the pot culture technique and 17 lines were found to have high levels of resistance to *Striga*. Some of these were also resistant to *Alectra* **(Table 23)**. Interestingly, all sources of *Striga* and *Alectra* identified to date orginated from germplasm lines from East and Southern Africa. These are being crossed to B 301, and IT82D-849 to ascertain whether they have the same or different genes for resistance.

## 6.7 Emergence of a new *Striga* strain in Benin Republic

In 1990, a few plants of IT82D-849 and B 301 were found susceptible at Zakpota, Republic of Benin. Systematic studies were then undertaken to elucidate whether this was due to seed mixture or existence of a new strain. A number of known susceptible and resistant lines to cowpea *Striga* were evaluated in 1991 and 1992 at and around Zakpota and data on *Striga* infestation was collected. The data on *Striga* emergence are presented in **Table 24**. The results suggest some level of susceptiblity in B 301 as well as in IT82D-849 which indicated the presence of a new strain at Zakpota . It was good to observe that IT81D-994, which is moderately resistant to *Striga* and *Alectra* in Nigeria is completely resistant to the new strain at Zakpota. Thus, it should be possibleto develop cowpea varieties resistant to all known strains of *Striga* by crossing B 301 derived lines and IT81D-994. This work is already in progress.

## 6.8 Long term experiment on *Striga* control

An experiment was initated in 1990 at Kano Airport involving B 301, IT82D-849, TVx 3236 (pure crop stand), TVx 3236 intercropped with millet, IT86D-472 and fallow treatments to study their long term effect on the *Striga* population. Each plot consists of 20m x 15m with two replications. Each variety is a treatment and is planted on the plot each year with two 2m x 3m windows of the susceptible variety, TVx 3236 randomly located to estimate the level of *Striga* concentration in the plot. The data collected so far suggest that a reduction of the *Striga* population has occurred in all the plots compared with the fallow plot (**Table 25**), with more reduction occurring in the plots of B 301 and IT82D-849. This experiment will continue for two more years.

## 7. PYRAMIDING GENES FOR PEST AND DISEASE RESISTANCE

In view of the fact that cowpea is attacked by several diseases, insects and parasitic weeds, the improved varieties must have resistance to all these if possible. As indicated in previous sections, good sources of resistance are available for important diseases like *Septoria*, scab, brown blotch, bacterial blight, blackspot, *Cercospora* and insects such as aphid, bruchid, and thrips as well as the parasitic weeds, *Striga* and *Alectra*. Systematic efforts are underway to combine all these resistances into a range of plant type, maturity groups and seed types both in photosensitive and non-photosensitive genetic backgrounds. The main strategy is to select parents which have desirable sets of genes, cross them and use the desired populations for recurrent selection and crossing so that in each cycle a few genes are added. An example is given in **Figs. 3 and 4**. IT84S-2246-4 was developed through systematic crossing and selection and possesses resistance to several diseses and insect pests (**Fig. 3**). This was crossed with local varieties on one hand and B 301 on the other hand and then the resulting F6 progenies of the two streams crossed back again to develop a range of plant types combining resistance to diseases, insects and *Striga* (**Fig. 4**). Recently parents with resistance to bacterial blight, *Septoria*, scab, blackspot and viruses have been included in this stream. With every generation definite progress is being made and it is expected that in the next few years, most of the breeding lines will have resistance to major diseases, aphid, bruchid, thrips, *Striga* and *Alectra*. These will be simultanteously crossed with parents having a low level of resistance to *Maruca* and PSB for further improvement.

## 8. BREEDING FOR DROUGHT TOLERANCE

### 8.1 Background

Cowpea suffers considerable damage due to drought in the Sahelian Region. Therefore, a systematic program was initiated in 1988 to screen cowpea varieties for drought tolerance and to develop screening methods. Thirty cowpea varieties were screened for drought tolerance and root characteristics.

### 8.2 Screening for drought tolerance

Drought tolerance was measured as the number of days taken for permanent wilting after termination of watering of the plants. Test lines were planted in single rows in wooden boxes about 90cm x 60cm x 10cm filled with a mixture of sand and top soil (1:1). Each row contained about 12 plants. The experiment was replicated four times. The plants were watered upto two weeks after planting. When the first trifoliate leaf had emerged, the watering was stopped. Notes on cumulative percent wilting each day after termination of watering were taken for each variety. When most of the lines had wilted, water was applied again to study the recovery percentage for the different lines. Based on the first screening, the experiment was repeated using 12 varieties which represented a range of drought tolerances. The results are presented in **Table 26**. Two varieties , Gorom Local and IT81D-994 appeared to be the most drought tolerant. These lines also showed the best recovery after watering was resumed. Field data and subsequent work has further confirmed the results, (see Annex 1).

### 8.3 Root characteristics

The same 12 varieties used in the previous study were screened for root characteristics. This was done using polythene pipes which were 1m long and of 15cm diameter. These pipes were filled with a mixture of sand and top soil (1:1) and three seeds of each variety were planted but thinned to one plant after germination. Each variety was replicated four times. Normal watering was done each day. For four weeks after planting the polythene pipes were cut open and submerged in water tanks. The roots were carefully washed out and for subsequent measurements. The results are presented in **Table 26**. A great deal of variability was noticed among varieties. There was no correlation between drought tolerance and root length. IT81D-994 had long roots and appeared to be drought tolerant whereas IT83S-818 had long roots and was drought susceptible.

These studies demonstrated apparent genetic variability in drought tolerance and root characteristics in cowpea and provide a foundation for further work.

## 8.4 Dry season planting

Several countries in the savanna region have developed irrigation facilities where wheat or vegetables are being grown in dry season. Often, wheat planting is delayed for various reasons and the late planted wheat gives very poor yield. Therefore, several improved early maturing cowpea varieties were evaluated at Wudil and Kadawa in 1991 and 1992 by planting in late January to assess whether cowpea will be a good alternative crop in cases where a farmer could not plant wheat in time. The results (**Table 27**) have been encouraging. Varieties like IT84S-2246-4, IT90K-76 and IT90K-59 have yielded between 1.5-1.9MT/ha when harvested in late April, well before the onset of rains **Table 27**. The seed quality is excellent and the produce comes into the market when cowpea prices are very high. This will not only be a profitable alternative to late planted wheat but it would also break up repeated cereal-cereal planting and thus improve the soil.

## 9. INTERACTION WITH NATIONAL AND REGIONAL PROGRAMS

Collaboration with national programs has been considerably strengthened during the last five years. In view of the budget constraints, cowpea improvement work by IITA at the ICRISAT Sahelian Centre was phased out and this is now being accomplished through collaboration with the scientists of the National Institute of Agronomic Research of Niger (INRAN). They manage IITA's preliminary and advanced trials at Kolo, Gabougoura and Maradi and assist in selection of promising lines for the dry regions. Similarly IITA's preliminary and advanced trials are conducted by scientists at IRA, Maroua (Cameroon) and CRI, Nyankpala (Ghana). Efforts are underway to develop similar arrangements with scientists at Ouagadougou and Bamako so that all the agro-ecological zones in West and Central African Savanna and Sahel can be covered. Needed assistance is provided to strengthen these national programs.

IITA's cowpea breeding program works hand in hand with cowpea scientists of Nigeria as an active member of the Nationally Co-ordinated project. We are also receiving considerable assistance from IAR/ABU scientists in breeding for *Striga* resistance. The cowpea breeder from IAR, Samaru, spent two weeks in 1992 at IITA Kano Station to obtain a better insight into IITA's cowpea breeding program.

**Table 28** shows the results of the coordinated cowpea trial jointly planned and conducted in 1992 at various locations in Nigeria. The results of these trials form the basis of variety releases in Nigeria. Through the collaborative work of IITA and Nigerian scientists, three new varieties IT84S-2246-4, IT86D-719 and IT86D-721 were recently released in Nigeria for general cultivation in 1992/93 and two *Striga* resistant varieties IT90K-59 and IT90K-101 have been identified as very promising.

We also have very active links with SAFGRAD and SADC cowpea inprovement programs as well as the Bean/Cowpea Co-operative Research Support Program of USAID in Cameroon and Ghana.

The most promising breeding lines selected from preliminary and advanced trials are multiplied and distributed to over 50 countries in the form of cowpea international trials. This has been a very effective program and over 45 countries have tested and released IITA's cowpea varieties (**Table 29**). The demand for these trials is always more than we can supply. Efforts are made to visit national programs and provide on the spot technical advice and also learn from them about regional/site specific problems. In 1992, principal cowpea scientists from Burkina Faso, Nigeria, Niger Republic, Ghana, Cameroon, Benin Republic, Tanzania, Zambia, Zimbabwe, Mozambique, and Lesotho participated in a grain legume monitoring tour covering Ibadan, Mokwa, Samaru and Kano, followed by a group discussion lasting one full day.

# TABLES

**Table 1. Cowpea in the cropping systems of West Africa**

A. Forest and Southern Guinea Savanna

1. Cassava-cowpea
2. Maize-cassava-cowpea
3. Maize-cowpea
4. Maize-cowpea, relay or double crop in second rainy season

B. Northern Guinea Savanna

5. Groundnut-cowpea
6. Groundnut-sorghum-cowpea with or without millet
7. Sorghum-cowpea

C. Sudan Savanna

8. Millet-sorghum-cowpea, relay with or without groundnut.
9. Millet-groundnut-cowpea

D. Sahelian Zone

10. Millet-cowpea

Table 2. Yields of component crops in different cropping systems (Minjibir and Gazawa LGA: 1991)

| Farmer | Grain Yield kg/ha | | | | Fodder Yield kg/ha | | | Total kg/ha |
|---|---|---|---|---|---|---|---|---|
| | E. Cowpea | Millet | Sorghum | G.Nut | L. Cowpea | Millet | Sorghum | |
| 1. | 123 | 1455 | - | - | 1643 | 1300 | - | 4521 |
| 2. | 138 | - | 2150 | 168 | - | - | 3270 | 5726 |
| 3. | 405* | - | 905 | - | - | - | 7083 | 8393 |
| 4. | 128 | - | 945 | - | 2963 | - | 4710 | 8746 |
| 5. | 173 | - | 280 | - | - | - | 14065 | 14518 |
| 6. | 83 | 1858 | - | - | 2365 | 3060 | - | 7366 |
| 7. | 60 | 1563 | - | 43 | 1598 | 3075 | - | 6339 |
| 8. | 75 | - | 1605 | 38 | - | 7060 | - | 8778 |
| 9. | 160 | 693 | 628 | - | 1365 | 1602 | 965 | 5413 |
| 10. | 23 | 750 | 1318 | - | 775 | 1105 | 5030 | 9001 |
| 11. | - | 1363 | - | - | 1920 | 4208 | - | 7491 |
| 12. | 148 | 700 | 105 | - | - | 2283 | 830 | 4066 |
| 13. | 125 | 1348 | - | - | 748 | 3815 | - | 6036 |
| 14. | 85 | - | 503 | 270 | 850 | - | 643 | 2351 |
| | 110 | 1216 | 937 | 129 | 1580 | 3056 | 4575 | |

* Not included in the mean because it was sprayed with insecticide

Table 3. Sequence and method of testing improved cowpea breeding lines

| Materials | Trial Type | Design | No. of Reps. | Locations |
|---|---|---|---|---|
| New Breeding lines | IET | Augumented | 1 | Gumel, Kano, Samaru |
| Selection from IET | PVT | RBD | 3 | Gumel, Kano, Samaru, Ibadan, Maiduguri, Niamey |
| Selections from PVT | AVT | RBD | 4 | Gumel, Kano, Samaru, Ibadan, Maiduguri, Niamey, Maradi, Maroua Nyankpala |
| Selection from AVT | CIT | RBD | 4 | National collaborators |

Table 4. Number and types of cowpea variety trials conducted in different years

| Types of Trial | Number of trials in different years | | | | |
|---|---|---|---|---|---|
| | 1988 | 1989 | 1990 | 1991 | 1992 |
| IET | 4 | 3 | 3 | 1 | 1 |
| PVT | 4 | 10 | 8 | 8 | 4 |
| AVT | 6 | 7 | 7 | 9 | 10 |

**Table 5. Performance of most promising cowpea breeding lines evaluated in different advanced variety trials 1988 (monocrop with insecticide sprays)**

| Variety | Grain Yield kg/ha | | | | | Reaction to* | | | |
|---|---|---|---|---|---|---|---|---|---|
| | IITAF | IITAS | Mokwa | Samaru | Kano | BB | Aphids | Bruchid | Thrips |
| | Advanced Trial-1 (White-early) | | | | | | | | |
| IT87S-1475 | 1608 | 2228 | 1793 | 637 | 968 | R | S | S | R |
| IT86D-718 | 2021 | 1794 | 1799 | 866 | 491 | R | S | S | R |
| IT86D-719 | 2169 | 1811 | 1659 | 639 | 705 | R | MR | S | R |
| IT84S-2246-4(check) | 1646 | 2081 | 1798 | 689 | 1086 | S | R | R | R |
| LDS-5% | 543 | 848 | 421 | 232 | 409 | | | | |
| | Advanced Trial-2 (White-medium) | | | | | | | | |
| IT85D-3517-2 | 1562 | 1224 | 196 | 626 | 1273 | R | S | S | R |
| IT86D-715 | 1133 | 855 | 2607 | 939 | 1315 | R | S | S | R |
| IT86D-957 | 1112 | 861 | 1874 | 637 | 1587 | R | S | S | R |
| IT82D-699 (check) | 952 | 675 | 1735 | 564 | 543 | R | S | S | R |
| LSD-5% | 456 | 556 | 595 | 301 | 339 | | | | |
| | Advanced Trial-3 (Brown-early) | | | | | | | | |
| IT87S-1304 | 1670 | 1865 | 2091 | 1315 | 731 | R | S | S | R |
| IT86D-792 | 1797 | 2499 | 1710 | 741 | 491 | MR | R | R | R |
| IT84S-2246-4 (check) | 2109 | 1763 | 2043 | 1023 | 1200 | S | R | R | R |
| LSD-5% | 526 | 826 | 352 | 322 | 356 | | | | |
| | Advanced Trial-4 (Brown smooth-early) | | | | | | | | |
| IT86D-633 | 1116 | 1236 | 2295 | 1200 | 1545 | S | S | S | R |
| IT86D-472 | 776 | 1457 | 2136 | 511 | 2119 | S | R | S | R |
| IT86D-534 | 962 | 1261 | 1924 | 898 | 1900 | S | R | R | R |
| VITA-7 (check) | 1397 | 736 | 1954 | 1106 | 1030 | R | S | S | S |
| LSD-5% | 382 | 645 | 580 | 346 | 445 | | | | |
| | Advanced Trial-5 (Brown medium | | | | | | | | |
| IT85F-2246 | 1179 | 1654 | 2283 | 1200 | 1472 | R | S | S | R |
| IT86D-627 | 1025 | 1248 | 3013 | 981 | 887 | R | S | S | R |
| IAR-48 (check) | 1172 | 1286 | 2522 | 595 | 741 | S | S | S | MR |
| LSD-5% | 440 | 586 | 386 | 265 | 470 | | | | |

F = First season (May-July) S = Second season (Aug - Oct)
*BB = Bacterial Blight R = Resistant MR = Moderately Resistant S = Susceptible

**Table 6. Performance of most promising breeding lines evaluated in different advanced trials in 1989 (monocrop with insecticide sprays)**

| Variety | Grain Yield kg/ha | | Reactions to* | | | |
|---|---|---|---|---|---|---|
| | Kano | Samaru | BB | Aphid | Bruchid | Thrips |
| Advanced Trial-1 (White early) | | | | | | |
| IT86D-721 | 1534 | 1503 | MR | S | S | R |
| IT87D-829-5 | 1241 | 2547 | R | S | S | R |
| IT86D-719 | 1187 | 1962 | R | MR | S | R |
| Kano Early (Check) | 587 | 407 | | | | |
| LSD-5% | 437 | 358 | | | | |
| Advanced Trial-2 (White medium) | | | | | | |
| IT87D-661 | 2287 | 1732 | S | S | S | R |
| IT86D-715 | 2237 | 2464 | R | S | S | R |
| IT86D-975 | 2086 | 2150 | R | S | S | R |
| Kano Early (check) | 326 | 400 | R | S | S | S |
| LSD-5% | 707 | 488 | | | | |
| Advanced Trial-3 (Brown early) | | | | | | |
| IT87D-939-1 | 765 | 1587 | R | S | S | R |
| IT87D-298 | 697 | 1419 | MR | R | R | R |
| IT84S-2246-4 (check) | 750 | 1524 | S | R | R | R |
| LSD-5% | 284 | 649 | | | | |
| Advanced Trial-4 (Brown smooth early) | | | | | | |
| IT86D-400 | 1291 | 2338 | MR | R | R | R |
| IT86D-486 | 1216 | 1962 | MR | R | R | R |
| IT86D-477 | 1165 | 1941 | MR | R | R | R |
| IT84E-124 (check) | 1148 | 1294 | S | S | S | R |
| LSD-5% | 560 | 590 | | | | |
| Advanced Trial-5 (Brown medium) | | | | | | |
| IT85F-2264 | 1248 | 2486 | R | S | S | R |
| IT87S-1357 | 1517 | 1795 | S | R | S | R |
| IT87D-1891 | 1396 | 2088 | S | R | S | R |
| IT87D-697-2 | 1254 | 2651 | R | R | R | R. |
| IAR-48 (check) | 408 | 2004 | R | R | R | R |
| LSD-5% | 464 | 549 | S | S | S | MR |

*BB = Bacterial Blight R = Resistant MR = Moderately Resistant S = Susceptible

Table 7. **Performance of most promising breeding lines evaluated in different advanced trials in 1990 (monocrop with insecticide sprays)**

| Variety | Grain Yield kg/ha | | | Reactions to* | | | |
|---|---|---|---|---|---|---|---|
| | Kano | Samaru | Gumel | BB | Aphid | Bruchid | Thrips |
| Advanced Trial - 1 (White and brown early) | | | | | | | |
| IT87D-879-1 | 1191 | 2216 | 947 | R | R | S | R |
| IT87D-885 | 1177 | 1529 | 1064 | R | S | R | R |
| IT87D-298 | 1668 | 1263 | 547 | MR | R | R | R |
| Kano early (check) | 856 | 207 | 529 | R | S | S | S |
| Advancedd Trial - 2 (White and brown medium) | | | | | | | |
| IT87D-697-2 | 1251 | 1343 | 744 | R | R | R | R |
| IT86D-715 | 1025 | 1687 | 515 | R | S | S | R |
| IT87D-1629 | 1075 | 1573 | 534 | R | S | S | R |
| TVx 3236 | 590 | 1505 | 281 | R | S | S | R |
| LSD - 5% | 399 | 359 | 203 | | | | |
| Advancedd Trial - 3 (Medium spreading) | | | | | | | |
| IT87D-2075 | 1430 | 903 | 876 | R | S | S | R |
| IT88DM-361 | 1385 | 1460 | 720 | R | S | S | R |
| IT88DM-363 | 1363 | 974 | 536 | R | S | S | R |
| Kano late (check) | 492 | 453 | 226 | R | S | S | S |
| LSD - 5 % | 406 | 654 | 287 | R | S | S | S |
| Advancedd Trial - 4 (Medium smooth) | | | | | | | |
| IT88S-496-5 | 661 | 1503 | 1462 | S | R | R | R |
| IT88S-715 | 616 | 1575 | 898 | R | R | S | R |
| IT87D-611-3 | 521 | 1204 | 376 | R | R | S | R |
| TVx 1948-01F (check) | 344 | 860 | 507 | R | S | S | S |
| LSd - 5% | 406 | 472 | 573 | | | | |
| Advancedd Trial - 5 (Photosensitive early) | | | | | | | |
| IT88DM-400 | 499 | 229 | 337 | R | S | S | R |
| IT89KD-245 | 477 | 195 | 328 | MR | R | R | R |
| Kano Late (check) | 277 | 322 | 347 | R | S | S | S |
| LSD - 5% | 197 | 203 | 153 | | | | |

* BB = Bacterial blight R = Resistant MR = Moderately Resistant S = Susceptible

Table 8. **Performance of most promising breeding lines evaluated in different advanced trials in 1991 (monocrop with insecticide sprays)**

| Variety | Grain Yield kg/ha | | | | | | Reactions to* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kano | Samaru | Gumel | Maroua | Niamey | Maiduguri | BB | Aphid | Bruchid | Thrips |
| | | | Advanced Trial - 1 (Early maturing) | | | | | | | |
| IT89KD-792 | 1225 | 1042 | 390 | 1309 | 882 | - | MR | R | R | R |
| IT89KD-374-57 | 915 | 624 | 702 | 1650 | 1011 | - | R | R | S | R |
| Dan Ila | 514 | 533 | 518 | 1279 | 786 | - | R | S | S | S |
| IT84S-2246-4(check) | 961 | 688 | 124 | 746 | 356 | - | S | R | R | R |
| LSD - 5% | 437 | 308 | 215 | 418 | 590 | | | | | |
| | | | Advanced Trial - 2 (Medium maturing) | | | | | | | |
| IT89KD-374-57 | 1692 | 779 | 806 | 2261 | 720 | - | R | R | S | R |
| IT88D-867-11 | 1293 | 862 | 829 | 1306 | 740 | - | R | R | S | R |
| IT88DM-363 | 1502 | 1096 | 476 | 2339 | 595 | - | R | S | S | R |
| IAR-48 (check) | 1697 | 823 | 432 | 2100 | 330 | - | S | S | S | MR |
| LSD-5% | 496 | 319 | 232 | 518 | 374 | | | | | |
| | | | Advanced Trial-3 (Photosensitive early) | | | | | | | |
| IT88DM-400 | 693 | 825 | 820 | 839 | 474 | 634 | R | S | S | R |
| IT89KD-337 | 999 | 819 | 1009 | 1044 | 208 | 625 | R | S | R | S |
| Dan Ila (check) | 754 | 710 | 1119 | 1364 | 731 | 528 | R | S | S | S |
| LSD-5% | 478 | 296 | 359 | 465 | 428 | 411 | | | | |
| | | | Advanced Trial-4 (Photosensitive late) | | | | | | | |
| IT89KD-245 | 1535 | 835 | 887 | 419 | 81 | 149 | MR | R | R | R |
| IT89KD-260 | 1219 | 791 | 1161 | 622 | 133 | 193 | R | R | R | R |
| Kananado (check) | 708 | 1215 | 246 | 31 | 0 | 0 | S | S | R | S |
| LSD-5% | 546 | 308 | 539 | 237 | 245 | | | | | |

*BB = Bacterial Blight, R = Resistant, MR = Moderately Resistant, S = Suscesptible

Table 9. **Performance of most promising breeding lines evaluated in advanced trials in 1992 (monocrop with insecticide sprays)**

| Variety | Grain Yield kg/ha | | | | | | Reactions to* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kano | Samaru | Gumel | Maiduguri | Maradi | Niamey | BB | Aphid | Bruchid | Thrips |
| | | | Advanced Trial - 1 (Early maturing) | | | | | | | |
| IT91KD-45 | 1493 | 773 | 1033 | 550 | - | - | R | R | R | R |
| IT90K-59* | 1190 | 936 | 1108 | 7 | - | - | R | R | R | R |
| IT90K-284-2 | 904 | 1004 | 991 | 469 | - | - | R | R | S | S |
| IT88D-643-1 | 725 | 358 | 1422 | 606 | - | - | R | R | S | S |
| IT84S-2246-4 (check) | 499 | 250 | 83 | 61 | - | - | S | R | R | R |
| LSD-5% | 286 | 438 | 324 | 328 | | | | | | |
| | | | Advanced Trial-2 (Medium maturing) | | | | | | | |
| IT90K-277-2 | 1537 | 375 | 952 | 1058 | - | - | R | R | R | R |
| IT89KD-374-57 | 808 | 810 | 1511 | 1018 | - | - | R | R | S | R |
| IAR-48 (check) | 1395 | 553 | 406 | 519 | - | - | S | S | S | S |
| LSD-5% | 408 | 465 | 374 | 365 | | | | | | |
| | | | Advanced Trial-3 (Medium spreading) | | | | | | | |
| IT88D-367-11 | 636 | 187 | 805 | 428 | 1347 | 755 | R | R | S | R |
| IT89KD-347-57 | 993 | 431 | 1067 | 403 | 1264 | 630 | R | R | S | R |
| IT90K-319 | 1458 | 470 | 401 | 509 | 1123 | 266 | R | R | R | R |
| Dan Ilan (check) | 1096 | 313 | 906 | 460 | 1012 | 255 | R | S | S | S |
| LSD - 5% | 367 | 233 | 308 | 198 | 317 | 225 | | | | |
| | | | Advanced Trial-4 (Photosensitive late) | | | | | | | |
| IT89KD-288 | 1081 | 427 | - | 659 | - | - | S | R | R | R |
| IT89-256 | 506 | 232 | - | 941 | - | - | R | R | R | R |
| Kananado (check) | 357 | 132 | - | 462 | - | - | S | S | R | S |
| LSD - 5% | 301 | 332 | | 420 | | | | | | |

* Also resistant to *Striga*

**Table 10. Variety performance in advanced trials from 1988 to 1992 (abstracted from Tables 5-9), monocrop with insecticide sprays**

| | Grain Yield kg/ha | | |
|---|---|---|---|
| Year | Samaru | Kano | Gumel |
| | **A. Early maturity check: IT84S-2246-4** | | |
| 1988 | 689 | 1086 | - |
| | 1023 | 1200 | - |
| 1989 | 1524 | 750 | - |
| 1990 | - | - | - |
| 1991 | 688 | 961 | 124 |
| 1992 | 250 | 499 | 83 |
| | **B. Medium maturity (IAR-48)** | | |
| 1988 | 595 | 741 | - |
| 1989 | 2004 | 408 | - |
| 1990 | - | - | - |
| 1991 | 823 | 1697 | 432 |
| 1992 | 553 | 1395 | 406 |

Table 11. **Mean performance of millet and cowpea varieties (grain yield, kg/ha) in different trials grown as intercrop without insecticides at Kano 1991**

| Trials | Yield of cowpea (kg/ha) | | | | Yield of millet (kg/ha) | |
|---|---|---|---|---|---|---|
| | Grain | | Fodder | | | |
| | Mean | Range | Mean | Range | Stalk | Grain yield |
| Advance 1 | 89 | 13-216 | 992 | 281-1563 | 2500 | 487 |
| Advance 2 | 116 | 6-248 | 1493 | 625-2500 | 3944 | 1003 |
| Advance 3 | 162 | 23-448 | 199 | 177-214 | 3236 | 626 |
| Advance 4 | 80 | 22-264 | 784 | 81-2000 | 2500 | 386 |
| Advance 5 | 88 | 20-213 | 807 | 281-1469 | 4395 | 885 |
| Advance 6 | 45 | 12-100 | 531 | 125-1500 | 3860 | 680 |
| Advance 7 | 61 | 15-162 | 380 | 62-1188 | 3721 | 585 |
| Advance 8 | 39 | 5-68 | 535 | 125-1563 | 2638 | 578 |
| Advance 9 | 78 | 10-155 | 1360 | 625-3062 | 3375 | 788 |
| Prelim 1 | 78 | 41-143 | 1016 | 250-1625 | 3055 | 489 |
| Checks: | | | | | | |
| Dan Ila | 80 | 26-134 | 808 | 200-1437 | | |
| Kananado | 71 | - | 2000 | - | | |
| IAR 1696 | 69 | - | 1312 | - | | |
| LSD 5% | | | | | 381 | 998 |

**Table 12. Performance of most promising cowpea varieties intercropped with millet in different trials at Minjibir 1991 without insecticide spray**

| Trial | Mean grain yield (kg/ha) of top 3 varieties | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | VI | Yield | V2 | Yield | V3 | Yield | Trial Mean | SE |
| Advance 1 | 89KD-381 | 216 | 89KD-792 | 169 | 89KD-457 | 153 | 89 | 35 |
| Advance 2 | 89KD-451 | 248 | 89KD-391 | 224 | 88DM-363 | 224 | 115 | 41 |
| Advance 3 | 88DM-400 | 448 | 89KD-444 | 279 | 87KD-2075 | 246 | 162 | 54 |
| Advance 4 | 89KD-107-5 | 263 | 89KD-353 | 155 | 89KD-260 | 134 | 80 | 42 |
| Advance 5 | 89KD-355 | 213 | 88DM-400 | 192 | 84D-666 | 182 | 88 | 31 |
| Advance 6 | 88S-496-5 | 100 | 89KD-43-3 | 75 | 89KD-76-6 | 67 | 45 | 18 |
| Advance 7 | 89KD-107 | 162 | 90K-(APL-1) | 136 | 90K-59 | 134 | 61 | 33 |
| Advance 8 | 88D-584-1 | 75 | 86D-1056 | 71 | 89KD-260 | 68 | 39 | 21 |
| Advance 9 | 87D-697-2 | 155 | 89KD-374 | 145 | 88DM-345 | 121 | 77 | 32 |
| Prelim 1 | 89KD-307 | 144 | 90K-59-3 | 133 | 90K-300-9 | 104 | 78 | 30 |
| Check | Dan Ila | 114 | Dan Ila | 26 | Dan Ila | 134 | 80 | - |
| Across all trials mean | All vars | 194 | All vars | 145 | All vars | 140 | 83 | |

Table 13. Performance of improved cowpea varieties without spray in Pure and Intercrop culture, 1992

| Variety | Minjibir | | Wudil | | Gumel | | Maroua | | Reaction to* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pure | InterCp | Pure | InterCp | Pure | InterCp | Pure | InterCp | BB | Aphid | Bruchid | Thrip |
| IT89KD-374-57 | 319 | 228 | 73 | 27 | 334 | 42 | 688 | 225 | R | R | S | R |
| IT88D-867-11 | 216 | 95 | 16 | 32 | 250 | 22 | 19 | 28 | R | R | S | R |
| IT89K-107-5 | 186 | 233 | 0 | 25 | 87 | 23 | 256 | 53 | R | R | R | R |
| IT90K-319 | 54 | 147 | 0 | 25 | 367 | 9 | 44 | 106 | R | R | R | R |
| Dan Ila | 73 | 58 | 9 | 7 | 164 | 1 | 175 | 69 | R | S | S | S |
| IT90K-59** | 639 | 261 | 81 | 476 | 264 | 27 | 6 | 63 | R | R | R | R |
| IT88DM-400 | 0 | 198 | 0 | 62 | 92 | 5 | 506 | 166 | R | S | S | R |
| IT89KD-391 | 87 | 169 | 0 | 13 | 263 | 1 | 38 | 38 | R | R | R | R |
| IT89KD-355 | 457 | 242 | 19 | 44 | 326 | 15 | 75 | 41 | R | R | R | R |
| IT88DM-363 | 46 | 97 | 9 | 32 | 58 | 10 | 544 | 556 | R | S | S | R |
| IT90K-261-3 | 269 | 269 | 35 | 134 | 160 | 36 | 56 | 22 | R | R | R | R |
| IT89KD-457 | 180 | 179 | 167 | 171 | - | - | - | - | R | R | R | R |
| LSD-5% | | 187 | | 114 | | | | | | | | |

*BB = Bacterial Blight, R = Resistant, MR = Moderately Resistant, S = Susceptible
**Also resistant to *Striga*

**Table 14. Grain yield (kg/ha) of improved cowpea varieties on farmers fields 1992**

| Variety | Farmers* | | | | | Resistance to: | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | Mean | [1]BB | Aphid | Bruchid | Thrips |
| IT89KD-374 | 53 | 148 | 474 | 38 | 178 | R | R | S | R |
| IT89KD-374-57 | 37 | 95 | 205 | 144 | 120 | R | R | S | R |
| IT89KD-319 | 181 | 50 | 65 | 90 | 102 | R | R | R | R |
| Dan Ila | 43 | 12 | 85 | 201 | 64 | R | S | S | S |
| IT88D-867-11 | 68 | 54 | 7 | 122 | 62 | R | R | S | R |
| IT88DM-400 | 54 | 67 | 13 | 81 | 54 | R | S | S | R |
| IT89KD-107-S | 18 | 2 | 105 | 59 | 46 | R | R | R | R |
| IT89KD-245 | 42 | 70 | 18 | 42 | 44 | MR | R | R | R |
| IT90K-59 | 43 | 8 | 43 | 76 | 42 | R | R | R | R |
| Mean | 60 | 56 | 112 | 94 | 79 | | | | |

[1]Bacterial Blight
*Each farmer had only one variety thus, farmer ≠1 is not a replication (see text Section 4.2.1)

**Table 15. Grain and fodder yield of dual purpose cowpea varieties evaluated at Kano 1990 (insecticide used, monocrop)**

| Variety | Yield kg/ha | | |
|---|---|---|---|
| | Grain | Fresh Fodder | Dry Fodder |
| IT89KD-275 | 1306 | 4773 | 1443 |
| IT88D-249-3 | 1120 | 7548 | 2442 |
| IT89KD-260 | 955 | 3330 | 1199 |
| IT89KD-245 | 761 | 6105 | 1776 |
| IT89KD-355 | 977 | 3552 | 1110 |
| IT89KD-288 | 847 | 4773 | 1332 |
| Kananado | 254 | 2220 | 610 |
| LSD-5% | 699 | | 1260 |

**Table 16. Performance (kg/ha) of improved cowpea varieties in different cropping systems, 1992 with insecticide, grown in a demonstration at Kano**

| Variety | Pure Stand Cowpea | Cowpea Strip | Cowpea Inter | Millet Strip | Millet Inter | Growth Habit |
|---|---|---|---|---|---|---|
| IT90K-284-2 | 2010 | 921 | 441 | 559 | 2345 | Early erect |
| IT87D-941-1 | 1468 | 867 | 523 | 605 | 1697 | Early erect |
| IT90K-59 | 1508 | 600 | 523 | 829 | 1654 | Early semi-determinate |
| IT86D-719 | 1533 | 670 | 433 | 595 | 941 | Medium semi-determinate |
| IT86D-715 | 1312 | 833 | 302 | 814 | 2081 | Medium semi-determinate |
| IT89KD-349 | 979 | 916 | 310 | 852 | 1865 | Medium spreading, photosensitive |
| Dan Ila | 493 | 511 | 205 | 753 | 1947 | Medium spreading, photosensitive |
| IT89KD-355 | 550 | 624 | 596 | 805 | 1593 | Medium spreading, photosensitive |

**Table 17. Promising breeding lines with resistance to different insect pests**

| Breeding Lines | Reaction to | | |
|---|---|---|---|
| | Aphid | Thrips | Bruchid |
| IT84S-2246-4 | R | MR | R |
| IT86D-534 | R | MR | R |
| IT88D-867-11 | R | MR | S |
| IT89KD-374-57 | R | MR | S |
| IT89KD-775 | R | MR | R |
| IT90K-101 | R | MR | R |
| IT90K-81-4 | R | MR | R |
| IT90K-59* | R | MR | R |
| IT90K-76* | R | MR | R |
| IT90K-77* | R | MR | R |
| IT90K-361-3 | R | MR | R |
| IT90K-277-2 | R | MR | R |
| IT90K-284-2 | R | MR | R |
| IT89KD-245 | R | MR | R |
| IT89KD-260 | R | MR | R |
| IT89KD-288 | R | MR | R |
| IT89KD-256 | R | MR | R |

*Also resistant to *Striga*

**Table 18. Range in grain yield (kg/ha) of cowpea varieties grown as pure crop without insecticide sprays**

| Year | Trial | Range* | Best Varieties |
|---|---|---|---|
| 1989 | Ad -1 | 0-995 | IT84S-1463, IT86D-721, IT86D-719 |
| | Ad -2 | 0-856 | IT86D-715, IT86D-714, IT86D-957 |
| | Ad -3 | 0-891 | IT87F-491, IT87D-415, IT84S-2246-4 |
| | Ad -4 | 0-783 | IT87S-1357, IT87D-1134, IT85F-2264 |
| | Ad -5 | 0-438 | IT84E-124, IT86D-534, IT86D-486 |
| | Ad -6 | 0-383 | IT86D-633, IT86D-551, IT87D-569 |
| 1990 | Ad 1-5 | 0-<50 | Several and prolonged attacks of *Maruca* |
| | Ad- 6 | 0-530 | IT89KD-455, IT88DM-345 |
| 1991 | Ad -1 | 35-651 | IT89KD-457, IT89KD-386, IT90K-59 |
| | Ad-2 | 0-254 | IT88DM-363, IT86D-715, IT89KD-374-57 |
| | Ad-3 | 0-525 | IT89KD-95-13, IT89KD-355, IT89KD-389 |
| | Ad-4 | 0-465 | IT89KD-353, IT89KD-260, IT89KD-374 |
| | Ad-5 | 0-917 | IT89KD-455, IT89KD-345, IT89KD-355 |
| | Ad-6 | 0-570 | IT88S-715, IT89KD-455, IT86D-534 |
| 1992 | Ad-5 | | |
| | Kano | 0-639 | IT90K-59, IT89KD-355, IT89KD-374-57 |
| | Wudil | 0-167 | IT89KD-457, IT90K-59, IT89KD-374-57 |
| | Gumel | 58-367 | IT90K-319, IT89K-374-57, IT89KD-355 |
| | Maroua | 6-688 | IT89KD-374-57, IT88DM-400, IT88DM-363 |

* Each trial had 20 varieties

** For disease and insect reaction of best lines from these, see Table 13

**Table 19. Cowpea breeding lines resistant to different diseases**

| Diseases | Resistant Lines |
|---|---|
| Brown Blotch | IT82E-16, IT82//d-699, IT86D-719, IT86D-715, IT84S-2246-4 |
| *Septoria* | IT86D-1056, IT88S-501-8, IT81D-994, IT90K-82-2, IT90K-81-4, IT85D-3577, IT86D-885, IT90K-284-2 |
| Scab | IT86D-1056, IT88S-501-8, IT90K-81-4, TVx 3236, IT84S-2246-4, IT90K-59, IT90K-76, |
| Bacterial blight and *Cercospora* | IT90K-284-2, IT90K-277-2, IT86D-719, IT85D-3517-2, IT89KD 374-57, IT89KD-391, IT89KD-109, IT88D-867-11, IT86D-782, IT81D-1228-14 |
| Black spot | IT87D-590-5, IAR-48, IT88S-524-7, IT84D-666 |
| Ashy-stem blight | Screening in progress |

Table 20. **Cowpea breeding lines resistant to different viruses (results from IITA-Virologist)**

| Breeding line | Reaction to different virus strains | | | | | | |
|---|---|---|---|---|---|---|---|
| | CAMV (Onne) | CAMV IT-16 | CAMV 81-11 | CAMV K 5-9-90-3 | CYMV-6 | CuMV Kano | CMMV Gumel |
| IT86D-1010 | 1 | 1 | 1 | 1 | 1 | 2 | 1 |
| IT86D-880 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| IT82D-849 | 1 | 3 | 2 | 1 | 1 | 1 | 1 |
| IT83S-818 | 1 | 1 | 4 | 2 | 1 | 1 | 1 |
| IT87D-611-3 | 2 | 1 | 4 | 1 | 1 | 1 | 1 |
| IT82E-16 | 1 | 4 | 4 | 1 | 1 | 1 | 1 |
| IT90K-59 | 1 | 5 | 1 | 2 | 1 | 1 | 1 |
| IT86F-2089-5 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| IT82D-889 | 1 | 1 | 2 | 3 | 1 | 1 | I |
| Ife Brown | 3 | 5 | 5 | 5 | 4 | 4 | 1 |

1 = Resistant 2 = Moderately Resistant 3 = Moderately susceptible & 5 = Susceptible

Viruses:
CAMV = Cowpea aphid borene mosaic,
CYMV = Cowpea yellow mosaic,
CUMV = Cucumber mosaic
CMMV = Cowpea mild mottle virus

**Table 21. Performance of cowpea lines under *Striga* and *Alectra* infestation in the field at Kano, 1989***

| Variety | Days to 50% *Striga* infection | Parasitic weeds per plot* *Striga* | *Alectra* | Grain Yield kg/ha |
|---|---|---|---|---|
| IT86D-534 | 66 | 135 | 1 | 656 |
| B 301 | - | 0 | 0 | 599 |
| Suvita-2 | 46 | 98 | 110 | 413 |
| IT86D-472 | 66 | 56 | 0 | 559 |
| IT86D-371 | 50 | 160 | 3 | 428 |
| IT84D-666 | 50 | 92 | 0 | 410 |
| IT82D-849 | - | 0 | 63 | 292 |
| IT82D-957 | 35 | 324 | 20 | 35 |
| IT86D-843 | 43 | 362 | 25 | 70 |
| Vita-3 | 34 | 439 | 3 | 35 |
| LSD - 5% | 11 | 196 | 20 | 228 |

*Average of 4 plots of 6 sq.m each, sprayed 2-3 times with insecticide

**Table 22. Performance (kg/ha) of *Striga* resistant cowpea varieties at different locations in Nigeria 1991**

| Variety | Kano | Gumel | Maiduguri | *Striga* Reaction* |
|---|---|---|---|---|
| IT90K-59-5 | 1289 | 1653 | 1763 | 1 |
| IT90K-59-3 | 1055 | 1544 | 1171 | 1 |
| IT90K-101-1 | 1164 | 1081 | 1117 | 2 |
| IT90K-102-6 | 1089 | 1657 | 1027 | 2 |
| IT90K-82-2 | 1104 | 1320 | 778 | 1 |
| IT90K-76-7 | 1114 | 1106 | 976 | 1 |
| IT84S-2246-4 | 1028 | 583 | 733 | 4 |
| LSD 5% | 337 | 474 | 475 | |

* 1 = completely resistant 5 = Highly susceptible

Sprayed 2-3 times with insecticide

**Table 23. Reaction of selected cowpea germplasm lines to *Alectra* and *Striga***

| Germplasm line | Reaction | |
|---|---|---|
| | *Striga* | *Alectra* |
| TVu 1271 | R | S |
| TVu 1272 | R | S |
| TVu 1330 | R | S |
| TVu 1331 | R | S |
| TVu 1332 | R | S |
| TVu 4642 | R | S |
| TVu 8337 | R | S |
| TVu 12415 | MR | MR |
| TVu 12430 | R | S |
| TVu 12431 | R | S |
| TVu 12432 | R | MR |
| TVu 12449 | R | S |
| TVu 12470 | MR | R |
| TVu 11788 | MR | MR |
| TVu 9238 | MR | R |
| TVu 13035 | R | S |
| TVu 8453 | R | S |

R = Resistant, MR = Moderately resistant,
S = Susceptible

**Table 24. Number of cowpea plants infested with *Striga* per plot (6m2) in different cowpea varieties at Zakpota (Republic of Benin)**

| Varieties* | 1990 | 1991 | 1992 |
|---|---|---|---|
| IT82D-849 | 0.5 | 15.5 | 33.0 |
| IT86D-371 | 32.5 | 25.8 | - |
| IT86D-472 | 19.3 | 26.8 | - |
| IT86D-534 | 22.5 | 20.0 | - |
| IT84D-666 | 14.3 | 13.8 | - |
| IT81D-994 | 0 | 0 | 0 |
| IT81D-985 | 7.8 | 1.5 | 8.0 |
| B 301 | 2.8 | 6.0 | 28.0 |
| SUVITA-2 | 0.8 | 0 | 1.0 |
| Tvx 3236 | 22.8 | 22.3 | 41.0 |

* Sprayed 2-3 times with insecticide

**Table 25. Number of emerged *Striga* in suscepti;ble windows ($6m^2$) of different varieties and cultural treatment**

| Treatment* | Year | | |
|---|---|---|---|
| | 1990 | 1991 | 1992 |
| Fallow | 78 | 131 | 189 |
| TVx 3236 | 123 | 84 | 64 |
| TVx 3236 + millet | 89 | 46 | 30 |
| IT86D-472 | 166 | 39 | 56 |
| IT82D-849 | 81 | 46 | 36 |
| B 301 | 115 | 32 | 27 |
| LSD-5% | NS | NS | 139 |

All sprayed 2-3 times with insecticide

**Table 26.** **Daily cumulative % from Day 6 to Day 15 wilting of nil watering regime (for the second screening in wooden boxes) and root characteristic of different cowpea varieties**

| Genotypes | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | Root length | Root dry wt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IT84S-2246-4 | 0 | 2 | 14 | 39 | 76 | 91 | 96 | 98 | 98 | 98 | 100 | 49.5 | 0.13 |
| Gorom Local | 0 | 0 | 0 | 5 | 5 | 7 | 9 | 29 | 48 | 52 | 52 | 61.8 | 0.13 |
| IT83S-818 | 0 | 0 | 0 | 20 | 80 | 100 | 100 | 100 | 100 | 100 | 100 | 97.7 | 0.2 |
| IT82dE-18 | 0 | 0 | 26 | 63 | 79 | 87 | 95 | 97 | 97 | 97 | 100 | 47.4 | 0.2 |
| IT82D-889 | 1 | 5 | 15 | 50 | 72 | 79 | 89 | 92 | 96 | 96 | 100 | 65.8 | 0.19 |
| VITA 3 | 31 | 40 | 58 | 80 | 80 | 80 | 100 | 100 | 100 | 100 | 100 | 44.2 | 0.16 |
| IT82D-1020 | 0 | 0 | 16 | 48 | 64 | 75 | 75 | 100 | 100 | 100 | 100 | 47.2 | 0.10 |
| TN 5-78 | 0 | 2 | 9 | 16 | 21 | 21 | 26 | 68 | 89 | 89 | 100 | 73.6 | 0.17 |
| TVx 3236 | 6 | 9 | 15 | 23 | 50 | 65 | 79 | 98 | 100 | 100 | 100 | 53.0 | 0.13 |
| IT85D-3850-1 | 0 | 8 | 26 | 47 | 91 | 94 | 94 | 94 | 94 | 94 | 100 | 45.6 | 0.14 |
| IT81D-994 | 0 | 0 | 3 | 3 | 6 | 6 | 12 | 21 | 33 | 60 | 79 | 84.1 | 0.18 |
| IITA Local | 0 | 21 | 28 | 42 | 63 | 63 | 100 | 100 | 100 | 100 | 100 | 20.8 | .08 |
| LSD-5% | | | | | | | | | | | 18.6 | 26.6 | .03 |

**Table 27. Mean grain yield (kg/ha) of some cowpea varieties over three different planting dates in dry season**

| Variety* | Yield at different planting dates | | | |
|---|---|---|---|---|
| | 19-1-91 | 31-1-91 | 20-2-91 | 31-1-92 |
| IT86D-715 | 405 | 1104 | 24 | - |
| IAR-48 | 573 | 1042 | 155 | - |
| Local (Dan Ila) | 1524 | 1119 | - | 851 |
| IT84S-2246-4 | 1524 | 1980 | 196 | 1638 |
| IT86D-719 | 1146 | 1269 | 236 | - |
| IT90K-76 | - | - | - | 1570 |
| IT90K-59 | - | - | - | 1148 |
| LSD 5% | 693 | 682 | 220 | 491 |
| CV % | 24 | 19 | 45 | 29 |

* Sprayed 2-3 times with insecticide

**Table 28. Grain yield (kg/ha) of different varieties evaluated in 1992 Nigerian National Cowpea Short Duraction Trial**

Number of Locations: 16, all sprayed 2-3 times with insecticides

| | Mokwa | Badeggi | Makurdi | Samaru | Marafa | Bauchi | IITA Kano | Maiduguri | UnIbadan | Abeokuta |
|---|---|---|---|---|---|---|---|---|---|---|
| IT90K-101* | 1156 | 1069 | 307 | 1421 | 1174 | 1716 | 1773 | 1350 | 709 | 2250 |
| IT90K-59* | 961 | 989 | 375 | 879 | 1011 | 1490 | 2106 | 1325 | 770 | 1250 |
| IT86D-719 | 1080 | 1031 | 277 | 1135 | 947 | 1550 | 1290 | 1375 | 761 | 881 |
| IT86D-721 | 1386 | 963 | 367 | 642 | 1188 | 1572 | 1560 | 825 | 724 | 1581 |
| IT85D-3577 | 1412 | 1233 | 194 | 781 | 1172 | 1450 | 1614 | 1012 | 761 | 887 |
| IT87D-941-1 | 1254 | 750 | 114 | 597 | 944 | 1749 | 867 | 950 | 812 | 1218 |
| IFL 132 (Ife Univ.) | 959 | 616 | 318 | 1453 | 836 | 966 | 1389 | 825 | 684 | 1193 |
| IT90K-261-3** | 1083 | 667 | 198 | 836 | 986 | 1756 | 767 | 650 | 686 | 1331 |
| IT84S-2246 (check) | 1220 | 698 | 174 | 767 | 877 | 1183 | 1029 | 625 | 683 | 1256 |
| IT90K-76 | 1353 | 588 | 389 | 883 | 944 | 1231 | 694 | 425 | 738 | 1168 |
| LSD-5% | 502 | 330 | 171 | 386 | 393 | 598 | 652 | 595 | 199 | 957 |

continued over page

**Table 28 (contd)**

| | Agdiwoye | Ile-Ife | Ado-Ekiti | Inua | Owerri Mean | Uyo | General | Reaction to: Aphid | Bruchid | Thrips | Maruca | BB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IT90K-101 | 596 | 575 | 951 | 668 | 262 | 1419 | 1115 | R | R | R | S | R |
| IT90K-59 | 754 | 466 | 993 | 668 | 664 | 1503 | 992 | R | R | R | S | R |
| IT86D-719 | 319 | 713 | 956 | 542 | 371 | 1878 | 970 | MR | S | R | LS | R |
| IT85D-3577 | 689 | 554 | 814 | 584 | 659 | 1252 | 942 | R | S | S | LS | R |
| IT87D-941-1 | 538 | 238 | 768 | 542 | 484 | 1419 | 826 | R | S | R | S | MR |
| IFL 132 (Ife Univ.) | 393 | 618 | 688 | - | 178 | 1210 | 822 | S | S | S | S | R |
| IT90K-261-3 | 427 | 476 | 672 | - | 309 | 1127 | 789 | R | R | R | LS | R |
| IT85S-2246 (check) | 202 | 463 | 450 | 876 | 520 | 1503 | 783 | R | R | R | S | S |
| IT90K-76 | 288 | 463 | 672 | - | 252 | 1419 | 768 | R | R | R | S | S |
| LSD-5% | 206 | 180 | 401 | 282 | 200 | 367 | | | | | | |

R = Resistant, MR = Moderately resistant, * Also resistlant to *Striga*.
**Highly susceptible to *Striga* otherwise it has good level of resistance to many pests, LS = Low Susceptible,
S = Susceptible

**Table 29. Improved cowpea varieties from IITA selected by different national programs (revised July 1993)**

| Country | Variety Released | Varieties under large scale On-farm test and seed multiplication for release |
|---|---|---|
| Angola | TVx 3236 | |
| Argentina | | IT82D-716 |
| Belize | VITA-3 | IT82E-18, IT82D-889, IT82D-789 |
| Benin Republic | VITA-4, VITA-5 | IT82E-32, IT81D-1137, IT84D-513, IT84S-2246 |
| Bolivia | IT82D-442, IT82D-889 | |
| Botswana | ER-7, TVx 3236 | |
| Brazil | 4R-0267-01F<br>VITA-6, VITA-3 | |
| Brazil | VITA-7, TVx 1836-013J | |
| Burkina Faso | TVx 3236, VITA-7 (KN-1) | |
| Burma | VITA-4 (Yezin-1) | |
| Cameroon | IT81D-985 (BR2)<br>IT81D-994 (BR1)<br>TVx 3236 | IT82E-18, IT82D-812, IT81D-1137<br>TVx 1850-01E |
| Central Africa Rep. | VITA-1, VITA-4,<br>VITA-5 | |
| Chad | IT81D-994 (BR1) | |
| Colombia | IT835-841 | TVu 352, TVu 256-1, TVu 335-1<br>TVx 1193-059D |

contd over page

**Table 29 continued**

| Country | Variety Released | Varieties under large scale On-farm test and seed multiplication for release |
|---|---|---|
| Costa Rica | | VITA-1, VITA-3, VITA-6 |
| Cyprus | | IT81D-1137, IT85D-3577 |
| El Salvador | TVx 1836-013J (Castilla deseda) VITA-3, (Tecpan V-3) VITA-5 (Tecpan V-5) | |
| Equador | VITA-3 | TVx 1836-013J, TVx 3380 |
| Equatorial Guinea | | IT82D-885 |
| Ethiopia | | VITA-4, IT82E-16, IT82E-32 |
| Fiji | VITA-1, VITA-3 | |
| Ghana | IT82E-16 (Asonteni) IT83S-728-13 (Ayiyi) IT83S-818 (Bengpla) TVx 1843-1C (Boafo) TVx 2724-01F (Soronko) | IT81D-1137 IT82E-16, IT82E-18, IT82E-32 |
| Guinea | IT85F-867-5 (Pkoku Togboi) | 84S-2246 |
| Guyana | ER-7, TVx 2907-02D, TVx 66-2H, VITA-3 | |
| Guatemala | VITA-3 | |
| Haiti | VITA-5 | |
| India | VITA-4, TVx 1502 | TVx 1843-01C |

contd over page

**Table 29 continued**

| Country | Variety Released | Varieties under large scale On-farm test and seed multiplication for release |
|---|---|---|
| Jamaica | VITA-3, ER-7 | TVx 2724-01F, TVx 1850-01E<br>IT84S-2246, IT84E-124 |
| Liberia | IT82D-889<br>TVx 3236, VITA-5,<br>VITA-4, VITA-7 | |
| Malawi | | IT82E-25, IT82D-889 |
| Mauritius | TVx 3236 | TVx 1836-013J<br>TVx 4654-44E |
| Mozambique | IT82E-18 | IT82D-887 |
| Nepal | IT82D-889 (Prakash)<br>IT82D-752 (Aakash) | |
| Nicaragua | VITA-3 | |
| Nigeria | IT84S-2246<br>TVx 3236, IT82E-60<br>IT81D-994, IT86D-719<br>IT86D-721 | IT81D-994, IT82D-951<br>IT84E-124, IT84E-108, IT82D-716 |
| Pakistan | VITA-4 | |
| Panama | VITA-3 | |
| Peru | VITA-7 | |
| Philippines | IT82D-889 | |
| Senegal | TVx 3236 | |
| Sierra Leone | TVx 1999-01E | |

contd over page

**Table 29 continued**

| Country | Variety Released | Varieties under large scale On-farm test and seed multiplication for release |
|---|---|---|
| Somalia | TVx 1502 | IT82D-889, IT82E-32, IT82D-1137 |
| South Korea | VITA-5 | |
| South Yemen | VITA-5, VITA-7 | |
| Sri Lanka | IT82D-789 (Wijaya)<br>IT82D-889 (Waruni)<br>TVx 309-01G, VITA-4<br>TVx 930-01B, (Iita) | |
| Surinam | | IT82D-889, IT82D-789 |
| Swaziland | IT82E-18, IT82E-32<br>IT82E-71 | IT82E-18, IT82E-27 |
| Tanzania | TK-1, TK-5<br>IT82D-889 (Vuli-1) | IT82D-890 |
| Thailand | | VITA-3, IT82D-889 |
| Togo | VITA-5, TVx 3236 | |
| Uganda | TVx 3236, IT82E-60 | |
| Venezuela | VITA-3 | IT81D-975, IT82D-504-4 |
| Yemen | TVx 3236, IT82D-789<br>VITA-5 | |
| Zaire | IT82E-18 | VITA-5, VITA-7, TVx 3236, IT82E-32 |
| Zambia | TVx 456-01F,<br>TVx 309-1G | IT82E-32, IT82E-16<br>TVx 3236, TVx 30901G, IT82D-889 |
| Zimbabwe | | ER-7, VITA-4, TVx 3236, IT81D-935,<br>IT82D-952, IT81D-1157 |

# FIGURES

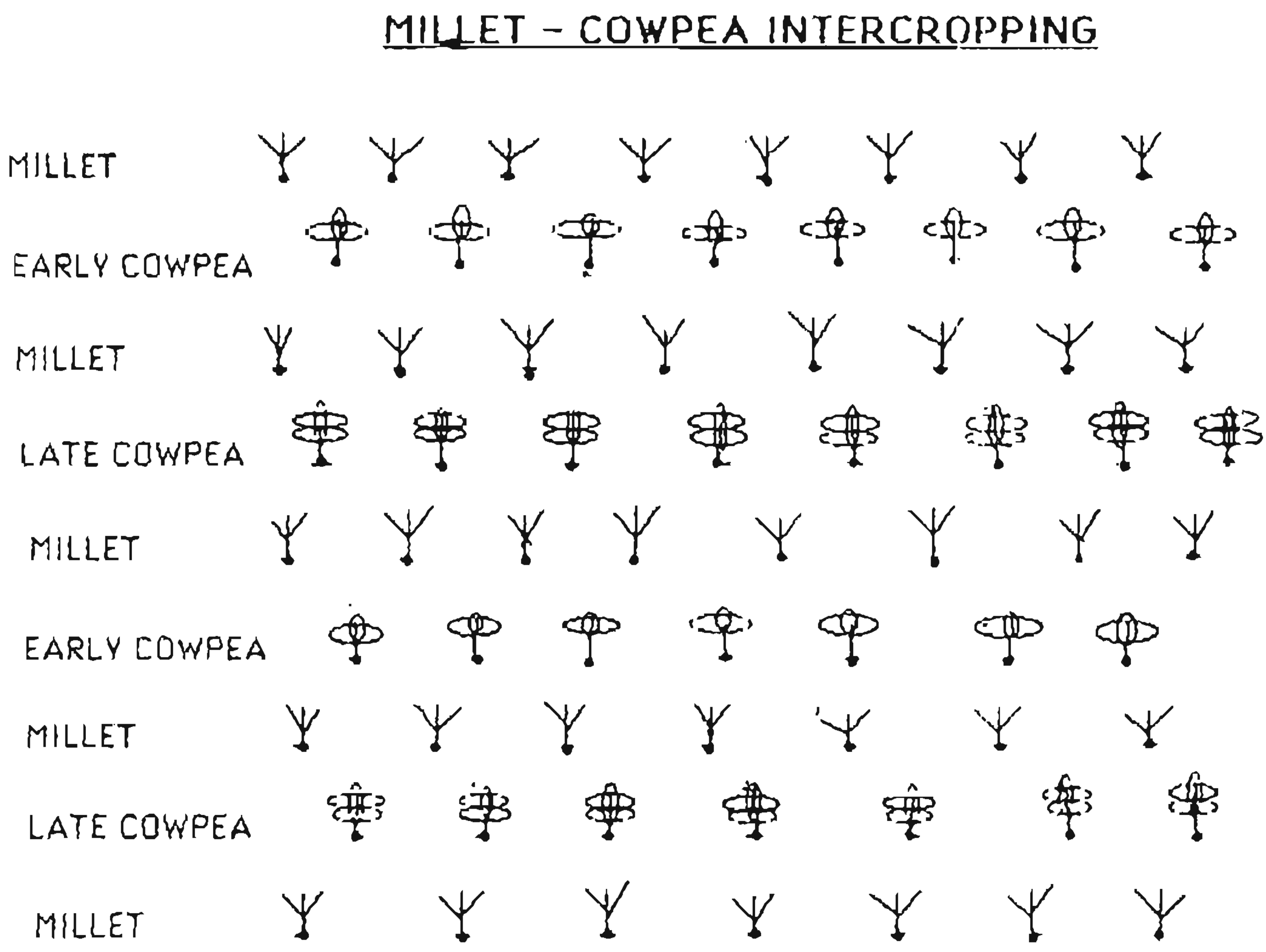


Fig. 1 Traditional intercropping systems involving relaly with early and late cowpeas in millet fields

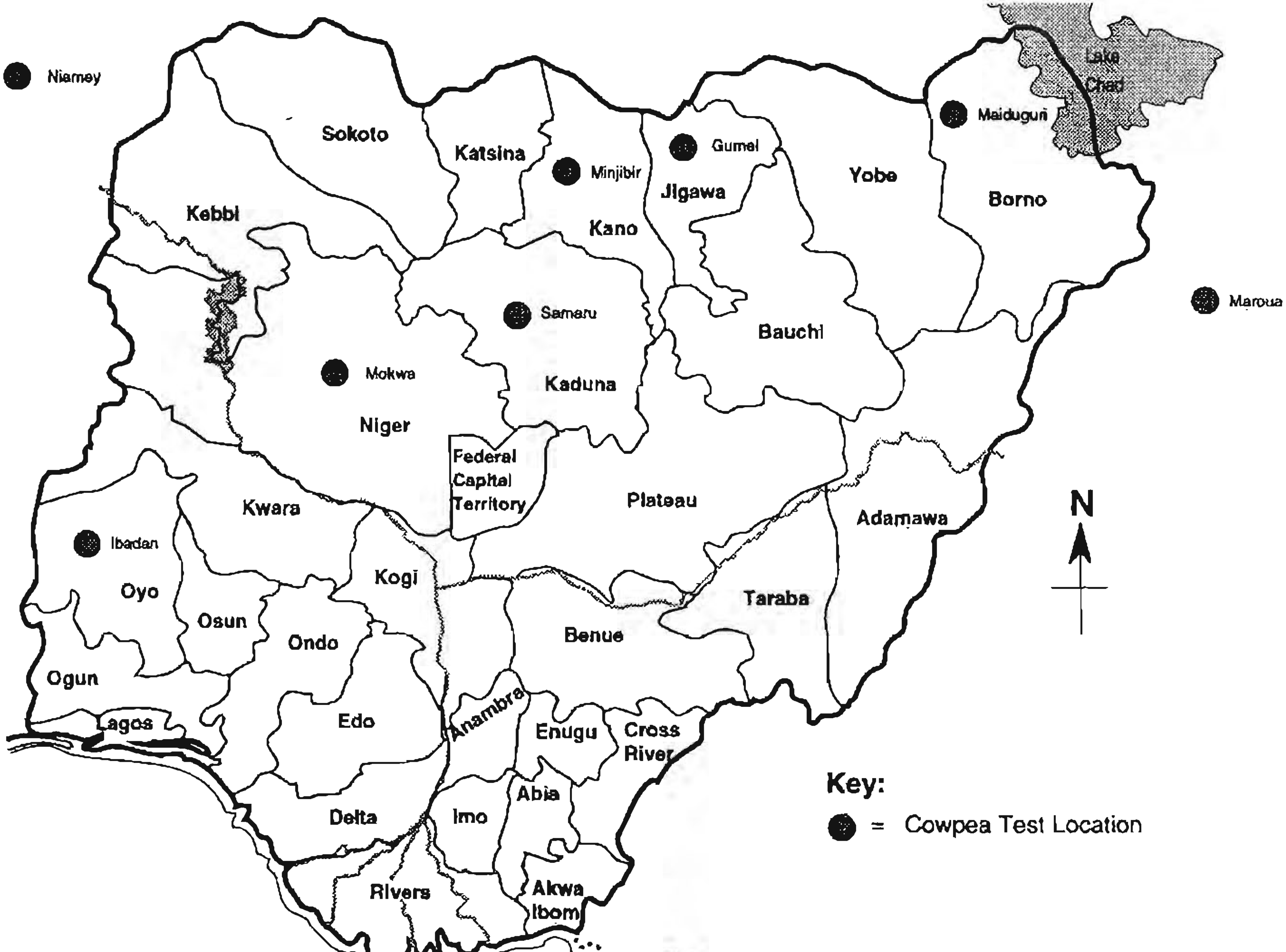


Fig. 2: Cowpea Test Locations in Nigeria, Cameroon and Niger

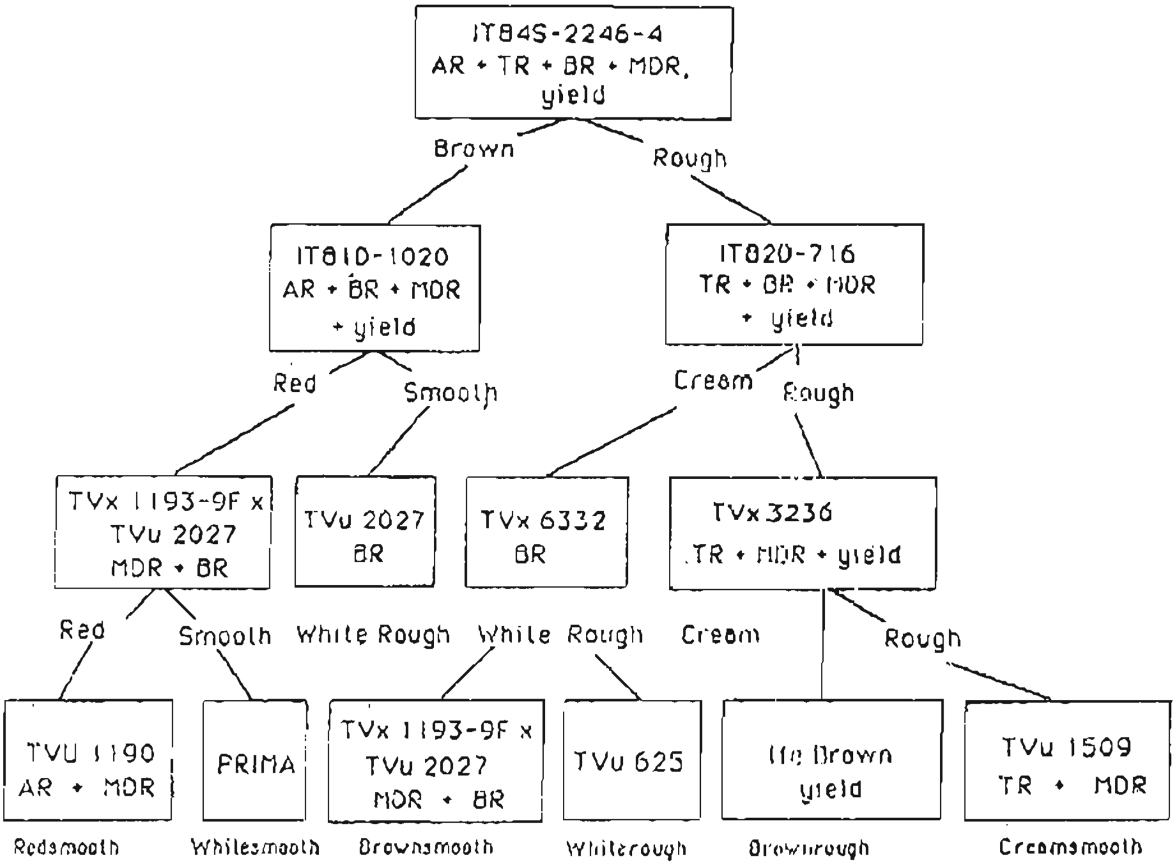


**Fig. 3** Pedigree of IT84S-2246-4 and sequence of selection

Resistances:

| | | | |
|---|---|---|---|
| AR | = Aphid | BR | = Bruchid |
| TR | = Thrips | MDR | = Multiple Disease |

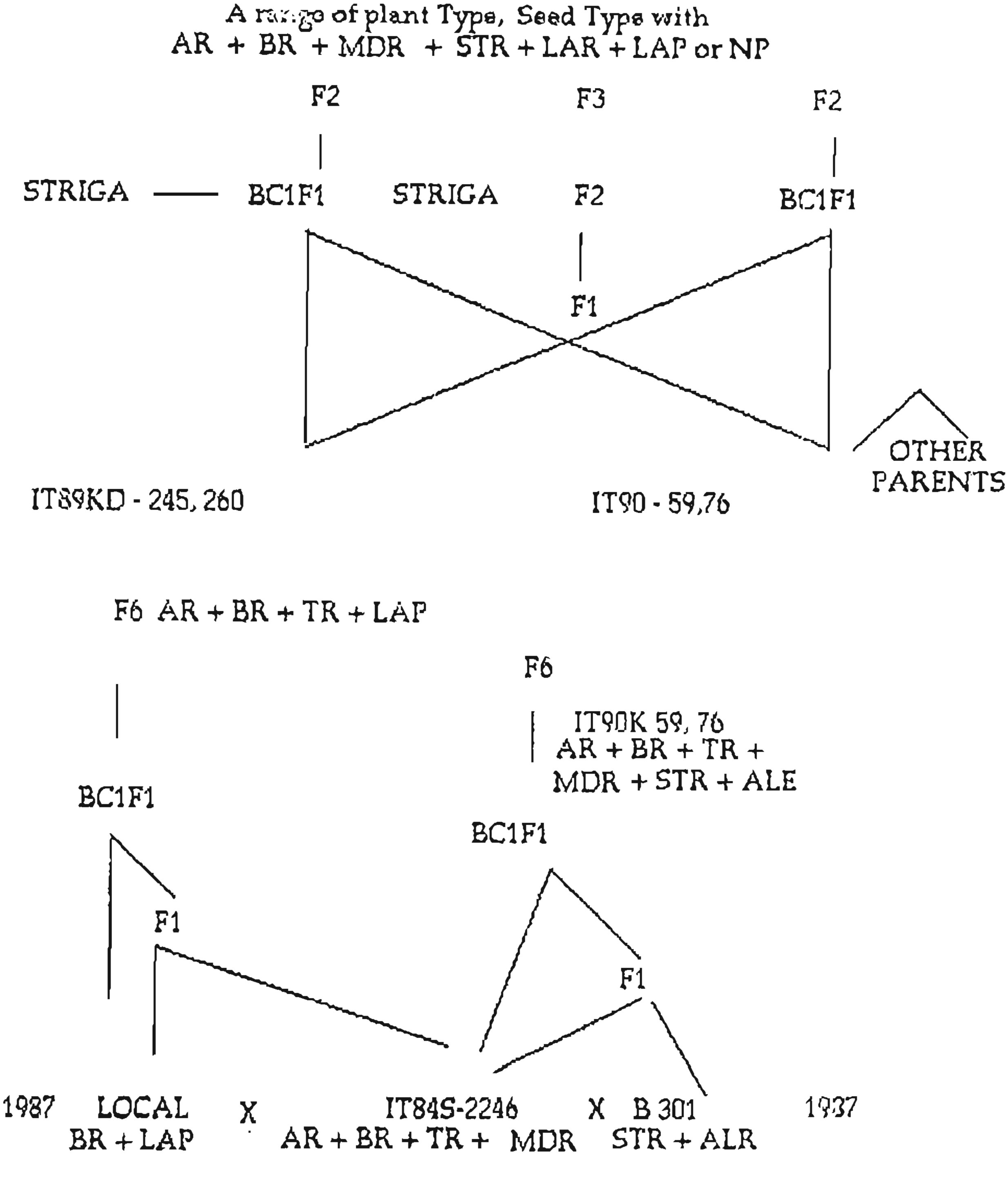


Fig. 4 Pyramiding desirable genes in a range of plant types

Resistances:

| | | | |
|---|---|---|---|
| AR = | Aphid | BR = | Bruchid |
| TR = | Thrips | MDR = | Multiple Disease |
| SRT = | *Striga* | ALR = | *Alectra* |
| LAP = | Local Adaptation and Photosensitive | | |
| NP = | Non-Photosensitive | | |

# Physiological Studies of Drought Tolerance

# ANNEX

## PHYSIOLOGICAL STUDIES OF DROUGHT TOLERANCE[1]

### 1. INTRODUCTION

Rainfall in the Sudan Savanna is both small in absolute amount and erratic in distribution. As a result, even though cowpea is a crop which is adapted to the semi-arid tropics, there are occassions during crop growth when dry soil conditions may adversely affect the crop's performance. The improvement of drought tolerance in cowpea is therefore a justifiable aim and is part of IITA's cowpea breeding programme. This paper reports some physiological studies which were undertaken at IITA's Kano Station, in relation to this aspect of breeding. The work was a collaborative project with the Tropical Agricultural Research Centre (TARC), Japan

### 2. DEVELOPMENT OF SCREENING METHODS

#### 2.1 Field and pot screening

As a first step, evaluation methods for plant tolerance of dry conditions were investigated in the field and in pots experiments. In the dry season of 1990, about 900 cowpea germplasm accessions from the IITA Genetic Resources Unit were planted in the field at Kano Station. To secure germination and early growth, the field was watered for about 2 weeks after sowing. Thereafter, the seedlings were left unwatered until the evaluation at about 3 months after sowing. In this trial, a wide range of plant responses to dry conditions were observed (**Photo 1**) suggesting the possibility of breeding more tolerant cultivars. The precision of evaluation was affected by the unevenness of residual soil moisture. For this reason, in 1991, evaluation was tried with potted seedlings in a glasshouse. Based on the observations of the field evaluation in 1990, 25 cowpea lines were chosen to cover the range of plant responses, from highly tolerant to dry conditions to highly susceptible. Seeds were planted in small pots with a fixed weight of dry soil in order to regulate soil mositure by weighing procedures. Seedlings were grown with enough water for about 2 weeks. Then they were subject to three watering

---

1. The research reported here was carried out by Dr Iwao Wantanabe, a Visiting Scientist from the Tropical Agriculture Research Centre (TARC), Japan working at IITA Kano Station and at TARC, Japan during 1990 and 1991

regimes for 2 weeks to create three soil moisture content treatments. Each morning, individual pots were weighed on an electric balance. The soil moisture was adjusted by adding water so as to reach three fixed levels of soil moisture, 5% of pot weight, 3% of pot weight and 2% of pot weight.

### 2.2 Results

At the end of the stress treatment, some lines were completely dead (tolerance score 1) and some were less affected and alive (score 5), albeit with some adverse effects on leaf development (**Photo 2**). The tolerance of dry conditions was best discriminated under the 3% soil moisture level treatment (**Table 1**). The correlation coefficient between the evaluation scores in the field experiment in 1990 and those in the pot experiment in 1991 was highly significant ($r$=0.663**, $n$=25). The pot evaluation was found to be reliable in the repeated evaluation of the same materials, where a highly significant correlation (r=0.655**, n=98) was observed between the repeated experiments.

### 2.3 Conclusion

It was concluded that field evaluation in the dry season could be used for a first round screening of a large number of materials and that the pot evaluation at 3% soil moisture in a glasshouse is recommeded for precise evaluation of a smaller number of materials, preferable less than 100 lines at one time.

## 3. SHOOT AND ROOT STUDIES

### 3.1 Grafting experiment

In order to clarify the specific roles of tops and roots in relation to drought tolerance, a grafting experiment was carried out in 1992 at TARC in Japan.

Four highly tolerant lines were paired up with four highly susceptible ones, making four pairs from eight lines. At the completion of the expansion of the first true leaf of each seedling, shoots were grafted mutually within pairs. In 10 days after grafting, when grafted plants began to grow vigorously again, they were subjected to the 3% soil moisture treatment for 2 weeks, (as described in Section 2.1).

In each of the four pairs, the tolerance of soil moisture conditions of the grafted plants was completely dependent on the top (**Photo 3**). That is, the top of a tolerant line remained tolerant when grafted on the root of the susceptible one. Conversely, the top of the susceptible line when grafted onto the root of a tolerant line, conferred susceptibility on the whole plant. From this experiment it was concluded that when both the root zone and the soil moisture are limited, it is tops and not roots which determine the plant characteristic in respect of drought tolerance.

## 3.2 Root growth study

Comparisons of root growth in conditions where rooting was unrestricted were made between lines of different tolerances, both in stressed and stress-free conditions. Five lines, two highly susceptible and three highly tolerant ones, were grown outdoors in transparent tubes of length 1m and diameter mm 25cm. They were inserted in long holes in the soil so as to keep the root zone dark and cool. They were protected from rain with a polyethylene cover. In the stressed plot, no water was given after germination. In the stress-free plot, soil moisture was maintained at 21%.

Root length from soil surface to the furthest point of root extension down the tube was recorded over a two week period. Root growth of highly susceptible lines was severely retarded in the water stressed treatment. That of highly tolerant ones, on the other hand, was little affected by the stress. Roots were roughly double the length of the water stress susceptible lines (**Table 2** and **Photo 4**). In the case of Suvita-2 (highly tolerant), root growth in the stressed plot was even better than that in the stress-free plot.

## 3.3 Conclusion

From these two experiments, the roles of tops and roots with respect to drought tolerance appeared to differ in their importance depending on the time course of the development of drought. The pot experiments on grafting examined plant responses to the onset of drought because the pots were small and the duration of the experiment was only a few days. In these circumstances, the soil moisture of the root zone was consumed rapidly. Drought tolerance of tops seemed to be playing a more important role than roots at this stage, but highly tolerant lines survived 5 to 6 days longer than highly susceptible ones.

In the rooting studies, where roots had opportunity for unlimited extension down into the soil, roots seemed to play a more important role than tops. In non-stressed soil moisture conditions, roots elongated at about 2cm per day. When moisture stress was imposed, root extension in susceptible lines slowed to 0.9cm per day but in tolerant lines it remained more or less the same at 2cm per day. Thus the roots of highly tolerant lines were able to reach deeper into the soil. In a field situation, this might ensure plant survival because the roots might find water, and even nutrients, in deeper parts of the soil profile.

Thus it could be postulated that the tolerance of the plant top plays a initial role in the plant survival in dry conditions and subsequently, new roots ensure longer term plant survival.

## 4. FUTURE WORK

Further studies will be undertaken on the mechanism of tolerance, especially in tops, to develop a more simple and efficient method for screening and to obtain a better understanding of drought tolerance mechanisms.

**Table 1. Pot evaluation of drought tolerance of cowpea at three levels of soil moisture**

| No. | Line (TVu No) | Percent soil moisture | | | Score in field evaluation in dry season |
|---|---|---|---|---|---|
| | | 5 | 3 | 2 | |
| 1. | 11982 | 5.0 | 4.7 | 1.0 | 4 |
| 2. | 14914 | 4.7 | 4.7 | 1.0 | 5 |
| 3. | 11979 | 5.0 | 4.0 | 1.7 | 5 |
| 4. | 9167 | 5.0 | 4.0 | 2.0 | 3 |
| 5. | 6914 | 4.3 | 3.7 | 1.0 | 5 |
| 6. | 7841 | 4.5 | 3.0 | 1.0 | 5 |
| 7. | 59 | 5.0 | 2.7 | 1.0 | 2 |
| 8. | 7381 | 3.7 | 2.7 | 1.0 | 3 |
| 9. | 8715 | 3.0 | 2.7 | 1.0 | 3 |
| 10. | 8713 | 5.0 | 2.3 | 1.0 | 5 |
| 11. | 433 | 5.0 | 2.3 | 1.0 | 4 |
| 12. | 928 | 5.0 | 2.0 | 1.0 | 4 |
| 13. | 127 | 5.0 | 2.0 | 1.0 | 1 |
| 14. | 85 | 5.0 | 2.0 | 1.0 | 4 |
| 15. | 7878 | 3.0 | 2.0 | 1.0 | 2 |
| 16. | 760 | 3.0 | 2.0 | 1.0 | 2 |
| 17. | 8885 | 4.3 | 1.7 | 1.0 | 4 |
| 18. | 7426 | 3.0 | 1.7 | 1.0 | 3 |
| 19. | 8365 | 4.7 | 1.3 | 1.0 | 2 |
| 20. | 7778 | 3.7 | 1.3 | 1.0 | 1 |
| 21. | 9357 | 3.0 | 1.3 | 1.0 | 2 |
| 22. | 12355 | 4.7 | 1.0 | 1.0 | 1 |
| 23. | 7758 | 3.7 | 1.0 | 1.0 | 3 |
| 24. | 8401 | 3.0 | 1.0 | 1.0 | 1 |
| 25. | 8048 | 3.0 | 1.0 | 1.0 | 1 |
| Variance | 0.70 | 1.25 | 0.05 | | |

Scores: 1 = highly susceptible 5 = highly tolerant

**Table 2. Time course of soil depth reached by the longest root (average of two pots)**

| Line | Distance from soil surface (cm) on: Day: 1 | 4 | 7 | 10 | 14 |
|---|---|---|---|---|---|
| **A. Without water stress** | | | | | |
| *Highly susceptible* | | | | | |
| TVu 7778 | 19.5 | 32.5 | 41.5 | 53.0 | 59.0 |
| TVu 9357 | 12.0 | 17.5 | 24.5 | 32.0 | 39.0 |
| Mean | 15.8 | 25.0 | 33.0 | 42.5 | 49.0 |
| *Highly tolerant* | | | | | |
| TVu 11979 | 17.5 | 26.0 | 33.0 | 48.5 | 54.5 |
| TVu 14914 | 14.0 | 23.0 | 32.5 | 41.0 | 44.5 |
| Suvita-2 | 9.5 | 13.0 | 19.0 | 27.0 | 36.0 |
| Mean | 10.3 | 20.7 | 26.2 | 38.8 | 44.3 |
| **B. With water stress** | | | | | |
| *Highly susceptible* | | | | | |
| TVu 7778 | 6.5 | 6.5 | 10.0 | 16.0 | 24.5 |
| TVu 9357 | 6.0 | 10.5 | 17.5 | 25.5 | 32.0 |
| Mean | 6.3 | 8.5 | 13.8 | 20.7 | 28.3 |
| *Highly tolerant* | | | | | |
| TVu 11979 | 16.0 | 28.5 | 38.5 | 44.5 | 52.5 |
| TVu 14914 | 12.5 | 21.0 | 30.0 | 36.5 | 45.0 |
| Suvita-2 | 18.5 | 30.0 | 41.0 | 49.0 | 52.5 |
| Mean | 15.7 | 26.5 | 36.5 | 43.3 | 50.0 |

# PHOTOGRAPHS

Photo 1. Field evaluation of drought tolerance of cowpea in dry season


Photo 2. Pot evaluation of drought tolerance of cowpea at a moisture level of 3 %
1: highly susceptible
5: highly tolerant

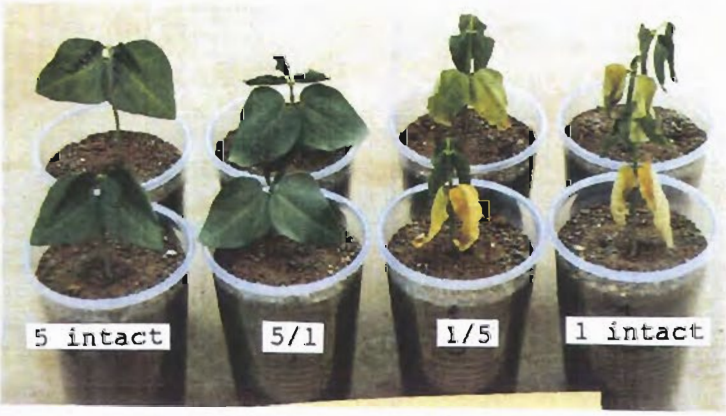


Photo 3. Drought tolerance of grafted cowpea
1 intact: TVu 9357 (highly susceptible)
5 intact: TVu 11986 (highly tolerant)
1/5 : TVu 9357 grafted on the root of TVu 11986
5/1 : TVu 11986 grafted on the root of TVu 9357

stress-free stressed
TVu 7778 (highly susceptible)

stress-free stressed
TVu 11979 (highly tolerant)

Photo 4. Root growth as affected by drought tolerance and water stress