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Genetic Stocks in World Collections: Useful Genetic Stocks in the World Collections of Germplasm Maintained At ICRISAT

INTRODUCTION

The world collections of sorghum (*Sorghum bicolor* L.), pearl millet (*Pennisetum glaucum* (L.) R. Br.), chickpea (*Cicer arietinum* L.), pigeonpea (*Cajanus cajan* (L.) Millsp.), groundnut (*Arachis hypogaea* L.), and six minor millets consisting of 102,560 accessions have been assembled and maintained at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India. They are characterised and evaluated, and economically important traits have been identified. Sources of resistance to biotic and abiotic stress factors have been identified by scientists of the concerned disciplines. Exploitation of host-plant resistance to biotic and abiotic stress factors will contribute to stability in production and protect the environment from chemical pollution. Hence the need for international exchange of germplasm (1, 2, 3). The accessions with known economic traits are maintained as genetic stocks, which are described in this paper.

SORGHUM

RESISTANCE TO BIOTIC STRESSES

Insect resistance

At ICRISAT Centre, exhaustive screening was carried out for shoot fly and stem borer resistance, and sources of resistance were identified (4).

Shoot fly (*Atherigona soccata*). Out of the 14,874 germplasm accessions screened, 60 accessions were less susceptible to shoot fly damage (Table 1). Four germplasm lines were found to be stable across locations (5, 6). Seedling vigour, glossiness, and biochemical factors were associated with resistance (5). Most of the less-susceptible accessions are from India, and belong to the race Durra.

Stem borer (*Chilo partellus*). Out of the 15,724 germplasm accessions screened, 70 were less susceptible to stem borer (Table 1). Most of them are from India and Nigeria, and belong to the race Durra. Sources having stable resistance for both shoot fly and stem borer are: IS 1082, IS 2205, IS 5604, IS 5470, IS 5480 (India), IS 18577, IS 18554 (Nigeria), IS 2312 (the Sudan), IS 1855 (Ethiopia), IS 2122, IS 2134, and IS 2146 (USA).

Midge (*Contarinia sorghicola*). Resistance to midge was found in 14 accessions (Table 1). Most of the promising lines are from Sudan or USA, and belong to the race Caudatum (4).

Head bug (*Calocoris angustatus*). Very few accessions were tolerant of head bug. A majority of them belong to races Guinea and Caudatum from Sudan or Ghana.

Disease resistance

Grain mold (*Curvularia* spp., *Fusarium*). Out of the 7,934 accessions screened, 156 were resistant, and all except one had coloured pericarp (Table 1). However, 24 accessions with coloured pericarp had negligible amounts of tannin, and 14 lacked the testa layer (7). Most of them belong to the race Caudatum and are from Southern, East and West Africa, and North and Central America.

Anthracnose (*Colletotrichum graminicola*). Resistance to anthracnose was found in 15 lines (Table 1). A majority of them are from USA, Sudan and Uganda, and belong to the race Caudatum.

Downy mildew (*Sclerospora sorghi*). Most of the promising lines for downy mildew resistance are from eastern Africa, India and Nigeria. Though they belong to all the five races, a majority of them are Durra, Guinea, Caudatum, and their intermediate races (Table 1).

Rust (*Puccinia purpurea*). Rust resistance was found in accessions from Sudan and USA, and most of them belong to the race Caudatum (Table 1).

Table 1. Sources of resistance to biotic and abiotic stresses identified in sorghum

Important genetic stocks	No. of accessions evaluated/ screened	No. of resistant stocks identified	Major source	Examples
BIOTIC STRESS				
Pests				
Shoot fly	14874	60	India	IS 1071, 2123, 2205, 2394, 3962, 5470, 5484, 18368
Stem borer	15724	70	India/Nigeria	IS 2375, 2376, 4757, 5619, 22039, 22091
Midge	12100	14	Sudan	SI 3461, 7005, 15107, 18697
Head bug	10915	6	Ghana	SI 17610, 17618, 17645, 9692
Diseases				
Grain mold	7934	156	S. Africa	IS 9308, 9326, 13885, 14375
Anthracnose	6970	15	USA	IS 2058, 2586, 15665, 17141
Rust	602	31	USA	IS 194, 458, 460, 18564
Downy mildew	8914	155	Australia	IS 18757, 22227, 22228, 522229, 22230, 22231
ABIOTIC STRESS				
Drought				
Seedling emergence through soil crust	814	53	Botswana	IS 22236, 22238, 22240, 22256, 22291, 22336
OTHERS				
Striga	300	24	India	IS 4242, 8744, 9830, 18831, 18475

Multiple disease resistance
Based on multilocational evaluation, the following lines were found to have resistance to more than one disease: ICS 1, ICSV 120, ICSV 138, IS 2058, IS 18758, and SPV 387 (anthracnose and rust); IS 3547 (grain mold, downy mildew, and rust); IS 17141 (grain mold and anthracnose); IS 2333 and IS 14387 (grain molds and downy mildew); and IS 3413, IS 14390, and IS 214544 (grain mold and rust). These lines are being used in breeding programmes.

Three populations with multiple resistance are being developed at ICRISAT, using the resistant sources. These are ICSP 1BR/MFR (for resistance to grain mold, stem borer, shoot fly, and midge) and ICSP 2BR/MFR (for resistance to grain mold and *Striga*, and improved stand establishment), which have rainy season adaptation, and ICSP 3BR/MFR (for resistance to stem borer, shoot fly and rust, and improved grain quality), which has post-rainy season adaptation.

Striga. The *Striga* species *S. asiatica* and *S. hermonthica* attack sorghum and cause considerable yield reduction. Some germplasm lines used in *Striga* resistance breeding are IS 18331 (N 13), IS 87441 (Framida), IS 2221, IS 4202, IS 5106, IS 7471, IS 9830, and IS 9951. Some of the breeding lines like 555, 168, SPV 221, SPV 103, etc., proved to be useful resistant sources. The *Striga*-resistant variety SAR 1 developed at ICRISAT from the cross 555 × 168 was released for cultivation in *Striga*-endemic areas. Most of the *Striga*-resistant lines are from India and belong to the race Durra.

RESISTANCE TO ABIOTIC STRESSES
Most of the promising lines for seedling emergence through soil crust are from China, Mali, Nigeria, and Botswana (8) which belong to the basic races caudatum and Guinea. Some 814 germplasm accessions were screened for seedling emergence through soil crust. Several germplasm lines were screened for temperature stress and seven were found to be promising. The most promising lines for early and mid-season drought stresses are: E 36-1, DJ 1195, DKV 3, IS 12611, IS 6928, and DKV 18 for early season and terminal drought, and DKV 1, DKV 3, DKV 7, DJ 1195, ICSV 572, ICSV 272, ICSV 273, and ICSV 8295 for mid-season stress.

DIVERSIFYING THE CYTOPLASM

To avoid possible hazards associated with using narrow cytoplasm base, it is desirable to diversify the male-sterile sources. Among the new male-sterile lines isolated, M 35-1A, M 31-2A, VZM 2A, and GI A from India are important. Sterility in IS 12662C cytoplasm is different from milo (A_1), and is designated as A_2. The sterility mechanism in IS 1112C was probably that of a different cytoplasm and has been designated as A_3 (4).

MULTIPURPOSE SORGHUMS

Sweet stalks. Sugar content in stalks ranged from 12-38% on dry weight basis. In the juice, sugar content varied from 7.0-15.9% (9). Water stress increased the stalk sugar percentage, while nitrogen fertiliser application had little effect. Stalk rot incidence decreased with stalk sugar concentrations. Most of the sweet stalk lines are from Sudan , Ethiopia, Kenya, Cameroon, and Malawi.

High-lysine. The high-lysine sorghum lines, IS 11167 and IS 11758 from Ethiopia were used to transfer the high-lysine gene to a desirable agronomic background. However, this trait is associated with grain yield-reducing factors (9).

Popping quality. Of the 3,682 accessions screened, 36 showed good popping quality. They are from India and a majority of them belong to the race Durra. In general, pop sorghums have small grains, medium thick pericarp, hard endosperm and a very low germ/endosperm size ratio (9).

Scented sorghum. A landrace called 'Basmati' belonging to the race Guinea is grown in Madhya Pradesh, India. The leaves, grains, and food recipes, particularly the stiff porridge, are distinctly scented (9). The seeds are dimpled, white and have a soft endosperm.

Broomcorn. Inflorescences of broomcorn with their long panicle branches are used to make various types of brooms. The grains are small and this type belongs to the race Bicolor.

Glossy. Sorghum seedlings with light yellow green colour and shining leaf surfaces are glossy (6). Most of the glossy lines are of Indian origin but some are from Nigeria, Sudan, Cameroon, Ethiopia, Kenya, Uganda, South Africa, and Mexico. They belong to the races Durra, Guinea, Caudatum, and Bicolor. Glossy lines contribute to shoot fly resistance and seedlings' drought resistance.

PEARL MILLET

MORPHOLOGICAL VARIANTS

Dwarfs. During the course of germplasm evaluation and rejuvenation, several morphological variants were found which were isolated, purified and maintained as genetic stocks. Some of them are of academic interest as they are useful in basic studies. However, some of them may be useful in crop improvement.

After testing dwarfs for allelism, two new dwarfing genes, designated as d_3 and d_4, were identified. These dwarfs possess several agronomically desirable characters besides reduced height (10). They can be used to produce new cultivars with reduced height and increased harvest index.

Glossy. Glossy trait found in eight accessions was distinguishable at seedling emergence and persisted for 28 days. Mist accumulates as droplets on glossy leaves of pearl millet. Three non-allelic genes, gl1, gl2, and gl3, control glossiness (11).

Midribless. The midribless mutants are characterised by leaf blades that tend to droop because of the absence of a keel in the midrib portion of the leaf lamina. Reproductive organs were affected in the mutant. Two different genes for midribless character were found (12).

Stripe. Stripe plants which are sectorial chimeras show longitudinal yellow or white stripes, alternating with varying shades of green, on leaves and other parts (13). Plastids in the mutant tissue were irregular and relatively smaller than the normal plastids but equal in number.

Early flowering and maturity. Seven genotypes that flowered earlier than Tift 13E, the earliest flowering stock, were identified (12). Among them, IP 4021 ("Bhilodi") from Gujarat flowered in 33 days and is less sensitive to day length. Accessions from Ghana, Togo, and Benin not only flower early but also produce large grains.

Sweet stalks. Considerable variation for juiciness and sweetness observed (14). Sugar content in the stalks was up to 20%. The sweet stalk forms are good fodder types. Popularisation of sweet-stalked pearl millet, coupled with extraction of jaggery as in sweet sorghums, may be beneficial.

Large spikes. Large spikes contribute to higher grain number and thereby to grain yield. Most of the accessions are from India and southern Africa. The largest spikes are from Nigeria and Niger where the Gero, Zongo and Maiwa forms produce spikes which are more than 1 m long. Those with longer spikes produce fewer tillers, mature later, and are often strongly photoperiod-sensitive.

Large grains. Seed mass in pearl millet varies from 3–19 mg/100 grains. Bold-grained collections predominantly come from Burkina Faso, Benin, Ghana, Togo, and Uganda.

Pearly white grains. Pearl millet grains that vary in colour from white to yellow are found in Chad, Central African Republic, Ghana, Togo, Sudan, and Namibia (14). These pearly pearl millets are generally sweeter and contain higher protein (more than 15 per cent) and may be useful in improving nutritional quality and appearance of bakery products.

Cytoplasmic male sterility (CMS). Four sources of sterile cytoplasm, viz., A1, A2, A3 and A4, are available. As the male-sterile lines became susceptible to downy mildew, new downy mildew-resistant male-sterile lines were developed from the existing sterile cytoplasm (15). Male-sterile lines were also identified from Ghana and Botswana germplasm (16). Some of these male-sterile lines flower earlier than most of the existing CMS lines, and they have larger grain size.

Disease resistance

Downy mildew, ergot, smut, and rust are the important diseases of pearl millet (17). Downy mildew, in particular, devastated the single cross hybrids in India. Ergot and smut occur in favourable seasons and may be less widespread and less threatening. Rust occurs sporadically. Nevertheless, all these diseases need to be effectively controlled to reduce losses in productivity and to eliminate the toxic principles in food grains and forage. Incorporation of host-plant resistance offers the best choice to effectively restrict the occurrence and spread of these diseases (17).

Downy mildew (*Sclerospora graminicola*). Downy mildew resistance occurs widely in the germplasm. Ex-Bornu from Nigeria, 3/4 Ex-Bornu and 3/4 Hainei Kirei from Niger have contributed to downy mildew resistance (17). Sources of resistance were found in germplasm from West Africa, mainly from Mali, Niger, Nigeria and Senegal (Table 2). This is mainly because the host plant also appears to have evolved along with the pathogens and resistance was found along the centre of origin. Some of the morphological variants like the midribless and glossy lines as well as the purple and yellow mutants are completely free of downy mildew (S.D. Singh, ICRISAT personal communication).

Ergot (*Claviceps fusiformis*). All advanced breeding lines were highly susceptible and only very low levels of resistance were detected in a few germplasm accessions from India, Nigeria, and Uganda (Table 2). Ergot-resistant lines were developed by intermating relatively less-susceptible plants by pedigree selection for several generations under high disease pressure. Mean ergot severities in these lines across locations ranged from < 1-7% compared with 30-65% in the susceptible controls. These lines are also resistant to smut and downy mildew at Patancheru (18).

Smut (*Tolyposporium penicillariae*). All advanced breeding lines were susceptible, but resistance was detected in several germplasm accessions originating from Nigeria, Senegal, Mali, Cameroon, Uganda, Lebanon, and India. Selections from six germplasm accessions (SSC FS 252-S-4, ICI 7517-S-1, ExB 132-2-S-5-2-DM-1, ExB 46-1-2-S-2, ExB 112-1-S-1-1, and P-489-S-3) had more resistance, and agronomically elite lines (ICMPS 100-5-1, 900-9-3, 1600-2-4, and 2000-5-2) showed consistently high levels of smut resistance. These lines had across-location mean smut severities of less than 5% compared with 35% or more in the susceptible controls (17). These lines were also resistant to downy mildew in India.

Rust (*Puccinia penniselli*). Rust is known to reduce dry matter yield, particularly yield of leaves and grain, total sugars, and in *vitro* digestibility. A dominant gene for resistance in 2696-1-4 S2, a selection from a germplasm line originating from Chad, was found (17, 19). A dominant gene for rust resistance was identified in three accessions of *Pennisetum americanum* subsp. monodii from Senegal.

CHICKPEA

Sources of resistance to drought and various insect pests are limited, though a few accessions are relatively more resistant than the others (Table 3).

Table 2. Sources of resistance to biotic and abiotic stresses and other genetic stocks identified in pearl millet.

Important genetic stock	No. of accessions evaluated/ screened	No. of source stocks identified	Major source
BIOTIC STRESS			
Pests			
Mythimna spp.	100	0	Niger, Senegal
Shoot fly	424	45	Niger, Cameroon
Aphids	100	14	Mali
Shoot bugs	100	8	East Africa
Thrips	29	3	Nigeria
Spider mites	234	31	Niger
Diseases			
Downy mildew	3163	1220	Niger, Senegal, Nigeria, Mali, Cameroon, India
Ergot	2524	151*	Niger, Senegal, Ghana
Smut	941	161*	Cameroon, Mali, India
Rust	2670	392	Niger, Cameroon, Togo
ABIOTIC STRESS			
Drought	509	2	Niger, Ghana, Mali
OTHERS			
High protein	3523	100	Benin, Ghana
Sugar	8	4	India, Tanzania
Male sterility	16968	5	Ghana, Botswana
Glossy leaf	16968	8	Niger, Sudan
Dwarf lines	15388	6	India, Niger
Mutants	16968	311	Nigeria

* Less susceptible plants

Most of the 16,346 accessions of chickpea germplasm assembled have been evaluated for morpho-agronomic traits and for their reactions to biotic and abiotic stresses (20). Several morphologically distinct and useful lines (genetic stocks) have been identified (Table 3). These genetic stocks were classified into four types: (1) distinct morpho-agronomic types, (2) insect-resistant types, (3) disease-resistant types, and (4) abiotic-stress resistant types.

Table 3. Sources of resistance to biotic and abiotic stresses and other genetic stocks identified in chickpea

Important genetic stocks	No. of accessions evaluated/ screened	No. of resistant stocks identified	Major source	Examples
BIOTIC STRESS				
Pests				
Pod borer (*H. armigera*)	16346	14	India	ICC 506
Diseases				
Fusarium wilt	15000	980	India, Iran, Bangladesh, Ethiopia	ICC 4918
Ascochyta blight	3000	1	India	ICC 120
Botrytis gray mold	2400	1	Iran	ICC 4014
Colletotrichum blight	9000	1	Israel	ICC 2278
ABIOTIC STRESS				
Drought	1000	11	India	ICC 4953
Salinity	500	4	India	ICC 4918
DISTINCT MORPHO-AGRONOMIC TYPES				
Dwarfs	16346	3	India	ICC 14332
Tall, erect growth	16346	86	CIS	ICC 8923
Twin-podded	16346	120	India	ICC 4951
Glabrous stem	16346	1	India	ICC 15566
Polycarpy	16346	1	India	ICC 12951

DISTINCT MORPHO-AGRONOMIC TYPES

Some distinct morphological types were found occurring naturally in chickpea fields and were also identified from populations after chemical mutagenesis. These lines differ from normal chickpeas with respect to one or two major genes. The following are some examples of the morpho-agronomic genetic stocks of chickpea.

Dwarfs. Three accessions are distinctly shorter than the rest of the accessions, with plant canopy height being about 15 cm, compared with about 40 cm in normal types. The dwarf plants produce more branches. These types were found occurring naturally, probably as a result of natural mutation. Dwarf types were also identified as a result of chemical mutagenesis.

Erect growth habit. In these types, the number of branches is relatively less and they grow at narrow angles with vertical axis, compared with the wider angle of branches in normal chickpeas. Some 86 accessions have been identified with erect growth habit. These accessions are mostly from the CIS. The erect growth habit particularly facilitates mechanical field operations.

Twin podded. One hundred and twenty accessions have been identified, which often bear two pods per leaf axil in contrast to one in normal chickpeas. This results in more pods and increased grain yield. A majority of these accessions have originated from India. This character is of particular advantage in drought-stress environments.

Glabrous type. This is a rare character in chickpea, which originated through chemical mutagenesis (21). Normal chickpeas have plenty of shoot hairs on all aerial parts whereas the glabrous chickpea is devoid of them. Glabrousness is a valuable trait for pathological, entomological and physiological studies in chickpea (21).

Polycarpy. This spontaneous mutant genotype is unique in that it has twin polycarpellary flowers per peduncle, in contrast to single monocarpellary flowers. They often produce two to three pods with normal seeds from a single flower (22).

RESISTANCE TO BIOTIC STRESSES

Insect resistance

Pod borer (*Helicoverpa armigera* Hub.). Pod borer is the most important insect pest of chickpea. The entire collection at ICRISAT was evaluated in pod-borer infested plots by entomologists, and after repeated tests 14 resistant accessions have been identified (Table 3).

Disease resistance. Germplasm collections were evaluated in disease-infected plots or in special growth room by pathologists to identify resistant sources.

Fusarium wilt (*Fusarium oxysporum* f. sp. *Ciceri*). Fusarium wilt is the most widespread disease of chickpea and a total of 980 resistance accessions were identified (Table 3). This disease is mostly soil-borne and is more damaging in heavy soils/short seasons/subtropical environments. To identify broadbased resistance to this disease, 225 genotypes earlier identified as wilt and

Table 4 Contd...

Important genetic stocks	No. of accessions evaluated/screened	No. of source stocks identified	Major source	Examples
Genetic markers	11148	2	India (U.P.), Kenya	ICP 5529, 9150
Mutants	11148	5	India (A.P., Orissa)	ICP 9879, 8001
Modified flowers	11148	2	ICRISAT, Australia	ICP 13695, 14056
Extra early	11148	7	ICRISAT	ICP 11538, 11737
High-branching lines	11148	892	India (Bihar, U.P.)	ICP 8081, 8679
Determinate flowering	11148	397	India (U.P.), Puerto Rico	ICP 9080, 13879
Spreading habit	11148	253	India (Karnataka, Tamil Nadu)	ICP 7954, 13691
Compact habit	11148	1356	Kenya, Malawi	ICP 9150, 13533
Many seeds/pod	11148	10	Guadeloupe, Grenada	ICP 8504, 13555
Large seed	11148	679	Kenya, Tanzania	ICP 9176, 12145
White seed	11148	123	India (M.P., Bihar)	ICP 7526, 8044
Vegetable types	11148	125	Kenya, Tanzania	ICP 9150, 12005
Agroforestry lines	1000	36	Tanzania, Malawi	ICP 12119, 13525
Accs. from arid areas	11148	15	India (Rajasthan, Haryana)	ICP 8738, 8800
Accs. from acid soils	11148	260	India (Kerala, Orissa)	ICP 11908, 12918
Cold tolerance high altitudes	11148	268	Kenya, Tanzania	ICP 9150, 12100
Widely used cultivars	11148	150	India (M.P., U.P.)	ICP 7035, 7626

1. M.P. = Madhya Pradesh
2. U.P. = Uttar Pradesh
3. A.P. = Andhra Pradesh

pigeonpea. The identification of genotypes with extended perenniality opened a new area of utilisation of this unique crop in social forestry and agroforestry experiments.

Wild relatives of pigeonpea present a large scope in transferring desirable traits such as high seed protein content and tolerance to insects and resistance to diseases. A unique example is the recent identification of a source with combined resistance and desirable agronomic traits, ICPW 89. This is an accession of *Cajanus scarabaeoides* with earliness, high seed protein content, and resistance to cyst nematode and fusarium wilt. The species crosses readily with cultivated pigeonpea and is now being utilised in crossing programmes. The discovery of genetic male sterility and development of technology to produce commercial hybrid seed led to the exploitation of hybrid vigour in pigeonpea. The development of early-maturing dwarf stock increased pigeonpea production.

Nearly all the released pigeonpea cultivars are selections from time-tested traditional landraces. In many cases the landraces have been released directly as cultivars for different geographical regions. Examples of recent releases follow. Fiji released ICP 7035, a landrace collected from Madhya Pradesh, India. It combines multiple disease resistance against fusarium wilt and sterility mosaic with excellent vegetable-type characteristics and high sugar content in seed. ICP 9145, collected from Kenya, was released in Malawi, due to its desirable agronomic traits, high productivity, and wilt resistance. ICP 11384 was released in Nepal due to its consistent superior performance in the plains.

To stimulate and facilitate further effective and expanded utilisation of germplasm in crop improvement, all the available data on passport information and evaluation have been compiled into a catalogue (24). A unique feature of this catalogue is the constitution of several natural and artificial groups and ready-to-use short lists of genotypes that breeders will find extremely useful in their selection and hybridisation programmes. Its imaginative use will accelerate and revolutionise pigeonpea germplasm enhancement and utilisation on a global level. Currently 97 countries draw germplasm and relevant data from ICRISAT for pigeonpea improvement.

GROUNDNUT

The cultivated groundnut and the wild *Arachis* species offer a wide range of variability for morphological characters, nutritional factors, and biotic and abiotic stresses. At ICRISAT a multidisciplinary approach has been adopted for evaluation of groundnut germplasm, using groundnut descriptors developed by IBPGR/ICRISAT in 1981. In characterisation more emphasis has been given to highly heritable characters and evaluation of accessions for their reactions to different diseases, insect pests, drought, and nutritional components.

The available germplasm has expressed a wide range of variation for morphological characters such as growth habit, branching pattern, leaf and flower characteristics and to agronomic traits such as maturity, pod and seed characteristics. We have accessions such as ICG 476, ICG 4117 and ICG 4118 which mature in about 75-85 days, accessions like ICG 4489, ICG 6398, ICG 8331, and ICG 10877 with a 100-seed mass between 115 and 136 g, and ICG 232, ICG 2177, ICG 5181, ICG 7518, ICG 11322, and ICG 11614 with a shelling percentage between 70 and 75%. These accessions are of great value in genetic improvement of the existing cultivars for the above characteristics and in developing them to suit a cropping system.

ICRISAT scientists of different disciplines have developed simple and effective techniques to screen groundnut germplasm against different stress factors to identify useful genetic stocks. For example, groundnut pathologists have developed effective screening methods for foliar diseases such as rust caused by *Puccinia arachidis* Speg. and late leaf spot caused by *Phaeosariopsis personata* (Berk. & Curt.) V. Arx., using infector row technique to highly susceptible cultivar, for use in areas where natural pressure is high or where such pressure can be artificially induced. Using this technique, over 12,000 germplasm lines from the world collection have been successfully screened for these two diseases and several sources of resistance have been identified (25). The stability of resistance to the diseases was established through multilocational trials. Most of the germplasm lines resistant to these diseases are not agronomically acceptable. Hence, a large-scale hybridisation programme was initiated and several high-yielding, agronomically superior lines with resistance to these two diseases were bred. Wild *Arachis* species have also been screened against these two diseases and several accessions of wild *Arachis* species were found to be completely disease-free or highly resistant and promising for many other important biotic stresses. The gene(s) conferring resistance in these wild species for rust and late leaf spot have been successfully transferred to cultivated groundnuts producing a large number of interspecific derivatives (26). These are now being used in a breeding programme at ICRISAT and several national programmes.

Following similar effective techniques in other disciplines, a large number of accessions have been screened against other common groundnut diseases and pests (27, 28). They have also been screened against common abiotic factors such as drought and for their nutritional quality, resulting in identification of many more accessions with desirable features (Table 5). We now have a number of lines resistant or tolerant to various stresses, such as 198 for rust, 103 for late leaf spot, 21 for *Aspergillus flavus*, 24 for *A. niger*, 23 for bud necrosis disease, 5 for peanut mottle virus, 31 for jassids, 14 for thrips, 2 for aphids, 9 for termites, 2 for nematodes, and 38 for drought. There are many accessions with multiple resistances. Table 5 provides a summary of these results along with ICRISAT identity of certain representative lines in each case. Most of the promising sources for resistance to various biotic and abiotic stresses are from landraces originating from primary and secondary centres of diversity in South America.

CONCLUSIONS

Concerted efforts in germplasm evaluation have shown that a wide range of variation and diversity exists in all the world collections of mandated crops that are maintained at ICRISAT Centre (Table 6). Such diverse materials are freely available to all national scientists and crop improvement programmes. Many of them have already been used to increase crop productivity and ensure agricultural sustainability through stable or higher grain or fodder production. The potential of such well-known, classified, and documented diverse materials is very important in terms of the need to produce more for the ever-growing population, particularly in developing countries (29, 30, 31). With the imaginative manipulation of the diverse genetic resources

Table 5. Sources of resistance to biotic and abiotic stresses and other genetic stocks identified in groundnut

Important genetic stocks	No. of accessions evaluated/ screened	No. of source stocks identified	Major source of origin	Examples
BIOTIC STRESS				
Pests				
Termites	520	9	USA	ICG 156, 2271, 2306, 5043
Aphids	500	2	USA/ Taiwan	ICG 5240, 5725
Leaf miner	930	14	No trend	ICG 1697, 2271, 6544, 7404
Jassids	6500	31	USA	ICG 156, 273, 2271, 2307
Thrips	5000	14	USA	ICG 799, 2320, 2741, 5037
Diseases				
Late leafspot	9400	103	Peru	ICG 1702, 1703, 1705, 1710
Rust	9400	198	Peru	ICG 1697, 1703, 1707, 1710
Aspergillus flavus	580	21	India	ICG 1326, 2800, 3263, 3700
Bud necrosis	7400	23	USA	ICG 848, 862, 885, 2271
Peanut mottle virus	800	5	USA	ICG 5043, 1260, 1697, 2716
ABIOTIC STRESS				
Drought	578	38	India	ICG 1697, 1708, 2738, 3657
OTHERS				
High oil*	8868	44	India	ICG 1694, 820, 2378, 2379
High protein*	8868	51	USA/ India	ICG 2338, 3108, 3378, 4601
Nitrogen fixation	342	4	USA	ICG 274, 404, 1561, 2405

*One season data

Table 6. Variability range in some selected characters of ICRISAT mandate crops evaluated at ICRISAT Centre, Patancheru.

Characters	Sorghum	Pearl millet	Chickpea	Pigeonpea	Groundnut
Days to 50% flowering	36-199	33-140	28-96	55-210	16-58
Plant height (cm)	55-655	11-475	16-93	39-385	*
Peduncle exsertion (cm)	0-55	-21-+30	*	*	*
Head length (cm)	2.5-71	6-165	*	*	*
Head thickness (mm)	10-290	10-64	*	*	*
Number of tillers	1-15	1-210	*	*	*
Stalk sugar content (%)	12-38	5-19.7	*	*	*
Grain seed colour	white-dark brown	white-dark purple	cream-black	white-black	off-white-dark purple
Seeds/pod	*	*	1-2.8	1.6-7.6	1-5
100-seed mass (g)	0.58-8.56	0.3-1.93	4.9-59.4	2.8-22.4	19.8-121.5
Plant width (cm)	*	*	18-70	*	*
Pods/plant	*	*	few-168	*	*
Harvest index (%)	*	*	21.9-64.8	*	*
Seed protein (%)	*	*	15.4-30.9	12.4-29.5	*
Oil content %	*	*	*	*	31.8-53.1

* Not applicable

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