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Status of global research in cowpea and its impact on Indian Agriculture

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Abstract

Cowpea has originated as heat loving crop (20 to 35°C) with lower moisture and soil fertility requirements than many other crops that had given a misconception that the crop is suitable for less endowed areas. However, the crop has vast potential in varied agricultural situations in general and intensive agriculture in particular. The productivity in cowpea is dismally low for which use of obsolete varieties with low inherent yields, poor growing milieu particularly under-nutrition of phosphorus, poor plant population, biotic and abiotic stresses, no plant protection measures; and above all the crop is grown as second rung / companion crop with condition more conducive to main crop are mainly responsible. Over a dozen diseases, half a dozen insects, two parasitic plants and three abiotic constraints bog down attainable yield. Cowpea has vast variability for maturity duration, plant type, growth habit, leaves and leaf characters like petiole length and branching. Similarly there is enormous variation for pod and seed size, shape, colour and texture of grain (different hues, texture and size with varying physical and nutritional qualities) and reaction to biotic and abiotic stresses. Genetic studies for morphological traits, biotic resistance, biotic stresses, male sterility, heterosis and nutritional quality may help in improvement of specific traits through conventional breeding and biotechnological tools like MAS. The impact of the global research in cowpea is evident particularly in Africa by supporting the crop-livestock system with over all improvement of health and livelihood. Today about 40 varieties are grown in 65 countries that has resulted four times increase in production of cowpea from 1.1 m Mt to 4.5 m MT since 1980s. The research conducted at the global level on development of early varieties for enhancing pulses production, diversifying ailing cropping systems, long duration drought tolerant varieties for sustainable agriculture, situation specific varieties with holistic approach, enhancement of organic agriculture, biotechnology for combating invincible problems and quality seed production that may quite helpful to Indian context. In nutshell, improved new 60 day cowpea varieties have enhanced food security, family nutritional sustenance and income generation in less endowed areas like Africa and have good potential in India particularly for increasing production of pulses to meet the short fall of 2 million metric tons besides all important rejuvenation of ailing cropping systems.

Key words : Agriculture, cowpea, genetic variability, resistance

Introduction

Cowpea is an important multi utility crop introduced in Indian sub continent about 3500 years ago along with sorghum and millets. The most primitive wild types are found in Transvaal region of South Africa suggesting that the speciation of *Vigna unguiculata* (L.) Walp. took place in that particular area. Pasquet (1) studied more than 150 wild accessions of cowpea and concluded on the basis of genetic distances that initial diversification took place from out crossing perennial species (*baoulensis* and *burundiensis*) adapted to humid climate particularly around Cameroon and from there it spread to drier Congo (*dekindtiana*) to Ethiopia and the Transvaal through the Congo-Zambezi water shed. The climatic changes led to the break down of the proto-taxon to more related perennial subspecies (*pubescens*) that culminated in the present day inbreeding annual subspecies (*unguiculata*, *cylindrical* and *sesquipedalis*). As such, cowpea has originated as heat loving crop (20 to 35°C) with lower soil fertility requirements than many other crops that had given a misconception that the crop is suitable for less

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endowed areas. However, the crop has vast potential in varied agricultural situations in general and intensive agriculture in particular.

Presently cowpea cultivation is done over 65 countries stretched over all the five continents on around 14 million hectares. Central and West Africa account for 63 per cent of the global area followed by central and southern America (19%), Asia (10%) and East & South Africa (8%). Some cowpea is also cultivated in the middle east and southern Europe. West Africa, Nigeria and Brazil are the major cowpea growing countries covering 36, 21 and 11 per cent acerage, respectively, thereby encompassing over 2/3 of the global area under cowpea. India, Bangladesh, Nepal, Sri Lanka, Indonesia, China, and Philippines grow cowpea in Asia. The exact statistics of acerage under cowpea in India is not available, as the crop is predominantly grown under varied mixed cropping systems. However, the wild speculation evince that the crop is grown over one million hectare. Thus India supports around 7 per cent of the global acerage under cowpea. The concerted efforts of the scientists have exhibited a significant increase in production that has increased four time during the last two and half decades. At present the global production of cowpea hovers around 4.5 million metric tons there by pitching the productivity around 321 kg per hectare. In India the exact productivity statistics are not available though the broad estimates put it around five to six quintals per hectare. However, the experimental yields of the improved genotypes have been reported to yield around 15 quintals per hectare.

Yield and yield limiting factors

Empirically the seed yield in cowpea is the function of variety, soil, water, package technology and the weather conditions. However, on plant basis it is the function of pods/plant, seeds/pod and seed weight. On ground realities, the yield may be bogged down by different restrictions that may be explained with 4As of productivity; Absolute (no limiting factor except genetic potential), Attainable (limit is imposed by environmental conditions), Affordable (impose economic restrictions) and Actual (the limit imposed by pests/diseases & such other hazards). The productivity in cowpea is dismally low for which use of obsolete varieties with low inherent yields, poor growing milieu particularly under-nutrition of phosphorus, poor plant population, biotic and abiotic stresses, no plant protection measures; and above all the crop is grown as second rung / companion crop with condition more conducive to main crop are mainly responsible.

Over a dozen diseases (bacterial blight, cercospora, septoria, scab, brown blotch, nematodes, aphid borne mosaic, black eye cowpea mosaic), half a dozen insects (aphids, thrips, *maruca*, pod bugs, curculio, bruchids), two parasitic plants (striga, alectra) and three abiotic constraints (heat, drought and low fertility) bog down attainable yield. The crop can be divided in to four phases (i) germination to flowering where aphids ravage it most, (ii) flowering where thrips are the major menace, (iii) flowering to maturity where *maruca*, pod borers and pod sucker take the toll and (iv) storage where *bruchids* are the serious problem.

Indian scenario

Cowpea in India is predominantly grown as a great diversity of crop mixtures and in such situations the growing conditions are more appropriate to the major crop. For example in cereals–cowpea mixed/ intercropping, nitrogen application is favourable for cereals but phosphorus is always limiting and the crop is customarily raised without any insecticidal spray. Pure crop on the other hand is grown under two situations with and without spray but the varieties in vogue are invariably land races that are late maturing with low absolute yields. This is despite a good number of improved varieties have been released at national (like RC 101, GC 3, V2-40, V585) and state level (GC 4 , GC 5) with maturity duration of around 70 days with particular emphasis on plant type, grain quality, and resistance to biotic and abiotic stresses. Location specific package of practices are meagerly available. Common mosaic virus, aphids, thrips, *maruca* and sucking bugs are the main biotic, and drought, heat and low fertility are the main abiotic hindrances in realizing attainable yield levels. Now in this background of cowpea cultivation in India, the development of extra early varieties with 60 days duration with high protein, Fe, Zn and K, less cooking time, lines with higher BNF and tolerance to low P, integrated pest management package, basic genetics and cytogenetics studies, progress in constructing molecular map and development of protocols for genetic transformation at the global level was conspicuous and can improve shortage of pulses in the country.

Global research scenario

Genetic Variability

Over fifteen thousand cultivated lines and 560 wild types have been screened and maintained at IITA besides good numbers of them in other major cowpea growing countries like USA, India, Brazil and Nigeria. These collections have vast variability for maturity

duration (late, mid late ands early), plant type (grain/ vegetable/fodder/dual purpose; erect/semi erect / climbing; compact/semi spreading/spreading), growth habit (determinate/indeterminate; erect /semi-erect/ spreading; climbing/bushy), leaves and leaf characters like petiole length and branching. Similarly there is enormous variation for pod and seed size, shape, colour and texture of grain (different hues, texture and size with varying physical and nutritional qualities) and reaction to biotic and abiotic stresses. Generally the seed shape is related to pod. The seed has visually distinguishable colour and hilum that may be restricted or unrestricted with characteristic shape and size of eyes (round, small, long, watson and self). The crop has multi facet uses like food, feed, fodder, vegetable, soil nutrition enhancer, weed suppression and sustenance of predators and parasite. The grain can be termed as protein tablet as it contains around 25 per cent protein. The seeds also contain reasonable amount of vitamin namely â-carotene, thiamin, riboflavin, niacin, folic acid and ascorbic acid. Probably appreciating these scientific reasons un-volitionally, the *Hausa* and *Yaruba* ethnic group of Nigeria used to ward of evil and cure children with cowpea leaves. Even today, people of Southern USA celebrate their new year with a dish called "Hoppin John" prepared from black eyed cowpea with ham and pork. In Africa there is a popular adage "cowpea colour rice for those who cannot afford sauce".

Genetic studies

Morphological Traits

Aliboh *et al.* (2) reported monogenic dominant inheritance for V-shaped leaf mark, pod dehiscence and black dry pod colour and assigned *Vsm, Dhp* and *Bk-2* gene symbols for them respectively. Kehinde and Ayo-Vaughan (3) and Singh and Ishiyaku (4) reported involvement of two pairs of genes for seed coat texture in cowpea. The smooth seed coat was dominant when only seed coat was considered. However, when colour was considered with seed texture and white rough seed were crossed with brown rough seed the F_1 was smooth showing complementary gene action (9: 7) and gene *rt 1* and *rt 2* was assigned to rough testa. Rough testa is an important trait in African countries as it helps in better removing of the seed coat after soaking.

The studies have revealed that varieties with brown rough seeds have no pigment on any plant part except faint purple lining on the inner margin of the

Table 1. Progress in pyramiding genes for resistance in cowpea Singh *et.al.* (11)

Year / Pest/disease	Ife Brown	TVX 3236	IT82D-716	It84S-2246	IT90K-59	IT97K499-35	IT00K-1251
	1973	1978	1982	1984	1990	1997	2000
Anthracnose	S	R	R	R	R	R	R
Cercospora	S	R	R	MR	R	R	R
Brown Blotch	S	R	R	MR	R	R	R
Bacterial Pustule	S	R	R	R	R	R	R
Bacterial Blight	MR	MR	MR	MR	MR	R	R
Septoria	S	S	S	S	S	R	R
Scab	S	MR	MR	MR	MR	R	R
Web blight	S	MR	MR	MR	MR	R	R
Yellow Mosaic	S	S	R	R	R	R	R
Aphid Borne Mosaic	S	S	R	R	R	R	R
Golden Mosaic	S	R	R	R	R	R	R
Aphids	S	S	S	R	R	R	R
Thrips	S	MR	MR	MR	MR	R	R
Bruchids	S	S	R	R	R	R	R
Striga	S	S	S	S	R	R	R
Alectra	S	S	S	S	R	R	R
Nematodes	S	S	S	R	R	R	R

* The earlier variety is the parent of next variety

standard petal (5). Similarly all the white rough seeds have purple pigmentation on the joints (bases of the branch, peduncle, petiole and leaflets) and is inherited as one gene. However, the pigmentation on the whole stem, peduncle, petiole and pod is independent of the pigmentation on the joints. It was also communicated that the calyx pigmentation has pleiotropic pigmentation on the tip of the pod and is also independent of other pigmentations. Further, pod tip pigmentation and branched peduncle play important role in insect resistance. Kehinde *et al.* (6) identified the five linkage groups. Linkage group I comprised Pg(nodal pigmentation) → Na(narrow eye) → Br(brown seed coat) → Pc(smooth seed coat) → Pf (purple flower) while linkage group II consisted Bpd (branched peduncle) → Bp (brown dry pod) → Dhp (pod dehiscence). The third linkage group was Crl (crinkled leaf) → Pt (sessile leaf). Ha (Hastate leaf) and spt (septafoilate leaf) evinced independent segregation of others and comprised linkage group IV and V, respectively. Twelve linkage groups were identified on the basis of markers (7). Myers *et al.* (8) identified one RFLP marker to be tightly linked to the aphid resistant gene. Ouedraogo (9) identified three AFLP markers tightly linked to *Striga* resistant gene *Rsg* setting the stage set for marker assisted selection. However, still there are many informational gaps to identify more markers before putting MAS to routine practice.

Biotic resistance

Ogbuinya (10) screened over 8000 cultivated cowpea genotypes but could not ascertain any resistance in them simply because they do not have genes for resistance against major pests. Obviously their utility in any cross breeding programme is limited. However, excellent sources of resistance were observed in wild species viz. *V vexillata* and *V oblongitelia*. Hairiness on different plant parts of these species thwart aphids sustenance and can be regarded as non-preference mechanism for breeding aphid resistance. However, conventional crossing was difficult and embryo aborted spontaneously after 4-5 days. Embryo rescue technique was used successfully to transfer genes for resistance to aphids, leafhoppers and storage weevil. *Bambara* groundnut, a *Vigna* group plant, is quite tolerant to aphids due to hairiness. The same is also being tried for breeding resistance but regeneration is difficult in this case. The conventional breeding has primarily focused on transferring desirable multiple resistant genes by using earlier variety as parent for the new variety and different genes have been pyramided in different varieties (11).

Cowpea is susceptible to a wide range of pathogens that include bacteria, virus and fungi (12). Vale *et al.* (13) reported that resistance to cowpea severe mosaic comovirus (CpSMV) is controlled by single recessive gene using Macaibo and Pitiuba as resistant and susceptible parents, respectively. Arshad *et al.* (14) designated a single recessive gene as *bcm* that controlled resistance to blackeye cowpea mosaic virus (BICMV). Rust is not an important disease in India. It has been reported to be controlled by multiple genes with involvement of both recessive and dominant factors (15). Major gene inheritance has been observed for scab too (16).

Roberts *et al.* (17) screened different genotypes for resistance to different populations of nematodes (*Meloidogyne incognita* and *M javanica*) and identified IT 84 S-2049 as completely resistant. They identified one dominant gene Rk2 controlling resistance in this variety that was different to Rk gene identified earlier. Rodriguez *et al.* (18) have also reported nine cultivars highly resistant to root nematode (*M incognita*).

Abiotic stresses

Ishiyaku and Singh (19) observed that the photoperiod reduced the vegetative phase and height rather than reproductive phase as reported earlier. As such when the photosensitive cowpea genotypes were grown under short day conditions, they not only flowered early but became extremely dwarf. Photosensitivity gene evinced monogenic recessive inheritance and gene symbol *ps* was assigned to it.

Mai-Kodomi *et al.* (20) reported simple inheritance for shoot drought tolerance. They identified two types, Type I remained green after long spell of drought but there after the plant died with continued dry conditions. Type II did not die but the growing tips remained alive and dropped leaves first such that the plant resuscitated when watering was done. Both were inherited as monogenic dominant traits and gene symbol *Rds1* (resistance to drought stress) and *Rds2* were assigned to them.

Male sterility and heterosis studies

Sterility has been reported in cowpea and is controlled by single recessive gene designated as pms (21). They reported that sterile plants can be easily identified in field by thick leathery leaves with a fleshy one to three seeded pods with gaps. Heterosis has been reported from 20.4 per cent to 121 per cent for various traits (22). High value for heterosis though indicated good diversity among materials offering good possibilities

of isolating transgressive segregants, yet the values seemed biased due to spaced planting rather than planting as per farmers' practices.

Nutritional quality

The cowpea in general has better nutritional profile compared to other crops grown in less endowed areas. On an average cowpea evinced 25.4 per cent crude protein with the best line having 29.4 per cent crude protein compared to 20.6, 15.4, 12.5 and 7.8 of *bambara* groundnut, millets, sorghum and maize, respectively. In India, people suffer from anemia due to general deficiency of iron and zinc in diet. Cowpea genotypes developed at IITA were reported to have higher iron contents (average 48 mg/kg & best 69.1 mg/kg) compared to 22.0, 32.5, 34.7 and 20.1 mg/kg of mandated crops of drier areas like bambara groundnut, millets, sorghum and maize in that order. Similarly zinc profile was also better contents (average 36.0 mg/kg & best 47.0 mg/kg) compared to 21.2, 23.6, 21.2 and 16.2 mg/kg of *bambara* groundnut, millets, sorghum and maize, respectively.

The impact of global research on Indian cowpea

The impact of the global research in cowpea is evident particularly in Africa by supporting the crop-livestock system with over all improvement of health and livelihood. Today about 40 varieties are grown in 65 countries that has resulted four times increase in production of cowpea from 1.1 m Mt to 4.5 m MT since 1980s. The research conducted at the global level can have following applications in Indian context:

1. Early varieties for enhancing pulses production

The production of pulses in the country have not kept pace with the over all agricultural development. This is evident from the fact that where as increase in production of cereals is quite matching (2.59 times) to global rate of increase (2.57 times) with 1961 as base year, the rate of enhancement in pulses is just 1.14 times compared to 1.51 times at the world level. This is despite the predominant pulses area lays in India. Obviously increase in area of pulses cannot be contemplated by replacing remunerative crops but short duration day neutral pulses like cowpea can play a pivotal role in this endeavor. Sixty days varieties can easily be taken as summer/spring crop after wheat harvest in northwestern plain zone of wheat that supports more than 10 m hectares. Mere covering 20 per cent of the area with 60-day duration variety having productivity of around one ton per hectare can easily solve the problem of 2 m tons shortage of pulses in the country. The all India coordinated experiments done with IITA materials have revealed that 12 to 15 q/ha yield can be achieved during both kharif and summer season with a maturity of 62 days.

2. Diversifying Ailing Cropping Systems

In African continent, it was possible to take two crops of high yielding cowpea within the same crop season by replacing local variety of cowpea grown traditionally as intercrop with maize with improved 60-day cowpea variety planted in 4 cowpea: 2 rows maize. The gain was more than 300 per cent over local types.

Early maturing cowpea with 60 days maturity has opened a new horizon of squeezing in cowpea crop in between main crops or taking two crops of cowpea in one *kharif* season. Thus, 60-day cowpea varieties introduced from IITA can be grown as a niche crop after harvest of wheat and before rice planting that will not only substantially increase pulses production in India but resuscitate the ailing soil health particularly in wheat-rice, rice after rice and sugarcane based cropping system. The varieties can be further tailored to suit Indian conditions. Possible cultivation of 60-day cowpeas to diversify and intensify Indian cropping systems as intercrop in sugarcane (March); in rotation with potato or early mustard (March); after wheat harvest and other fallow lands (early April); as a first *Kharif* season crop (May-June); as a second *Kharif* season crop (August-September) and as a niche crop in rice-rice / rice-wheat cropping system. Needless to emphasize, the crop that can yield 12 - 15 quintals of all important but ever scarcer pulses in 60 days without requiring extra acreage can play a pivotal role in intensive agriculture too. A beginning in breeding extra early varieties has already been done since last season and potential lines of 62 days maturity have been screened with yield potential as high as 18 q/ha with better resistance to common mosaic virus.

3. Long Duration Drought Tolerant Varieties for Sustainable Agriculture

India has vast diversity both in culture and agriculture. Therefore, the current activities and future plans of cowpea research in India as impacted by global research should not overlook drought prone areas where indeterminate medium duration varieties are expected to do well besides sustaining agriculture under small holding and poor growing conditions. This is pertinent, as it will ensure sustained supply of readily available green pods for vegetable and fodder for animals besides production of pulses over a longer period.

4. Situation Specific Varieties with Holistic Approach
At present every thing is generalized i.e. *kharif* varieties are grown in summer without a least care for other specific requirement in intercropping or mixed cropping or for that matter pure cropping system. The situation specific research areas like the one prevalent in cereals like wheat may be identified and situation specific research may be focused precisely. For this the research may be supported by a multidisciplinary approach for developing new situation specific cowpea varieties with better insect resistance and higher yield potential and quality attributes. The cowpea producing pockets under different cropping system may be identified and the subjective research may be undertaken to address the situation specific problem on mission mode. The problem specific stations for specialized work like disease resistance, pest resistance, quality etc may be identified to strengthen research facilities. Alternatively the facilities already available in the country may also be shared for effective screening. Needless to emphasize the programme should have better indicators in terms of food security, income generation, livelihood integration and conservation of natural resources.

5. Enhancement of Organic Agriculture
Cowpea is a crop especially suitable for high temperatures and low moisture conditions. Its *Rhizobium* bacteria are specific and are effective under high temperatures as well where other *Rhizobium* species become ineffective. Similarly it also works as a good component for supporting predators and parasites and thereby is a potential candidate for encouraging organic agriculture particularly under less endowed areas of arid and semi arid conditions where most of agriculture is already practiced organically by default. It would add value to the produce of the areas and thereby may improve socio-economic status.

6. Biotechnology for Combating Invincible Problems
Lot of advances have taken place in cowpea for combating problems like resistance to *Maruca* pod borer, sucking pests and bruchids, where none or only moderate levels of resistance have been identified, it is recommend that aggressive efforts be made to transfer resistance genes from other species with genetic engineering. Also, for traits such as bacterial blight, Striga, photosensitivity, drought, etc, that are difficult to select in the field, the markers may be identified and marker-assisted selection (MAS) techniques may be implemented. In the immediate future, genetic engineering is likely to offer great potential benefits to cowpea producers, especially in helping to greatly reduce losses in yield and reductions in grain quality due to insect pests. For this to happen, strong national breeding programs are needed to develop locally adapted varieties with the improved traits. However, this should not be at the cost of conventional breeding methods where high level of genetic variability has been identified and effective screening methods are available. Further, recent advances in molecular genetics, such as marker-assisted selection, that have the potential to speed up progress of breeding programs, are unlikely to be utilized in cowpea improvement unless the national programs in the regions are strengthened

7. Quality Seed Production
The cowpea seed supply system is ineffective in supplying seed of improved varieties and therefore, ways may be identified to make the system work. This study should also address the cost and logistical implications of selling genetically modified (GM) seed of cowpea to smallholder farmers in the near future.

In nutshell, improved new 60 day cowpea varieties have enhanced food security, family nutritional sustenance and income generation in less endowed areas like Africa and have good potential in India particularly for increasing production of pulses to meet the short fall of 2 million metric tons besides all important rejuvenation of ailing cropping systems.

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