Success of Soybean in India: The Early Challenges and Pioneer Promoters

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Abstract

Soybean originated in China and was introduced to India centuries ago 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. Because of its high protein and oil content, and other attributes such as its beneficial effects on soil fertility, several attempts were made in the past to popularize soybean cultivation in India. However, these initiatives were far from successful, mainly because of the inadequate knowledge about its cultivation, lack of high-yielding varieties, lack of marketing, and unfamiliarity with its utilization. To deal with the country's perennial protein malnutrition due to the stagnant pulse production, fresh efforts were initiated in the mid-1960s by the G B Pant University of Agriculture and Technology (GBPUAT), Pantnagar (Uttaranchal) and the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (Madhya Pradesh), in collaboration with the University of Illinois, USA to popularize soybean cultivation in India. The preliminary trials conducted at Pantnagar in 1965–66, using soybean varieties from southern USA, yielded 3 to 4 t ha^{-1} within 110–130 days, which prompted the Indian Council of Agricultural Research (ICAR) to initiate, on 1 April 1967, an all-India project for coordinated research on soybeans. Through the well-coordinated and collaborative efforts of a number of national, international, and private-sector organizations over the years, soybean has now become an important crop in India. From about 11,000 ha until 1961, soybean occupied over 6 million ha in 2003 producing over 6 million t. This has made India the 5th largest producer of soybean in the world today. Among the many partners in this success story, GBPUAT played a major role in the initial phase of soybean variety improvement, soybean market development, and coordination of the national soybean research and development in India.

Soybean (*Glycine max*), otherwise known as a 'miracle crop' with over 40% protein and 20% oil, originated in China. As early as in 2853 BC, the Emperor Sheng-Nung of China named it as one of the five sacred grains. Thus, soybean has been cultivated in China for more than 4,000 years (Hymowitz, 1970). It is believed that with the development of sea and land trades, soybean moved out of China to nearby countries such as Burma (Myanmar), Japan, India, Indonesia, Malaysia, Nepal, the Philippines, Thailand, and Vietnam between the first century AD and 1100 AD. However, it remained a minor crop everywhere except in China. With its introduction into USA in the 18th century, and its systematic breeding in that country in the 1940s and 1950s, soybean was transformed from an inefficient fodder type crop to a highly productive erect plant type, and USA became the largest producer of soybean in the world ever since (Hymowitz and Harlan, 1983). Soybean has now become the largest source of vegetable oil and protein in the world, and its large-scale cultivation is concentrated in a few countries such as Argentina, Brazil, Canada, China, India, Paraguay, and USA, which together produce about 96% of the world's 189 million t annual soybean production (Table 1). The world's average soybean yield has also increased from less than 1 t ha^{-1} to 2.3 t ha^{-1}.

Soybean cultivation in India was negligible until 1970, but it grew rapidly thereafter, crossing over 6 million t in 2003 (Table 1). This has made India the 5th largest producer of soybean in the world today. This remarkable success is a result of the well-coordinated and collaborative efforts of a number of committed individuals and national, international, and private-sector organizations. Among these, G B

Pant University of Agriculture and Technology (GBPUAT), Pantnagar, Uttaranchal played a major role in the initial phase of soybean variety improvement, soybean market development, and coordination of the national soybean research and development in India. This paper briefly describes how it all began, and how the early hurdles were overcome through technical, industrial, and political interventions.

Soybean in India – early attempts

The origin of soybean's introduction into India is not known, but it probably came from China through the Himalayan mountains centuries ago. Some believe that it was also brought in via Burma 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. The bean is referred to locally as *bhat*, *bhatman*, *bhatmas*, *ramkulthi*, *garakalay*, and *kalitur*. Because of its high protein and oil content, and other attributes such as its beneficial effects on soil fertility, several attempts were made in the past to popularize soybean cultivation in India, including the initiative taken by Mahatma Gandhi himself in 1935.

The first systematic attempts to develop improved varieties of soybean suitable for Indian environments were made in the early 1900s at the Pusa Agricultural Research Farm in Bihar State, and the work was eventually extended to West Bengal, Orissa, Uttar Pradesh, Delhi, Punjab, Madhya Pradesh, Maharashtra, Tamil Nadu, and Rajasthan (Woodhouse and Taylor, 1913; 1914; Lal, 1968). Several varieties were evaluated at Pusa Farm between 1917 and 1924; single plants selected and found promising included No. 1 (yellow), No. 2 (chocolate), and No. 3 (black). These were found superior to cowpea (*Vigna unguiculata*), guar (*Cyamopsis tetragonoloba*), and moth bean (*Phaseolus aconitifolia*) with respect to grain as well as fodder yields. Research in Uttar Pradesh was initiated in 1943 at Kanpur with 100 lines from USA and 139 lines from other sources. A number of selections were made. T-1 and T-33 (both black), T-49 (yellow), and T-2 (brown) were the most promising; T-1 and T-49 were recommended for cultivation on the plains; T-33 was recommended for the hills; and T-2 was recommended for fodder. T-1 and T-49 are still grown in a few pockets in Uttar Pradesh. Work on soybean improvement in Punjab began in 1947 and about 90 varieties were evaluated. Punjab Soy No. 1 was developed and recommended for cultivation in the Kangra valley. The Indian Agricultural Research Institute (IARI) also initiated work on soybean at Delhi in 1947, and a number of varieties from USA were evaluated. Monnetta was found to yield well for both grain and fodder.

Considerable work was also done on soybean improvement in West Bengal at Kalimpong and Berhampore, resulting in three improved varieties: Soyamax, K-30, and Barameli. Soyamax is still cultivated in the Kalimpong area. Soybean improvement in the central and southern parts of India began in the early 1900s – almost at the same time as at Pusa Farm – and continued until the late 1950s. A number of lines were evaluated at Jabalpur, Seoni, Indore, and Powerkheda (Madhya Pradesh), Nagpur and Yavatmal (Maharashtra), and Chennai (Tamil Nadu), and several selections were made. Some of these were recommended for general cultivation. A variety called Kalitur is still being grown in Madhya Pradesh.

Despite all these efforts, soybean did not become established on the plains of India except within a few pockets in Uttar Pradesh, Madhya Pradesh, and West Bengal. This was mainly because of: (i) inadequate knowledge about its cultivation; (ii) lack of high-yielding varieties; (iii) lack of marketing; and (iv) unfamiliarity with its utilization. Most of the Indian households tried to use soybean as dhal (like other pulses) and failed, because it required much more time to cook and yet did not disintegrate like the other dhals. Also, some people did not like its beany flavor. As a result, soybean did not gain wide popularity in India. Farmers remained indifferent toward soybean, perhaps because of problems in production combined with the unsuitability of soybean for use as dhal. Also, at the time, no oil or other processing industries existed to create a market for the crop.

Soybean in India – new attempts and challenges

To deal with the country's perennial food shortages, a total of 23 agricultural universities were established in India during 1960–63 (on the land-grant pattern), supported by the Government of India and the United States Agency for International Development (USAID), and selected universities from USA. Also, several projects to boost food production in the mid-1960s received synergistic support from agriculture-related industries and the Government, which not only ensured seed production, farm credit, irrigation water, fertilizers, and pesticides, but also provided food storage and processing capacity to create a market for the produce. The country's agriculture was about to take off, with improvements already under way for dwarf wheat (*Triticum aestivum*) and rice (*Oryza sativa*) varieties. At the same time, the growing protein shortage in the country due to the stagnant pulse production also became apparent, and efforts were initiated to take a fresh look at soybean cultivation in India.

The pioneering work on testing new soybean varieties in India was initiated by GBPUAT, Pantnagar, and the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, in collaboration with the University of Illinois, USA. The preliminary trials conducted at Pantnagar and Jabalpur in 1965–66 using soybean varieties from southern USA were very encouraging. Some of the varieties, such as Bragg and Hardee, for example, yielded 3 to 4 t ha^{-1} within 110–130 days. These yields were 200% to 300% higher compared with the average yields of 1–1.5 t ha^{-1} from other pulses such as mung bean (*Vigna radiata*), black gram (*Vigna mungo*), and pigeonpea (*Cajanus cajan*). This was very encouraging, because the annual production of pulses and oilseed crops in India had plateaued at 11–12 million t, and the rapid increase in population was reducing the per-person availability of protein and oil, resulting in serious malnutrition.

These results prompted the Indian Council of Agricultural Research (ICAR) to initiate, on 1 April 1967, an all-India project for coordinated research on soybeans, with the main centers located at Pantnagar, Jabalpur, and Delhi, and several sub-centers across the country. Substantial funds were committed to the project by ICAR as well as USAID, which was providing technical assistance to a number of agricultural universities in India at that time. Each main center had at least one breeder, one agronomist, one plant pathologist, one entomologist, one microbiologist, one food scientist, and one economist. Varietal trials were conducted at several locations in 1967 and 1968, and based on outstanding performance, Bragg (a soybean variety from Mississippi, USA) was released in 1968 for general cultivation. Sizable quantities of seed were imported and multiplied on the farm at Pantnagar University and on large farmers' fields around Pantnagar in 1969. The first commercial crop was grown by farmers in 1970 and, with this, came numerous problems, questions, and challenges.

First of all, Bragg seeds produced in India germinated poorly on farmers' fields and the yellow mosaic virus – which was earlier restricted to mung bean and had been noticed only sporadically on soybean – became very serious on farmers' fields (Nene, 1972). This was further complicated by a severe rust epidemic, which had not been noticed at all before (Singh *et al.*, 1974). As if this were not enough discouragement to the farmers, their produce could find no market (Rathod, 1976). Soybean's detractors caused further confusion among the farmers and policymakers, overemphasizing anti-nutritional factors and forecasting that soybean would compete with other food crops and upset the country's food balance, which was already precarious. A letter from ICAR came to the soybean coordinator at Pantnagar with a threat that if solutions to yellow mosaic, rust, and other production problems were not found soon, the project would be phased out. The soybean research team was, thus, faced with multifaceted problems that needed immediate solutions, and the young Indian scientists at Pantnagar and other centers were determined to make their efforts a success (Singh and Saxena, 1979).

Developing a market for soybean

In the early 1970s, women's group at Pantnagar developed several recipes for home-level use of soybean, but none of these became popular. Also, unlike other pulses, soybean could not be used directly as dhal or flour because of its different taste and cooking properties, and it was too expensive to be used as animal feed. Industrial processing was the only immediate route to creating a market for soybean in India.

Fortunately, more than 85 solvent-extraction plants existed in India in 1970, and most of them were running well below their planned capacity for want of raw materials. This provided an opportunity to use soybean for oil extraction. To sensitize the oil millers, the author and three other scientists from Pantnagar University (B B Singh, M C Saxena, J N Singh, and R M Matsura) went to Prag Oil and Rice Mills, a private milling unit located at Aligarh, Uttar Pradesh, and explained the merits of using soybean as a raw material for the oil plant. They convinced the proprietor that the venture would be economically feasible. Partly out of respect for the scientists, and partly because of his adventurous nature, the mill owner installed the necessary equipment for roasting and flaking soybeans for oil extraction. A successful and happy entrepreneur, he managed to extract all the oil from soybean, and produced a food-grade good quality defatted cake with over 50% protein.

To find a food use for the defatted cake resulting from the solvent plant at Aligarh, the food scientists at Pantnagar University (led by Surjan Singh) had several discussions with the missionaries running the Knave Technical Institute, Bareilly, Uttar Pradesh, on adopting the textured soybean protein technology from USA. This led to the establishment of an extruder cooking plant at Bareilly, which converted the defatted soybean cakes into textured soybean protein (TSP). Under the brand name Nutri Nugget, this product emerged as an ideal substitute for *paneer* (coagulated milk) and meat for the vast masses of vegetarians in India. The two products – soybean oil and Nutri Nugget – immediately became popular, marking the beginning of a revolution in soy-based industries in India. In the first year, both operations were so successful that the entrepreneurs came to Pantnagar and hired four agricultural graduates each to promote soybean cultivation on contract around Aligarh and Bareilly. At the Bareilly plant, the personnel developed several other snack foods using soybean with maize (*Zea mays*) and rice. Several other plants started operations in Madhya Pradesh, and soon soybean production fell short of demand. Today, there are numerous extraction plants and extruder cookers in India, and Nutri Nugget has become the common people's meat, being sold in every nook and corner of India.

At the same time, the food scientists and agricultural engineers at Pantnagar collaborated with the scientists at the University of Illinois and developed a pilot plant to produce soybean milk without the beany flavor, which used all except the seed coat of the beans. The process yielded 10 L of milk from 1 kg dry soybeans – about five times as cheaply as the production of bovine milk (Nelson *et al.*, 1976). Also, several recipe books were published to popularize soybean consumption within homes (Kanthamani *et al.*, 1978). All these put together, soybean marketing no longer posed a problem in India. Rather, the problem was to maintain and ensure an adequate supply of soybeans as raw material.

Developing improved soybean varieties

With the marketing problem out of the way, the next challenge was to develop improved, high-yielding soybean varieties with good seed viability and resistance to yellow mosaic and rust. The variety trials conducted at Pantnagar in 1970 and 1971 were adversely affected by two new diseases – yellow mosaic and rust – and the overall yields of the most promising varieties such as Bragg and Hardee were drastically reduced. In normal years, these varieties yielded more than 4 t ha^{-1}, but during 1970–71, their yield went down to 1.2 t ha^{-1}, with the severe incidence of these diseases. Furthermore, the soybean seeds of these varieties stored under ambient conditions quickly lost viability; when planted in the next season, their germination was very poor. Because of the hot and humid conditions prevailing from March to June, the seed viability of Bragg and Hardee dropped below 50%. Therefore, breeding for resistance to yellow mosaic and rust as well as for increased seed longevity was the major challenge for soybean breeders in India.

The soybean breeding program at Pantnagar led by the author screened about 1,400 available germplasm lines in 1970, but none of these were found to be resistant. Therefore, the USAID advisors present at Pantnagar were requested to arrange import of the world collection of soybean germplasm lines maintained by the United States Department of Agriculture (USDA). Initially, the USAID advisors were not sure that the USDA would donate the entire soybean germplasm collection to India. But after personal appeal, and the urgency explained by the author to R L Bernard (Head, Soybean Germplasm at the University of Illinois) and E E Hartwig (Head of the Soybean Germplasm at Stoneville, Mississippi), both of them agreed to provide the entire set of soybean germplasm lines maintained by them. The author had done his PhD from the University of Illinois under the co-supervision of R L Bernard, and he had also met E E Hartwig in professional meetings. A total of about 3500 lines were packed and sent to India through USAID. Some of the lines were rejected by the Plant Quarantine Office at Delhi, and a total of 3047 lines were screened in 1971 and followed up in 1972 for resistance to yellow mosaic and rust. Of these, only 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 (Singh *et al.,* 1974). Genetic studies revealed that the inheritance of resistance to rust was controlled by a single dominant gene (Singh, 1977), whereas the inheritance of yellow mosaic was controlled by two pairs of recessive genes (Singh and Malick, 1978). 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. Without the germplasm from USDA, the soybean breeding program at Pantnagar would have reached a dead end.

Seed viability during storage was observed to be related to seed size: varieties with a 100-seed mass of more than 15 g lost viability quickly, whereas varieties with a 100-seed mass of 10 g or less showed little loss of viability even after a year. However, these small-seeded varieties had low yield and low oil content. On the other hand, varieties with a 100-seed mass of 12–15 g maintained good viability for 7–8 months, had good yield potential, and contained high levels of oil and protein. Therefore, seed mass became one of the selection criteria in the breeding program for improved seed viability. These findings paved the way for a systematic soybean breeding program, and a number of new improved varieties were developed (Singh, 1975; Singh and Saxena, 1975). A few of the improved varieties were tested at many locations under the All-India Coordinated Soybean Research Project and subsequently released for general cultivation in India. Of these, Ankur, Alankar, PK-262, PK-327, and PK-308 were moderately resistant to yellow mosaic, whereas PK-416 was almost immune to the virus. In addition to these varieties, several others were developed at Jabalpur and Delhi, and released for the northern and central parts of India. Along with the variety improvement program, considerable research was also done by agronomists, microbiologists, plant pathologists, entomologists, food scientists, and economists under the auspices of the national coordinated project (Saxena *et al.,* 1971). This led to the development of a complete package of practices for soybean production for different agroclimatic zones and cropping systems, and to the initial spread of soybean cultivation in parts of Uttar Pradesh and Madhya Pradesh.

Finding a niche for soybean production

With the rapid spread of the high-yielding varieties of wheat and rice in India during the early 1970s, even the marginal lands were being used by the farmers for these crops, and the question of where soybean would fit in the cropping system arose. It was mentioned by M S Swaminathan, the then Director General of ICAR, that unless a crop is grown in one million ha and produces at least a million t per year, it may not make much difference in the Indian economy. Soybean scientists in India started looking for possible niches, including intercropping, relay cropping, rotation, and utilizing fallow lands where soybean could be grown. A major niche was found in Madhya Pradesh, where a large area used to be left fallow in the rainy season to conserve moisture and fertility. Williams *et al.* (1974) estimated that if all the fallow and marginal lands were brought under soybean, Madhya Pradesh alone would have over two million ha under soybean. This eventually came to be true, thanks to the concerted efforts of the Madhya Pradesh Government and the M P State Cooperative Oilseed Growers Federation in promoting soybean cultivation and marketing in the State. Consequently, the total area under soybean in Madhya Pradesh rose to 808,000 ha by 1983–84 (Bhatnagar, 1984; 1985, Directorate of Agriculture, Madhya Pradesh, 1984; Tedia, 1985) compared with 102,000 ha in Uttar Pradesh, 30,000 ha in Rajasthan, 12,000 ha in Himachal Pradesh, and about 6,000 ha in Bihar and Gujarat, bringing the national total close to about one million ha! With a total production of about 723,000 t, this was a very impressive achievement and it further catalyzed the allocation of more funds for promoting soybean cultivation.

Political will and private-sector support

The rapid increase of soybean cultivation raised a good possibility of meeting the edible oil shortage in India. The Government of India therefore established the National Research Centre for Soybean (NRCS) at Indore, Madhya Pradesh, an institution headed by a Director with a full complement of scientific staff to intensify research and development of the crop in India. This was in addition to the enlarged All-India Coordinated Research Project on Soybean with several main centers and sub-centers. The political will and financial support from the State and central governments were matched by the private-sector investment in soybean utilization and marketing in India. This brought about a rapid increase of soybean cultivation in all the potential niches, but as expected, the major expansion took place in Madhya Pradesh, which alone accounts for 81% of the area under soybean today. Consequently, India is currently cultivating about 6 million ha with an annual production of 6 million t, and it proudly occupies the 5th place in the world for soybean production. The dreams of the Pantnagar and Jabalpur pioneers have been more than fulfilled.

Future challenges

The average yield of soybean in India is about 1 t ha^{-1}, compared with 2.3–2.8 t ha^{-1} in other countries. Therefore, the greatest challenge for Indian scientists and development programs is to increase the average yield of soybean. This would mean doubling of the production to about 12 million t from the same 6 million ha cultivated area – a net increase of US$ 1.8 billion yr^{-1}. The other challenges include exploitation of biotechnological innovations in crop management using herbicide-tolerant soybeans and diversification of soybean uses through the development of high-value and health-oriented food products. A lot of hard work is needed, but it is possible.

Acknowledgment

This brief history of the success story of soybean in India is based on the dedicated and hard work of a large number of scientists, administrators, and politicians. The GBPUAT was instrumental in ushering the Green Revolution in India, through its role in the establishment of the first private-sector seed company in the country (the Tarai Development Corporation), and through the promotion of improved wheat and rice varieties. This institution was also the crucible in which the necessary research and development environment was created in order to bring about a soybean revolution in India. The author feels honored and privileged to be a graduate and former staff of this great seat of learning, which has been the flag-bearer of the agricultural revolution in India.

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