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Cowpea Breeding

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Introduction

Inroduction

Cowpea (Vigna unguiculata L. Walp.) (2n=2x=22) belongs to the Leguminosae family. It is an important legume crop due to its dual application for food and feed.

Objectives

- Familiarize students with Cowpea crop, breeding institution working on it, classification on system, adaptation and usage, production constraints and breeding method used to develop pureline cowpea cultivars
- Learn step by step procedure using CB-27 cowpea cultivar as an example

Origin, Domestication and Diversification

Cowpea is native to and was domesticated in southern Africa and later spread to East and West Africa and Asia. The wild relatives of cowpea are found all over Africa.

Domesticated cowpea has been classified into five cultivar groups (cultigroups) (Baudoin and Marechal, 1985) as shown below.

1. Unguiculata (seed testa thick and shiny) - This is a major group.
2. Textilis (long inflorescence peduncle) - Mostly found in West Africa
3. Sesquipedalis (fleshy pod, wrinkled when ripe) - Mainly found in East Africa
4. Melanophthalmus (seed testa thin & often wrinkled, flower & seed partly white) –Originated in West Africa
5. Biflora (seed testa thick and shiny, flower and seed most often colored) - Grown in South East Asia

Biology of the Crop

General Characteristics

General Characteristics and Development of the Crop

Cowpea is a warm-season, annual, herbaceous and similar in appearance to common bean (Phaseolus vulgaris L.) except that the leaves are generally darker green, shinier and rarely pubescent. It has twining stems varying in erectness and bushiness. The trifoliate leaves develop alternatively, and petioles are 2 to 12 cm long. A wider range exists for leaf shape and size in cowpea than in common bean.

Plant growth habit is categorized as erect to semi-erect, prostrate (trailing type) or climbing, and indeterminate to determinate, depending on the genotype. However, most cowpea accessions have indeterminate type of growth habit. Cowpea has a strong taproot system and the depth of the root has been measured up to 95 inches after 8 weeks of seeding. Flowers are born in axillary racemes on stalks with 15 to 30 cm peduncles. Usually a single peduncle has two to three pods, however, under favorable growing conditions, a single peduncle often carries four or more pods. The presence of long peduncles is a unique feature of cowpea among legumes, and this characteristic facilitates hand harvesting. The cowpea flowers vary in color from white, cream and yellow to purple, and the seeds, which are smooth or wrinkled, range in color from white, cream or yellow to red, and are characterized by a marked hilum surrounded by a dark arc (Fig. 1).

Fig. 1 Picture shows diverse seed color, shape, size and texture in cowpea. Photo by J.D. Ehlers; cited in M.P. Timko et al., 2007.

Photosynthesis, Photoperiod and Temperature

Cowpea is a short day plant and like other grain legumes, cowpea processes its food using a C3 photosynthetic pathway. Different cowpea genotypes show photoperiod sensitivity in connection with floral bud initiation and development. Some genotypes are day neutral, while other genotypes display a wider range of photoperiods (Craufurd et al. 1997). In addition, few cowpea genotypes exhibit various degrees of sensitivity to photoperiod (extent of delay in flowering) and temperature (Ehlers and Hall 1996). Warmer temperatures speed up flowering time in both photoperiod sensitive and insensitive cowpea genotypes. Development of improved cowpea genotypes for warm environments requires an understanding of the developmental responses to heat and photoperiod. Cowpea cultivars show a wide range of reproductive characteristics. The flower initiation ranges from 30 to 90 days after planting, and attaining physiological maturity (dry seed maturity) ranges from 55 to 240 days after planting (Wien and Summerfield, 1984). Wien and Summerfield (1984) reported that cowpea cultivars that flower early have a shorter or more concentrated flowering period than cultivars that flower late. In Sub-Saharan Africa, selection for different degrees of photosensitivity has occurred in different climatic zones and this resulted in pod ripening coinciding with the rainy season in some given location. This condition helps the plant during pod set and ripening to escape damage from excessive rainfall and diseases attack. Therefore, photoperiod and temperature responses of particular cowpea genotypes allow cowpea breeders to make parental choices to best utilize exotic and adapted germplasm to serve particular environments.

General Classification

Utilization or Mode of Consumption

Classification by Utilization or Mode of Consumption

Cowpea is used as food as well as feed, including forage, hay and silage for livestock in Sub-Saharan Africa, Asia, Europe, USA and Central and South America. In Africa, people consume young leaves, immature pods, immature seeds and dried seeds. The stems, leaves, and vines of the cowpea serve as animal feed. Cowpea is also used as green manure and cover crop for maintaining the productivity of the soil. The grain contains 25% protein and several vitamins, minerals and fibers. Breeding efforts at the International Institute of Tropical Agriculture (IITA) and national programs have resulted in dual purpose varieties (with good grain and fodder yields). The dual purpose varieties have provided both grain and fodder while fitting the different cropping systems, economic, and climatic conditions encountered in Africa. In addition, cowpea has great flexibility in terms of its use as farmers can choose to harvest the cowpea for grains or for forage to feed their livestock, depending on economic or climatic conditions.

Classification by Seed Characteristics

Cowpea seed size ranges from small wild types to 0.5-1 cm long. The 1000 seed weight of cowpea is 150-300 grams. Most of the time, seeds develop a kidney shape if not restricted within the pod. If the development of seed is restricted by the pod, the seed becomes more globular. The seed coat in cowpea can either be smooth or wrinkled and an assortment of colors has been observed (including white, cream, green, buff, red, brown and black). Sometimes, the seed is either speckled or mottled. Many of the cowpea seeds are also referred to as eye bean (black eye, pinkeye purple hull) (Fig 2) where they are covered with a white tissue, with a blackish rim-like aril. In cowpea, the seed size is important because it directly influences productivity, and together with different color standards, can determine grain quality for the market. Therefore, seed size and color should also be considered as major traits of interest for breeding programs.

In the United States, different cowpea cultivar classes with a broad range in characteristics are grown for horticultural use. All cultivars that are grown in USA are day neutral members of the subspecies Unguiculata cultivar group Unguiculata. The cultivars grown for seed are classified as Blackeye beans, are known for good yield production), the Crowders type are known for their largest peas, and are often used for canning. Cream peas are the most popular and have become increasingly important for home gardening, while field types have few popular cultivars and most cultivars are old agronomic types.

Fig. 2 Popular blackeye bean seed.

Classification by Growth Habit

Cowpea has substantial genetic diversity for growth habit. The major growth habits are categorized as erect to semi-erect, prostrate (trailing) or climbing types. Growth habit in cowpea ranges from indeterminate to fairly determinate with the non-vining types tending to be more determinate. Meanwhile, some of the early maturing groups have a determinate growth types.

Classification by duration of growth period

Cowpea is grouped into early, medium and late maturity group. However, the range for growth-period duration varies from one region to another or among varieties of different growth habits. According to growth habit and region, cowpea cultivars range from 55 to 240 days to physiologically mature. The difference is not only varietal but also environmental, especially for the factors of day-length and temperature.

Adaptation and Economic Importance and Uses

Adaptation

Adaption

Cowpea is widely cultivated throughout the tropics and subtropics between 35°N and 30°S, across Africa, Asia and Oceania, the Middle East, Southern Europe, Southern USA and Central and South America. Cowpea is a crop adapted to hot and dry tropical conditions. It is also considered drought tolerant compared to other legumes. They grow best at low altitude with a precipitation of 400 to 700 mm per annum. Optimum crop production requires temperatures between 20-35°C during the growing season, and soil pH between 5.5 and 8.3. Cowpea is grown on a wide range of soil textures but the crop shows preference to sandy soil. It has low tolerance to salt but somewhat tolerant to aluminium. Like other legumes, the crop does not withstand waterlogged or flooded conditions. Cowpea is sensitive to chilling conditions. The crop is grown in 45 countries across the globe. An estimated 14 million ha is planted to cowpea each year across the globe with total annual production of about 6 million MT, the current average is estimated at about 0.45 tonnes/ha (FAOSTAT, 2010). The production trend of cowpea across the world is shown in a Fig 3. Cowpea is primarily an African crop. The largest producers are Nigeria, Niger, Brazil, Haiti, India, Myanmar, Sri Lanka, Australia and the United States. Among these high cowpea producing countries, Nigeria and Niger each grow over 4 million ha and account for 45% and 15%, respectively, of the total world production (FAOSTAT, 2010).

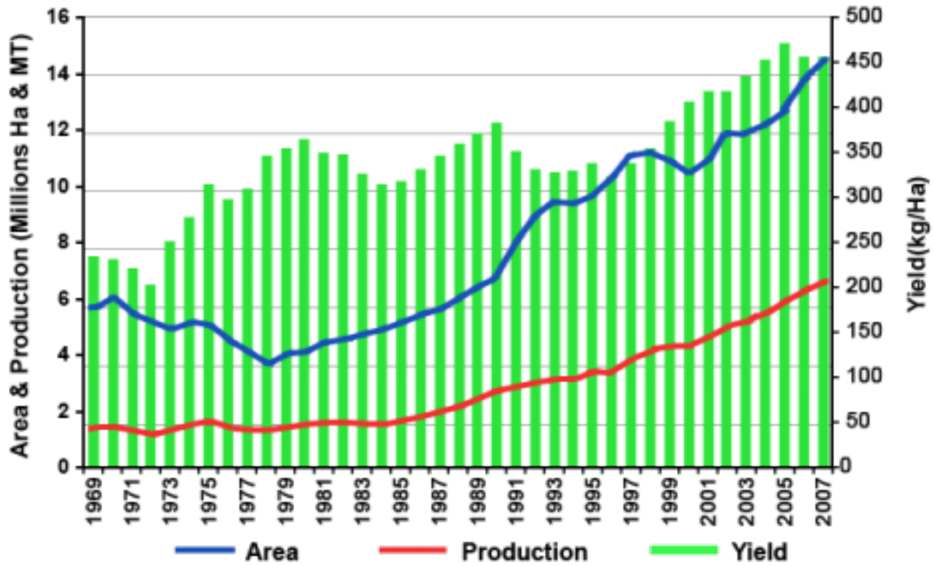


Fig. 3 Cowpea world trends. Illustration by Abate et al., 2012.

Cowpea in the Human Diet and Nutrition

Cowpea is one of the most widely used legumes in the tropical parts of the world. It can be used at all growth stages as a vegetable crop. The grain is mainly used for human nutrition, making cowpea one of the most important dual purpose legumes. The nutritional content of cowpea grain is comparable to common beans, with relative low fat content. The protein in cowpea grains is rich in tryptophan compared to cereal grains. In Africa, immature green pods are used similar to snap bean in common bean.

Cropping System

Cowpea grows well in association with cereal crops through intercropping. Cowpea is a major component of the traditional cropping system in Africa, Asia, and Central and South America, where it is mainly grown with other crops in various combinations. It is grown as a millet-cowpea mixture (exhibit 22% of the field sampled), a predominant crop mixture system in the Sudan savanna of Nigeria (Henriet at al., 1997). In the dry savanna cropping system, millets have been grown with different crop mixtures including millet-sorghum-cowpea (represent 19%), sorghum-cowpea (10%) and millet-cowpea-groundnut (8 %) (Olufajo and Singh, 2002). Cowpea grain yield in the mixture is lower than under sole crop condition. The factors contributing to low yields under intercropping systems include low plant population, shading effects, and competition for nutrients. Cowpea is also used as green manure, where it is incorporated into soil and can provide nitrogen to subsequent crops, minimize soil erosion and suppresses weeds.

Production Constraints

Biotic Constraints

Several biotic factors that cause yield reduction in cowpea include insect pests, fungal, bacterial, viral diseases, plant parasites, other organisms.

Insect Pests - Aphids are the main insect pests of cowpea, and are important vectors of cowpea mosaic virus. Other insect pests attacking cowpea are flower thrips and pod borers.

Dieases - Cowpea diseases are due to fungi, bacteria and viruses. Examples of diseases include, Cercospora leaf spot, ashy stem blight, bacterial blight, blackeye cowpea mosaic polyvirus (BICMV), and cowpea mosaic comovirus.

Plant Parasites - Certain weeds are important in cowpea production and most notable examples are the parasitic weedy plants Striga and Alectra.

Nematodes - Nematode also causes root damage to the crop and result in significant yield loss.

Abiotic Constraints

Extreme drought and heat, soil acidity, low phosphorous are some of the abiotic factors that limit the yield of cowpea.

International Breeding Centers

The International Institute of Tropical Agriculture (IITA) (http: //www.iita.org/cowpea) has a global mandate for the development and improvement of cowpea. Its main duty and responsibility is to develop and distribute improved cowpea varieties to over 65 national cowpea research programs in Africa. Variety requirements for cowpea differ from region to region in respect of the seed color preference, use patterns, maturity and growth habit. Therefore, IITA located additional scientists and breeding centers in Philippines, Nigeria, Burkina Faso, Cameroon, Congo and Brazil in order to address the regional constraints in cowpea production at the global level.

A general strategy for IITA is to develop different cowpea breeding lines with diverse maturity (to feed specific adaptation across wide agro-ecological zones where cowpea is grown), plant type, and seed types combined with resistance to major biotic (diseases, insect-pests, and weeds) and abiotic (drought, heat and low phosphorous) stresses.

IITA's genetic resources account for the world's largest and most diverse pool of cowpea germplasm. The collection consists of over 15,000 cultivated varieties from over 100 countries, and 560 accessions of wild cowpeas (Singh et al., 1997). The IITA collection constitutes a valuable resource for the cowpea improvement worldwide. Scientists from IITA center and regional centers have identified various cowpea genotypes with numerous desirable genes, which govern plant architecture and physiological traits (like plant type, root architecture, growth habit, pod traits, seed traits, photosensitivity, maturity and nitrogen fixation), quality traits (fodder quality and grain quality), abiotic stress (heat and drought tolerances), biotic stress (resistance to major bacterial, fungal and viral diseases, resistance to rootknot nematodes, resistance to aphids, bruchid, thrips, and resistance to parasitic weeds such as Striga gesneriodes, and Alectra vogelii).

Breeding Methods and Strategies

Introduction

Cowpea is a true diploid species with a chromosome number of 2n = 2x = 22. It is primarily a self-pollinating crop in most production environments, although up to 5% outcrossing can occur in some environments, possibly associated with pollen transfer by insects. Different cowpea breeding programs have their own priority of target production zones including the cropping systems, consumption preferences and major constraints to cowpea production in their agro-ecological zones.

Most Cowpea breeders at IITA and National programs use bulk, backcross, and pedigree breeding methods to deal with large numbers of segregating populations because cowpea is an autogamous crop and most cultivars grown by farmers are pure lines. The primary objective in all cowpea breeding programs is higher grain yield and improved grain quality. In addition, to yield and quality traits, most breeders seek to breed in a wide range of abiotic and biotic stress resistance traits. The breeding strategy of IITA and regional breeding program is to develop broad range of breeding lines with high yield and adapted to different agro-ecological zones that possess regionally preferred characters for plant type, growth habit, days to maturity, seed type, combined with resistance to biotic and abiotic stress, along with quality. In general, the main focus of breeding programs is to develop extra early maturity (60-70 days) and medium maturity (75-90 days), non-photosensitive lines with good grain quality and possibility for dual purpose use, either for use as sole crop or as intercrop in multiple cropping systems.

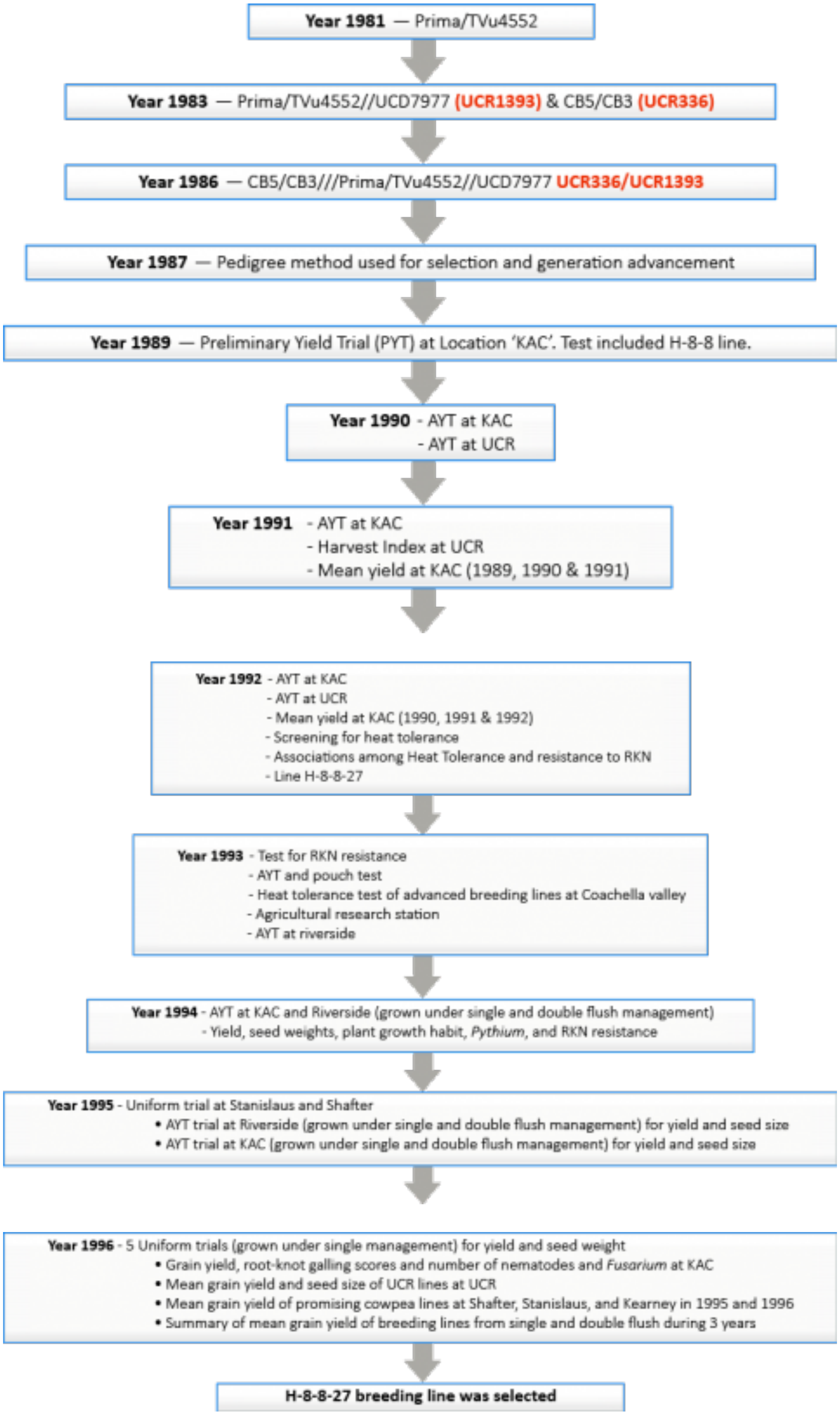
Example of Development of Blackeye Cowpea Cultivar "CB27" at University of California Riverside

California Blackeye 27 (CB27) was developed by the University of California, Riverside (UCR) and released in 1999 for its better performance in the following characteristics:

1. High yielding
2. Reproductive-stage heat tolerance
3. Broad-based resistance to Fusarium wilt
4. Broad-based resistance to root-knot nematodes
5. Semi-dwarf and less vegetative shoot biomass
6. Bright white seed coat
7. Good seed weight
8. Non-leaky pigments during boiling and excellent canning quality.

Cultivar Flow Chart

Flow Chart for the Development of Blackeye Cowpea Cultivar "CB27"



Year - 1989

Actual data from Preliminary Yield Trials (PYT), Advanced Yield Trials (AYT) and Uniform Yield Trials (UYT) along with different test conducted on agronomic, disease and quality traits (from 1989 - 1998) lead to the development of CB-27.

1989 - Preliminary Blackeye Trials at Kearney Agricultural Center (KAC)

Entry	Origin	Score	Yield (lbs/acre)	Seed weight g/100
H8-14	336 x 1393	H	3281	24.5
H8-9	336 x 1393	H	3236	24.7
H8-8	336 x 1393		3152	23.5
H8-7	336 x 1393	H	3022	25.9
H8-4	336 x 1393	H	2861	23.6
CB5			2995	26.3
CB46			3017	21.5
LSD			715	13
CV (%)			16.2	3.4

H = Heat Tolerance

Year - 1990

1990 - Advanced Blackeye Trials at University of California Riverside (UCR)

Entry	Origin	Yield (lbs/acre)	Seed weight (mg)	Seed density g/cm^3	Lodging	Earliness	Vigor
H8-14	336 x 1393	1805	235	1.10	erect	early	compact
H8-9	336 x 1393	1805	248	1.09	erect	early	compact
H8-8	336 x 1393	1497	233	1.11	erect	early	compact
CB5	CB x Iron	1889	254	1.06	erect	med	moderate
CB46	CB5 x 166146	2274	224	1.09	erect	med	moderate
$LSD_{.05}$		266	10	0.03			
CV (%)		10	3	2			

1990 - Advanced Blackeye Trials at Kearney Agricultural Center (KAC)

Entry	Origin	Yield (lbs/acre)	Seed weight (mg)	Seed density g/cm^3	Lodging	Earliness	Vigor
H8-14	336 x 1393	2855	208	1.11	erect	med	moderate
H8-9	336 x 1393	3007	223	1.14	slight	med	moderate
H8-8	336 x 1393	2744	217	1.12	erect	early	compact
CB5	CB x Iron	2389	241	1.11	erect	early	compact
CB46	CB5 x 166146	2688	202	1.17	erect	med	moderate
$LSD_{.05}$		420	9	0.02			
CV (%)		11	3	1			

Year - 1991

1991 – Advanced Blackeye Trials at Kearney Agricultural Center (KAC)

Entry	Origin	Yield (lbs/acre)	Seed weight (mg/seed)	Seed density g/cm^3
H8-14	336 x 1393	2825	195	1.10
H8-9	336 x 1393	3647	227	1.09
H8-8	336 x 1393	306	217	1.10
CB5	CB x Iron	2244	234	1.09
CB46	CB5 x 166146	2514	200	1.15
$LSD_{.05}$		374	15	0.01
CV (%)		10	5	1

1991 – Advanced Blackeye Trials at Kearney Agricultural Center (KAC) over several years

A.	Entry	Mean Grain Yield (lbs/acre) 1990 & 1991	Seed weight (mg)
	H8-14	2840	202
	H8-9	3327	225
	H8-8	2902	217
	CB5	2316	238
	CB46	2601	201
	CB88	2662	221
B.	**Entry**	**Mean Grain Yield (lbs/acre) 1989-1991**	**Seed weight (mg)**
	H8-14	2987	216
	H8-9	3297	232
	H8-8	2985	223
	CB5	2543	246
	CB46	2740	206

1991 – At University of California Riverside (UCR) – Harvest Index (Ratio of grain weight to total shoot biomass x 100) and Seed Weight

Entry	Harvest Index %	Seed weight (mg/seed)
H8-14	43	247
H8-9	51	232
H8-8	43	234
CB5	43	252
CB46	47	203
$LSD_{.05}$	4	16

Entry	Harvest Index %	Seed weight (mg/seed)
CV (%)	7	5

Year - 1992

1992 – At Kearney Agricultural Center (KAC) – Advanced Blackeye Trials

Entry	Origin	Yield (lbs/acre)	Seed weight (mg/seed)	Seed density g/cm^3
H8-14	336 x 1393	2949	213	1.01
H8-9	336 x 1393	2805	219	1.02
H8-8	336 x 1393	2865	209	1.02
CB5	CB x Iron	2831	229	1.00
CB46	CB5 x 166146	3164	194	1.06
$LSD_{.05}$		404	11	0.02
CV (%)		10	3.5	1.3

1992 – At University of California Riverside (UCR) – Advanced Blackeye Trials

Entry	Origin	Yield (lbs/acre)	Seed weight (mg/seed)	Seed density g/cm^3
H8-14	336 x 1393	2777	209	0.98
H8-9	336 x 1393	2684	207	0.97
H8-8	336 x 1393	2615	216	0.97
CB5	CB x Iron	2373	225	0.95
CB46	CB5 x 166146	2461	193	0.99
$LSD_{.05}$		318	19	0.03
CV (%)		85	6.0	2.0

1990, 1991 and 1992 – At Kearney Agricultural Center (KAC) – Advanced Blackeye Trials over several years

Entry	Yield (MEAN of years 1990, 1991 and 1992)	Seed weight (mg)
H8-14	2876	206
H8-9	3153	223
H8-8	2890	214
CB5	2488	235
CB46	2789	199

Year - 1992 Part 2

1992 – Screening for Heat Tolerance

Line	Total # of Sub-lines	# Heat Tolerance – Flowering (CVARS & GH)	Heat Tolerance – % Podding (Hot Glasshouse at UCR)	# Selected sublines	Average Podding
H8-14	45	26	57	9	4.7
H8-9	54	54	92	14	9.4
H8-8	46	24	70	12	5.0

1992 – Associations among heat Tolerance and Resistance to Root Knot Nematode

Line	[1]Nematode Resistance	#[2]Heat Tolerance – Floral buds	#[2]Heat Tolerance – Pod set
H8-8-1	R	N	3
H8-8-2	S	S	–
H8-8-3	R	N	6
H8-8-4	S	S	–
H8-8-5	R	N	2
H8-8-6	S	S	–
H8-8-8	R	N	0
H8-8-9	R	N	7
H8-8-10	R	N	0
-to-			

H-8-8-27	R	N	

[1] **Non-aggressive** *Meloidogyne incogonita*

[2] **Summer glasshouse with day/night temperatures of 34/30 degree centigrade**

Year - 1993

The blackeye cowpea cultivators follow three management schemes:

1. Single-flush main crop cut after ~ 100 days
2. Single-flush double crop, sown later and cut after ~ 100 days
3. Double-flush main crop, sown early and cut after ~ 140 days

Short-term goal – to develop blackeye varieties with resistance to the

a. common race of Fusarium wilt in California (race #3)
b. wide range of root knot nematodes
c. heat tolerance
d. increased yield potential

Medium-term goal – to develop blackeye varieties which have resistance to early cut-out and greater ability to produce pods over an extended season (140 days from planting to cutting)

Long-term goal – resistance to lygus, resistance to cowpea aphid

In 1993 non-aggressive *Meloidogyne incognita* eggs mass number was counted on breeding lines using “pouch” tests. Data are means of four to five plants replicates. R indicates resistance and S indicates susceptible.

	Date of Test			
Line	**13-May**	**27-Feb**	**25-Aug**	**R/S**
CB5	2	-	-	R
CB46	2	-	-	R
H-8-8-2	2	0	-	R
H-8-8-4	4	<1	-	R
H-8-8-6	<1	<1	0	R
H-8-8-8	2	0	-	R
H-8-8-13	0	0	0	R
H-8-8-15	0	0	0	R
H-8-8-16	10	0	0	R
H-8-8-27	<1	<1	<1	R
H-8-8-28	5	-	-	R
H-8-8-30	0	-	-	R
H-8-8-32	43	-	-	S
H-8-8-35	0	<1	<1	R

Year - 1993 Part 2

In 1993 non-aggressive *Meloidogyne incognita* eggs mass number was counted on breeding lines using “pouch” tests. Data are means of four to five plants replicates. R indicates resistance and S indicates susceptible. Lines highlighted in yellow were in the 1993 Advanced Yield Trial.

	Date of Test		**Clasification**	
Line	**May 13**	**April 9**	**Ag**	**NAg**
CB3	32	190	S	S
CB46	15	24	S	R
H-8-8-2	6	-	R	R
H-8-8-4	-	4	R	R
H-8-8-6	7	12	R	R
H-8-8-8	-	17	R	R
H-8-8-13	2	29	R	R
H-8-8-15	6	7	R	R
H-8-8-16	11	20	R	R
H-8-8-27	2	31	R	R
H-8-8-31	-	85	S	S
H-8-8-35	8	22	S	R

Ag = aggressive
NAG = non-aggressive
- = not tested

Year - 1993 Part 3

1993 – Heat–tolerance of advanced blackeye breeding lines evaluated in a hot glasshouse (day/night temperature of 35/30 degree Celsius) and Coachella Valley Research Station.

Entry	Grain Yield g/plant	Plots/Plant	Seeds/Pod	Seed Weight Mg/seed	Flower Production	Pods/Peduncle #
CB5	0	0	-	-	NO	-
CB46	2	4	2.7	166	NO	-
H8-8-6	22	28	4.2	192	YES	2.5
H-8-8-13	21	27	4.1	190	YES	2.75
H-8-8-15	22	27	4.1	196	YES	3.00
H-8-8-16	30	34	4.6	195	YES	2.75
H-8-8-27	26	30	4.2	207	YES	2.75
H-8-8-35	28	30	4.6	201	YES	2.75

1993 – Advanced Blackeye Trial – Rverside. Sown June 14, cut September 17 (95-day season)

Entry	Grain Yield lbs/ac	Seed weight mg/seed	Heat tolerance	Root Knot Resistance	
				Non-aggressive	Aggressive
CB5	1975	260	SUS	RES	SUS
CB46	1996	225	SUS	RES	SUS
H8-8-6	1631	240	TOL	RES	RES
H-8-8-13	1951	228	TOL	RES	RES
H-8-8-15	1938	227	TOL	RES	RES
H-8-8-16	2156	231	TOL	RES	RES
H-8-8-27	1767	246	TOL	RES	RES
H-8-8-35	2049	229	TOL	RES	RES
$LSD_{.05}$	405	22			
CV%	15	6			

Year - 1994

1994 – At UCR and KAC – Advanced blackeye yield trial – Grain Yields (lbs/ac) under single and double management and Mean yield over locations

Entry	Riverside Single Flush	Riverside Double Flush	Kearney Single Flush	Kearney Double Flush	Mean
CB-46	1860	2996	3046a	3916	2955
CB-5	2063	2869	2222	3479	2658
H8-8-1N	1985	3199	2629	3786	2900
H8-8-6	2039	2677	2051	3366	2531
H8-8-13	1800	2318	2637	2717	2668
H8-8-15	1703	3040	2589	3175	2627
H8-8-27	1742	2979	2398	3728	2712
H8-8-35	1771	2658	2414	3399	2561
$LSD_{(.05)}$	NS	581	245	NS	288
CV(%)	13	14	15	16	16

a – indicates the top yielding group based on statistical analysis

1994 – At UCR and KAC – Advanced blackeye trial – Seed Weights (mg/seed) under single and double management and Mean yield over locations

Entry	Riverside Single Flush	Riverside Double Flush	Kearney Single Flush	Kearney Double Flush	Mean
CB-46	234	211	221	211	219
CB-5	273	255	265	246	260
H8-8-1N	249	233	242	225	237
H8-8-6	243	238	230	220	233
H8-8-13	231	206	209	213	215
H8-8-15	239	227	240	218	231
H8-8-27	240	229	242	221	233
H8-8-35	237	220	234	222	228
$LSD_{(.05)}$	11	12	6	13	6
CV(%)	3.1	3.6	3.9	3.9	3.6

Year - 1994 Part 2

1994 – Plant growth habit for entries in advanced trials grown at KAC and UCR and Pythium incidence (no. of infected plants/plot) in the 1994 double flush advanced trial at UCR

Entry	Growth habit Plant Size	Growth habit vininess	Pythium
CB-46	M	M-L	5.3
CB-5	L	H	7.5
H8-8-1N	M-L	H	2.3
H8-8-6	L	M	2.5
H8-8-13	M	M	4.3
H8-8-15	M	L	1.3
H8-8-27	M	L	1.5
H8-8-35	M	L	1.3
$LSD_{(.05)}$			4.3

Growth habit Plant size: M = medium; M-L = mediaum-large; L = large
Growth habit vininess: L = low; M = medium; H = high; M-L = moderately low

1994 – Advanced blackeye trials – At KAC – Average grain yields (lbs/ac) and seed size over single and double flush management systems for the resistance to three nematode strains

Entry	Grain yield lbs/ac	Seed weight mg/seed	RKN resistance *non-aggr*	RKN resistance *aggr*	RKN resistance *javanica*
CB-46	3481a	216	R	S	S
CB-5	2851	255	R	S	S
H8-8-1N	3208a	234	R	S	S
H8-8-6	2709	225	R	R	R
H8-8-13	2677	211	R	S	S
H8-8-15	2882	229	R	R	R
H8-8-27	3063a	231	R	R	R
H8-8-35	2907	228	R	R	R
$LSD_{(.05)}$	472	9			
CV(%)	16	3.9			

a – indicates the top yielding group based on statistical analysis

Year - 1995

1995 – Uniform Trial – Grain Yields (cwt/ac) at Stanislaus and Shafter

Entry	Stanislaus	Shafter	Mean
H8-8-27	24.5	55.5	40.2
H8-8-15	23.0	55.2	39.1
CB46	20.8	55.9	38.4
CB88	11.5	54.3	32.9
$LSD_{(.05)}$	3.4	3.8	2.5
CV(%)	14.8	6.1	8.5

1995 – UCR Advanced Blackeye Trials – Grain Yields (cwt/ac) at UCR

Entry	Origin	Single Flush	Double Flush	Mean
H8-8-27	CB5/CB3//1393	22.3	29.6	26.0
H8-8-15	CB5/CB3//1393	23.9	29.2	26.6
CB46	CB5/CB3 //PI1166146	23.3	25.9	24.6
CB88	CB5/CB3 //PI1166146	24.5	29.6	27.1
$LSD_{(.05)}$		2.1	NS	3.4
CV(%)		8	14	16

1995 – UCR Advanced Blackeye Trials – Grain Yields (cwt/ac) at KAC

Entry	Origin	Single Flush	Double Flush	Mean
H8-8-27	CB5/CB3//1393	38.3	42.8	41.3
H8-8-15	CB5/CB3//1393	38.3	41.9	40.1
CB46	CB5/CB3 /PI1166146	31.7	47.2	39.4
CB88	CB5/CB3 /PI1166146	34.0	44.4	39.2
$LSD_{(.05)}$		4.6	8.0	4.8
$CV_{(\%)}$		12	16	15

Means followed by the same letter are not sig. different at P = 0.05

Year - 1995 Part 2

1995 – UCR Advanced Blackeye Trials – Grain Yields (cwt/ac) at KAC

Line	**Nematodes** *Non-aggres*	**Nematodes** *aggres*	**Nematodes** *M.jay.*	*Fusarium* **Race 3**	*Fusarioum* **Race 4**	Heat
H8-8-27	Yes	Yes	Yes	Yes	Yes	Yes
H8-8-15	Yes	Yes	Yes	Yes	Yes	Yes
CB46	Yes	No	No	Yes	Yes	No
CB5	Yes	No	No	No	Yes	No

Types of RKN; non-agg = non-agg *M. incognita* **- not able to overcome standard 'Rk' gene resistance**
Agg = strain of *M. incognita* **- able to overcome 'Rk' resistance**

1995 – UCR advanced blackeye trials – Seed Size (mg/seed) at KAC and UCR

Line	Kearney	Riverside	Mean
H8-8-27	208	215	212
H8-8-15	207	209	208
CB46	203	201	202
CB88	216	210	213
$LSD_{(.05)}$	11	19	11
CV(%)	4.4	7.7	6.3

1994 and 1995 – Comparison of seed size (mg/seed) at two locations (KAC and UCR) of high yielding line

Line	1994	1995	Mean
H8-8-27	231	212	222
H8-8-15	229	208	219
CB46	216	202	209
CB88	231	213	222
$LSD_{(.05)}$	6	11	-

1994 and 1995 – Mean Yields at four locations (KAC, UCR, SHAFT and STANI) of high yielding lines

Line	Mean
H8-8-27	33
H8-8-15	33
CB46	33
CB88	32

Year - 1996

1996 – at KAC – Grain Yields (cwt/ac) of high yielding breeding lines and check varieties CB46 and CB88 in 5 uniform trials and individual seed weight from single flush trial

Entry	Shafter	Tulare	Kearney double	Kearney single	Westside	Mean	Seed weight mg/seed
H8-8-27	53.1	42.6	38.0	26.1	24.5	36.9	213
H8-8-15	45.8	40.3	33.3	23.9	23.8	33.4	207
CB46	46.6	49.1	40.5	25.5	24.6	37.3	215
CB88	46.2	41.1	37.0	23.4	20.9	33.7	215
$LSD_{.05}$	8.3	8.1	NS	2.7	1.4	2.7	7
CV(%)	11.7	12.5	13.8	7.7	4.0	12.1	2.1

1996 – Grain Yields (cwt/ac), root-knot galling scores and number of nematodes (juveniles per liter of soil) of high yielding UCR blackeye breeding lines in a field at KAC and at the Muller Farm-Chance Field, Stanislaus Co. that are infested with Rk gene virulent stains of M.javanica and M.incognita. Fusarium wild races 3 and 4 from the Chance Field alone

Entry	Grain Yield (KAC)	Grain Yield (Muller)	Galling (KAC)	Galling (Muller)	No. juveniles (KAC)	No. juveniles (Muller)	Resistance Nematode	*Fusarium* Wilt
H8-8-27	21.1	21.0	2.3	2.1	1672	328	Rk+	3 & 4
H8-8-15	19.9	23.1	1.6	2.0	1061	239	Rk+	3 & 4
CB46	21.2	16.5	4.9	4.7	1833	572	Rk	3
CB88	22.9	10.2	4.5	5.1	2478	572	Rk	3
$LSD_{.05}$	2.9	3.1	0.6	0.9	750	NS		

1996 – Grain Yields (cwt/ac) and seed size (mg/seed) of high yielding UCR blackeye breeding lines and checks (C46 and CB88) under single and double flush management at UCR.

Entry	Grain Yield (Single)	Grain Yield (Double)	Seed Size (Single)	Seed Size (Double)	Means Yield	Means Seed Size
H8-8-27	20.8	32.7	223	249	26.8	236
H8-8-15	22.4	36.1	226	245	29.3	236
CB46	24.7	34.9	223	234	29.8	228
CB88	22.7	34.7	226	232	28.7	229
$LSD_{.05}$	2.5	NS	9	9	2.5	6
CV(%)	7.5	9.0	2.7	2.5	8.7	2.6

Year - 1996 Part 2

1996 – Grain Yields of promising blackeye breeding lines and checks (CB46 and CB88) over years and locations in the Central Valley. Overall mean includes 1996 data from Tulare and Westside Field Station trials.

Entry	Shafter mean Yield 1995 and 1996	Stanislaus mean Yield 1995 and 1996	Kearney Mean Yield 1995 and 1996	Overall Mean
H8-8-27	55	23	34	36
H8-8-15	50	23	33	34
CB46	51	19	36	36
CB88	50	11	33	31

1994, 1995, 1996 – At KAC – Summary of grain yields (cwt/ac) of selected blackeye bean breeding lines and check cultivars (CB46 and CB88) from single-flush and double-flush trials

Entry	1994 Single flush	1994 Double flush	1995 Single flush	1995 Double flush	1996 Single flush	1996 Double flush	Mean Single	Mean Double
H8-8-27	30.5	39.2	31.7	47.2	25.5	40.5	29.2	42.3
H8-8-15	25.1	35.5	34.0	44.4	23.4	37.0	27.5	39.0
CB46	25.9	31.8	38.3	42.8	23.9	33.3	29.4	36.0
CB88	24.0	37.3	38.3	41.9	26.1	38.0	29.5	39.1
$LSD_{.05}$	2.4	NS	4.6	8.0	2.7	NS	2.2	4.2
CV(%)	15	16	12	16	8	14	10	13

Year - 1997

1997 – Strip Trial near Wasco, CA – Grain yield, bean weight and bean quality grade of selected H8-8-27 cowpea breeding line

Entry	Grain Yield (Dirt Wt) Cwt/ac	Grain Yield (Clean Wt) Cwt/ac	Clean Out %	Bean Size Gm/100 seeds	Total Damage (%)	Splits	Grade
H8-8-27	49	44	8.1	24.1	2.0	0.3	UN No. 1
CB46	48	44	7.7	21.7	4.2	0.3	US No. 3

1997 – Uniform Trials – Grains yield of selected H8-8-27 cowpea breeding line

Entry	Westside	Riverside	Tulare	Shafter	Mean
H8-8-27	1790	3491	2840	4446	3147
CB46	1990	3772	3769	5231	3638
$LSD_{(.05)}$	NS	472	302	NS	241
CV(%)	11.4	7.8	7.0	16.6	11.3

1997 – Grain Yield and bean size of selected H8-8-27 cowpea breeding line and check (C46) at Shafter and KAC

Entry	Shafter Mean Yield 1995, 1996, and 1997	Kearney mean Yield 1994, 1995, 1996, and 1997	Overall Mean
H8-8-27	51	35	42
H8-8-15	51	33	41
Seed size			
CB46			21.1
CB88			22.1

1997 – Uniform Trials – At UCR and Tulare – Grain Yields and rating for 'greenness' after the first pod plush of selected H8-8-27 cowpea breeding line and check (C46) in the 1997

Entry	Riverside Yield	Riverside Greenness	Tulare Yield	Tulare Greenness	Mean Yield	Means Greenness
H8-8-27	3491	0	2840	0.7	3166	0.4
CB46	3772	0	3769	2.2	3771	1.1
$LSD_{.05}$	472		699		302	
CV(%)	7.8		7.0		7.6	

1998 - Uniform Blackeye Trials

1998 – Uniform Blackeye Trials – Grain yields (lb/ac)

Entry	Shafter	Tulare	Kearney	Riverside	Mean
H8-8-27	5156	4967	4629	3113	4466
CB46	4732	5178	4268	2938	4271
$LSD_{(.05)}$	521	478	806	529	295
CV(%)	8	6	13	13	10

1998 – Uniform Blackeye Trials – Individual seed weights (grams/100 seeds) and % split seedcoat

Entry	Shafter	Tulare	Kearney	Riverside	Mean	% Split
H8-8-27	22.8	4967	22.6	24.9	23.0	13
CB46	22.6	5178	21.9	25.8	23.0	18
$LSD_{.05}$	1.3	478	1.1	1.7	0.7	6
CV(%)	4	6	3	5	4	42

1998 – At UCR – Effect of row spacing and play type on yield and yield contributing traits of cowpea lines

Genotype	Spacing	Yield	HI %	Seed weight g/100 seed	Seeds/pod	Pods/peduncle
Compact type						
H8-8-27	30"	3642	47.0	24.7	8.4	1.7
	40"	3407	50.6	24.6	8.7	1.5
	40" x 2	4111	47.1	23.8	8.4	1.5
	Mean	**3721**	**48.2**	**24.4**	**8.5**	**1.6**
CB46	30"	3583	47.0	23.6	8.5	2.1
	40"	3081	45.8	24.1	8.3	1.9
	40" x 2	3692	42.7	24.2	8.6	1.6
	Mean	**3665**	**45.2**	**24.0**	**8.5**	**1.9**

1998 – At Shafter – Effect of row spacing and plant type on yield and yield contributing traits of cowpea genotypes

Genotype	Spacing	Yield	HI %	Seed weight g/100 seed	Seeds/pod	Pods/peduncle
Compact type						
H8-8-27	30"	2717	48	23.8	8.4	2.1
	40"	2399	48.1	23.3	8.8	2.2
	40" x 2	2643	48.2	23.7	8.0	2.0
	Mean	**2587**	**48.1**	**23.6**	**8.4**	**2.1**

Genotype	Spacing	Yield	HI %	Seed weight g/100 seed	Seeds/pod	Pods/peduncle
CB46	30"	2472	42.0	23	9.5	1.9
	40"	2328	45.5	21.9	8.0	2.0
	40" x 2	2498	44.0	23.3	8.1	1.8
	Mean	**2432**	**43.8**	**22.8**	**8.5**	**1.9**

Year - 1999

1999 – Performance of CB27 compared to checks CB5 and CB46 for disease (Fusarium), pest (nematode) and Agronomic performance (heat and chill tolerance)

Entry	Fusarium wilt Race 3	Fusarium wilt Race 4	RKN (M. incognita) Avirulent	RKN (M. incognita) Virulent	RKN (M. javanica)	Heat Tolerance	Chill Tolerance
CB5	No	No	Yes	No	No	No	No
CB46	Yes	No	Yes	No	No	No	No
CB27	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Example Using Participatory Varietal Selection

Recent example of Cowpea cultivar released by IITA in parts of Africa using participatory varietal selection (source: **www.IITA.org**)

1. In Burkina Faso two improved cowpea varieties developed by IITA have been released.
    i. IT99K-573-2-1 and
    ii. IT98K-205-8,
2. Using participatory varietal selection approach, local farmers and researchers choose varieties from various options after two years of trial in the central and northern regions of Burkina Faso.
3. Selected varieties are early maturing (60 days), high yielding (2170 kg/ha), resistant to parasitic weed striga along with big size, preferred color and cooking qualities pertaining to farmers taste.
4. New cowpea varieties also have better adaptability to climate change and can be grown successfully in the drier regions with low rainfall.

Important Traits

Example of Participatory market led cowpea breeding in Sub-Saharan Africa (Tanzania and Malawi).

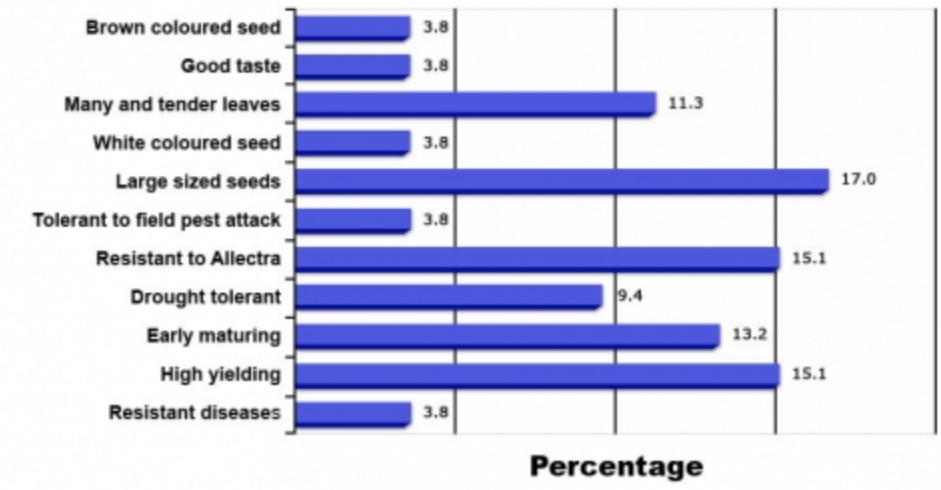


Fig. 4 Important traits of Cowpea required by farmers (%). Illustration by Hella et al, 2013, Merit Research Journal of Agricultural Science and Soil Sciences.

Pathway Based on Preferences

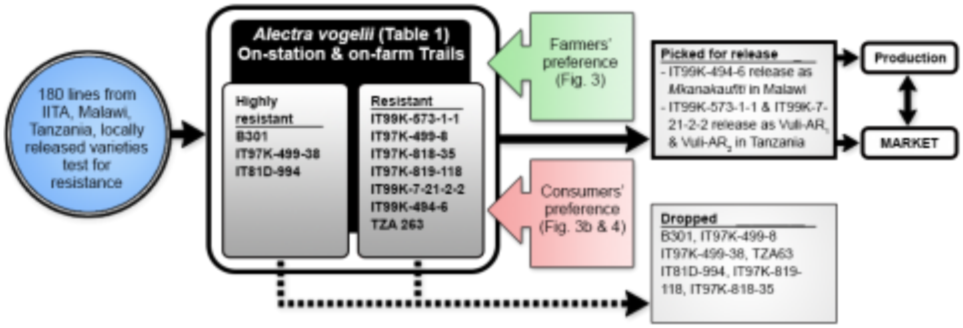


Fig. 5 Pathway showing the release of cowpea cultivar based on farmers and consumers preference along with resistance to Alectra vogelli. Click the image to see a larger version.

Notes to Consider

1. *Alectra vogelii* is a parasitic weed that causes considerable amount of damage to cowpea plant by attaching onto it and tapping nutrients.
2. In Tanzania and Malawi, Alectra is one of the major weed growing in almost all cowpea growing areas.
3. In **Figure 4** is shown important traits of cowpea required by farmers. Out of 11 traits used in selection of best cowpea lines by farmers, only five traits (brown seed color, white seed color, good taste, large seed, many leaves and tender leaves) are specific to the final consumer, while the other six traits (early maturity, high yield, resistance to Alectra, resistance to diseases, tolerant to pest, drought tolerance) are agronomic traits. Large seed size is the most important trait from marketing perspective, whereas high yield, early maturity, and resistance to *A. vogelli* are the main agronomic traits which are the deciding criteria used by farmers to select varieties for growing on their farm.
4. In **Figure 5** is shown an example of value chain approach used to develop cultivars (for example-IT99K-573-2-1)
5. This approach resolves biases and takes care of farmers, consumers and market preference and will not let breeders effort go waste like in past where outstanding varieties with excellent agronomic traits failed due to inability to satisfy needs of farmers, consumers and market at the same time.

Marker Assisted Selection

Marker assisted selection approaches are being developed in cowpea with high density marker maps and SNP markers becoming available. As cowpea is gaining acreage globally more investment is being made for breeding and marker development. This will assist in further development of MAS in cowpea. Genetic loci controlling important pest and disease resistance genes and agronomic traits have been placed on genetic map (for example, Kelly et al, 2003). Closely linked markers to some of the biotic traits have been identified (Gowda et al., 2002). Most of these traits are governed by major genes and are potentially good candidates for MAS. Along with MAS for simply inherited traits, genomic selection approach offer usefulness in future breeding efforts. Currently, joint efforts are being made by IITA, Bean/Cowpea Collaborative Research Support Program (Bean/Cowpea CRSP), advanced laboratories in the USA, Australia, African Agricultural Technology Foundation (AATF), Network for Genetic Improvement of Cowpea for Africa (NGICA) and Monsanto Corporation to exploit biotechnology tools to complement conventional breeding methods for improving resistance to diseases and insects.

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