Plant Introductions in Soybean – Achievements and Opportunities

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Soybean presently covers about 8 million hectares in the country and significantly contributes towards agrarian economy and farm-prosperity. Although soybean has originated in China, the north-eastern region of the Indian sub-continent has a degree of endemic variability. The earlier soybean introductions have been owing to propinquity of these areas with China. Early varieties like Punjab White/ Punjab-1 and a host of strains grouped under Bhat/ Bhatmash / Kalitur are also part of this endemic variability. These have saved the Indian soybean variability from the founder-effect as, later, most of the yellow-seeded varieties and strains of soybean in India have been introduced via USA. Several important genes such as those for resistance to yellow mosaic virus and other diseases, nutritional characteristics, photoinsensitivity, long-juvenility etc. have been introduced in India, mainly from USA followed by Taiwan, Brazil and other countries. Of late, a sizable number of black-seeded soybean varieties of Indian provenance have been repatriated from USDA, USA. The introductions particularly for specific genes of interest have helped in bringing about a renaissance of this ancient crop of northern India into a commercial crop of the country. Opportunities exist to further have directed-introduction for several traits and genes of interest which were hitherto unimportant but are presently assuming significance such as those for food and nutritional quality, lack of anti-nutritional factors etc.

Key words : Soybean, Introduction, Evaluation, Crop improvement

Owing to a consortium approach under the Technology Mission on oilseeds, which was set up in May 1986, a breakthrough in oilseed production could be achieved which was christened as "Yellow Revolution". The present oilseed production is about 26 million tonnes. Out of nine oilseed crops of India, the major contributors towards this revolution were rapeseed-mustard and soybean. We have to (i) defend the gains made, (ii) extend the gains to potential areas yet uncovered, and (iii) make new gains on sustainable basis.

Soybean (*Glycine max.* (L.) Merrill) is the most important oilseed crop in the world, accounting for more than 50% of oilseeds produced and about 30% of the total supply of all vegetable oils. It is unique crop having both high quality protein (43%) and oil (20%) content. It also helps in improving soil fertility through nitrogen fixation. The protein from soybean is equivalent to that of meat, milk products and eggs in quality. Among the leguminous crops, soybean is a relatively higher yielder and farmers get better returns. It is one of the most popular source of protein in the world. It is used for making diversified products with a wide range of uses. Besides being a source of vegetable oil, soybean is moving towards being utilised as a functional food.

Soybean is the unique oilseed crop in view of its contribution to agrarian economy and farm-prosperity. The research and developmental efforts in soybean have yielded not only outputs but also outcome; socio-economic uplift of Malwa farmers in Madhya Pradesh is an example of it (Badal *et al.*, 2000). It has established itself as one of the most important oilseed crops of India along with groundnut and rapeseed-mustard. The estimates show that soybean presently covers an area of about 8 million hectares with a production of over 8 million tonnes and a productivity of about 1.1 tonne per hectare.

The crop is concentrated in the central Indian niche predominantly in Madhya Pradesh, Maharashtra and Rajasthan states around a latitude range of about 16 to 26° N and longitude range of about 73° to 84° E wherein Indore, the epicentre of soybean renaissance is situated at 22° 44 N and 75° 50 E. Some area is beyond this range also and it is feasible to grow soybean in most parts of the country. Soybean is generally grown as a rainy season crop under rainfed situation. Soybean, particularly in its early years of spread, largely occupied the rainy season fallow land. This resulted in an enhancement in the cropping intensity and an increase in the unit area profitability from the land use. Soybean also replaced some less remunerative crops like sorghum and minor millets. In western Madhya Pradesh, Maharashtra and Karnataka, some area under cotton is also being replaced by soybean.

Origin, Evolution and Domestication

Soybean is native to eastern Asia particularly Korea and China border. The first record of its cultivation

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dates back to 2838 B.C. in China (Morse, 1947). This is based on the occurrence of the *Glycine ussuriensis* which is considered as a progenitor of the cultivated soybean *Glycine max.* Cytogenetic evidence suggests that *G. max* and *G. ussuriensis* are the same species. Thus, *Glycine soja* Sieb & Zucc. is the probable progenitor of cultivated soybean. The eastern half of North China is believed to be the primary centre and Manchuria, the secondary centre of origin of soybean.

Some of the early workers as Nagata (1959, 1960) consider China proper to be the homeland whereas others suggested eastern Asia to be the centre of origin of soybean. Nagata thinks that soybean was introduced into Korea and later disseminated to Japan. According to Hymowitz (1970), *G. ussuriensis* grows wild in Korea, Taiwan, Japan, North East China and adjacent areas of USSR. He further suggested North East China as the area where soybean was first domesticated around 11th century B.C. Chang Ruzhen (1989) discussed different hypothesis suggesting centre of origin and largely accepted that lower and middle Yellow River valley is the main centre of origin of soybean.

Global Spread and Introductions of Soybean

The available evidences suggest dissemination of cultivated form of soybean from North China to Korea and then to Japan, sometime between 200 B.C. and 3rd Century A.D. (Nagata, 1959, 1960). Another route of dissemination could have been from North China to Southern Japan (Morse, 1950). Morse (1950) presented a comprehensive review of the history of soybean production and suggested that soybean seeds were sent to Paris by missionaries around 1740. Its cultivation in England was done as early as 1790 (Alton, 1842). According to Brooks (1966), soybean was known in Europe in the 17th Century as an exotic plant from orient. However, it was not until 1712 when the Western world finally recognized soybean as a food plant. Its cultivation in Europe started since 1875.

In the USA, mention of soybean in literature dates back to 1804 but its commercial production picked up only in 1930s. Afterwards, the Perry expedition to Japan in 1854 brought two soybean varieties viz. 'Japan pea' or 'Japan beans'. However, at the end of the Nineteenth century a systematic introduction of soybean started in the USA from Asian countries. Today it has occupied such a position that there is no other crop plant in the USA that has found such a diversified utilization as the soybean. During the World War I and II soybean was recognized as most essential in the manufacture of various food and industrial products. Likewise, in Germany, during the II World War soybean flour was used in making of ration for the soldiers (Burns, 1941).

Today, United States, Brazil, Argentina, China and India are the major soybean growing countries accounting for 90% of the soybean production and area.

Indian Soybean Introduced in USA : Quid Pro quo?

While in the later part of the history, most of the soybean varieties and germplasm has been introduced in India from and via USA, it is interesting to note that in the early times, and even later the Indian soybean material went to USA. It is documented that at the beginning of the twentieth century, there were perhaps eight soybean cultivars growing in the USA. It will be interesting to know that during the first two decades, new soybean accessions were introduced from India and China, into the USA by USDA plant explorers Charles V. Piper and Frank N. Meyer, respectively (cf. Hymowitz and Bernard, 1991). Owing to seed viability and germinability problems, these introductions could not be kept well in USA. Later in sixties, USA soybean varieties and lines started to be introduced largely from USA and to some extent from Taiwan to India.

Some indigenous material from India is well documented. For example, the USDA Germplasm Collection Inventory (1989) records that USA introduced 258 accessions from India during the years 1945 to 1985. Further, it also records "to have imported 54 PI numbers i.e. serially from 374.154 to 374.207 collected from central India (Table 1) which were all black-seeded and belonged to the maturity groups VIII and Xth.

Introduction of Soybean in India

In India, soybean has been grown for a considerable length of time on the borders of North West Frontier provinces and in Mirpurkhas in Sindh and in Nepal. In those days it has been used as forage and as a food crop. It appears that soybean was introduced into the country from north-eastern India and Himalayan regions, especially from where the area that is contiguous to or near China. The advent and renaissance' of soybean in India has been depicted by Tiwari *et al.* (1999). The soybean renaissance resulting in phenomenal growth of soybean in India started with the use of indigenous black soybean variety 'Kalitur' as a vehicle of this revolution. The black soybean, ruled 'for several years thereafter. Yellow-seeded introductions helped later in consolidation of early gains made through this black indigenous variety. 'Kalitur' was and is still

Table 1. Indian soybean strains in the USA germplasm collections (1945-1985)

Year	PI No.	No. of strains	Source
1948	163.308, 165.524-165.583, 165.896-166.105, 166.437-166.439	17	Almora, Kulu, Garhwal regions of Uttar Pradesh (U.P.)
1949	174.852, 174.856-174.868, 175.174-175.176, 175. 179-175.199, 179.935, 180.051-180.052, 180.444, 183.929-183.930	42	Kumaon, Tehri Garhwal, Dogra regions of U.P., Khasia (Assam) and Punjab
1951	194.771-194.773, 198.078	2	Punjab and U.P.
1957	239.484	1	Vidarbha
1959	255.734, 256.376	2	Punjab no. 1 (New Delhi)
1965	307.597, 307.836-307.900	61	IARI (New Delhi), JNKVV (Jabalpur)
1967	319.525-319.533, 323.550-323.581	39	Almora, Nainital (U.P.)
1969	346.298-346.312	10	IARI (New Delhi)
1972	374.154-374.207	54	Mhow, Ujjain, Dewas, Simrol, Indore, Nagpur (Central India)
1978	428.691-428.692	2	Imphal (Meghalaya)
1981	462.312	1	Ankur from Pant Nagar (U.P)
1982	468.373-468.375	2	Imphal (Meghlaya)
1984	486.327-486.335	6	Jabalpur, Ranchi,Pune
1985	497.952- 497.970	19	Pusa (Bihar), Jammu and Kashmir, Sikkim
	Total	**258**	

Source: Bernard et al. (1989) The USDA Germplasm Collection Inventory, Volume 2, P. 190

recognised for its high seed longevity, tolerance to a degree of water-logging, general resilience to changes in weather etc. The Indian varieties of today represent different groups based on their breeding history. There are soybean varieties that are land races or selections from them and have been known since long. These are:

(a) A pool of black-seeded indigenous varieties/stocks such as 'Bhat'/Bhatmash' which represent the habitat of northern region but are also cultivated in scattered pockets of central India under names such as 'Kalitur' and 'Kala Hulga'.

(b) Yellow-seeded pool of northern Tehri-Garhwal region presently represented by the variety 'JS 2', and

(c) A pool of indigenous varieties with yellow-coloured small seeds such as those represented by 'Type 49'. These varieties, in their original form, have been cultivated in small pockets since long. Plant breeders have either identified them through trials or practised simple selection on them. The variety 'Punjab 1' (a maturity group VII variety later entered as PI 198.078 in the year 1951 and further as PI 255.734 in the year 1959), although representing a selection from the exotic 'Nanking' variety, is also known to have been adopted quite early by the farmers. Old reports from Central India clearly state that 'Punjab White', a promising 'desi' type (country or indigenous types having long history of cultivation), was being grown in small plots in several states (IPI, 1934).

Around 75% of the accessions in the Indian collections maintained at the NRCS, Indore are exotic (Table 2). USA, the Philippines and Taiwan were the major donor countries. Of the total germplasm accessions available in India, NRCS is the largest holder and also the National Active Germplasm Site (NAGS) for soybean. Other major centres holding soybean germplasm are JNKVV, Jabalpur, IARI, New Delhi and GBPUAT, Pantnagar (Table 3).

Table 2. Source of Indian soybean accessions maintained at NRCS (ICAR), Indore

Country	No. of collections
India	1,014
USA	1,474
Taiwan	610
Philippines	365
Argentina	90
Japan	14
Australia	20
Myanmar	10
Nigeria	43
Brazil	16
Srilanka	5
Others	294
Total	**3,955**

Table 3. Soybean collections in India

Institute/SAU	Total no. of germplasm collections
National Research Centre on Soybean, Indore	3,954
Jawaharlal Nehru Krishi Viswavidyalaya, Jabalpur	1,364
ARI, MACS, Pune	609
Jawaharlal Nehru Krishi Viswavidyalaya, Sehore	180
Indian Agricultural Research Institute, New Delhi	1,200
Govind Ballabh Pant University of Agriculture and Technology, Pantnagar	978
Panjab Agricultural University, Ludiana	795
Marathwada Agricultural University, Parbhani	674
University of Agricultural Sciences, Dharwad	374
Total	**10,128**

Recently collected data shows, that the above trend of introduction is broadly being maintained and USA and Taiwan remain to continue as the two major donors (Table 4).

At the NBPGR (ICAR), Akola centre also, majority of the accessions are exotic. The prominent donor countries are USA (582 accessions), Argentina (190 accessions), Germany (152 accessions), Australia (109 accessions), Taiwan (71accessions), Hungary (58 accessions) and USSR (45 accessions) (Table 5). Exotic material from other countries was also obtained. From the bordering Nepal, 24 accessions were obtained. Surprisingly, not much material was directly obtained from China. It came to India through USA. However, the USA material itself was obtained largely from three major countries viz. South Korea, Japan and China (Bernard *et al.,* 1989).

Table 4. Introduction of soybean (mainly *Glycine max*) germplasm during 1994-2006

Year	No. of acc.	Source/countries
1994-95	90	China, Russia, Taiwan, USA
1995-96	154	Indonesia, Japan, Philippines, Taiwan
1996-97	651	Australia, Brazil, Korea, Russia, Taiwan, USA
1997	62	North Korea, Russia, Taiwan, USA
1998	199	Mexico, Taiwan, USA
1998	10	Taiwan
1999	421	Canada, Taiwan, USA
2000	1,235	Nigeria, Taiwan, USA
2001	1,753	Australia, Japan, Taiwan, USA
2002	169	USA
2003	378	Nigeria, Taiwan, USA
2004	81	Myanmar, Brazil, Sri Lanka, USA
2005	34	Taiwan
2006	281	Sri Lanka, Taiwan, Thailand, USA
Total	**5,518**	

Of late, introductions of soybean have become trait-specific. Some people prefer to call this as "directed introduction". Recent introductions of soybean in India are listed in Table 5 and the specific trait characteristics of these are mentioned in Table 6.

At NRCS, Indore, there are 36 collections of wild relatives of soybean representing eleven wild species of the sub-genus *Glycine* and one accession of *G. soja* of the sub-genus *soja (Table 7)*. These species are *G. tabacina, G. falcate, G. arenaria, G. latrobeana, G. tomentella, G. arygyrea, G. cyrtoloba, G. canscens, G. latifolia, G. clandestine* and *G. microphylla*. These have been obtained mainly from USA and AVRDC, Taiwan.

Table 5. Sources of exotic soybean accessions in India (NBPGR, Akola Centre)

Country	Frequency	Country	Frequency
Argentina	190	Morocco	4
Australia	109	Nepal	24
Brazil	16	Nigeria	22
Canada	7	P. New Guinea	3
Sri Lanka	2	Philippines	3
China	16	Rhodesia	3
Fiji	4	Romania	10
Germany	152	S. Africa	2
Ghana	8	Taiwan	71
Hungary	58	Thailand	6
Indonesia	3	Trinidad	1
Israel	1	UK	1
Italy	36	USA	582
Japan	35	USSR	45
Korea	2	Yugoslavia	1

Evaluation of Introduced Germplasm in Soybean

For a successful variety development program utilization of possible diversity available in germplasm is primary need. Evaluation of exotic germplasm, in particular, is necessary to widen the genetic base by facilitating the identification and eventual incorporation of the desired traits lacking in the existing varieties. Use of exotic germplasm along with indigenous ones often results in the increased genetic variability for desired selection. Khalaf *et al.* (1984) reported that there was greater variability for yield in populations where exotic genotypes contributed to the crosses. In this concern, the three way or multiple crosses are found suitable. A greater number of suitable lines may be identified from such crosses. Evaluation of exotic germplasm in India has resulted in identification of donor sources (Table 8) several of which have been used in breeding for crop improvement.

In India, there are about 3,094 soybean accessions in the long-term storage for base collection at gene bank at NBPGR, New Delhi. About, 3,250 accessions are at NRCS, Indore; 3,000 at NBPGR Centre, Akola; 809 at Pune; 636 at Pantnagar; 650, at Bangalore; 592 at Coimbatore; 287 at Sehore and 286 at Jabalpur (Tiwari, 2001b). Despite this it is very less compared to USA collections. Several accessions are not duplicated at different centres and therefore, are not in use in breeding programmes extensively.

Tiwari (2001 b,c) and Karmakar (2001) reviewed the soybean improvement programme in India and found that the genetic base of Indian released varieties is narrow

Table 6. Characteristics of soybean germplasm introduced during 1994-2006

EC Number	No. of Acc.	Countries	Characteristics
EC 426727-744	18	Taiwan	Grain and vegetable type
EC 439597-622	26	Taiwan	Rust resistant, insect resistant and early maturing lines
EC 434782-812	31	USA	Transgenic
EC 468377-629	253	USA	Lines resistant to root knot nematode, drought, heat, soybean moasic virus, multiple foliar disease, downy mildew
EC 473111-138	28	Taiwan	Rust resistant and wild perennial lines
EC 473265-288	24	Taiwan	Vegetable types and rust resistant lines
EC 478225	1	USA	Resistant to soybean cyst-nematode
EC 483041-61	21	USA	Lines resistant to foliar feeding insects, rust/and stem canker, having high protein, genetic male sterility, low trypsin inhibitor,
EC 497964	1	USA	High yielding, mid-maturity with indeterminate habit, high protein content
EC 528619-629	1	USA	High yielding and widely adapted
EC 537946	11	Taiwan	Rust resistant lines
EC 537947	1	USA	High yielding, resistant to shattering, lodging and root knot nematode
EC 538792-800	1	USA	High yielding, resistant to soybean cyst and root knot nematode
EC 538801-804, 538806	9	USA	Rust resistant lines
EC 538810	6	USA	Rust differential lines
EC 538805,538811, 558812	3	USA	Drought tolerant lines
EC 538815, 558807-538809,			
EC 538813-14, 538816	7	USA	Insect resistant lines
EC 538817-818	2	USA	Concentric black over brown seed coat
EC 538820-821	2	USA	Saddle patterns on seed coat
EC 538822-823, 538830	3	USA	Drought and heat resistant
EC 538824	1	USA	Low lipoxygenase
EC 538825-829	5	USA	Resistant to root knot nematode
EC 538831-833	3	USA	5.5% linolenic acid
EC 538834	1	USA	Resistant to soybean scab
EC 538835-841	7	USA	Resistant to soybean cyst nematode
EC 539008	1	USA	Resistant to phytophtora rot, races 3 and 14 of soybean cyst nematode
EC 559539-271	33	Taiwan	Vegetable Type
EC 559572	1	Taiwan	Rust tolerant vegetable type
EC 592181-212	32	Taiwan	Late/early maturity, whitefly and downy mildew resistant
EC 592211-219	9	Taiwan	High oil content
EC 5986966	1	USA	Early, resistant to stem canker and soybean mosaic virus
EC 586967	1	USA	High yield, shattering resistant, resistant to stem canker, soybean cyst nematode, sudden death syndrome and frog eye leaf spot
Total	**533**		

*EC =Exotic Collection

Table 7. List of wild species of soybean introduction

S. No.	Crop	EC number	Source coutries
1	*Glycine argyrea*	EC 468551	USA
2	*G. canescens*	EC 56371-73, 468421-22	Taiwan, USA
3	*G. centennial*	EC 1468570	USA
4	*G. clandestinea*	EC 456369-70, 468426-33	Taiwan, USA
5	*G. cyrtoloba*	EC 468423-24	USA
6	*G. latifolia*	EC 56379, 468418-420	USA
7	*G. microphylla*	EC 468425	USA
8	*G. soja*	EC 456384-86, 473120-137	Taiwan, USA
9	*G. soja clandestine*	EC 468426-433, 473138	USA
10	*G. tabacina*	EC 456380-8, 1, 468375-416	Taiwan, USA
11	*G. tomentella*	EC 56382-83, 468453-54	Taiwan, USA
12	*G. falcate*	EC 456374-75	Taiwan, USA
14	*G. javanica*	EC 56376-78	USA

and the trend of hybridization is elite x elite germplasm lines. Therefore, there is a need for broadening the genetic base for soybean varieties. Verma *et al.* (1995) have evaluated the genetic resources at NBPGR and reported several donors for different characters. Lal *et al.* (2001) evaluated the germplasm for rust resistance and Pushpendra and Sidhu (2001) reported some sources of resistance for disease-insect complex. The original Indian accession Kalitur has played a key role for revolution in Indian soybeans. This black seeded variety is still used as a donor for multiple characters such as high seed number per plant, better seed longevity and higher germination percentage, wide adaptability and resistance to water lodging. Evaluation of soybean germplasm has been done at Agharkar Research Institute

Table 8. Important characteristics of soybean and the donor sources, including introductions and their derivatives, for use in breeding programme

Characters	Donor varieties/lines
Early maturity	EC 4478(61DAS) EC 34116, EC 39171, EC 95284, EC 39237 (All 69 DAS), EC 7849, EC 28177, EC 32526, EC 34066, (All 70 DAS)
High yield	JS335, Hardee, Bragg, Carroll, MACS 13, MACS-124, MACS 450, NRC-37, MAIS 2, TS 98-21, PK 472, Pusa 16, JS 80-21
Seed longevity	Type 49, Kalitur, Punjab 1, JS 80-21, NRC 1
High seed germination	Kalitur, MACS 111, MACS 450, Type 49.
Pod shattering resistance	Bragg, PK 416, NRC 7, Pusa 22, VLS 1, Himso 1520, Nathan, JS 71-05, MACS 124
Resistance to insect pests	*Glycine soja* (for Bihar hairy caterpillar, girdle beetle, etc.) PI 171451, PL 227687 and PI 229358, L592 (for girdle beetle)
Resistance to diseases	
Yellow mosaic virus	*Glycina soja*, UPSM 534, PK 416
Bacterial pustules	Bragg, Hardee, PK 564, PK 416
Aerial blight	PK 472, JAVA 16, Kalitur
Rust	PI 200492, PI 462312, PI 230970, PI 459025, Ankur, PK 1029
Early maturity	Monetta, Shelby, Punjab-1, JS 71-05, PK 327, MACS 330
High oil content (more than 21%)	PK 416, Lee (non-nodulating), MACS 58, MACS 942, MACS 943, MACS 944, MACS 945, MACS 948, MACS 957, MACS 959 and MACS 961
Low linolenic acid	A 16 and A17
lodging resistance	PK 262, JS 71-05, PK 472, MACS 13
Enhanced efficiency and Promiscuity for nodulation	Carroll, JS 335, MACS 124, MACS 450, Pusa 16
Higher insertion of first pod	PK 416, MACS 58 and JS 80-21
Suitability for food uses	Hardee, Punjab 1, PK 472, PI 408251, PI 86023, 'Wase Natsu' (PI 417458), 'I-Higo-Wase' (PI 205085), Himso 1563, Kunitz

(Pune), NBPGR Regional Station (Akola) and National Research Centre for Soybean (Indore). The data have been presented in the form of catalogues. Important breeding objectives for soybean and their sources for use in breeding programme have been given in the Table 8.

The performance of newly bred lines depends upon how much diverse the parents were. Genetically diverse parents are likely to produce high heterotic and desirable segregates. The concept of Mahalanobis D^2 analysis for measuring divergence between populations has been applied by several workers. Murthy and Arunachalam (1966) stated that the genetic drift and selection in different environments could cause greater diversity among genotypes than their geographical distribution. Joshi (1979) reported that genetic diversity involving genetically diverse parents in crossing would be advantageous as it would provide an opportunity for bringing together gene constellations of divergent origin. Raut *et al.* (1998) evaluated the germplasm lines for seed oil content and reported 21 lines having more than 21.5% oil content. Chauhan and Singh (1982) studied the segregating populations and explained that there was greater variability in the populations of the medium to high divergent parents. Raut *et al.* (1984) studied genetic divergence in soybean and grouped variable genotypes into 12 clusters irrespective of geographical distribution or origin. They suggested that EC2586, EC077, PLSO-24-A and IC10037 were most divergent. After evaluation of 41 Indian cultivars for 10 yield components, Karmakar *et al.* (1998) have observed that there was maximum diversity between JS71-05 and T-49 and the crosses between JS-2 and Monetta were identified as good possible combinations for earliness. Thus the diversity analysis of the present germplasm lines is important for design of the future breeding strategies to get higher genetic gain. Tiwari (2001) have put forward some strategies as, i) assessment of genetic base through pedigree and other analyses, ii) introduction should be extensively initiated, iii) consolidation of national germplasm collection to different research stations, iv) evaluation of core collection for various qualitative and quantitative characters, and v) pre-breeding and germplasm enhancement using cultivars as well as wild relatives and land races.

Broadening the Genetic Base

Results of pedigree analysis and diversity analysis in soybean have indicated narrow genetic base of cultivated varieties. Studies in major soybean growing countries like USA (Delannay *et al.*, 1983; Manjarrez-Sandoval, *et al.*, 1997; Kisha *et al.*, 1998; Thompson and Nelson, 1998), Brazil (Hiromoto and Vello, 1986; Vello *et al.* 1988), India (Karmakar and Bhatnagar, 1996) and China (Gai, 1999) have indicated that up to now breeders have used only a small part of available genetic resources and the soybean varieties have a very narrow genetic base. Germplasm enhancement and pre-breeding is needed. There is a need to strengthen the activities in this aspect by resorting to crossing between unadapted genotypes (cultivated) allied species especially *Glycine soja* Siebet Zucc. and elite cultivars.

Strategies for broadening the genetic base of soybean in breeding and production in India have been suggested (Tiwari, 2001). These comprise : (i) assessing the genetic base through pedigree and other analyses, (ii) directed introductions, (iii) consolidating the national germplasm collections, (iv) evaluation and establishment of a core collection of soybean genetic resources, (v) pre-breeding and germplasm enhancement using the cultigen as well as wild species, (vi) population improvement, (vii) enhancing genetic diversity at farm level by farmer participatory approaches, and (viii) facilitated access to soybean genetic resources for the users. Directed introductions, further enhancement of genetic resources, pre-breeding and ultimate widening of the genetic base of the cultivars at farm level will eventually lead to the realisation of high productivity.

Successful use of Plant Introductions in Soybean Improvement

Introductions used as varieties per se

There is a sizable number of early soybean varieties which are introduced and used per se for cultivation after their evaluation to suit Indian conditions. The improtant introduced varieties are Bragg, Clark 63, Davis, Hardee, Hill, Improved Pelican, KM 1, Lee, and Monetta. It is to be remembered that these varieties played an important role during early phase of soybean spread in India along with the landraces or indigenous varieties like Kalitur, JS 2, Type 49 and Punjab White/ Punjab 1 (Selection from Nanking).

Depending on their breeding history, the Indian varieties can be grouped into two. The first group comprises varieties viz. Bragg, Lee, Improved Pelican, Hardee, Monetta, Shilajeet, Co 1, Gujarat Soy, Gujarat Soy 1, Gujarat Soy 2, VL Soy 2 and JS 71-05 which owe their evolution to direct selection from exotic and indigenous material. The second group comprises a bulk of the rest of the Indian varieties which were developed through hybridization among and mutation in the varieties of the first group (Karmakar and Bhatnagar, 1996).

The introductions were also used as base for mutation breeding and used in hybridization to develop varieties. The details are given in Table 9.

Table 9. Soybean introductions released *per se* and / or used for crop improvement

S. No.	Name of the introduction	Country from where introduced (Year of introduction)	Cultivar developed from it	Mode of development	Year of release of the cultivar
1.	Hill		ADT-1	Selection	1990
2.	Bragg	USA (1967)	Bragg	Introduction	1969
			NRC2	Mutation	1997
			NRC12	Mutation	1997
			Durga	Hybridization	1982
			Hara soya	Hybridization	2001
			JS 76-205	Hybridization	1984
			JS 79-81	Hybridization	1994
			MACS 450	Hybridization	1999
			Pant Soybean 564	Hybridization	1991
			Pant Soybean 1024	Hybridization	1997
			Pant Soybean 1029	Hybridization	1997
			Pant Soybean 1042	Hybridization	1997
			Pusa 20	Hybridization	1988
			Pusa 24	Hybridization	1987
			Pusa 37	Hybridization	1985
			SL4	Hybridization	1990
			SL 295	Hybridization	1997
			VL Soya-1	Mutation	1985
3.	S69-96		NRC7	Selection	1997
4.	D63-6094		Alankar	Hybridization	1978
5.	D61-4249		Alankar	Hybridization	1978
6.	Dortchsoy 67A	Italy	Ankur	Selection	1976
			Pant Soybean 564	Hybridization	1991
			SL295	Hybridization	1997
7.	Clark 63	USA	Clark 63	Introduction	1969
			JS 80-21	Hybridization	1991
			JS 90-41	Hybridization	1999
			JS335	Hybridization	1994
			MAUS 47	Hybridization	2000

	Name of the introduction	Country from where introduced (Year of introduction)	Cultivar developed from it	Mode of development	Year of release of the cultivar
			MAUS 32	Selection	2000
			MAUS 61	Selection	2001
			MAUS 61-2	Selection	2002
			Pusa 22	Hybridization	1983
			Shivalik	Selection	1987
			MAUS 81	Hybridization	2003
8.	S.3	Thailand	Co-1	Selection	1982
		Taiwan	JS 80-21	Hybridization I	1991
			JS 90-41	Hybridization	1999
			JS335	Hybridization	1994
			KHSb2	Hybridization	1979
			MAUS 47	Hybridization	2000
			MAUS 32	Selection	2000
			MAUS 61	Selection	2001
			MAUS 61-2	Hybridization	2002
			Shivalik	Selection	1987
			MAUS 81	Hybridization	2003
9.	Shihshi	Taiwan	Co Soya-2	Hybridization	1997
10.	Davis	USA	Davis	Introduction	1973
11.	C.6	Australia	Durga	Hybridization	1982
12.	D60-9647	USA	Gaurav	Hybridization	1982
13.	CNS		Gaurav	Hybridization	1982
			MACS-13	Hybridization	1985
			RAUS5	Hybridization	2002
			Pusa 16	Hybridization	1987
14.	Nanking		Punjab-1	Selection	1975
			Gujarat Soybean 1	Selection from Punjab-1 (from Nanking)	1983
			Pant Soybean 471	Hybridization	1988
			PK 472	Hybridization	1986
			Pusa 22	Hybridization	1983
15.	Geduld		Gujarat Soybean 2	Selection	1983
16.	Hardee		Hardee	Introduction	1976
			Pant Soybean 471	Hybridization	1988
			PK262	Hybridization	1983
			PK.308	Hybridization	1985
			PK472	Hybridization	1986
			MAUS 61-2	Selection	2002
			KB 79	Hybridization	1997
17.	Improved Pelican		Improved Pelican	Introduction	1976
			JS 75-46	Hybridization	1987
			MACS-57	Hybridization	1992
			MACS-58	Hybridization	1989
			MACS-124	Hybridization	1992
18.	Lee type material		JS 71-05	Selection	1991
			MAUS 71	Hybridization	2002
			JS335	Hybridization	1988
			MAUS 81	Hybridization	2003
19.	Semmes	USA	JS 75-46	Hybridization	
			PK327	Hybridization	1983
20.	Harsoy-Deciduous		JS 79-81	Hybridization	1994
21.	Hark		JS 90-41	Hybridization	1999
			MAUS 47	Hybridization	2000
22.	Manloxi	Australia	KHSb2	Hybridization	1979
23.	KM1	AVRDC	KM1	Introduction	1982
24.	Lee		Lee	Introduction	1973
			Pusa 16	Hybridization	1987
			RAUS5	Hybridization	2002

	Name of the Introduction	Country from where introduced (Year of introduction)	Cultivar developed from it	Mode of development	Year of release of the cultivar
			Pusa 20	Hybridization	1988
			Pusa 40	Hybridization	1981
25.	Monetta		Monetta	Introduction	1985
			MACS 330	Hybridization	1990's
			KB 79	Hybridization	1997
26.	5831	USSR (1971)	MACS 330	Hybridization	1990's
			LSbl	Selection	2001
27.	Hampton		MACS-13	Hybridization	1985
28.	PI 171443		Pant Soybean 564	Hybridization	1991
			PK416	Hybridization	1986
			SL295	Hybridization	1997
29.	Bulomi No.3		PK327	Hybridization	1983
30.	8-3		Pusa 40	Hybridization	1981
31.	Rikun No 8	Japan	Shilajeet	Selection	1980
32.	Botato	Australia	SL96	Hybridization	1986
33.	Shelby		Pusa 24	Hybridization	1987
34.	Java 16		Pusa 37	Hybridization	1985

H = Hybridization, I = introduction, S = Selection.

For insect-resistance

Breeding for insect-pests is a priority in soybean improvement programme. During recent past, four accessions i.e. PI 171444, PI 171451, PI 227687 and PI 229458 were found to be resistant to various defoliators and stink bugs at AVRDC, Taiwan. All of them were not resistant to entire range of insect species, but together they covered practically all insect-pests prevalent in Taiwan. The resistance present in three multiple resistance donors namely PI171451, PI227687 and PF229358 was reported to be controlled by different genes. One of the insect aspects was reviewed by Maxwell and Jennings (1980). The pubescence on soybean i.e. density, length and orientation of hairs appears to be one of the resistance imparting factors. This has been observed that the pubescence characters interfere with oviposition, feeding, attachment mechanism and normal development and behaviour of insects (Tumipseed, 1977; Lee, 1983). Introduction of such sources and breeding advances utilizing the available sources of resistance are needed and are continuing in order to develop agronomically acceptable insect resistant varieties.

Two insect resistant strains, UPIR-1 and UPIR-2 were found promising at Pantnagar, in Northern India and are in use as resistant sources (Bhatnagar and Tiwari, 1996). Emphasis is given on leaf miner resistance and stem fly at Parbhani and Pune. They reported some resistant sources, viz. NRC-41, NRC-42, JS 92-22, MACS 124 and VLS 52 for leaf miner and Himso-1578, JS-92-12, JS(SH)-93-01, JS(SH)-93-07, JS(SH)-93-48, MACS 124, MACS 569, MAUS 63, TS 98-21, TS 98-91 and UGM 47 for stem fly. Previously reported resistant donor MACS 613 and MACS 74 are being used in breeding programme.

At NRCS Indore, in Central India, introduced *G. soja* as well as germplasm line L-592 were found to have resistance to girdle beetle and stem-fly (Tiwari, 2001b). *Glycine soja* was suggested as a promising source of resistance to Bihar hairy caterpillar (Ram *et al.*, 1989). Also, germplasm line Tax 855-53D was least damaged by lepidopterous defoliators. Such promising sources are being further evaluated for confirmation. The resistance appeared to be due to feeding preference rather than due to antibiosis or avoidance. The species was utilized in hybridization with the cultigen and a highly tolerant line, PK 515, was developed.

For resistance to diseases

Sinclair and Backman (1989) have summarized the sources of disease resistance for their use in breeding programme. Several introductions with these resistance genes have been obtained. The work for evaluation of existing germplasm diversity and development of new elite lines with advanced desired characters is continuing under the AICRPS and by various independent workers for different diseases. Also the large number of early generation segregants are being evaluated. All these efforts have led to resistance in soybean lines viz., high resistance to yellow mosaic virus (PK 416), bacterial pustules (PK 416, PK 472, PK 564, Bragg), pod blight (Bragg, Hardee, PK 472), rhizoctonia aerial blight (PK 472, PK 262, PK 416) and rust resistant (PK 1029, Ankur).

Besides, use of introduced germplasm and genes thereof has been made and is being made for crop improvement in regard to other economic characters including quality characters for food uses of soybean.

Specific PGR Needs for Meeting the Plant Breeding Objectives in India

In India, several breeding methods have been employed for attaining different breeding objectives and cultivar development in soybean (Table 10). Earlier soybean varieties cultivated were largely introductions from the U.S.A. The exotic soybean varieties released in India are 'Bragg', 'Clark 63', 'Davis', 'Hardee' 'Improved Pelican', 'KM 1' (Introduced from AVRDC, Taiwan) and 'Monetta' (EC 2587).

Table 10. Breeding methodology used in the development of varieties

Sl. No.	Breeding methodology	Number of varieties developed
1.	Pedigree/pureline selection	47
2.	Selection from variety/line	7
3.	Indigenous native variety or selection indigenous material from	5 *
4.	Mutation	4 **
5.	Introduction	2 ***
	Total Varieties	**65**

* Kalitur, ADT-1, JS 2, Gujarat Soybean 2, Punjab 1
** Birsa Soybean 1, MAUS 1, NRC 2, NRC 12
*** KM 1, Monetta

Most of the Indian varieties viz. JS 76-205, JS 75-46, JS 335, PK 262, PK 327, PK 308, PK 416, PK 472, PK 564, SL 96, MACS 13, MACS 58, KHSb 2, Pusa 16, Pusa 20 and Pusa 24 have been developed using pedigree method. Out of different breeding methodologies employed, the pedigree method and pureline selection have made predominant contributions (Table 5).

Till today 75 improved varieties of soybean have been bred and released for cultivation in the country since the mid-sixties. A study of genetic diversity among elite Indian soybean varieties was carried out at the NRCS. The varieties were grouped into six clusters with 75 percent of the varieties falling under two genetically less divergent clusters. These clusters were characterized by a moderate and probably balanced expression of the economically important characters. Maximum genetic divergence was observed between varieties JS 71-05 and T 49.

The following specific areas need focussed attention for soybean improvement.

i) High yield potential : 35-40 q in case of medium maturity and 25-30 q in case of early maturing varieties.
ii) Appropriate maturity and earliness in varieties to fit in existing and emerging cropping systems.
iii) Good seed longevity and resistance to mechanical damage in seeds.
iv) Resistance to rust and YMV diseases especially for Central zone.
v) Resistance to insect-pests like defoliators, girdle beetle, stemfly and leaf miner.
vi) Drought tolerance.
vii) Suitability for food uses; varieties with mill or low anti-nutritional factors.
viii) Suitability for mechanical harvest.
ix) High nitrogen fixing efficiency and promiscuity of the host in the soybean varieties.

These areas may be grouped as either germplasm need or breeding need as given in Table 11.

Genetic incorporation of promiscuity for nodulation as reported by I.I.T.A. (Pulver *et al.* 1985; Dashiel *et al.*, 1986) as also the use of supenodulating mutants of 'Bragg' (Carroll *et al.*, 1985) and 'Williams' (Gremaud and Harper, 1989) could lead to evolution of such improved soybeans which could have upto 25% higher yields over the present levels and yet require less fertilizers. The germplasm needs can be met by directed introductions and germplasm enhancement or pre-breeding. The elite lines can, then, be utilized for crop improvement.

Summarisingly, the collections of soybean PGRs in India have an abysmally small size. Introduction especially directed introductions are needed. Very little exotic material has been obtained from the known centres of origin, and diversity. A few accessions have come from China directly. Same is the case for obtaining accessions from Japan especially for food uses. Accessions from Australia, known for its diversity especially in case of wild soybeans, are also less. Directed introduction from these countries will improve the situation.

Introgression of desirable wild genes, both at intra-subgeneric and inter-subgeneric levels, could provide

Table 11. Breeding objectives and germplasm needs for soybean improvement in India

Sl. No.	Objective	Sources available: Source	Details	Nature and comment
1.	Resistance to soybean rust	Cultivars viz. PI 462312 (Ankur), JS 8021,PK 1024, PK 1029, Indira Soya 9 with tolerance to rust are available.	Only tolerance or moderate resistance is available. PI 459025 is not available.	More of a breeding need than a germplasm need. ii. High resistance sources are needed which can be evaluated in hot spots and utilized.
2.	Varieties for food uses (null lines for trypsin inhibitor and lipoxygenases)	Relatively low level of trypsin inhibitor and lipoxygenases has been observed in some Indian varieties.	i. No null lines for antinutritional factors available. ii. Lines with improved protein and fatty acid composition are needed. iii. Vegetable types need to be introduced especially from AVRDC, Taiwan.	A germplasm need. The null lines are to be introduced and the character is to be put in the background of adapted genotypes (germplasm enhancement)
3.	Early maturity	Sources like 'Shelby,' 'Monetta' and others are available.	Early maturing varieties are available but diversification is needed.	The breeding programme needs Supplementation/diversification of parental lines by ay of availability of sources for long juvenility and early maturity.
4.	Stagnant genetic potential for yield	i. Diverse germplasm not available. ii. Early maturing bold seeded Indian varieties lines have relatively rapid seed fill.	Source for characters viz., long juvenility and rapid seed fill are needed. Some sources of long juvenility have been recently obtained from Brazil.	Both germplasm and breeding need. The present base of Indian soybean varieties is very narrow. Directed introduction from diverse components (representing different groups of a core collection) needed within a required photoperiodic adaptation. Sources with characters viz. long juvenility, rapid seed fill, high biomass, are etc. needed.
5.	High nitrogen fixation efficiency and promiscuity of the host.	Not available	Diverse Indian conditions call for promiscuity of host.	It is a germplasm need.
6.	Introgression of desirable genes from *Glycine soja* into the cultigen.*	*Glycine soja* is represented by probably one accession only in India.	i. Serveral resistant genes and other desirable characters like high protein are available in *G. soja*. ii. Some back cross derivatives are available.	It is a germplasm need. *Glycine soja* accessions should be introduced. Germplasm enhancement/pre-breeding may follow.

* *G. tomentella* derived elite diploid lines (Riggs *et al.*, 1998: Singh and Hymowitz, 1999) may also be introduced and utilised.

novel combinations of genes and stretch the range of present variability to ultimately evolve efficient soybean varieties suitable for diverse growing conditions. The wild species are represented meagrely. The genetic diversity within a wild species is also very low. In many cases, one wild species is represented by only one accession. Surprisingly, this is the case with *G. soja* also which is being utilized to some extent in the Indian soybean improvement programme.

Plant introduction and germplasm exchange, especially on *quid pro quo* basis, are important endeavours facilitating regional and global interdependence towards sustainable utilization of genetic resources. These efforts should be carried out to uphold the value of partnership for making the most of agricultural biodiversity i.e. diversity for well-being.

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