3

Recent advances in cowpea breeding

B.B. Singh[1], O.L. Chambliss[2], and B. Sharma[3]

Abstract

Cowpea is an important grain legume throughout the tropics and subtropics, covering Asia, Africa, and Central and South America, as well as parts of southern Europe and the United States of America. The use patterns, seed preferences, and cropping systems vary from region to region. Insect pests, diseases, nematodes, parasitic weeds, and drought are major production constraints. Early maturity is preferred everywhere so that cowpeas can be grown in the niches of cereal-based cropping systems, but medium- and late-maturing varieties, with and without photosensitivity, are also required in some regions, to suit the prevalent cropping systems and meet grain and fodder needs. Considerable progress has been made during the past decade in cowpea breeding, and a range of varieties has been developed, combining diverse plant type and maturity with resistance to several diseases, insect pests, and parasitic weeds. Improved varieties have also been developed for grain and fodder and for intercropping with maize, cassava, yam, millet, and sorghum for the benefit of smallholder farmers who practice intercropping and use little or no inputs.

Introduction

Cowpea, *Vigna unguiculata* [L.] Walp., is an important food legume and a versatile crop cultivated between 35 °N to 30 °S of the equator, covering Asia and Oceania, the Middle East, southern Europe, Africa, southern USA, and Central and South America (Fery 1985, 1990; Mishra et al. 1985; Singh and N'tare 1985; Watt et al. 1985; Heij 1987; Hadjichristodoulou 1991a,b; Perrino et al. 1992, 1993). However, being a drought-tolerant crop with better growth in warm climates, cowpea is most popular in the semiarid regions of the tropics, where other food legumes do not perform as well. Cowpea has the unique ability to fix nitrogen even in very poor soils (pH range 4.5–9.0, organic matter < 0.2%, and a sand content of > 85%). Also, it is shade-tolerant and, therefore, compatible as an intercrop with a number of cereals and root crops, as well as with cotton, sugarcane, and several plantation crops. Coupled with these attributes, its quick growth and rapid ground cover have made cowpea an essential component of sustainable subsistence agriculture in marginal lands and drier regions of the tropics, where rainfall is scanty and soils are sandy with little organic matter. At the same time, if early-maturing erect/semi-erect varieties are grown as a pure crop with required inputs, cowpea has the potential of yielding as high as cereals on a productivity per day basis (Singh and Sharma 1996).

---

1. International Institute of Tropical Agriculture (IITA), Kano Station, Sabo Bakin Zuwo Road, PMB 3112, Kano, Nigeria.

2. Department of Horticulture, 301 Funchess Hall, South College Street, Auburn University, Auburn, AL 36849, USA.

3. Indian Agricultural Research Institute, Pusa, New Delhi 110 012, India.

World cowpea production

It is rather difficult to obtain reliable statistics on cowpea area and production because most countries do not maintain separate records on cowpea. Probably because of these difficulties, the Food and Agriculture Organization (FAO) suspended formal publication of cowpea production data several years ago. However, based on information available from FAO and via correspondence with scientists in several countries, it can be estimated that cowpea is now cultivated on at least 12.5 million hectares, with an annual production of over 3 million tonnes worldwide. Cowpea is widely distributed throughout the tropics, but Central and West Africa accounts for over 64% of the area (with about 8 million hectares, followed by about 2.4 million hectares in Central and South America, 1.3 million hectares in Asia, and about 0.8 million hectares in East and southern Africa). Some cowpea is also cultivated in the Middle East and southern Europe. The important cowpea growing countries are Nigeria, Niger Republic, Mali, Burkina Faso, Senegal, Ghana, Togo, Benin, Cameroon, and Chad in Central and West Africa; Sudan, Somalia, Kenya, Malawi, Uganda, Tanzania, Zambia, Zimbabwe, Botswana, and Mozambique in East and southern Africa; India, Bangladesh, Nepal, Myanmar, Sri Lanka, Indonesia, China, and Philippines in Asia; and Brazil, Cuba, Haiti, USA, and the West Indies in Central and South America. However, a substantial part of the cowpea production comes from the drier regions of northern Nigeria (about 4 million ha, with 1.7 million tonnes), southern Niger Republic (about 3 million ha, with 0.3 million tonnes) and northeastern Brazil (about 1.9 million ha, with 0.7 million tonnes). With availability of new varieties, cowpea cultivation is increasing in Brazil, Cuba, Ghana, Mozambique, Nigeria, Sri Lanka, Sudan, Zambia, and Zimbabwe.

Diverse variety requirements

Cowpea is a single crop species, but the varietal requirements in terms of plant type, seed type, maturity, and use pattern are extremely diverse from region to region, making breeding programs for cowpea more complex than for other crops. The seed color preference and use patterns differ from region to region, and the maturity, growth habit, and photosensitivity requirements depend upon the cropping systems (Barrett 1987; Paul et al. 1988; Timsina 1989; Akundabweni et al. 1990; da Silva 1990; Tian and Xu 1993). Cowpea is also an important fodder crop (Kohli 1990; Nandanwar and Patil 1990; Tarawali et al. 1997). Thus, no single variety can be suitable for all conditions. There is a need to develop varieties with different attributes and resistance to major biotic and abiotic constraints, to suit the specific needs of different regions and cropping systems.

Cowpea breeding programs and progress

The advances made after 1984 are the focus of this paper, since earlier developments have been well covered by papers already cited here.

IITA'S program

The International Institute of Tropical Agriculture (IITA) develops and distributes improved cowpea materials and new germplasm lines to over 60 countries, and many national programs depend solely upon IITA to the generate breeding materials for development of new cowpea varieties suitable for their regions. The general objectives and strategies to meet these requirements were described by Singh and N'tare (1985), but these have now been enlarged. Prior to 1987, IITA devoted most of its efforts towards developing cowpea varieties for sole cropping. Since then, the objectives have been diversified, to include breeding for intercropping as an important component of IITA's overall cowpea improvement program, as the bulk of cowpea in West and Central Africa is still grown as an intercrop (Singh 1993). IITA's cowpea breeding program currently focuses on developing the following types of varieties:

1. Extra-early maturing (60–70 days) nonphotosensitive grain type, for use as sole crop in multiple cropping systems and short rainy seasons.
2. Medium-maturing (75–90 days) nonphotosensitive grain type, for use as sole crop and intercrop.
3. Late-maturing (85–120 days) nonphotosensitive dual-purpose (grain + leaf) types, for use as sole crop and intercrop.
4. Photosensitive early-maturing (70–80 days) grain types, for intercropping.
5. Photosensitive medium-maturing (75–90 days) dual purpose (grain + fodder) types, for intercropping.
6 Photosensitive late-maturing (85–120 days) fodder type, for intercropping.
7. High-yielding, bush-type vegetable varieties.
8. Desirable seed types and seed colors, with high protein content and low cooking time.
9. Resistance to major diseases, insect pests, and parasitic weeds.
10. Tolerance to drought, low pH, and adaptation to sandy soils and low fertility.

Breeding for sole cropping. Cowpea has a great potential for increasing food legume production, if grown as a sole crop. With the advent of input-responsive, high-yielding varieties of wheat, rice, and hybrid varieties of maize and sorghum, the cultivation of food legumes has been marginalized everywhere, causing serious protein malnutrition among populations of the tropics and subtropics who derive the bulk of their dietary protein from food legumes. There is an urgent need, therefore, to enhance food legume production by breeding varieties that fit into existing niches in cereal-based cropping systems.

60–70 day cowpea varieties. The ideal cowpea variety for sole crop was conceived to have erect/semi-erect growth habit, with medium leaves and short basal branches to avoid lodging and 60–70 day crop duration with near synchronous maturity, long peduncles, and pods over the canopy for easy harvesting by manual or mechanical means.

A breeding program to develop extra-early cowpea varieties was initiated in 1979 (Singh 1982), and tests of promising varieties at several locations have led to identification and release of some of these varieties for general cultivation in many countries (Table 1). Most of the varieties developed earlier had seeds with a smooth coat and were, thus, not well accepted in parts of West Africa. Therefore, concerted efforts were made to develop early-maturing cowpea varieties with a range of seed types acceptable to different regions. Performance of selected new varieties ranged from 2 t/ha to 2.8 t/ha (Table 2). These varieties have been distributed to several national programs. Thus, various early-maturing varieties with erect/semi-erect growth habit, which yield > 2 t/ha in 60–69 days are now available. These varieties have opened the possibility of successful sole cropping in areas

Table 1. Extra-early (60–70 day) cowpea varieties released in different countries, as of 1996.

Country	Varieties released/identified for cultivation
Benin Republic	IT82E-32
Bolivia	IT83D-442, IT82D-889
Botswana	ER-7
Colombia	IT83S-841
Cuba	IT84D-449 (Titan), IT84D-666 (Cubinata-666), IT86D-314 (Mulatina-314), IT86D-386 (IITA-Peroz),IT86D-782 (Tropico-782), IT86D-792 (Yarey-792), IT88S-574-3 (OR574-3)
Ghana	IT82E-16, IT83S-728-13, IT83S-818
Guinea	IT85F-867-5
Guyana	ER-7
Liberia	IT82D-889
Mozambique	IT82E-18
Nepal	IT82D-889, IT82D-752
Nigeria	IT84E-124, IT82E-60, IT82D-716, IT84E-1-108, IT84S-2246-4, IT86D-721, IT86D-719, IT90K-76
Philippines	IT82D-889
Sri Lanka	IT82D-789, IT82D-889
Suriname	IT82D-889, IT82D-789
Swaziland	IT82E-18, IT82E-32, IT82E-71
Tanzania	IT82D-889
Thailand	IT82D-889
Uganda	IT82E-60
Yemen	IT82D-789
Zaïre	IT82E-18, IT82E-32
Zimbabwe	IT82D-889

Table 2. Performance of early-maturing varieties at Kano, Nigeria, with 2 sprays of insecticides, 1993.

Variety	Days to maturity	Grain yield (kg/ha)	Seed type
IT87D-879-1	70	2868	white rough
IT86D-1010	71	2750	white blackeye
IT90K-284-2	67	2611	tan smooth
IT87D-829-5	70	2595	white rough
IT86D-719	68	2318	white rough
IT87D-697-2	68	2232	brown rough
IT87D-611-3	68	2221	cream smooth
IT87D-941-1	68	1948	brown rough
Dan 'Ila (local)	79	1657	white rough
LSD (5%)	4	328	

with a short rainy season, double/triple cropping in rice- and/or wheat-based systems, relay cropping in areas with relatively longer rainfall after millet, sorghum, or maize, as well as parallel multiple cropping with cassava, yam, and cotton (Singh 1986, 1987a).

Dry-season cowpeas. Several countries in Asia and Africa have developed irrigation facilities and 'Fadamas' (river beds) with residual moisture, where cowpea can be grown in the dry season (IITA 1984; Parameswaran et al. 1988; Sharanappa et al. 1991; Blade and Singh 1994). Cowpea fits very well as a rotation/alternate crop during the dry season, as it requires a moderate amount of water and matures within 60–80 days.

The major constraints during the dry season are viruses, leaf thrips, nematodes, and aphids. Several cowpea varieties developed at IITA with combined resistance to viruses, thrips, nematodes, aphids, bruchids, and *Striga* were evaluated at Wudil and Kadawa with irrigation and in the Nguru wetland area of Nigeria (with farmer participation) from 1991 to 1994 (Singh 1993; Blade and Singh 1994). As data in Table 3 indicate, these varieties had yields of 1–1.5 t/ha when planted at the end of January. They are harvested near the end of April, when prices of cowpea grain as well as fodder are high. A few selected varieties were again tested in 1993 and 1994. Their grain yields were > 1 t/ha, with fodder yields of 4–10 t/ha (Table 4).

On-farm evaluation of selected varieties, using a farmer participatory approach at several locations in northern Nigeria, confirmed on-station results, and farmers are adopting the cultivation of these improved cowpea varieties in the dry season. It is thus

Table 3. Mean grain yield (kg/ha) of some cowpea varieties at indicated planting dates in the dry season at Wudil and Kadawa, Nigeria.

	Wudil			Kadawa	Reaction to†				
Variety	19-1-91	31-1-91	31-1-92	31-1-92	Ap	Br	Tr	St	Nt
T86D-715	405	1104		–	S	S	R	S	S
IAR-48	573	1042		–	S	S	S	S	S
Local (Dan 'Ila)	1524	1119	398	851	S	S	S	S	S
IT84S-2246-4	1524	1980	1148	1638	R	R	R	S	R
IT86D-719	1146	1269		–	MR	S	R	S	S
IT90K-76	–	–	1776	1570	R	R	R	R	R
IT90K-59	–	–	1518	1148	R	R	R	R	R
IT90K-101	–	–	1033	1705	R	R	R	R	R
IT89K-288	–	–	–	1087	R	R	R	MR	R
IT89KD-374			711	1104	R	S	R	MR	R
LSD (5%)	693	682	378	491					
CV (%)	24	19	27	29					

† Ap = aphid; Br = bruchid; Tr = thrips; St = *Striga;* Nt = nematode; MR = moderately resistant; R = resistant; S = susceptible.

Table 4. Grain and fodder yield of cowpea varieties in the dry season at Kadawa, Nigeria.

	1993		1994	
Variety	Grain (kg/ha)	Fodder (t/ha)	Grain (kg/ha)	Fodder (t/ha)
IT87D-941-1	1773	4.1	1206	10.8
IT84S-2246-4	1293	6.5	925	9.9
IT90K-76	–	–	1009	9.2
Local check (Dan 'Ila)	1495	1.9	333	4.9
LSD (5%)	ns	1.5	443	2.9

expected that dry-season cowpea will gain popularity in Nigeria. Irrigated cowpeas in rice fallows are already popular in Sri Lanka and southern India.

Medium-maturing varieties. Some varieties have been developed which mature in 75–85 days (Singh 1994a). These are suitable for cultivation in areas where a full-season cowpea variety is required to fit the prevalent cropping system, soil type, and rainfall pattern. These varieties combine multiple disease and insect resistance and performed well in the subhumid and semiarid zones (see Table 5 for performance of a few promising varieties). Several varieties yielded 1.5–2 t/ha even at semiarid locations like Gumel (Nigeria) and Maradi (Niger). These varieties, along with others, have been distributed to various national programs.

Table 5. Performance of promising medium-maturing cowpea varieties (with 2 insecticide sprays) at several locations in West Africa, 1993.

Cowpea variety	Grain yield (kg/ha) Kano, Nigeria	Gumel, Nigeria	Maroua, Cameroon	Maradi, Niger	Days to maturity (Kano)	Reaction to† BB	CABMV	Aphid
IT90K-372-1-2	1871	1791	1491	1867	78	R	R	R
IT90K-277-2	2371	1432	1829	1843	75	R	R	R
IT88DM-363	1824	1617	1737	1988	80	R	R	S
IT89KD-374-8	2045	1494	1812	1910	81	R	R	R
IT89KD-374-57	1592	1249	1525	1808	76	R	R	R
IT90K-109	1693	1496	1387	1691	77	R	MS	R
IT89KD-349	943	1059	1358	1746	78	R	R	R
IT88D-867-11	1303	982	1271	1281	80	R	S	R
IT89KD-391	727	565	1054	1095	87	R	R	R
IT88DM-400	287	766	1571	1148	92	MR	MR	S
IT90K-319	409	395	1408	1117	87	MR	MR	R
Dan 'Ila (local)	53	487	1275	955	90	MR	S	S
LSD (5%)	664	462	292	405	2.4			
CV(%)	29	29	15	19	2.8			

† BB = bacterial blight; CABMV = cowpea aphid-borne mosaic virus; R = resistant; MR = moderately resistant; MS = moderately susceptible; S = susceptible.

Bush-type vegetable cowpea. Several countries grow cowpea as a vegetable crop. The most preferred types are the yardlong cowpeas with fleshy tender pods, but these varieties need staking to keep pods from touching the ground and rotting, which involves extra cost and thus restricts the area under cultivation. Bush-type vegetable varieties with 30-cm long succulent pods have been developed, such as IT81D-1228-10, IT81D-1228-14, IT81D-1228-15, and IT86D-880, which yield up to 18 t/ha green pods with 3–4 pickings starting at 45 days after planting. These varieties have semi-erect growth habit with extra-long peduncles (40–50 cm long), protruding well over the canopy and holding the pods above the ground. Picking green pods periodically reduces the weight on peduncles and they remain upright all the time. Frequent picking also stimulates further flowering and podding on the same peduncles, which ensures a continuous supply of green pods for a 6–7 week period after the start of picking, provided soil moisture is not limiting. These varieties have been distributed to several national programs. Some of these varieties have been found promising in China, Nepal, Sri Lanka, Philippines, the West Indies, and Nigeria (Timsina 1989; Tian and Xu 1993).

Breeding cowpea varieties for intercropping. Traditional cowpea is grown as an intercrop because farmers want cereals for home use and cowpea and groundnut as cash crops. Although growing sole crops of improved high-yielding cowpea varieties can be highly profitable when 2–3 sprays of insecticide are applied, the majority of smallholder farmers are unable to adopt such sole cropping; they thus practice intercropping. IITA established a station in 1990 at Kano, in northern Nigeria, to develop cowpea varieties for intercropping without insecticide sprays. One of the predominant systems in northern Nigeria involves millet and cowpea, in which farmers grow two types of cowpea varieties —an early-maturing type for grain, and a late-maturing type for fodder—often in the same field, planted in alternate rows as intercrops in millet and/or sorghum (Singh 1993).

Two approaches are being followed at IITA for developing varieties for intercropping: (1) the improvement of existing local varieties by incorporating resistance to aphid, thrips, bruchid, *Striga*, *Alectra*, and relevant diseases by partial backcrossing; and (2) the development of a range of new varieties with higher yield potential for both grain and fodder under intercropping.

The new breeding lines are evaluated in four systems, so that relative performance of new varieties can be assessed and the best selected for each system (Singh 1993): (1) sole crop, with 2–3 sprays of insecticide; (2) sole crop, without sprays; (3) intercrop with millet, without sprays; and (4) farmer participatory evaluation.

Improved local varieties. A number of selected local cowpea varieties (grown under intercropping) were crossed to an improved early variety, IT84S-2246-4, which has combined resistance to aphid, bruchid, thrips, and several diseases (Singh and Singh 1990). The F_1 plants were backcrossed to the respective local varieties. From the backcross populations, promising lines have been developed which resemble local varieties but combine resistance to aphid, thrips, and, in some cases, bruchids also. The most promising lines are listed below.

IT88D-867-11, derived from the cross IT84S-2246-4 × Jan Wake. It resembles 'Jan Wake', but has resistance to aphid and thrips. Its performance has been very good in the drier regions like Niamey, Maradi, and Gumel, where 'Jan Wake' (TN5-78) comes from. It has been released in Nigeria.

IT89KD-374-57, derived from the cross Dan 'Ila × IT84S-2246-4. It is similar to Dan 'Ila, but combines resistance to aphid and thrips, as well as several diseases, including viruses. Its performance has been very good at several locations in the semiarid region, and it has been released in Nigeria.

IT89KD-319, derived from the cross Kaokin Local × IT84S-2246-4. Resembles Kaokin Local and combines resistance to aphid and thrips and several diseases.

IT89KD-245, derived from the cross IT87F-1772-2 (Kanannado selection) × IT84S-2246-4. Resembles Kanannado but combines resistance to aphid, bruchid, thrips, and matures ~ 2 weeks earlier than Kanannado. It has done well as a dual-purpose variety.

IT89KD-288, derived from the cross IT87F-1772 (Kanannado selection) × IT84S-2246-4. It is as late as Kanannado, combines resistance to aphid, bruchid, and thrips, and yields more fodder and grain than Kanannado. It is becoming popular in the dry season.

Efforts are now under way to incorporate resistance to *Striga* and *Alectra* into these varieties.

New varieties. A number of new varieties for intercropping have been developed combining resistance to several diseases and insects (Singh 1991, 1993, 1994a). When the performance of new varieties was examined in pure crop and in intercrop in 1993 (Table 6), the early- and medium-maturing varieties had as good or higher grain yield potential

Table 6. Yield (kg/ha) of promising early, medium, and late-maturing cowpea varieties, with and without insecticide sprays, in different cropping systems at Kano, Nigeria, 1993.

	Pure crop — (2 sprays) —		Pure crop — (no spray) —		Intercrop — (no spray) —	
	Seed	Fodder	Seed	Fodder	Seed	Fodder
Early-maturing varieties (photo-insensitive)						
IT90K-284-2	2453	–	815	2166	252	595
IT90K-56	1949	–	715	1166	525	838
IT88D-643-1	1780	–	625	1666	241	353
IT89KD-389	1750	–	848	1166	328	434
IT91K-93-10	1628	–	541	1916	408	550
IT90K-59-4	1872	–	883	1250	495	431
IT84S-2246-4	1159	–	594	1000	284	483
LSD (5%)	511		257	ns	201	ns
Medium-maturing varieties (photo-sensitive)						
IT90K-277-2†	2371	–	1082	3250	452	625
IT90K-372-1-2	1871	–	600	1416	211	152
IT88DM-363†	1824	–	366	2500	569	542
IT89KD-374-8	2045	–	539	1583	279	308
IT89KD-374-57	1592	–	461	1083	196	148
IAR 48	1575	–	383	2833	494	681
Dan 'Ila	353§	–	68	1666	307	1484
LSD (5%)	664		316	1498	316	478
Late-maturing varieties (photo-sensitive)						
IT81D-985	1258	4900	470	3300	118	1042
IT89KD-252	630	5800	201	6900	102	833
IT89KD-260	617	5100	104	3100	74	646
IT89KD-288	302	5700	129	3700	19	1250
Kanannado	205	4700	0	3900	55	2083
Borno Local	204	4800	0	4300	0	2292
LSD (5%)	309	2033	450	3326	ns	1319

† Photo-insensitive.
§ Severe virus infection.

than the local varieties in both sole crops and intercrops and with or without sprays. Similar results were also obtained by Blade et al. (1992), using a different set of varieties. While the traditional varieties do not yield as much grain even with good management, they do give higher fodder yield. Thus, there is a need for dual-purpose varieties which will give reasonable grain and fodder yield. IT81D-985 and IT89KD-252 are improved dual-purpose varieties, which have higher grain yield than local varieties and similar fodder yield.

Farmer participatory evaluation. A 200 g seed sample of improved varieties for intercropping was given to selected farmers (one variety to 4–6 farmers) for evaluation. The crop was planted by farmers in their traditional systems, and totally managed by them. However, yield estimates were made by technical staff, using a 10 × 10 m sample plot on each farm. The results varied from field to field, as expected, but some varieties such as IT89KD-374-57, IT89KD-319, and IT88DM-867-11 consistently yielded higher than other test varieties and Dan 'Ila, the local variety (Singh 1993), indicating the adequacy of this method to detect promising varieties for intercropping in farmers' field situations. Farmers are saving the seed of promising varieties and looking forward to more materials each year.

Breeding method for intercropping. In developing improved cowpea varieties for intercropping, should the segregating populations be grown under intercrop or can they be grown and selected in sole crop up to the F_5–F_6 generations before testing under intercropping? Significant positive correlations between sole cropped and intercropped cowpeas have been reported (N'tare 1989; Blade et al. 1992; Ehlers 1994), but the results are not consistent when an insecticide is not applied. An experiment on breeding methodology is in progress at IITA Kano Station to help clarify this issue.

Breeding for disease resistance. Cowpea is attacked by over 35 major diseases caused by viruses, bacteria, fungi, and nematodes (Thottappilly and Rossel 1985; Emechebe and Shoyinka 1985; Mew et al. 1985; Lin and Rios 1985; Patel 1985). The occurrence, severity, and yield loss due to each disease and mixed infections vary from place to place, but some diseases occur and cause significant damage across the cowpea growing regions of the world (see chapters in this volume: Hampton et al. 1997; Emechebe and Florini 1997; Florini 1997). Considerable success has been achieved in breeding for resistance to major diseases.

Viral diseases. Several improved cowpea varieties combining resistances to multiple viruses have been developed at IITA (Singh et al. 1987; Thottappilly et al. 1988) and distributed to various national programs. Cowpea varieties IT82D-889, IT83S-818, IT83D-442, and IT85F-867-5 are resistant to CPMV, CAMV, CGMV, CMV, and SBMV. For a recent review of efforts elsewhere, see Hampton et al. (1997) later in this book.

Bacterial diseases. Two bacterial diseases, bacterial pustule (*Xanthomonas* spp.) and bacterial blight (*Xanthomonas vignicola*), cause severe damage to cowpeas worldwide. Several improved breeding lines have been developed at IITA which combine resistance to these two diseases: notably TVx 1850-01E, IT90K-284-2, IT90K-277-2, IT86D-715, IT86D-719, and IT81D-1228-14 (Singh et al. 1984; Singh 1993).

Fungal diseases. Sources of genetic resistance to several fungal diseases have been reported, and resistant varieties have been developed. These include resistance to anthracnose (N'tare et al. 1984), Cercospora leafspot (Singh et al. 1984), Verticillium wilt (Moore 1974), Phytophthora stem rot (Singh et al. 1984; Bateman et al. 1989), Septoria leaf spot (Abadassi et al. 1987), brown blotch (Abadassi et al. 1987), scab (Abadassi et al. 1987), Uromyces rust (Chen and Heath 1993), and leaf smut (Singh 1993). In all cases, resistance is simply inherited (one or two gene pairs) and easy to breed for. In some cases, such as Fusarium wilt and Phytophthora stem rot, considerable strain variation exists and strain-specific resistance needs to be combined to acquire broad protection. Varieties from the USA, such as 'Iron', have been used extensively as a source of resistance to Fusarium wilt and charcoal rot (Hare and Thompson 1990). Many other sources of resistance were also identified from IITA's world collection of cowpea germplasm (Singh et al. 1984). Using these sources in systematic crossing and evaluation of segregating progenies at sites known to have high levels of these diseases, IITA has developed many varieties which combine resistance to several major diseases (Singh 1993, 1994a).

Nematodes. About 55 species of nematodes have been reported on cowpea (Caveness and Ogunfowora 1985) but the most damaging and widespread species is *Meloidogyne incognita*. Extensive work has been done on developing varieties that are resistant to nematodes in the USA (Fery et al. 1994; Roberts et al. 1997), as well as in Africa (Singh 1993) and Asia (Singh and Reddy 1986). As a single dominant gene controls the resistance of *M. incognita*, it has been possible to develop a number of resistant cowpea varieties. Scientists at IITA have combined resistance to root-knot nematode, aphid, and bruchid in a number of varieties, such as IT84S-2246-4, IT89KD-288, IT90K-59, and IT90K-76 (Singh 1993).

Breeding for insect resistance. At least 85 insect species have been identified which attack cowpea (Booker 1965), but only some of them cause widespread damage (Chalfant 1985; Daoust et al. 1985; Singh 1985; Singh and Jackai 1985). For a review of pest management practices in cowpea, see Jackai et al. (1997), in this volume.

IITA has developed a number of varieties such as IT84S-2246-4 which combine resistance to aphid, thrips, and bruchids (Adjadi et al. 1985; Bata et al. 1987; Singh and Singh 1990; Singh 1993, 1994a). Despite the extensive germplasm screening, effective sources of resistance to *Maruca vitrata* and pod-sucking bugs have not been identified among cultivated varieties of cowpea. Controlling these pests necessitates 2–3 sprays during the flowering and pod development stages. This is a problem for small-scale farmers because insecticides are beyond their reach. Therefore, three mutually compatible approaches are being followed at IITA to develop cowpea varieties which give reasonable grain yield (500–1000 kg/ha) without sprays (Singh 1993). These are as follows:

1. Incorporating the best available level of resistance to aphid, thrips, and bruchid in all of the new breeding lines.

Table 7. Grain yield (kg/ha) of indicated cowpea varieties, without insecticide protection, at different dates of planting at Minjibir, Nigeria, 1993†.

	Date of planting				Reaction to			
Variety	9 Jun	9 Jul	9 Aug	Maturity	Viruses	Aphid	Thrips	Bruchid
IT90K-277-2	1356	1277	318	M	R	R	MR	R
IT88DM-345	340	502	128	EE	R	S	MR	S
ITIT89KD-455	532	921	192	EE	R	S	MR	S
IT89KD-374-57	831	915	346	E	R	R	MR	S
IT90K-59-2	976	891	586	E	R	R	MR	R
IT90K-391	742	616	289	L	R	R	S	R
IT89KD-457	1498	851	304	M	R	R	MR	R
IT84D-666	823	668	271	E	S	S	MR	S
IT90K-261-3	1126	295	414	E	R	R	MR	R
Dan 'Ila (local)	212	0	76	L	S	S	S	S
LSD (5%)	224	219	89					

† EE = extra early, E = early, M = medium, L = late, R = resistant, MR = moderately resistant, S = susceptible.

2. Screening breeding lines, as well as germplasm accessions, to identify those which suffer less damage than others in the field from attacks of *M. vitrata* and pod-sucking bugs, and initiating a recurrent selection program to raise the level of resistance in improved lines.
3. Breeding for extra early-maturing varieties (45–55 days) with vigorous growth and acceptable seed type, which can escape insect damage.

Significant progress is being made on several fronts, and except for the two difficult pests already named, selected breeding lines have shown good field performance without insecticide sprays (Table 7). Some of these lines have been distributed to national programs for further testing.

Breeding for resistance to *Striga* and *Alectra*. Cowpea is attacked by two parasitic weeds, *Striga gesnerioides* [Wild] Vatke and *Alectra vogelii* [Benth.], particularly in the semiarid regions of West and Central Africa. Sources of resistance have been identified and the genetics of resistance to *Striga* and *Alectra* have been studied (Aggarwal 1985, 1991; Singh and Emechebe 1990; Singh et al. 1993; Atokple et al. 1993, 1995). Some improved cowpea varieties with resistance to *Striga*, such as IT88D-867-11, IT90K-59, IT90K-76, and IT90K-82-2, have been developed and distributed to national programs (Singh and Emechebe 1991; Singh 1994b; Berner et al. 1995). A more detailed review is presented later in this volume (Singh and Emechebe 1997).

Pyramiding genes for disease and insect resistance. Systematic work on breeding cowpea varieties for multiple disease and insect resistance was initiated at IITA in 1980, and significant progress has been made (Singh et al. 1984; Singh and Singh 1990; Singh 1993, 1994a). Initially, individual crosses were made involving multiple disease resistant parents, on the one hand, and germplasm lines with thrips, aphid, and bruchid resistance, on the other. By growing 4 generations in a year, it was possible to select F_6 lines with

Table 8. Progress in pyramiding genes for resistance in cowpea†.

Pest/disease factor	Variety: Ife Brown (1973)	TVx 3236 (1978)	IT82D-716 (1982)	IT84S-2246 (1984)	IT90K-59 (1990)	IT90K-76 (1990)
Anthracnose	S	R	R	R	R	R
Cercospora	S	R	R	MR	R	R
Brown blotch	S	R	R	MR	R	R
Bacterial pustule	S	R	R	R	R	R
Bacterial blight	MR	MR	MR	MR	R	MR
Septoria	S	S	S	S	S	S
Scab	S	MR	MR	MR	MR	R
Web blight	S	MR	MR	MR	MR	R
Yellow mosaic	S	S	R	R	R	R
Aphid-borne mosaic	S	S	R	R	R	R
Golden mosaic	R	R	R	R	R	R
Aphid	S	S	S	R	R	R
Thrips	S	MR	MR	MR	MR	R
Bruchid	S	S	R	R	R	R
Striga	S	S	S	S	R	R
Alectra	S	S	S	S	R	R
Nematode	S	S	S	R	R	R

† The earlier variety is one parent of the next variety. See dates in parenthesis after each variety.
R = resistant; MR = moderately resistant; S = susceptible.

disease and insect resistance within 2 years, and recombine them again for another cycle. Several breeding lines have been developed with multiple resistance (Table 8), by segregating backcross populations and combining resistances.

Breeding for drought tolerance. Early-maturing cowpea varieties escape terminal drought (Singh 1987b), but perform poorly if exposed to intermittent drought during the vegetative stages. A simple technique, using wooden boxes, was developed to screen cowpea germplasm lines at the seedling stage, and to test their field performance at a mature stage under conditions of water deficit (Singh 1993). This work was expanded, in collaboration with the Japan International Research Center for Agricultural Sciences (JIRCAS), at the IITA Kano Station. Significant progress has been made and TVu 11979, TVu 11986, TVu 12349, Dan 'Ila, and IT90k-59-2 have been identified to be drought tolerant (Watanabe et al. 1997). The drought-tolerant lines are of two types: (1) lines such as TVu 11979 and TVu 11986 stop growth as soon as drought stress is imposed, probably to conserve moisture and survive for 2–3 weeks; whereas (2) Dan 'Ila and IT90K-59-2 mobilize moisture from lower leaves and remain alive for a longer time, while the lower leaves die one by one. Consequently, these varieties have a better regeneration potential than others. Genetic studies are in progress and suitable crosses have been made to incorporate these traits in improved varieties. The use of carbon isotope discrimination method (see Hall et al. 1997 in this volume, and other references cited therein) and assessment of other physiological parameters are too expensive for use in a breeding program. The wooden box technique is more appropriate for breeding programs in developing countries. Efforts are also being made to combine deep root systems with drought tolerance, to enhance adaptation of cowpeas to low rainfall areas (Singh 1993).

Breeding for seed type, nutritional quality, and short cooking time. Efforts are also being made to develop varieties with a range of seed types with high protein content and short cooking time. Improved lines showed significant genetic variability for these traits (Omueti and Singh 1987; Baker et al. 1989; Nielsen et al. 1993). Among 100 lines evaluated, protein content ranged from 22.9% to 32.5% and cooking time from 21.1 min to 61.9 min, indicating the possibility of enhancing protein content and shortening cooking time by genetic improvement. Seed color was not correlated with protein content or cooking time, but seeds with rough coat cooked faster than seeds with smooth coat.

Regional and national programs in Africa

Burkina Faso, Cameroon, Ghana, Nigeria, Niger Republic, and Senegal in West and Central Africa, and Botswana, Kenya, Mozambique, Tanzania, and Zambia in East and southern Africa have active cowpea improvement programs. Regional programs such as Semi-Arid Food Grains Research and Development Project (SAFGRAD), Bean/Cowpea Collaborative Research Support Program (CRSP), and the Southern Africa Development Community (SADC) have strengthened cowpea research, training, and development activities in several countries. However, the major focus of cowpea research in these countries is to develop varieties for sole cropping. Using improved materials from IITA, with those from national programs, several varieties have been released in West Africa: IAR-48, IT84S-2246-4, IT86D-719, IT86D-721, IT90K-76, IT89KD-374, and IT89KD-867-11 in Nigeria; Mouride and Melakh in Senegal; IT82E-16 (Asantem), IT83S-818 (Bengpla), and IT83S-728-13 (Ayiyi) in Ghana; IT81D-985 (BR-1), IT81D-994 (BR-2), and IT90K-277-2 in Cameroon; TN5-78, TN88-63, TN-27-80 in Niger Republic; IT85F-867-5 (Pkoku Togboi) in Guinea; and IT82E-32, IT81D-1137 in Benin Republic.

The traditional varieties in East and southern Africa are grown as intercrops or as sole crops for leaves as well as grain (dual purpose), and they are medium- and late-maturing. However, the more recent focus has been to develop early-maturing grain-type varieties with virus resistance. One such variety, IT82D-889, has done very well and has been released for cultivation in several countries, such as Tanzania (Vuli-1), Zambia, Zimbabwe, and Swaziland (Untilane) (Mligo 1989; Natarajan and Naik 1992). The SADC/EEC/IITA Cowpea Project has organized regional breeding and testing programs involving 10 countries of southern Africa, in order to develop cowpea varieties suitable for sole cropping and intercropping, as well as dual purpose varieties.

United States and Latin American programs

United States of America. Cowpea breeding in the United States of America has enjoyed more progress in this decade. There are 11 plant breeders in public breeding programs, 6 in public institutions, and at least 3 in private companies working on cowpea in the USA. Much work is being done at the University of California, Riverside, on breeding for heat and drought tolerance (Hall 1990; Marfo and Hall 1992). The potential of cowpea as an intercrop with citrus has been shown in southern Florida (Stoffella et al. 1986), but no efforts are being made in the USA to develop varieties for intercropping.

Cowpea breeders in the USA have released about 23 improved varieties over the past 10 years (Fery and Dukes 1988; Hare and Thompson 1988; Morelock et al. 1989; Fery and Dukes 1990a,b,c; Helms et al. 1991a,b; Fery and Dukes 1992; Morelock et al. 1992; Fery and Dukes 1993). The characteristics of these varieties, most of which are "horticultural" types rather than grain types, reflect the effort of breeders to serve the three segments of the industry: dry seed, vegetable, and processors (both canning and freezing). Most varieties released have resistance to one or more diseases, and four of them have resistance to cowpea curculio, the major insect pest in southern USA.

The discovery of a new gene for persistent green seed due to green cotyledon, *gc*, non-allelic to the gene for green testa, *gt*, represents a significant improvement in consumer appeal of the frozen product. The incorporation of these genes into currently popular horticultural types, especially for the frozen food trade, and for the fresh market as well, is expected to have an impact on varieties being developed for freezer/packers, and eventually also for dry packers.

Breeding for resistance to mosaic viruses, Fusarium wilt, and root-knot nematodes are major objectives. The release of 'Mississippi Pinkeye' marked the culmination of a long and successful breeding program at Mississippi State University, which resulted in improved varieties of the major horticultural types; blackeyes, crowders, creams, and pinkeyes, all of which have resistance to the three known races of *Fusarium oxysporum*, three root-knot nematode species (*Meloidogyne incognita*, *M. javanica*, and *M. arenaria*), and tolerance or resistance to mosaic viruses.

The only known releases made in the USA with resistance to insect pests are those with resistance to cowpea curculio, the most serious pest of cowpea in southeastern USA. Four recently released varieties are resistant to cowpea curculio, using as the source of resistance, Ala. 963.8 and/or its derivatives, CR 17-1-13, CR 18-13-1, and CR22-2-21. Curculio resistant varieties are AUBe, Bettergreen, Bettergro, and Carolina Cream. They have pod characteristics which interfere with the ability of the adult insects to damage the seed in the process of feeding and oviposition or they are less attractive to adult curculios, resulting in reduced seed damage.

The National Aeronautical and Space Agency (NASA) of the USA is funding a project at Purdue University to select suitable crop species and varieties for cultivation by 'future space colonies'. The studies have shown that cowpea is a good candidate crop (Ohler 1994). Two varieties from IITA, IT84E-124 and IT87D-941-1, both erect and early-maturing, have shown great promise from the standpoint of dry-matter production, protein content, and a versatility of uses.

Latin America. Cowpea is widely cultivated in Latin America, and a number of countries such as Brazil, Colombia, Guyana, Jamaica, Nicaragua, Panama, Trinidad, and Venezuela have made varietal releases. Brazil has about 1.9 million hectares under cowpea production, and since 1984 it has released seven improved varieties. The major production constraints in the region are drought and diseases, particularly the viruses (Watt et al. 1985). Cowpea is grown both as a sole crop (Ferreira and Silva 1987) and as an intercrop with maize and cotton (Beltroa et al. 1986). Except for Brazil, most countries in the region do not have comprehensive breeding programs, but they evaluate materials from IITA, as well as from USA and other sources, to select varieties. A number of varieties have been found promising from such evaluations in Belize (VITA-3), Brazil (VITA-7), Colombia (IT83S-841), Costa Rica (VITA-1, VITA-3, VITA-6), El Savador (VITA-3, VITA-5), Guyana (VITA-3), Guatemala (VITA-3), Haiti (VITA-3, IT87D-885), Jamaica (VITA-3, ER-7), Nicaragua (VITA-3), Panama (VITA-3), Peru (VITA-7), Surinam (IT82D-889, IT82D-789), and Venezuela (VITA-3). Cuba has identified several lines from IITA (Table 1) which are suitable for sole cropping and intercropping under sugarcane-based systems as a substitute for *Phaseolus* beans.

Asian programs

Half of about 1.3 million hectares under different forms of cowpea in Asia are in India alone. Other important cowpea growing countries include Pakistan, Nepal, Bangladesh, Sri Lanka, Myanmar, Malaysia, Thailand, Indonesia, Philippines, and China (Van der Massen and Somaatmadja 1990).

Cowpea is very important, but it is a minor legume in the cropping systems under which it is grown. In India, the largest country of the region, accurate data on cowpea area and production are not available. Sharma and Joshi (1993) have presented a good review of cowpea research in India, which has a comprehensive cowpea breeding program with a major emphasis on fodder type (Pal 1988; Kohli 1990; Lodhi et al. 1990; Sharma and Singhania 1992). However, sole cropping in arid regions, and in rice fallows, and in the spring/summer season is now becoming popular (Henry and Daulay 1988; Parameswaran et al. 1988). Several early- and medium-maturing varieties such as 'Amba', 'Rambha', and 'Shveta' have been developed, and are used for both green pods and dry grains.

The cowpea variety development programs in India aimed at transferring disease resistance, better grain quality, or earliness but paid less attention to developing an efficient plant type for intensive cultivation. Some varieties, such as V 16 (Amba) and V 38, were semi-spreading. V 38 has long peduncles and the pods are held above the crop canopy. The truly upright nontrailing varieties are still not available in Southeast Asia. However, a number of extra-early maturing varieties from IITA have shown great promise (Verma and Mishra 1989; Thiyagrajan et al. 1989). Several countries in Asia have identified promising grain-type varieties from IITA and released them for general cultivation: VITA-4 (Yezin 1) in India, Myanmar, and Pakistan; IT82D-889 (Prakash) and IT82D-752 (Aakash) in Nepal; IT82D-889 in Philippines and Thailand; and IT82D-789 (Wijaya) and IT82D-889 (Waruni) in Sri Lanka. Vegetable cowpeas, both yardlong and bush types, are most important in China, Indonesia, Korea, and the Philippines and several new varieties have been developed (Sunarjono et al. 1989; Zhang 1991; Tian and Xu 1993).

Conclusions and looking ahead

Thus, significant progress has been made in cowpea breeding in the past decade. Breeding for multiple disease and insect resistance, with acceptable seed quality, initiated in the early 1980s, has progressed well and should continue to be the major focus. IITA's decision in the late 1980s to include breeding for intercropping was timely and relevant to the needs of smallholder farmers in West and Central Africa. Advances in breeding for resistance to *Striga gesnerioides* and *Alectra vogelii* will have a major impact on cowpea cultivation in the dry savanna. Also, the current focus on developing varieties with differing plant type and maturity periods will enable the intensification of cropping systems in the tropics. Pyramiding genes for resistance to aphid, bruchid, thrips, and *Striga*, as well as field resistance to *Maruca* pod borer and pod bugs, should be pursued, so as to minimize or eliminate the need for insecticide protection. Cowpea breeders should also seek to increase the genetic potential of the plant for higher grain and fodder yield, to enhance the role of cowpea in sustainable (crop/livestock) farming systems in the tropics.

References

Abadassi, J.A., B.B. Singh, T.A.O. Ladeinde, S.A. Shoyinka, and A.M. Emechebe. 1987. Inheritance of resistance to brown blotch, *Septoria* leaf spot and scab in cowpea (*Vigna unguiculata* [L.] Walp.) India Journal of Genetics 47: 299–303.

Adjadi, O., B.B. Singh, and S.R. Singh. 1985. Inheritance of bruchid resistance in cowpea. Crop Science 25: 740–742.

Aggarwal, V.D. 1985. Cowpea *Striga* research. Pages 335–340 *in* Cowpea research, production and utilization, edited by S.R. Singh and K.O. Rachie. John Wiley and Sons, Chichester, UK.

Aggarwal, V.D. 1991. Research on cowpea *Striga* resistance at IITA. Pages 90–95 *in* Combating *Striga* in Africa, edited by S.K. Kim. IITA, Ibadan, Nigeria.

Akundabweni, L.S., C. Peter-Paul, and B.B. Singh. 1990. Evaluation of elite lines of cowpea (*Vigna unguiculata* [L.] Walp.) for leaf/fodder plus grain (i.e., dual-purpose). Tropical Agriculture 67(2): 133–136.

Atokple, I.D.K., B.B. Singh, and A.M. Emechebe. 1993. Independent inheritance of *Striga* and *Alectra* resistance in cowpea genotype B301. Crop Science 33: 714–715.

Atokple, I.D.K., B.B. Singh, and A.M. Emechebe 1995. Genetics of resistance to *Striga* and *Alectra* in cowpea. Journal of Heredity 86: 45–49.

Baker, T. A., S.S. Nielsen, R.E., Shade, and B.B. Singh. 1989. Physical and chemical attributes of cowpea lines resistant and susceptible to *Callosobruchus maculatus* [F.]. Journal of Stored Products Research 25: 1–8.

Barrett, R.P. 1987. Integrating leaf and seed production strategies for cowpea (*Vigna unguiculata* [L.] Walp.). MS thesis, Michigan State University, East Lansing, MI, USA.

Bata, H.D., B.B. Singh, S.R.Singh, and T.A.O. Ladeinde 1987. Inheritance of resistance to aphid in cowpea. Crop Science 27: 892–894.

Bateman, K.S., J.M. Hinch, J.E. Ralton, A.E. Clarke, J.A. McKenzie, B.C. Imrie, and B.J. Howlett. 1989. Inheritance of resistance of cowpea to *Phytophthora vignae* in whole plants cuttings and stem callus cultures. Australian Journal of Botany 37: 511–517.

Beltroa, N.E. M. de, J.C.F. de Santana, J.R. Crisos-Tomo, J.P.P. de Araujo, and R.P. de Sousa. 1986. Evaluation of cowpea cultivars under intercropping system with annual cotton. Pesquisa Agropecuária Brasileira 21(11): 1147–1153.

Berner D.K., J.G. Kling, and B.B. Singh. 1995. *Striga* research and control: a perspective from Africa. Plant Disease 79: 652–660.

Blade, S.F., and B.B. Singh. 1994. Providing options: improving dry season cowpea production in northern Nigeria. Agronomy Abstracts (1994): 75.

Blade, S.F., D.E. Mather, B.B. Singh, and D.L. Smith 1992. Evaluation of yield stability of cowpea under sole and intercrop management in Nigeria. Euphytica 61: 193–201.

Booker, R.H. 1965. Pests of cowpeas and their control in northern Nigeria. Bulletin of Entomological Research 55: 663–672.

Caveness, F.E., and A.O. Ogunfowora. 1985. Nematological studies worldwide. Pages 273–285 *in* Cowpea research, production and utilization, edited by S.R. Singh and K.O. Rachie. John Wiley and Sons, Chichester, UK.

Chalfant, R.B. 1985. Entomological research on cowpea pests in the USA. Pages 265–271 *in* Cowpea research, production and utilization, edited by S.R. Singh and K.O. Rachie. John Wiley and Sons, Chichester, UK.

Chen, C.Y., and M.C. Health 1993. Inheritance of resistance to *Uromyces vignae* in cowpea and correlation between resistance and sensitivity to a cultivar-specific elicitor of necrosis. Phytopathology 83: 224–230.

Daoust, R.A., D.W. Roberts, and B.P. das Neves. 1985. Distribution, biology and control of cowpea pests in Latin America. Pages 249–264 *in* Cowpea research, production and utilization, edited by S.R. Singh and K.O. Rachie. John Wiley and Sons, Chichester, UK.

Ehlers, J.D. 1994. Correlation of performance of sole crop and intercrop cowpeas with and without protection from insect pests. Field Crops Research 36: 133–143.

Emechebe, A.M., and D.A. Florini. 1997. Shoot and pod diseases of cowpea induced by fungi and bacteria. Pages 176–192 *in* Advances in cowpea research, edited by B.B. Singh, D.R. Mohan Raj, K.E. Dashiell, and L.E.N. Jackai. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria.

Emechebe, A.M., and S.A. Shoyinka. 1985. Fungal and bacterial diseases of cowpea in Africa. Pages 173–192 *in* Cowpea research, production and utilization, edited by S.R. Singh and K.O. Rachie. John Wiley and Sons, Chichester, UK.

Ferreira, J.M., and P.S.L.E. Silva. 1987. 'Green bean' yield and other characteristics of cowpea cultivars. Pesquisa Agropecuária Brasileira 22(1): 55–59

Fery, R.L. 1985. Improved cowpea cultivars for the horticultural industry in the USA. Pages 129–136 *in* Cowpea research, production and utilization, edited by S.R. Singh and K.O. Rachie. John Wiley and Sons, Chichester, UK.

Fery, R.L. 1990. The cowpea: production, utilization, and research in the United States. Horticultural Reviews 12: 197–222.

Fery, R.L., and P.D. Dukes. 1988. 'Kiawah' southernpea. HortScience 23: 645–646.

Fery, R.L., and P.D. Dukes. 1990a. 'Santee Early Pinkeye' southernpea. HortScience 35: 990–991.

Fery, R.L., and P.D. Dukes. 1990b. Registration of US-432 cowpea (southernpea) germplasm. Crop Science 30: 428.

Fery, R.L., and P.D. Dukes. 1990c. 'Santee Early Pinkeye' southernpea. HortScience 25: 990–991.

Fery, R.L., and P.D. Dukes. 1992. 'Carolina Crowder' southernpea. HortScience 27: 1335–1337.

Fery, R.L., and P.D. Dukes. 1993. 'Bettergro Blackeye' southernpea. HortScience 28: 62–63.

Fery, R.L., and P.D. Dukes, and J.A. Thies. 1994. Characterization of new sources of resistance in cowpea to the southern root-knot nematode. HortScience 29: 678–679.

Florini, D.A. 1997. Nematodes and other soilborne pathogens of cowpea. Pages 193–206 *in* Advances in cowpea research, edited by B.B. Singh, D.R. Mohan Raj, K.E. Dashiell, and L.E.N. Jackai. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria.

Hadjichristodoulou, A. 1991a. Evaluation of cowpea (*V. unguiculata*) lines for dry seeds. Technology Bulletin No. 134, Cyprus Agricultural Institute, Nicosia, Cyprus. 8 pp.

Hadjichristodoulou, A. 1991b. Evaluation of vegetable cowpea (*Vigna unguiculata* [L.]. Walp.) varieties. Technology Bulletin No. 128. Cyprus Agricultural Institute, Nicosia, Cyprus. 8 pp.

Hampton, R.O., G. Thottappilly, and H.W. Rossel. 1997. Viral diseases of cowpea and their control by resistance-conferring genes. Pages 159–175 *in* Advances in cowpea research, edited by B.B. Singh, D.R. Mohan Raj, K.E. Dashiell, and L.E.N. Jackai. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria.

Hall, A.E. 1990. Breeding for heat tolerance—an approach based on whole-plant physiology. HortScience 25: 17–19.

Hall, A.E., S. Thiaw, A.M. Ismail, and J.D. Ehlers. 1997. Water-use efficiency and drought adaptation of cowpea. Pages 87–98 *in* Advances in cowpea research, edited by B.B. Singh, D.R. Mohan Raj, K.E. Dashiell, and L.E.N. Jackai. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria.

Hare, W.W., and P.G. Thompson. 1988. Mississippi Pinkeye—a new protepea. Research Report, Mississippi Agricultural and Forestry Experiment Station 11: 4.

Hare, W.W., and P.G. Thompson. 1990. Progress in breeding cowpea for multiple disease resistance. Pages 24–31 *in* Cowpea research: a US perspective, edited by J.C. Miller, J.P. Miller, and R.L. Fery. MP 1639. Texas Agricultural Experiment Station, College Station, TX, USA.

Heij, G. 1987. Experiences in research with yard long bean: a crop with prospects (in Netherlands). Groenten en Fruit 42: 44–45.

Helms, D., L. Panella, I.W. Buddenhagen, C.L. Tucker, and P.L. Gepts. 1991a. Registration of 'California Blackeye 46' cowpea. Crop Science 31(6): 1703.

Helms, D., L. Panella, I.W. Buddenhagen, C.L. Tucker, K.W. Foster, and P.L. Gepts. 1991b. Registration of 'California Blackeye 88' cowpea. Crop Science 31(6): 1703–1704.

Henry, A., and H.S. Daulay. 1988. Grow cowpea variety 'Charodi-I' in arid regions. Indian Farming 38(3): 9–10.

IITA (International Institute of Tropical Agriculture). 1984. Dry season cowpea. Page 191 *in* Annual Report 1983. IITA, Ibadan Nigeria.

Jackai, L.E.N., and C.B. Adalla. 1997. Pest management practices in cowpea: a review. Pages 240–258 *in* Advances in cowpea research, edited by B.B. Singh, D.R. Mohan Raj, K.E. Dashiell, and L.E.N. Jackai. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria.

Kohli, K.S. 1990. "Kohinoor"—a nutritious fodder cowpea for animals. Indian Farming 39: 15–29.

Lin, M.T., and G.P. Rios. 1985. Cowpea diseases and their prevalence in Latin America. Pages 199–204 *in* Cowpea research, production and utilization, edited by S.R. Singh and K.O. Rachie. John Wiley and Sons, Chichester, UK.

Lodhi, G.P., K.S. Boora, S. Jain, and Balchand. 1990. Heterosis for fodder yield and quality characters in cowpea (*Vigna unguiculata* [L.] Walp). Crop Research (Hisar): 66–73.

Marfo, K.O., and A.E. Hall. 1992. Inheritance of heat tolerance during pod set in cowpea. Crop Science 32: 912–918.

Mew, T.W., F.A. Elazegui, and Y.P.S. Rathi 1985. Cowpea diseases in tropical Asia and control in rice based-cropping systems. Pages 193–197 in Cowpea research, production and utilization, edited by S.R. Singh and K.O. Rachie. John Wiley and Sons, Chichester, UK.

Mishra, S.N., J.S. Verma, and S.J.B.A. Jayasekara. 1985. Breeding cowpea to suit Asian cropping systems and consumer tastes. Pages 117–123 *in* Cowpea research, production and utilization, edited by S.R. Singh and K.O. Rachie. John Wiley and Sons, Chichester, UK.

Mligo, J.K. 1989. VULI-1, an extra-early maturing cowpea variety for Tanzania. Tropical Grain Legume Bulletin 36: 39–40.

Moore, W.F. 1974. Studies on techniques of hybridization and inheritance to Verticillium wilt in protepea (cowpea). PhD thesis, Mississippi State University, MS, USA.

Morelock, T.E., J.L. Bowers, D.R. Davis, W.A. Sistrunk, and D. Motes. 1989. 'Encore' southernpea. HortScience 24 (2): 401–402.

Morelock, T.E., J.L. Bowers, D.R. Davis, and D.R. Motes. 1992. 'Early Acre' a new southernpea for Arkansas. Arkansas Farm Research 41(3): 6–7.

Nandanwar, R.S., and A.N. Patil. 1990. Phenotypic stability analysis in fodder cowpea. Annals of Plant Physiology 4: 254–256.

Natarajan M., and D.M. Naik. 1992. Competitive effects of a short duration, bush type cowpea when intercropped with cotton in Zimbabwe. Experimental Agriculture 28: 409–416.

Nielsen, S.S., W.E. Brandt, and B.B. Singh. 1993. Genetic variability for nutritional composition and cooking time of improved cowpea lines. Crop Science 33: 469–472.

N'tare, B.R. 1989. Evaluation of cowpea cultivars for intercropping with pearl millet in the Sahelian zone of West Africa. Field Crops Research 20: 31–40.

N'tare B.R., B.B. Singh, S.A. Shoyinka, and C.A. Soglo. 1984. Disease resistance: fungal and bacterial diseases. Pages 72–73 *in* IITA Annual Report 1983. IITA, Ibadan, Nigeria.

Ohler, T.A. 1994. Evaluation of cowpea (*Vigna unguiculata* [L.] Walp.) as a candidate species for inclusion in controlled ecological life support systems. MS thesis. Purdue University, IN, USA.

Omueti, O., and B.B. Singh. 1987. Nutritional attributes of improved varieties of cowpea (*Vigna unguiculata* [L.] Walp.). Human Nutrition: Food Sciences and Nutrition 41F: 103–112.

Pal, R.N. 1988. Performance of fodder cowpea varieties in south Andaman. Journal of the Andaman Science Association 4: 83–84.

Parameswaran, N.S., K.A.L. Channamma, and P.S. Herle. 1988. Identification of suitable variety for rabi cowpea cultivation in Coastal Karnataka. Current Research, University of Agricultural Science, Bangalore 17(4): 46–47.

Patel P.N. 1985. Fungal, bacterial and viral diseases of cowpeas in the USA. Pages 205–213 *in* Cowpea research, production and utilization, edited by S.R. Singh and K.O. Rachie. John Wiley and Sons, Chichester, UK.

Paul, C.P., B.B. Singh, and C.A. Fatokun. 1988. Performance of dual purpose cowpea varieties. Tropical Grain Legume Bulletin 35: 28–31.

Perrino, P., T. Shagarodsky, M. Esquivel, H. Uranga, and K. Hammer. 1992. The cultivated races of *Vigna* Savi in Cuba. Feddes Repertorium 103: 509–514.

Perrino, P., G. Laghetti, P.L.S. Zeuli, and L.M. Monti. 1993. Diversification of cowpea in the Mediterranean and other centres of cultivation. Genetic Resources and Crop Evolution 40: 121–132.

Roberts, P.A. J.D. Ehlers, A.E. Hall, and W.C. Matthews. 1997. Characterization of new resistance to root-knot nematodes in cowpea. Pages 207–214 *in* Advances in cowpea research, edited by B.B. Singh, D.R. Mohan Raj, K.E. Dashiell, and L.E.N. Jackai. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria.

Sharanappa, C. Somashekar, C.K. Balachandra, and K.P. Chandrashekar. 1991. Cowpea (*Vigna unguiculata* [L.] Walp.) genotypes in rice fallows for hill zone. Current Research, University of Agricultural Sciences, Bangalore 20: 78–79.

Sharma, P.P., and A.K. Joshi. 1993. Improvement of cowpea. Advances in Horticulture: Vegetable Crops 5: 255–276.

Sharma, C.D., and D.L. Singhania. 1992. Performance of cowpea (*Vigna unguiculata* [L.] Walp.) genotypes for fodder traits. Annals of Arid Zone 31: 65–66.

Silva, G.S. da. 1990. Resistance of yard-long bean (*Vigna sesquipedalis* [L.] Fruwirth) to *Meloidogyne incognita* races 1 and 2. Nematologia Brasileira 14: 131–137.

Singh, B.B. 1982. Sixty-day cowpea varieties. Agronomy Abstracts (1982): 83.

Singh, B.B. 1986. Potential for intensive cropping in the tropics by using '60-day' cowpea varieties. Agronomy Abstracts (1986): 44.

Singh, B.B. 1987a. '60-day' cowpea varieties for Asian Farming Systems. Page 223 *in* Food legume improvement for Asian farming systems, edited by E.S. Wallis and D.E. Byth. Proceedings No. 18, Australian Council for International Agricultural Research (ACIAR), Canberra, Australia.

Singh, B.B. 1987b. Breeding cowpea varieties for drought escape. Pages 299–306 *in* Food grain production in semi-arid Africa, edited by J.M. Menyonga, T. Bezuneh, and A. Youdeowei. OUA/STRC-SAFGRAD, Ouagadougou, Burkina Faso.

Singh, B.B. 1991. Improving cowpea varieties for traditional intercropping systems of West African savanna. Agronomy Abstracts (1991): 66.

Singh, B.B. 1993. Cowpea breeding. Pages 10–53 *in* Archival report (1988–1992) of Grain Legume Improvement Program. IITA, Ibadan, Nigeria.

Singh B.B. 1994a. Breeding suitable cowpea varieties for West and Central African savanna. Pages 77–85 *in* Progress in food grain research and production in semiarid Africa, edited by J.M. Menyonga, T.B. Bezuneh, J.Y. Yayock, and I. Soumana. OAU/STRC-SAFGRAD, Ouagadougou, Burkina Faso.

Singh, B.B. 1994b. Collection and utilization of germplasm of cowpea resistant to *Striga* and *Alectra.* Pages 135–143 *in* Plant genetic resource management in the tropics. JIRCAS International Symposium 2. Japan International Research Center for Agricultural Sciences, Tsukuba, Japan.

Singh, S.R. 1985. Insects damaging cowpeas in Asia. Pages 245–248 *in* Cowpea research, production and utilization, edited by S.R. Singh and K.O. Rachie. John Wiley and Sons, Chichester, UK.

Singh, B.B., and A.M. Emechebe 1990. Genetics of *Striga* resistance in cowpea genotype B301. Crop Science 30: 879–881.

Singh, B.B., and A.M. Emechebe. 1991. Breeding for resistance to *Striga* and *Alectra* in cowpea. Pages 303–305 *in* Proceedings, 5th International Symposium on Parasitic Weeds, 24–30 Jun 1991, Nairobi, Kenya, edited by J.K. Ransom, L.J., Musselman, A.D. Worsham, and C. Parker. The International Maize and Wheat Improvement Center (CIMMYT), Mexico, D.F. Mexico.

Singh, B.B., and A.M. Emechebe. 1997. Advances in research on cowpea *Striga* and *Alectra.* Pages 215–224 *in* Advances in cowpea research, edited by B.B. Singh, D.R. Mohan Raj, K.E. Dashiell, and L.E.N. Jackai. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria.

Singh, B.B., and B.R. N'tare 1985. Development of improved cowpea varieties in Africa. Pages 105–115 *in* Cowpea research, production and utilization, edited by S.R. Singh and K.O. Rachie. John Wiley and Sons, Chichester, UK.

Singh, B.B., and B. Sharma. 1996. Restructuring cowpea for higher yield. Indian Journal of Genetics 56: 389–405.

Singh, B.B., and S.R. Singh 1990. Breeding for bruchid resistance in cowpea. Pages 219–228 *in* Bruchids and legumes: economics, ecology, and coevolution, edited by K. Fujii, A.M.R. Gatehouse, C.D. Johnson, R. Mitchel, and T. Yoshida. Kluwer Academic Publishers, Dordrecht, Netherlands.

Singh, D.B., and P.P. Reddy. 1986. Inheritance of resistance to root-knot nematode in cowpea. Indian Journal of Nematology 16: 284–285.

Singh, S.R., and L.E.N. Jackai. 1985. Insect pests of cowpea in Africa: their life cycle, economic importance and potential for control. Pages 217–231 *in* Cowpea research, production and utilization, edited by S.R. Singh and K.O. Rachie. John Wiley and Sons, Chichester, UK.

Singh, B.B., S.R. Singh, and L.E.N. Jackai. 1984. Cowpea breeding for disease and insect resistance. Pages 139–152 *in* Breeding for durable disease and pest resistance. FAO Plant Production and Protection Paper No. 55. FAO, Rome, Italy.

Singh, B.B., G. Thottappilly, and H.W. Rossel. 1987. Breeding for multiple virus resistance in cowpea. Agronomy Abstracts (1987): 79.

Singh, B.B., A.M. Emechebe, and I.D.K. Atokple. 1993. Inheritance of *Alectra* resistance in cowpea genotype B 301. Crop Science 33: 70–72.

Stoffella, P.J., R.R. Pelosi, and B.J. Williams. 1986. Potential of citrus-cowpea intercropping in South Florida. Proceedings, Interamerican Society for Tropical Horticulture 30: 165–170.

Sunarjono, H., H. Darliah, and R.P. Sundamo. 1989. Yield trial of dwarf asparagus bean in several lowland areas. Bulletin Penelitian Horticultura 17: 1–7.

Tarawali, S.A., B.B. Singh, M. Peters, and S.F. Blade. 1997. Cowpea haulms as fodder. Pages 313–325 *in* Advances in cowpea research, edited by B.B. Singh, D.R. Mohan Raj, K.E. Dashiell, and L.E.N. Jackai. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria.

Tian, M.H., and Y. Xu. 1993. New type of vegetable legume vineless cowpea. Bush type for USA: high yield and high quality. Crop Genetic Resources 1: 33.

Thiyagarajan, K., C. Natarajan, and R. Rathnaswamy. 1989. Variability in Nigerian cowpeas. Madras Agricultural Journal 76: 719–720.

Thottappilly, G., and H.W. Rossel. 1985. Worldwide occurrence and distribution of virus diseases. Pages 155–171 *in* Cowpea research, production and utilization, edited by S.R. Singh and K.O. Rachie. John Wiley and Sons, Chichester, UK.

Thottappilly, G., H.W. Rossel, and B.B. Singh. 1988. Virus diseases of cowpea in Nigeria and development of multiple virus resistant cowpea lines. Page 383 *in* Proceedings, 5th International Congress of Plant Pathology, 20–27 Aug 1988, Kyoto, Japan.

Timsina, J. 1989. Performance of grain and vegetable type cowpea under upland conditions at Chitwan, Nepal. Tropical Grain Legume Bulletin 36: 4–6.

Van der Massen, L.J.G., and S. Somaatmadja. 1990. Plant resources of southeast Asia. No. 1. Pages 77–81 *in* Pulses. University of Wageningen, Netherlands.

Verma, J.S., and S.N. Mishra. 1989. Evaluation of improved cowpea lines from IITA in humid-subtropical India. Tropical Grain Legume Bulletin 36: 38–39.

Watanabe, I., S. Hakoyama, T. Terao, and B.B. Singh. 1997. Evaluation methods for drought tolerance of cowpea. Pages 141–146 *in* Advances in cowpea research, edited by B.B. Singh, D.R. Mohan Raj, K.E. Dashiell, and L.E.N. Jackai. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria.

Watt, E.E., E.A. Kueneman, and J.P.P. de Araujo. 1985. Achievements in breeding cowpea in Latin America. Pages 125–135 *in* Cowpea research, production and utilization, edited by S.R. Singh and K.O. Rachie. John Wiley and Sons, Chichester, UK.

Zhang, W.Z. 1991. New long cowpea variety Qiou Jiang 512. Bulletin of Agricultural Science and Technology 6: 35.