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REVIEW

Soybean: Introduction, Improvement, and Utilization in India—Problems and Prospects

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Abstract The start of commercial exploitation of soybean in India is nearly four decades old. In this period, the crop has shown unparallel growth in area and production. Soybean has established itself as a major rainy season crop in the rainfed agro-ecosystem of central and peninsular India. Introduction of soybean has resulted in an enhancement in the cropping intensity and resultant increase in the profitability per unit land area. In India, soybean will continue to remain a major rainfed oilseed crop. A number of varieties that have been bred have resulted in this unprecedented growth. The simulation studies and on-farm demonstrations indicate that with current varieties, the rainfed potential of soybean in India is about 2.1 t/ha against the national average productivity of just 1.2 t/ha. Hence, large yield gaps exist between the potential and the actual yields harvested by the farmers. Narrowing of this yield gap may lead to doubling of soybean production. National Agricultural Research System has so far been successful in meeting the research demands of agrarian and industrial community. Further improvements in the yield of soybean grain and quality of soybean oil are possible by use of new research methodologies and by exploitation of recent advances in biology.

Keywords Soybean · Genetic improvement · Genetic resources

Soybean (*Glycine max* L. Merril) is the world's most important seed legume, which contributes to 25 % of the global edible oil, about two-thirds of the world's protein concentrate for livestock feeding. Soybean meal is a valuable ingredient in formulated feeds for poultry and fish. The cultivation and use of soybean could be traced back to the beginning of China's agricultural age. Chinese medical compilations, dating back 6,000 years, mention its utilization for human consumption [12]. To the populace of China, Japan, Korea, Manchuria, Philippines, and Indonesia, for centuries, soybean has meant to be meat, milk, cheese, bread, and oil. This could well be the reason, why in these countries, it has earned epithets like "Cow of the field" or "Gold from soil" [8]. Owing to its amino acids composition, the protein of soybean is called a complete protein. Its nutrition value in heart disease and diabetes is well known. It is significant that Chinese infants using soybean milk in place of cow's milk are practically free from rickets. Today, USA, Brazil, and Argentina are the "Big-3" producers of the world (Table 1). Versatility of soybean was recognized in the West quite recently. Around 1921, China produced about 80 % of the world's soybean [4]. In India, Soybean was introduced from China in tenth century AD through the Himalayan routes, and also brought in via Burma (now Myanmar) by traders from Indonesia. As a result, soybean has been traditionally grown on a small scale in Himachal Pradesh, the Kumaon Hills of Uttar Pradesh (now Uttaranchal), eastern Bengal, the Khasi Hills, Manipur, the Naga Hills, and parts of central India covering Madhya Pradesh. It has also been reported that the Indian continent is the secondary center for domestication of the crop after China [9, 11, 18]. At present, India ranks fifth in the area and production in the world after USA, Brazil, Argentina, and China (Table 1).

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The contribution of India in the world soybean area is 10 %, but the contribution to total world soybean grain is only 4 % indicating the poor levels of productivity of the crop in India (1.1 t/ha) as compared to other courtiers (world average 2.2 t/ha).

Indian Scenario

Soybean is the *numero uno* oilseed crop in India. Soybean has become an important oilseed crop in India in a very short period with approximately 10-million ha area under its cultivation. India is divided into five agro-climatic zones for soybean cultivation. These are northern hill zone, northern plain zone, north eastern zone, central zone, and southern zone. There are specific varieties released for each zone which are suited to their agro-climatic conditions. There has been an unprecedented growth in soybean; area which was just 0.03 m ha in 1970 and has reached to 9.30 million ha in 2010. The mean national productivity has increased from 0.43 t/ha in 1970 to 1.36 t/ha in 2010 (Fig. 1).

The major soybean growing states are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Andhra Pradesh, and Chattisgarh (Fig. 2). Due to rapid expansion, crop surpassed area and production of rest of the oilseeds in 2006–07. Soybean is now predominantly grown as rainfed crop in vertisols and associated soils with an average crop season rainfall of 900 mm, which varies greatly across locations and years. Introduction of soybean in these areas has led to a shift in cropping system from rainy season fallow followed by post-rainy season wheat or chickpea system fallow (wheat/chickpea) to soybean followed by wheat or chickpea (soybean–wheat/chickpea) system. This has resulted in an enhancement in the cropping intensity and resultant increase in the profitability per unit land area. Introduction of soybean has helped in improving the

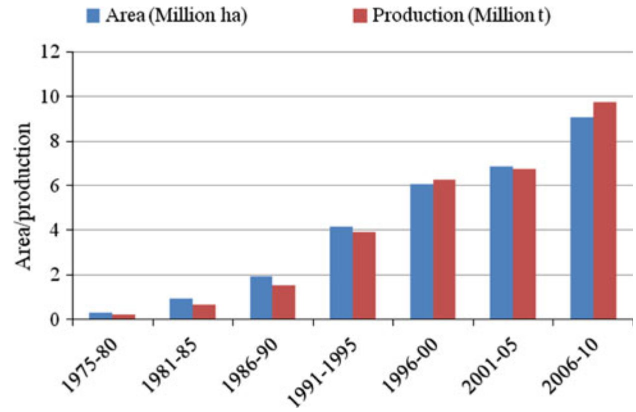

Fig. 1 Decade-wise changes in area and production of soybean in the country

socioeconomic conditions of large number of small and marginal farmers probably due to the fact that even under minimum agricultural inputs, management practices, and climatic adversities, it fetches profitable returns to the farmers. In fact, soybean is one of the most resilient crops for the rainfed kharif season as despite aberrant weather conditions in recent past, the crop has maintained its performance. The area under soybean is spread in latitudinal belt of about 15°–25°N comprising the states of Madhya Pradesh, Maharashtra, Rajasthan, Chhattisgarh, Andhra Pradesh, and Karnataka. These states together contribute to about 98 % of the total soybean production in the country. In recent years, soybean has shown a rapid increase in area in southern parts of the country, particularly in the states of Maharashtra, Andhra Pradesh, and Karnataka. Madhya Pradesh since beginning has been the major contributor to the soybean area and production, currently contributing 59 % of area and production followed by Maharashtra with a contribution of 28 and 26 % in terms of total area and production of the country. The crop can be grown in most parts of India, and states like northeast states, Himachal Pradesh and Jharkhand, have good potential of soybean.

Table 1 World area, production, and productivity of soybean

Country	2009-10			2010-11			2011-12		
	A	P	Y	A	P	Y	A	P	Y
USA	30.91	91.42	2,958	31.0	90.61	2,922	29.80	83.17	2,790
Brazil	21.75	57.35	2,637	23.32	68.76	2,948	25.00	72.00	2,880
Argentina	16.77	30.99	1,848	18.13	52.68	2,905	18.60	48.00	2,580
China	9.19	14.98	1,630	8.52	15.08	1,771	7.65	13.50	1,760
India	9.73	9.97	1,024	9.55	12.74	1,334	9.95[a]	12.57[a]	1,264[a]
World	99.27	223.29	2,249	102.56	264.99	25.84	103.29	251.47	2,430

Source FAOSTAT, March 2012

A area (m ha), *P* production (m t), *Y* yield (kg/ha)

[a] Department of Agriculture and Cooperation, GOI

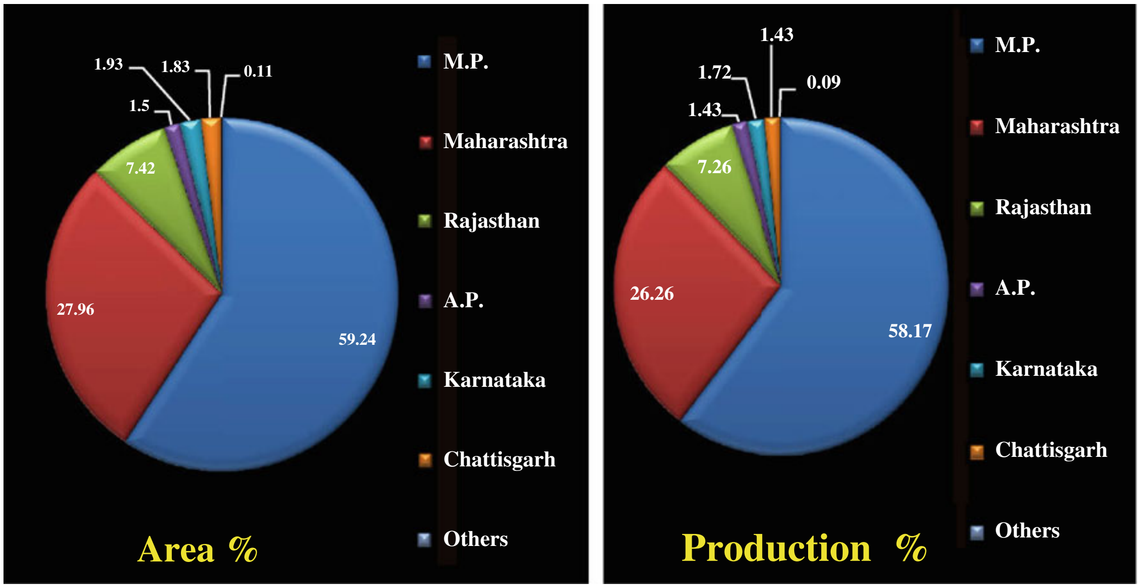

Fig. 2 Area and production of soybean in different states (2010)

Edible Oil Economy

India has the fifth largest vegetable oil economy in the world. After cereals, oilseeds are the second largest agricultural commodity, accounting for the 14 % of the gross cropped area in the country. However, the country is meeting its edible oil demand by importing almost 50 % of its requirement. The per capita consumption of the vegetable oil is increasing very rapidly due to increase in population and improved economic status of the population. The demand has increased to about 12.6 kg/year compared to 4 kg/year in 1961, and the projected demand for the year 2015 and 2020 is 14.57 and 16.38 kg/year, respectively. To meet this demand, the country will require nearly 18.3 and 21.8 million tons of edible oil. In this scenario, soybean could play a pivotal role. Due to the advances in knowledge of lipid biochemistry and the possibilities of enhancing quality and yield of edible oil in soybean, this has the potential of becoming a major oil producing crop worldwide.

Soybean contributes 40 and 25 % to the total oilseeds and edible oil production of the country and earns valuable foreign exchange by exporting soya meal. Current crushing capacity of soybean processing industry is about 20 million t/annum with the annual total production of 12.0 million t soybean oil. As far as consumption pattern is concerned, 100 % of soybean oil produced in the country is consumed domestically, and 8–10 % of total soybean produced is consumed at homes for direct food purposes. Thirty-five percent of total soy meal produced finds its way to the domestic market.

Forex Earner

Soybean is a key foreign exchange earner due to export of soybean defatted oil cake (DOC). Soybean DOC export of 1,321 million rupees in 1986–87 increased to 8,000 million rupees by 2010–11. The total expenditure on imported edible oil was offset by the export earnings by soybean. DOC, in fact, success of soybean venture, since its commercial cultivation began in India, has more or less been dependent on the export of defatted soybean oil cake. The prices of soybean fetched by the farmers have always been much higher than the minimum support price declared by the government due to better prices fetched by Indian DOC in the international markets. However, these prices have fluctuated a great deal due to ups and downs in international prices of DOC, and total dependency of soybean venture in India on export of DOC is of concern. Soybean being an international commodity and USA, Brazil, and Argentina being big players, the dependency of soybean in India on DOC export may threaten the soybean cultivation in India. Therefore, there is an urgent need to increase the domestic consumption of DOC, so the dependency on international markets is minimized.

Soybean Vis-a-Vis Nutrition Security

The unique chemical composition of soybean seed, which includes the number of nutraceutical compounds such as isoflavons, tocopherol, and lecithin besides 20 % oil and 40 % protein, has made it one of the most valuable agronomic crops in the world. The food derived from soybeans generally provides the health benefits and is a cheaper source of high-quality protein. The crop has potential to eliminate protein malnutrition prevailing in poor sections of society in the country. The foreign exchange earned from export of soy meal is encouraging draining out of high-quality protein from the country which poor sector of society needs at an affordable price. The utilization of soybean for food uses in India is meager [2], and it needs work in terms of blending with other foods to make taste acceptable. The high-quality soybean protein should be included in daily diet of Indian masses to mitigate the widespread energy-protein malnutrition. The Government of India as well as private sector should take aggressive approach to increase the food use of soybean in the country.

Constraints to Soybean Production

Despite having made rapid stride for both coverage and total production, soybean still suffers on productivity front. There are a number of constraints, pertaining to climate, edaphic, production, and technology aspects as mentioned below that hinder higher productivity.

- Most of the area under soybean cultivation are a *rainfed.*
- Erratic behavior of *monsoon* affecting planting.
- Large spatial and temporal variability in rainfall.
- Soil moisture stress at critical growth stages, especially seed-filling stage.
- High-temperature stress at critical growth stages.
- Biotic interferences to crop growth.
- Limited mechanization.
- Poor adoption of improved production technology—low risk covering ability.
- Monocropping and poor varietal diversification increasing risk chances.
- Timely availability of quality inputs.
- Poor/inadequate technological information.
- Poor utilization in food chain owing to characteristics beany flavor of soybean.
- Road blocks in utilization as pulses because of hard-to-cook characteristics of soybean.
- Psychological stigmas and conventional food habits.
- Lack of awareness about health/nutritional benefits.
- Presence of anti-nutritional factors in soybean.
- Limited entrepreneurship for processing.

Soybean Genetic Improvement

To ease the availability of edible oil and pulses, the Government of India has been consistently making efforts to gear up research and development programs through TMO (1986) and TMOPM (1991) and 2004 onward through ISOPOM programs. The ICAR started the All India Coordinated Research Project on Soybean (AICRPS) in 1967. Eventually, ICAR established the National Research Centre for Soybean (now upgraded to Directorate of Soybean Research during XIth Plan) at Indore in Central India in 1987 when soybean covered only about 1.5 million hectares, nearly one-sixth of the present coverage by the crop. At present, soybean has surpassed groundnut and rapeseed/mustard in cultivable area and production, the two most important edible oilseeds among nine oilseeds grown in the country.

The soybean research in India is being pursued by Directorate of Soybean Research (DSR) and All India Coordinated Research Project on Soybean (AICRPS). The AICRPS is an integral part of the DSR with 8 main, 14 sub, and 16 voluntary centers, spread across the nation. The system is well equipped with human resource equipments and infrastructure to conduct quality research. Through their unified efforts and with support from soybean industry, nongovernmental organizations, and farmers, soybean is playing a pivotal role in oil economy of the country. The advancement in research component culminating to improved varieties and agro-ecological zone-specific production technologies and crop protection modules has been the driving force in motivating the other components of production system to function in harmony leading to unparallel growth of the crop and elevated socioeconomic status of small and marginal farmers.

Soybean Genetic Resources

Directorate of Soybean Research is a National Active Germplasm Site (NAGS) for Soybean. It is also the national repository of soybean varieties and germplasm. The genetic resources of soybean have been extensively augmented, evaluated, and documented since the start of the project, and the total collection now stands at 4,248 accessions of cultivated soybean, 36 accessions of wild relative belonging to GP-3 and annual wild progenitor of cultigen of *Glycine soja*. The genetic resources of soybean have been extensively augmented, evaluated, and documented, and a core collection comprising of 51 accessions have been developed. A number of elite genetic sources possessing specific traits have been identified for further utilization through breeding programs (Table 2).

The soybean breeding program started at Pantnagar by screening of 1,400 available germplasm lines in 1970 for resistance to rust and YMV, but none of these were found to be resistant. Therefore, the United States Department of Agriculture (USDA) was requested to donate the entire soybean germplasm collection to India. A total of about

Table 2 Elite genetic sources identified for resistance to abiotic and biotic stresses

Photoperiod insensitivity	MACS 330, EC 325097, EC 333897, EC 34101, EC 325118 and EC 390977 and EC 538822
Drought resistance	EC 538828
Rust resistance	EC 241778 and EC 241780
Yellow mosaic virus resistance	PLSO 84, EC24660, and B463
Rhizoctonia root rot resistance	AGS48 and EC34117

3,500 lines sent to India, out of which, two lines—PI171443 [a cultivated soybean (*G. max*), originally from China] and Glycine formosana (a wild soybean, also from China) were found completely resistant to yellow mosaic. Six lines—Fusanaridaizu (PI200465), Gakubun (PI200466), Hondadaizu (PI200477), Keburi (PI200490), Komata (PI200492), and PI224268—all from Japan, were resistant to rust [17]. Genetic studies revealed that the inheritance of resistance to rust was controlled by a single dominant gene [15], whereas the inheritance of yellow mosaic was controlled by two pairs of recessive genes [16]. These resistant sources were used in a hybridization program, and a number of varieties were developed that combined the resistance with high yield potential and good seed viability.

Varietal Breeding

Improved varieties, in any crop, are essential for achieving higher productivity. Unlike traditional varieties, these varieties are developed with specific characters like higher yields, tolerance to various biotic and abiotic stresses, and suitable maturity duration for a particular crop rotation. Soybean is a short-day plant and is highly sensitive to day length. This results in narrow adaptability of individual soybean varieties across latitudes and planting times. The history of development of soybean varieties in India is comparatively new. The introduction of soybean started in 1963 with trials conducted at Pantnagar and Jabalpur agricultural universities, using varieties from the USA. Promising varieties in these trials like Bragg and Clark 63 were released for cultivation. During 1980–1990, these varieties were used as parent to develop further improved varieties for Indian conditions. The varieties developed after 1990 utilized breeding lines and indigenously developed varieties in hybridization programs. The yield of soybean has improved four times in comparison with traditional variety Kalitur. The varieties developed since 1990 have been grouped in 'Selection cycle-2.' The varieties of selection cycle-1 have produced 4 times higher yield than indigenous variety Kalitur by virtue of high number of pods per plant and seed weight, short duration, and increased biomass. The varieties in selection cycle-2 showed 19 % higher yield than selection cycle-1 varieties. This increase was due to improvement in harvest index and seed-filling duration. Genetic enhancement of yield in soybean and its stability under rainfed condition have been the focus. The ideal soybean plant for high yield should have determinate or semi-determinate growth habit (suited to short growing season), erect and non lodging, long juvenile period, broad leaves for maximum light interception, rapid LAI development and seed fill duration, and maturity duration of 95–100 days. Faster rate of LAI development allows for maximum light interception and curtails weed growth. Most of the improved varieties are capable of yielding 3–4 t/ha. The important yield contributing characters are high number of pods per unit area, seeds/pod, and seed size.

The amount of genetic improvement in yield through hybridization and selection has been substantial. Recent estimates indicate that soybean yields are improving at a rate of 23 kg/ha/annum [19]. Wilcox [21] estimated an increase of 60 % in seed yields over the past 60 years through public sector soybean breeding programs northern soybean production area of USA. The world average production stands at 2.6 t/ha. In India, soybean yields have improved from 700 to 1,000 kg/ha. The increase has come mostly through improvement in harvest index, increased biomass, high number of pods/plant, and increased seed-filling duration. The annual genetic gain in seed yield between 1969 and 1993 has been approximately 22 kg/ha. [10]. Most of Indian soybean varieties have yield potential of 2–3 t/ha, while some can yield up to 4 t/ha. Further improvement in yield will depend on genetic diversity of parents, plugging the yield loss due to stress and improving the genetic architecture of the plant.

Besides yield, the other essential characters required for soybean in tropics are resistance to pod shattering and good seed longevity. The varieties should be able to withstand 7–10-day delay in harvesting after reaching harvest maturity and should have minimum 70 % of germination after 8–9 months of storage under ambient conditions. Most of the recently released improved varieties are tolerant to pod shattering and have acceptable seed storability. However, bold-seeded varieties are inherently prone to loss of viability faster than small-seeded varieties.

The major biotic stresses, which reduce soybean productivity under Indian conditions, are diseases like yellow mosaic virus, rust, rhizoctonia, anthracnose, etc., and insect pests like stem fly, gridle beetle, and various defoliators. There is a need to enhance soil health by use of biological control agents that may control root diseases and nematodes. Varieties resistant/tolerant to many of these stresses have been bred, and the work is continuing. Being a rainfed crop, drought is a major abiotic stress, which limits the productivity of soybean in India. Therefore, tolerance to drought is one of the major areas where the current breeding program is focused. Looking at the future climate change, the breeding programs are also focussed on development of varieties with tolerance to high-temperature conditions. Despite its rich nutritional profile, use of soybean in food has been limited because of its beany flavor (lipoxygenases) and presence of anti-nutritional factors like trypsin inhibitor. Breeding for quality characters and development of food-grade varieties is becoming an important objective in future.

The total number of released/identified varieties in India till date is 102. Out of these maximum numbers of varieties, (38) have been released for central zone, (22) for northern hill zone, (23) for northern plain zone, (24) for southern zone, and (5) for north eastern zone. Some of these varieties are land races or selections from them and have been known since long. These are (a) a pool of black-seeded indigenous varieties such as *Bhat* or *Bhatmash* which represent the habitat of northern hill region, but are also cultivated in scattered pockets of central India under the names such as *Kalitur* and *Kala Hulga*, (b) yellow-seeded pool of northern or Tehri-Garhwal region presently represented by JS 2, and (c) a pool of indigenous varieties with small- and yellow-seeded varieties represented by Type 49. In Kumaon Hills, black soybean, locally known as bhat, was grown, while in northeastern India, viny-type yellow-seeded cultigens were grown. These land races have given rise to three varieties viz. Kalitur, JS-2, and Type 49. This includes central as well as state releases. A majority of Indian varieties have been developed using exotic parents. 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 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 Indian varieties which were developed through hybridization and mutation in/among the varieties of the first group. Soybean breeding programs across the country have also been successful in developing varieties with specific characters ranging from having resistance to biotic and abiotic stresses, special agronomic niches, important processing requirements, and product-specific quality traits (Table 3).

The traditional breeding techniques have been used for the improvement to yield and other traits. The yields have increased by 60 % in the last 60 years, and 3,900 varieties of soybean have been released worldwide. The advent of molecular techniques has speeded soybean breeding. The ability of genome sequence, the use of functional genomics, gene mapping, QTL analysis, and transgenic development are accelerating soybean improvement. Glyphosate-tolerant roundup ready (RR) soybean is the most widely grown GE crop in the world. These molecular techniques are the future of breeding programs. Consequently, soybean could become a major crop for producing high-quality protein, healthy oil, and oil for biodiesel.

Soybean is attacked by the number of fungal, bacterial, viral pathogens, and nematodes. The most important one are soybean rust, Phytophthora root rot, stem canker, bacterial blight, soybean mosaic virus, and soybean cyst nematode. In India, the prevalent diseases are rust, yellow mosaic virus, charcoal rot, and Rhizoctonia root rot. Rust is prevalent in southern India. The resistance to rust is governed by a dominant gene *Rpp*. Four alleles *Rpp1–Rpp4* at different loci have been reported [6, 7]. Indian varieties PS 1024, PS 1029, and JS 80-21 are tolerant to rust. In order to search for resistance sources, the germplasm collection is screened at hot spots. Two lines EC 241778 and EC 241780 show resistance. Development of YMV resistant varieties like PK 416 and PS 564 was made possible by a source of resistance PI 171443 (UPSM 534) and has made cultivation of soybean possible in north India [17]. The active breeding to obtain varieties with multiple disease resistances the need for sustainability in soybean production.

The most destructive insect pests of soybean include a variety of foliage feeders, stem borers, gram pod borer, and stink bug. Although considerable efforts have gone into breeding insect-resistant varieties, limited success has been achieved [5]. In India, germplasm lines and elite breeding lines are scored for resistance to major insect pests, e.g., stem fly, girdle beetle, and defoliator. Sharma and Shukla [13] identified germplasm lines TGX 855-53D and DS 396 as resistant to defoliators. The wild progenitor of soybean, *G. soja*, is a promising source of resistance to Bihar hairy caterpillar [14].

Secondary Agriculture-Based Breeding Initiatives

Despite its rich nutritional profile, use of soybean in food has been limited because of its beany flavor (lipoxygenases) and presence of anti-nutritional factors like trypsin inhibitor. Breeding for quality characters and development of food-grade varieties are important breeding objectives in soybean. Besides the conventional breeding approaches, new tools such as allele mining, marker-aided selection (MAS), functional genomics, and genetic engineering are being pursued to achieve the long cherished goals.

Secondary agriculture provides an important crop-linked enterprise to farmers so as to enhance their income from their farm business and also provide a stability and insurance to the crop economy in the country. Heavy reliance on export for a long period does not emit healthy sign for soybean in the country. To promote soybean-based secondary agriculture, Directorate of Soybean Research, Indore, has taken up a number of novel initiatives and have come out with a good number of technologies enhancing

Table 3 Varieties having specific characters

Character	Varieties
Resistance to pod shattering	PK 472, PK 416, JS 335, NRC 7, NRC 37, Bragg, JS 71-05 and most of the new varieties
Tolerance to drought	NRC 7, JS 71-05, Hardee
Tolerance to excessive soil moisture	JS 97-52
Good seed longevity	JS 80-21, NRC 37, Punjab 1, NRC 2, JS 335, Kalitur
Suitable for mechanical harvesting	MACS 58, NRC 37, Type 49, Durga, Punjab 1
Suitable for summer cultivation	MACS 57, Punjab 1, JS 335, Pusa 16, PS 564
Suitable for delayed sowing	JS 335, Ahilya-1, PK 472, Punjab 1 etc. Increased seed rate and reduced row to row distance
Resistance to lodging	JS 71-05, Pusa-16, Ahilya-1
Low trypsin inhibitor	Hardee, Punjab 1
Low lipoxygenase	Shilajeet, KHSb 2, Punjab 1
High protein (>40 %)	ADT 1, MACS 58
High oil (>20 %)	NRC 7, VLS 1, PK 416
Low linolenic acid	VLS 59
High oleic acid	LSb 1
High isoflavones	Hardee, ADT 1
Low oligosaccharide	SL 525
Tofu quality	Punjab 1, Hardee, PK 472
Collar rot or sclerotial blight *Sclerotium rolfsii*	NRC 37, PS 1225
Rust *Phakopsora pachyrhizi*	Rust tolerant varieties like Ankur, PK 1024, PK 1029, JS 80-21, Indira Soya 9, MAUS 61-2 or early maturing varieties
Myrothecium leaf spot *Myrothecium roridum*	Resistant/moderately resistant varieties like Bragg, JS 71-05, JS 335, MACS 13, MACS 124, MAUS 47, NRC 7, PK 564
Yellow mosaic Mung bean yellow mosaic virus	PK 416, PK 472, PK 1024, PK 1029, PK 1042, SL 525, SL 688, PS 1347, Pusa 9712, JS 97-52
Girdle beetle *Obereopsis brevis* (*Swedenbord*)	NRC 12, NRC 7, Bragg, Indira Soya 9, JS 93-05, RAUS 5, PK 262, Punjab 1
Defoliators Blue beetle (*Cneorane* sp.) Tobacco Caterpillar *Spodoptera litura* (*Fabricius*) Bihar Hairy Caterpillar *Spilosoma obliqua* (*Walker*)	NRC 12, NRC 7, JS 80-21, JS 90-41, MACS 450, MAUS 47, Monetta, RAUS 5, Pusa 16, JS 95-60
Stem fly	JS 335, NRC 12, NRC 7, MACS 124, JS 90-41, Indira Soya 9, JS 93-05, MACS 124, MAUS 47, PS 564, JS 95-60

these. A number of lines having high oil content (22–23 %) (AGS191, NRC7, G76), high oleic (42 %) (IC210 & NRC106), low linolenic acid (4 %) (VLS 59), high protein (44 %) (G288 & G688), Null KTI (NRC 101, 102), null lipoxygenase, and vegetable types (NRC 105) have been identified, developed, and registered.

Future Challenges

The productivity of soybean India though has increased from 426 kg/ha in 1970–71 to 1,264 kg/ha in 2011–12, which is still much below the potential of the crop in India. Thus, the poor productivity and great fluctuation in climate and yield are detrimental in India. Simulation studies carried out across India have revealed that the climatic potential of the crop is 3,000–3,500 kg/ha, while rainfed potential is 2,000–2,500 kg/ha as against national average of 1,100 kg/ha [1]. The average rainfed potential of 2,000 kg/ha has also been demonstrated in large number of on-farm trials conducted over years across India [3]. Several abiotic, biotic, and socio economic factors, responsible for poor productivity of soybean in India, have been identified ([20]). However, the major cause of large yield gaps between rainfed yield potential and actual yields harvested by farmers is attributed to non-adoption of improved production technology by the farmers.

Despite having established non-adoption of technologies as the foremost reason for stagnation of soybean productivity, maintaining the focus on providing the upward thrust to soybean production and productivity in the country in next 20 years to come, the following multi-pronged strategies have been formulated.

- Improving productivity of soybean through development of new gene technologies.
- Enhancing and enriching the gene pool to broaden the selection pool along with gene flagging to assign the worth to our genetic wealth.
- Development of new varieties that would fit into futuristic crop management regimes and can harness the opportunities created by shift in weather patterns.
- Exploitation of heterotic vigor to create an opportunity window for development of hybrids for further increasing the yield potential.
- Exploitation of new biotechnological tools in exercising efficient selection in reduced time frame.
- Development of varieties with efficient extraction metabolism to assimilate ever limiting phosphorous and zinc availability.
- Breeding varieties that could cope with abiotic stresses like water deficit and excesses.
- Using zinc-finger nuclease technology, the trypsin inhibitor and other undesirable genes can be deleted or modified. A thaumatin gene for sweet protein gene and cloning of omega and hydroxyl acids genes can make soybean the most valuable oil crop. There are no limitations of technology. Imagination and bold decisions to do are the scarce virtues holding soybean back.

References

1. Bhatia VS, Singh Piara, Wani SP, Chauhan GS, Kesava Rao AVR, Mishra AK, Srinivas. K (2008) Analysis of potential yields and yield gaps of rainfed soybean in India using CROPGRO-Soybean model. Agric For Meteorol 148:1252–1265
2. Bhatnagar PS, Joshi OP (2004) Current status of soybean production and utilization in India. In: Proceedings of VII world soybean research conference, IV international soybean processing and utilization conference, III Congresso Mundial de Soja (Brazilian Soybean Congress), Embrapa Soybean, Londrina, Brazil, pp 26–37
3. Billore SD, Joshi OP, Dupare BU (2004) Impact of frontline demonstrations on augmenting the soybean *Glycine max* L. productivity. J Oilseeds Res 21:352–353
4. Bisaliah S (1988) Soybean development in India. CGPRT NO. 5
5. Boethel DJ (1999) Assessment of soybean germplasm for multiple insect resistance. In: Clement SL, Quisenberry SS (eds) Global plant genetic resources for insect-resistant crops. CRC Press, Boca Raton, FL, pp 101–129
6. Hartwig EE (1986) Identification of a fourth gene conferring resistance to soybean rust. Crop Sci 26:1135–1136
7. Hartwig EE, Bromfield KR (1983) Relationship among three genes conferring specific resistance to rust in soybeans. Crop Sci 23:237–239
8. Horvath AA (1926) Changes in the blood composition of rabbits fed on raw soy beans. J Biol Chem 68:343–355
9. Hymowitz T (1990) Soybeans: the success story. In: Janick J, Simon JE (eds) Advances in new crops. Timber Press, Portland, OR, pp 159–163
10. Karmakar PG, Bhatnagar PS (1996) Genetic improvement of soybean varieties released in India from 1969 to 1993. Euphytica 90:95–103
11. Khoshoo TN (1995) Census of India's biodiversity; tasks ahead. Curr Sci 69:14–17
12. Krishnamurthy K, Shivashankar K (1975) Soybean production in Karnataka. UAS Tech. Series, No. 12. U University of Agricultural Sciences, Bangalore
13. Sharma AN, Shukla AK (1993) Field screening of soybean germplasm for resistance to insect-pests and diseases. Soybean Genet Newsl 20:73–78
14. Singh RJ, Nelson RL, Chung GH (2007) Soybean (*Glycine max* (L.) Merr.). In: Singh RJ (ed) Genetic resources, chromosome engineering, and crop improvement. Oilseed crops, vol 4. CRC Press, Boca Raton, pp 13–50
15. Singh BB (1977) Breeding for resistance to soybean rust in India. Soybean Rust Lett 1:13–16
16. Singh BB, Malick AS (1978) Inheritance of resistance to yellow mosaic in soybean. Indian J Genet Plant Breed 38:258–261
17. Singh BB, Gupta SC, Singh BD (1974) Sources of field resistance to rust and yellow mosaic diseases of soybeans. Indian J Genet Plant Breed 34:400–404
18. Singh RJ, Hymowitz T (1999) Soybean genetic resources and crop improvement. Genome 42:605–616
19. Specht JE, Hume DJ, Kumudini SV (1999) Soybean yield potential—a genetic and physiological perspective. Crop Sci 39:1560–1570
20. Tiwari SP (2001) Indian scenario and needs in soybean genetic resources. In: Proceedings of India soy forum 2001 in Soybean Processors Association of India, Malviya Nagar, Indore, India, pp 48–57
21. Wilcox JR (2001) Sixty years of improvement in publicly developed elite soybean lines. Crop Sci 41:1711–1716