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Quality Seed Production of Soybean in India: Current Status and Challenges

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ABSTRACT: Soybean, the primary oilseed crop in India, has experienced significant growth in recent years, yet its productivity remains relatively low at around 1 ton per hectare. One major factor contributing to this underperformance is the inadequate supply of quality seeds. Despite increasing demand for breeder seeds, production and availability have not kept pace, negatively impacting soybean yields. To address these challenges, strategic planning and policy support are essential. Expanding the seed production network, enhancing infrastructure, implementing scientific storage and handling practices, and providing training on seed production and supply chain management are crucial steps towards improving quality seed production and availability. Additionally, the seed replacement rate for soybean needs urgent attention. Collaboration between private players, farmers' producer groups, and government agencies can bolster seed production and ensure timely availability of quality seeds. Scientific production practices, including grading, packaging, and storing, are also critical aspects to consider. By implementing these measures, India can significantly enhance the production and availability of soybean seeds, driving increased yields and supporting the growth of the oilseed sector.

Keywords: Quality seed, seed viability, seed supply, seed availability

INTRODUCTION

Soybean (*Glycine max*) is a cornerstone of global food production, contributing 25% to global edible oil production and over two-thirds of the world's protein concentrate. Its nutritional profile is exceptional, boasting a rich source of quality protein (40%) with all essential amino acids and 18-20% oil. In India, soybean primarily serves as a source of oil, with only a fraction used for direct food consumption (10-15%) or as seed (about 10%) [1].

Beyond its nutritional value, soybean plays a pivotal role in India's socio-economic landscape, providing a livelihood for millions of small and marginal farmers. Its continued dominance in the country's oilseed sector since 2006 is a testament to its importance in meeting domestic oil needs and contributing to foreign exchange through soy meal exports.

While ongoing breeding efforts are focused on developing new soybean varieties to address local and global demands, the availability of high-quality seeds remains a critical factor in maximizing crop yields. Quality seeds, characterized by genetic purity, physiological soundness (germination, vigor), and freedom from impurities and diseases, are essential for enhancing crop production. Studies suggest that quality seeds can contribute significantly to overall food grain production, with estimates ranging from 15-20% to as high as 45% when combined with efficient management of other inputs [2, 3].

To ensure adequate supplies of quality soybean seeds, a robust seed production system is necessary. This involves multiplying new varieties through multiple generations to reach sufficient quantities for commercial distribution. India's regulatory framework and infrastructure for seed production, quality assurance, storage, and marketing provide a solid foundation for supporting this essential aspect of agricultural development.

Area, production and productivity

India is the fifth-largest producer of soybean in the world, following Brazil, the United States, Argentina, and China [4]. In the 2023–24 season, soybean was grown on 125.61 lakh hectares across the country, showing a modest increase from 124.79 lakh hectares in the previous year. Madhya Pradesh leads in soybean cultivation, covering 53.35 lakh hectares (42.4%), followed closely by Maharashtra with 50.72 lakh hectares (40.3%). Other key soybean-producing states include

Rajasthan, Karnataka, Gujarat, and Telangana (www.pjtsau.edu.in).

Soybean plays a major role in India's oilseed sector, contributing 33.6% to total oilseed production and covering 44.7% of the oilseed cultivation area as of 2020 [5,6]. All soybean oil produced in India is consumed domestically, highlighting its importance in meeting the country's edible oil needs. Moreover, about 8–10% of the soybean harvest is directly used as food in households.

Although soybean is mostly grown under rainfed conditions in India, its average yield remains low—around 1 tonne per hectare—despite having the potential to produce up to 4 tonnes per hectare. In comparison with other major soybean-growing countries, India's productivity is roughly one-third. However, field demonstrations have shown that by adopting improved farming practices, yields can be doubled to around 2 tonnes per hectare [7]. A key requirement for achieving this goal is the timely availability of good quality seeds of high-yielding varieties. Reliable access to such seeds can significantly enhance crop performance and help bridge the gap between potential and actual yields.

Seed multiplication system in India

India's seed multiplication system comprises four stages: nucleus, breeder, foundation, and certified seed [8]. This tiered approach ensures stringent quality control measures throughout the seed multiplication chain, safeguarding the genetic purity of varieties as they progress from breeder to farmer [9].

The generation scheme of seed multiplication is integral to the concept of certification and permits only limited seed classes to be produced from a given lot of breeder seed. The guiding principle followed in the generation system recognizes that maintaining the desired levels of variety purity is difficult in one-step large-scale seed production. Hence, stringent methods are followed to maintain the highest purity in the first step of multiplication, which is then taken to subsequent levels, increasing the scale of multiplication.

The effective seed chain commences with the production of an adequate quantity of breeder seed. It is expected that the breeder seed should be of high purity because in subsequent generations, genetic purity will mainly depend upon the quality of the breeder seed. Breeder seed production is the mandate of the Indian Council of Agricultural Research (ICAR) and is being undertaken with the help of:

- ICAR Research Institutions, National Research Centers, and All India Coordinated Research Projects of different crops
- State Agricultural Universities (SAUs)
- Sponsored breeders recognized by selected State Seed Corporations
- Non-Governmental Organizations

ICAR also promotes sponsored breeder seed production programs through the National Seeds Corporation (NSC), State Farms Corporation of India (SFCI), State Seeds Corporations (SSCs), Krishi Vigyan Kendras (KVKs), and other organizations (SeedNet India Portal). Table 1 outlines the key characteristics of each seed class.

Constraints in quality seed production

Several factors constrain quality seed production in soybean, including low productivity and sub-optimal seed quality. The poor performance on the productivity front is primarily attributed to soybean cultivation under rainfed conditions, coupled with factors such as inherent poor seed longevity, excessive plant population, monoculture practices, delayed sowing, inadequate seed treatment and inoculation, untimely availability of quality inputs, imbalanced fertilizer application, limited use of organic manures, inefficient pest and insect control, disproportionate water use in pesticide spraying, mixed sowing of seed with fertilizer, shattering losses due to delayed harvesting, and susceptibility of soybean to field weathering [10, 11]. Other factors like ensuring genuineness of cultivars are also important parameters for seed quality [12].

The term "seed quality" encompasses various attributes, including germinability, vigor, genetic and physical purity, and seed health. Environmental conditions such as temperature, rainfall, and relative humidity influence seed quality throughout the growing period. Seed moisture at harvest significantly affects seed quality, with a safe moisture content for mechanical harvesting and threshing recommended to be 13-14% [13].

Soybean seed has structural limitations that can hinder mechanization and large-scale handling. The radicle hypocotyl, crucial for germination, is vulnerable to damage during harvesting and processing due to its position and delicate seed coat [14]. Seeds exposed to

Table 1. Seed Classes in India's Seed Multiplication System

Class	Agency	Quality Control System	Tag Color
Nucleus seed	Concerned breeder of the variety or sponsoring institution	Maintenance breeding; nucleus seed crop should have 100% varietal purity.	No tag
Breeder seed	Concerned breeder of the variety or sponsoring institution	Produced from nucleus seed under direct supervision of breeder and monitored by breeder seed monitoring team; utmost care for genetic purity, physical and physiological quality, and seed health.	Golden yellow
Foundation seed	State Seeds Corporations (SSC), National Seeds Corporation (NSCI), public sector undertakings, non-governmental organizations, private seed companies, or farmers' producer organizations	First-generation progeny of breeder seed; periodic inspection by authorized seed certification agencies to ensure adherence to Indian Minimum Seeds Certification Standards.	White
Certified seed	State Seeds Corporations (SSC), National Seeds Corporation (NSCI), public sector undertakings, non-governmental organizations, private seed companies, or farmers' producer organizations	Produced from foundation seed; periodic inspection by authorized seed certification agencies to ensure adherence to Indian Minimum Seeds Certification Standards.	Blue

field weathering or drying at high temperatures are more susceptible to mechanical damage, which can include cracks or breaks in the seed coat, cotyledon, or hypocotyl radicle axis, ultimately rendering the seed unfit for planting [10].

To maintain soybean seed quality, timely harvesting and careful threshing are essential. Harvesting at the most appropriate time minimizes the effects of weathering and seed damage, while gentle handling during threshing prevents mechanical injury and reduces viability loss.

To endure assured and adequate supply, seed production has now been largely done in association with private producers. In such cases, in addition to regular monitoring, providing correct technologies, and imparting hands-on training to the seed producers is critical. It will not only enhance production but ensure quality of the seeds as well.

General guidelines for quality seed production in soybean

Seed Source, Land Requirements, and Crop Season

Seeds for soybean multiplication should originate from authentic sources, accompanied by bills and proper seed labels. To produce foundation seed, breeders' seed is used as the source material. Similarly, foundation seed is used to produce certified seed. For successful seed production, the field should be fertile, well-drained, and levelled, with high organic content. It must be free from volunteer plants and noxious weeds. Under OECD seed schemes, the previous crop requirement for legume species is three years for production of foundation and certified seeds.

Soybean is a *Kharif* crop in India, primarily grown as a rainfed crop. Sowing typically coincides with the onset of the monsoon, ideally between the last week of June and the first week of July. With irrigation, sowing can be advanced to the second week of June. Late planting may lead to multiple problems like poor plant stand, low pod bearing, improper seed filling and poor yield.

Sowing, Isolation Distance, and Seed Rate

As a highly self-pollinated crop, soybean has a low risk of outcrossing (~1%). However, to maintain genetic purity, a minimum isolation distance of 3 meters is recommended.

For grain production, the seed rate ranges from 65 to 80 kg/ha for small and medium seeds, respectively, and 75 kg/ha for large seeds. This results in a plant population of 4.0-4.5 lakh/ha. For seed production, seeds are sown at wider spacing to promote optimal plant growth and seed development. The seed rate should be adjusted based on seed size and germination percentage to achieve a plant population of 3.2-3.6 lakh/ha. Generally, 80% of the seed rate recommended for grain production is sufficient for seed crops. In case of delayed sowing,

Table 2. Zone-wise optimum sowing time, seed rate and spacing

Zone	Sowing Time	Seed rate (kg/ha)	Spacing (cm)
North-Eastern Hill	15th June - 30th June	55	45
North Plain	20th June - 5th July	65	45
Eastern	15th June - 30th June	55	45
Central	20th June-5th July	65	45
Southern	15th June-30th June	65	30

the narrow spacing i.e. 30 cm row to row and increasing the seed rate by 25% is advised [10]. The zone-wise details of recommended date of sowing time, seed rate and spacing is given in Table 2.

Seed Treatment and Sowing Practices

Soybean seeds should be treated at the time of sowing using premixed fungicides like Azoxystrobin 2.5% +Thiophanate Methyl 11.25% + Thiamethoxam 25% FS (10 ml/kg seed) or Penflufen + Trifloxystrobine 38 FS (1 ml/kg seed) or Fluxapyroxad 333 g/l FS(1 ml/kg seed) or Carboxin 37.5 + Thiram 37.5 (3g/kg seed) or Carbendazim 25%+ Mencozeb 50% WS (3g/kg seed) or *Trichoderma viride* @ 8-10 g/kg seed.

In areas where yellow mosaic virus (YMV) and stem fly are affecting the soybean crop every year, seed treatment with recommended insecticide i.e. Thiamethoxam 30 FS @10 ml/kg of seed or Imidacloprid 48 FS@ 1.25 ml/kg seed is recommended. For proper growth and development, it is advisable to inoculate the seeds with *Bradyrhizobium japonicum* @ 500 g/65 kg seed and dried in shade before sowing. Application of phosphate solubilizing bacteria @ 500 g/65 kg seed which is complementary to rhizobia is also recommended for improving phosphorus use efficiency for better yields.

Seeds should be sown at a spacing of 45 cm between rows and 5-10 cm between plants. Ridge and furrow sowing can help prevent seed damage due to water stagnation. Seeds should be sown at a depth of 2-4 cm and covered with a thin layer of soil.

Agronomic Management

The critical period for water requirement in soybean is planting to emergence, flowering and pod filling stage. A proper water management at these three stages is essential to optimize yield. Excess or deficit in soil moisture would be detrimental to yield. Soil moisture of 75% available soil moisture (ASM) should be preferably maintained during the crop growth period.

The field should be kept weed-free. Pre-emergence herbicide application can control early-stage weeds, and one or two manual weeding may be necessary for effective weed management.

The field should be enriched with good quality compost. The NPK fertilizer should be applied based on the soil test report. If necessary, application of Sulphur should be done in the soil. The integration of 5-10 t farmyard manure or 2.5 t poultry manure/ha with the basal application of 25:60-80:40-50:20 N: P_2O_5: K_2O kg/ha generally provides balanced nutrition for harnessing the yield potential of soybean.

The severity of insect pests and diseases varies by region. Therefore, control measures should be adopted based on the specific pest and disease pressures in the area.

Roguing, Field Inspection and Harvesting

Off-type plants, weeds, and other varieties should be removed from the seedling stage through harvesting. Roguing before flowering can help prevent outcrossing.

The seed plot should be inspected at least three critical stages: flowering, pod filling, and maturity. This ensures the maintenance of genetic purity in the produced seeds.

The soybean seeds should be harvested when it attains full maturity when the pods have lost their green color and attain the mature pod color characteristic of the variety and seed has become hard. It should be harvested and dried in the field or threshing floor to bring down the seed moisture content to 13-15% before threshing. The dried plants can be threshed by mechanical threshers at a low cylinder speed of 400-500 rpm at seed moisture levels of 14% and at a speed of 300-400 rpm at seed moisture of about 13% [10]. The soybean seed is highly prone to mechanical damage during harvesting if the seed moisture is below 13%. Therefore, desiccation should be avoided for the seed crop. If the crop is to be harvested by hand, it should be done, when the moisture is 17-18%. While threshing, care should be taken to avoid

mechanical damage and mixture from other seeds. Harvesting and threshing equipment must be thoroughly cleaned before harvesting each variety to avoid mechanical mixtures. An air screen cleaner is the most effective for soybean seed cleaning and grading. The recommended sieve size for processing is 8.0 mm round for top screen and 4.0 mm oblong for bottom screen.

Seed Processing and Storage

Soybean seeds should be graded and processed when the moisture content is around 12-13%. An air screen cleaner with a sieve size of 8.00 mm round in the top screen and 4.0 mm oblong in the bottom screen can effectively clean and grade the seeds.

Before storage, seed moisture should be reduced to 8-9%. Seeds should be packed in moisture-proof polyline jute canvas bags or HDPE bags at 30-40 kg/bag. Seed tags should be affixed based on the seed class.

Soybean seeds lose viability rapidly under high temperature and humidity conditions in tropical regions. The ideal temperature for maintaining the quality of the seeds for 8-9 months is recommended to be 20°C at a relative humidity of 50% [10].

Proper hygiene needs to be maintained at stores and seed processing equipment needs to be thoroughly cleaned after operating each seed lot. Seed storage godown should be well ventilated and has provision for prevention of entry of rodents. Stored seeds need to be monitored at regular intervals for insect infestation and fumigation may be done if need arises. The stacks of bags should not be made directly on the floor. These should be arranged on the wooden platform in dry, cool, clean and rat proof godown.

To meet the requirement of seed certification, the seeds of each class have to possess a few attributes. Table 3 has shown a few parameters essential for certification of foundation and certified seeds of soybean in India.

Conclusion

Soybean is the most important oilseed crop in India. Demand for it is going beyond supply. Hence a concerted effort is needed to enhance the production of soybean. For it, the production and assured supply of quality seed is essential. Appropriate policy, suitable technology and trained seed producers will certainly ensure higher production, and timely supply of quality seeds of soybean in India.

Table 3. Standard parameters for foundation and certified seeds of soybean

Parameter	Foundation Seed	Certified Seed
Minimum inspection (No.)	2	2
Isolation distance (m)	3	3
Maximum off-type plants (%)	0.1	0.5
Pure seed (Minimum)%	98	98
Inert matter (Maximum)%	2	2
Other distinguishing varieties (Max. No./kg)	5	10
Other crop seeds (Maximum No./kg)	None	10
Weed seeds (Maximum. No./kg)	5	10
Germination (Minimum)%	70	70
Moisture (Maximum)%		
a) Ordinary container	12	12
b) Waterproof container	7	7

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