The Seed Quality Assurance Regulations in Soybean Production

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Soybean is an important and valuable crop for global food and feed supply, providing high-quality nutrition. Globally, five countries—namely Brazil, the USA, Argentina, China and India—have dominated soybean production for many years.

soybean seed standard seed certification seed law cultivar registration

1. Introduction

Soybean is one of the most important cash crops in the world. It is among the few plant-based foods that provide high-quality proteins, with nine essential amino acids [1]. This unique quality makes it an ideal candidate as both a direct and indirect protein source for humans and farm animals. Today, more than 85% of soybean harvest is extracted for oil and crushed into meal to make animal feed, oil and biodiesel; the rest is used for human consumption and industrial ingredients [2][3][4]. The production and movement of this crop is closely associated with a country's economy, food security and social equality development [5][6][7]. Apart from the traditional soybean-producing countries/regions in America and Asia, Africa is also predicted to be next major soybean-producing continent [8]. Furthermore, soybean is also gaining importance in sustainable agriculture due to its nitrogen fixation ability. Soybean has been demonstrated to be an effective nitrogen supplier in cropping systems that can significantly reduce demand on synthetic fertilizers, nitrogen leaching and air pollution [9][10]. Shifting to a soybean-oriented plant-based diet could also significantly reduce $PM_{2.5}$ and consequential premature death [11].

Soybean is grown in many different parts of the world. Its production has expanded fast, with the USA leading the growth trend since the 1950s (**Figure 1**). Brazil first surpassed the USA in 2019, and grew steadily higher in the following two years. Global production quantity was estimated to be over 380 million metric tons in 2021/22 [3]. The top five producing countries (Brazil, the USA, Argentina, China and India) have accounted for over 80% of global production since 2012/13 and reached nearly 90% of the total output in 2020/21 (**Figure 2**) [12].

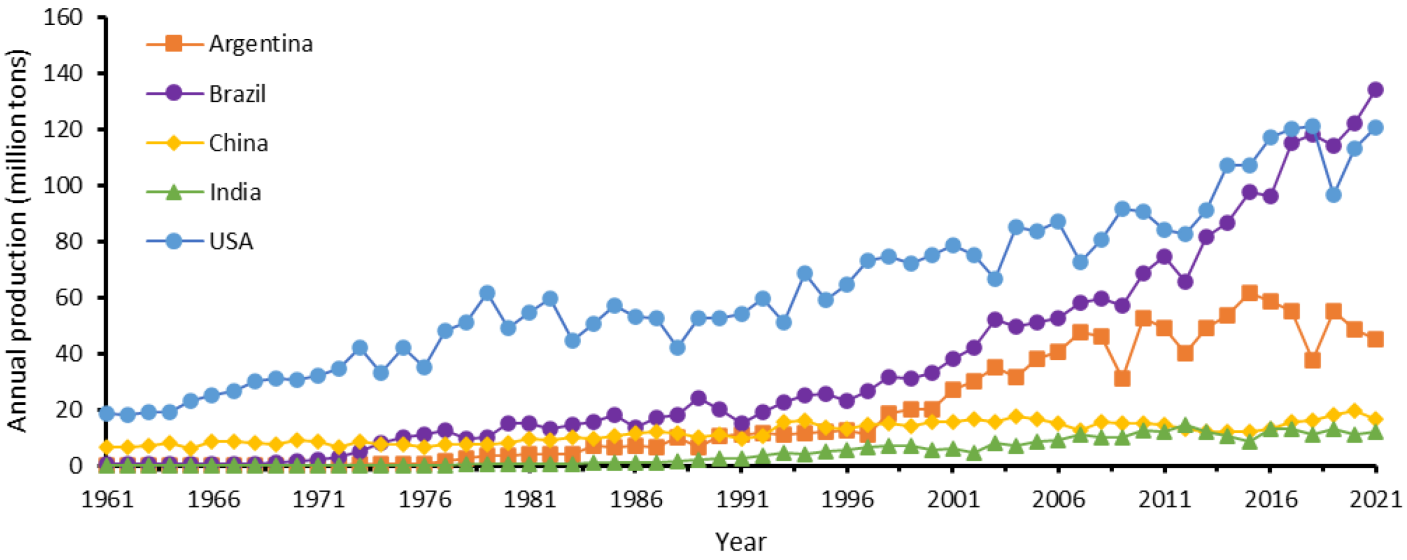

Figure 1. Soybean production in the five major soybean-producing countries from 1961 to 2021. Data from 1961–2019 were retrieved from FAOstat (https://www.fao.org/faostat/en/) on 1 February 2022. Data from 2020 were retrieved from USDA (https://ipad.fas.usda.gov/cropexplorer/Default.aspx) on 1 March 2022.

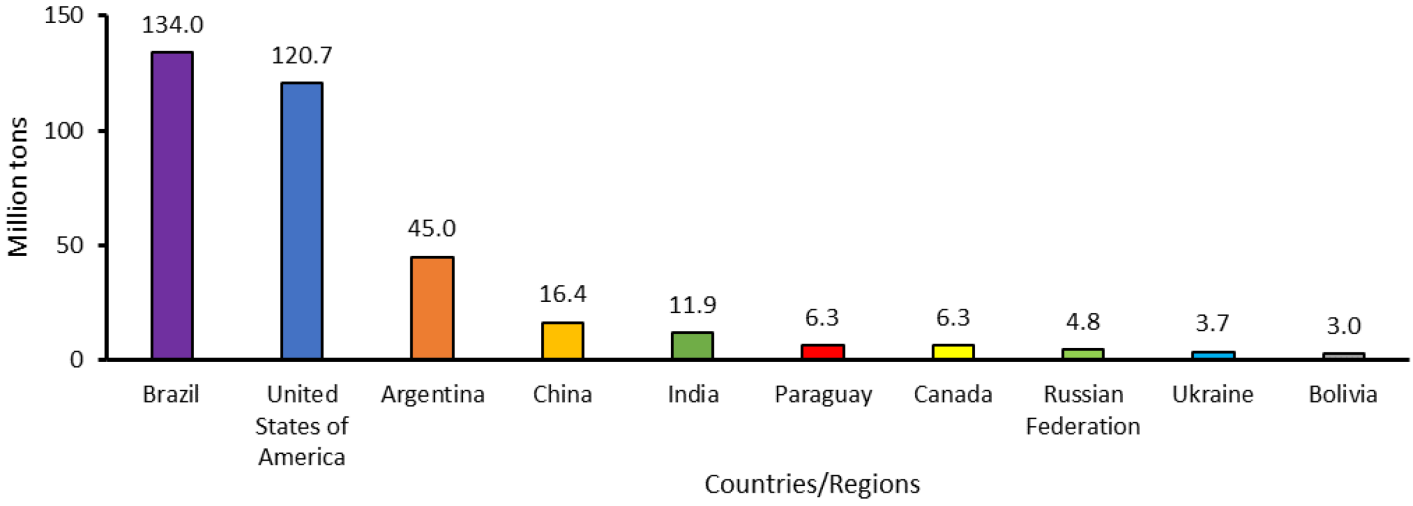

Figure 2. Production volumes of soybean in the top 10 producing countries/regions in 2021. Data were retrieved from USDA (https://ipad.fas.usda.gov/cropexplorer/Default.aspx) on 1 March 2022.

2. Factors Impacting Soybean Production and Supply Chain

Country-specific agriculture policies dictate crop production output [13]. The size of the arable land and freshwater resources allocated, the farming system, the choice of crop, and the decision of whether to plant genetically modified (GM) soybean are the important factors directly influencing crop yield, aside from the political and financial considerations and impacts of climate disasters. China hosts ~20% of the world's population but only possesses 9% and 6% of the world's arable land and freshwater resources, respectively [14]. In view of these limitations and the large population in China, staple cereal crops have a higher priority than soybeans. Moreover,

the prospect and regulation of the application of GM technology to soybeans has been unclear until the implementation of the revised national “Seed Law” very recently in 2022 (see later sections).

The areas in the USA and in Latin American countries under soybean cultivation are 2–3 times larger than those in India and China [12]. Larger farm sizes, along with investment, facilitate farm mechanization, allowing farmers to grow more at lower costs. The economics of competing crops among rice, corn, wheat and soybean vary by country and year, causing soybean production to fluctuate annually [15][16].

The USA was first to adopt the cultivation of genetically modified (GM) soybeans. Growing GM soybeans can help generate higher yields and reduce herbicide and pesticide usage [17][18]. Easier cultivation with a lower cost attracts more producers. USA commercialized Roundup Ready® soybean in 1996. Brazil and Argentina have adopted a similar GM soybean growing model/system with further innovations over the years. More than 90% of the total output from these top three producing countries are GM soybeans. Innovations in genetic modification have driven the rapid growth of soybean production [4]. The large-scale production of GM soybeans over the years has also generated concerns about long-term environmental pollution and adverse biodiversity impacts, particularly in the South American Amazon region [19][20]. Until now, China and India have only grown non-GM soybeans for local food consumption (China), oil crushing (India) and minor exports at premium prices (both China and India). Soybean yield in the top three countries is consistently higher than in China. India trails far behind China in total soybean production and yield per unit area despite having a larger area for soybean cultivation [21][22][23]. Although both China and India import GM soybeans for oil crushing and feed meals, local acceptance of GM soybeans as food is still low [24][25][26]. Debate over GM soybean cultivation also continues in other areas, particularly in the EU [27].

Good-quality seeds are the basis for successful agricultural production. Assurance of the seed quality using trusted and certified testing methods is critical for planting success. Well-organized production management by providing a proper seed supply to farmers and to markets is even more crucial to realize a significant output. The soybean production supply chain can be divided into three stages: seed breeding, farming, and harvesting and distribution (**Figure 3**) [3][22][28].

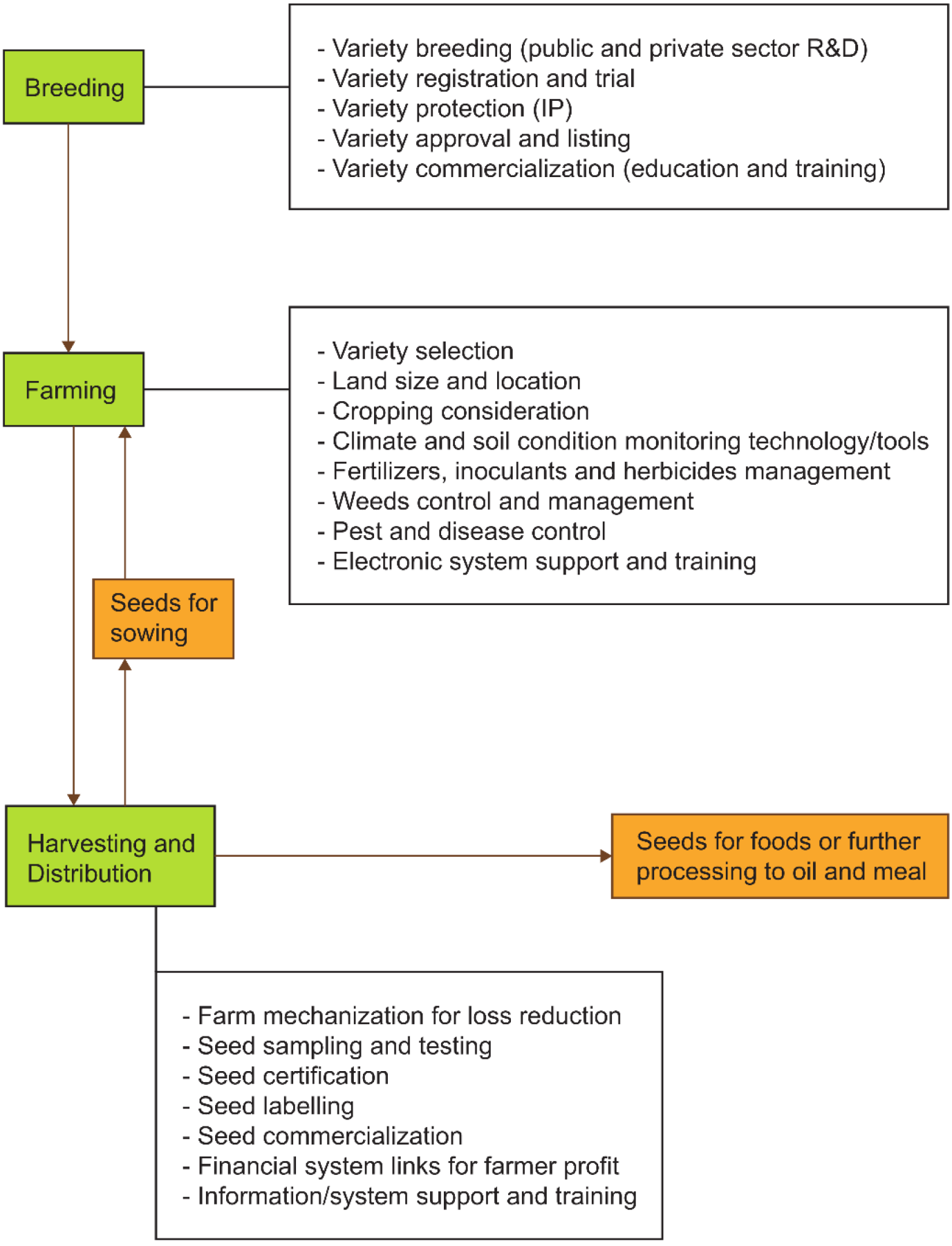
Breeding
- Variety breeding (public and private sector R&D)
- Variety registration and trial
- Variety protection (IP)
- Variety approval and listing
- Variety commercialization (education and training)
Farming
- Variety selection
- Land size and location
- Cropping consideration
- Climate and soil condition monitoring technology/tools
- Fertilizers, inoculants and herbicides management
- Weeds control and management
- Pest and disease control
- Electronic system support and training
Seeds for sowing
Harvesting and Distribution
Seeds for foods or further processing to oil and meal
- Farm mechanization for loss reduction
- Seed sampling and testing
- Seed certification
- Seed labelling
- Seed commercialization
- Financial system links for farmer profit
- Information/system support and training

Figure 3. Soybean production supply chain.

At the breeding stage, factors impacting production include basic research and cultivar development by private and public sectors (an elite cultivar will give a good yield if planted properly), cultivar registration, testing and trials, cultivar approval and listing, intellectual property (IP) protection, and cultivar commercialization. Since many new varieties are developed each year, it is essential to have an up-to-date, easily accessible database to provide farmers/buyers with the requisite educational and training information associated with the new varieties.

At the farming stage, farmers need to select the right cultivar for maximum yield; optimal adaptation to local geography, climate and soil conditions; and cost considerations. Preparation for sowing needs to include acreage/location planning and cropping considerations (crop rotation or intercropping). Electronic systems/tools for monitoring/recording climate (temperature, rainfall, day length, etc.) and soil (pH and mineral nutrient contents) conditions need to be made available for farmers' use. Other aspects of management, including the applications of fertilizers, inoculants, herbicides, insecticides and other disease-control measures, also require thorough planning, review and execution to ensure efficiency and maximize economic benefits.

At the harvesting and distribution stage, harvesting and processing by mechanical means to minimize loss and reduce cost is critical [29][30]. Harvested seeds are authenticated by various accredited technicians and labs, and they need to be certified/labeled based on their destination for the domestic/international markets. It is critical to ensure that farmers comprehend all the necessary processes and adhere to the established standards and systems. Providing support to farmers to connect them to reliable financial transaction networks will contribute to their success [18].

3. Rules and Regulations for Seed Quality Assurance

As shown in **Figure 3**, many parties, influencing factors, standard compliance and delivery steps are involved in the soybean supply chain. The whole supply chain can be complex and confusing. To strengthen the seed sector, it is crucial that seed producers and companies adhere to regulations, rules, policies and standards that have been consequentially established to guarantee quality. Subsequent management and enforcement of the rules and regulations by a centrally coordinated body is paramount for success.

An overview of the seed laws, rules, regulations and systems in the top five soybean-producing countries (the USA, China, Argentina, Brazil and India) is displayed in **Table 1**.

Table 1. Overview of soybean seed laws, rules, regulations and systems by country.

	The USA	China	Argentina	Brazil	India
Seed Law	Federal Seed Act [31]	PRC Seed Law [32]	Law No. 20247/73 on	LAW No. 10.711 [34]	Seed Bill [35]

	The USA	China	Argentina	Brazil	India
			Seed and Phytogenetic Creations [33]		
Initial Promulgation Year	1940	2000 (amended in 2021)	1973	1978	1966
Central Governing	USDA AMS	MARA NATESC	MAGyP, INASE, CONASE	MAPA, Consultative Seeds and Seedlings Commissions	Ministry of Agriculture and Farmers Welfare, Central Seed Committee
New variety R&D Public Sector	USDA, State Agricultural Experiment Stations	Nanjing Agricultural University, CAAS, HAAS, etc.	CONICET, INTA, Universities	Embrapa	ICAR, IISR
New Variety R&D Private Sector	Corteva Agrisciences	Shandong Shofine Seeds Technology Co., Beidahuang Kenfeng Seed Co., Syngenta	ADM, Criadero Santa Rosa, others	SLC Agricola, AMAGGI, BOM FUTURO, Terra Santa, others	Krishidhan Seeds Pvt. Ltd., Eagle Seeds, Bombay Super Hybrid Seeds Limited
National Variety	National list based on Plant	National list based on	National Catalog of Cultivars	National registration of	National Register of

	The USA	China	Argentina	Brazil	India
Registration and List (IP Protection)	Variety Protection certification database, plant patents, utility patents	Regulation of Protection of New Varieties of Plants and Measures	based on National Register of Cultivars on Article 9 of seed law, National Register of Cultivar Ownership	Seeds and Seedlings (RENASEM), National Registration of Cultivars (RNC), National Registry of Registered Cultivars (CNCR), Plant Variety Protection Law No. 9.456	Seeds, The Protection of Plant Varieties and Farmer's Rights Act
Rewards for New Variety Developed	No	Yes	Yes	No	Yes
Seed Classification	Breeder, Foundation, Registered, Certified	Breeder's original seeds, Breeder's seeds, Pure-breed seeds, Certified seeds,	Original (basic or initial), Certified (Registered) 1st propagation, Certified subsequent propagation 2 and 3, Identified certified	Basic, 1st generation certified C1, 2nd generation certified C2, Supervised S1 and S2	Breeder, Foundation Stage I, Foundation Stage II, Certified
Seed Testing Methods	AOSCA, ISTA	GB 3543 Rules for agricultural	OECD, ISTA, AOSCA,	OECD, AOSCA, ISTA	OECD, ISTA

	The USA	China	Argentina	Brazil	India
		seed testing (based on ISTA rule 1993)	National Inspection for Exclusive Export Destination		
Seed Certification Standards	Seed law of each state varies. General seed and specific standards for soybeans applied.	GB 4404.2 Seed of food crops—part 2: Legume	The Resolutions of the Secretary of Agriculture, Livestock and Fish of Argentina N°2270-93 Tolerances for soybean seed and other species.	MAPA in Normative Instruction No. 45, 17 December 2013 ANNEX XXIII Standards for the production and marketing of soybean seeds (*Glycine Max* L.), general and specifics.	INDIAN min seed certification standards (general and specific)
Seed Testing Technician Certification	Certified Seed Analyst (AOS) Certified Seed Technologist (SCST)	List of qualified Agricultural Seed Inspectors	List of Accredited Inspectors	Accredited Technicians	Accredited Seed Analysts
Seed Testing Labs Certification	OECD Accreditation Program 46 AOSCA seed certifying agency USDA ASL	2 ISTA-accredited labs Seed quality testing agency approved by MARA	1 ISTA-accredited lab (The Central Laboratory for Seed Analysis)	2 ISTA-accredited labs List of seed and seed analysis labs accredited in RENASEM	6 ISTA-accredited labs Central and state seed testing laboratory

	The USA	China	Argentina	Brazil	India
	7 ISTA-accredited labs				
Seed Certification Body	AOSCA, ISTA, OECD	MARA-approved Crop Seed Quality Testing Institutions	INASE	MAPA and its accredited legal entities	State Seed Certification Agencies appointed by Central Seed Committee
Certification System	OECD Seed Schemes (Soybean) AOSCA system Federal Seed Analysis Certificates	State standard (GB) enforced by competent agriculture and forestry departments	OECD Seed Scheme (Soybean) AOSCA system National Inspection system with Exclusive Export Destination	OECD Seed Scheme (Soybean) AOSCA system	OECD Seed Schemes (Soybean) ISTA Certification
Seed Label Contents	Variety and kind, Net weight, % Germination, % Purity, % Dormant or hard seeds, % Inert matter, % Other crop seed,	Variety and kind, Net weight, % Germination, % Purity, % Moisture, Variety registration number,	Cultivar Name (common and botanical name), Net contents, % Germination, % Purity, % Weeds, Seed classification,	Cultivar Name and category, Net weight, % Germination, % Purity, Seed classification, Information required by	Name and variety, Net contents, % Germination, % Purity, % Inert matter, Seed classification,

	The USA	China	Argentina	Brazil	India
	% Weed seed, Name of noxious weeds, Lot number, Origin, Test date, Name/Address, Tag color for quality	Standards applied, Suitable planting area and season, License number, Test date and expiration period	Name/Address, Registration number of the certifier and seller, Harvest year	specific standards Batch number, Name/address and registration number of the seed producer, Validity month/year of the germination test	Lot number, Name/Address of producing institution, Date of test, Tag color for quality
Label Governing Body	USDA AMS	MARA supervision and spot check of agricultural seed quality	INASE	MAPA	DA&FW, Central Seed Certification Board
Label Regulation	Federal Seed Act, relative regulations, state seed laws [37]	General directive	The Law of Seeds and Phylogenetic Creations No. 20247 /73 and its Regulatory Decree No. 2183/91.	[36] DECREE No. 5153, OF 23 July 2004	Seed Rule 1968 PART V—Marking or Labelling

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ed trade. ucers and rg, Seed e varietal rtification minimum tions and nes. Sixty China) in country to

collaborate with other member countries. The International Seed Testing Association (ISTA, http://www.seedtest.org, accessed on 13 October 2021) develops globally recognized standard procedures for seed sampling and testing. The International Union for the Protection of New Varieties of Plants (UPOV, http://www.upov.int, accessed on 1 November 2021) provides the breeders of new plant varieties with intellectual property protection. The International Seed Federation (ISF, http://www.worldseed.org, accessed on 1 November 2021) sets the trade and arbitration rules. The food and Agriculture Organization of the United Nations (FAO, http://www.fao.org, accessed on 14 October 2021) provides the international regulatory framework for related aspects of the seed trade, including plant health and phytosanitary measures, access, and benefit-sharing for plant germplasm and pesticide uses [36][37].

Nationally, each country promulgates its own national seed laws that govern domestic and international seed trades (**Table 1**). Domestically, each state/province/zone complies with the national principles and implements them with variations to suit local needs. The purpose of the seed laws, rules and regulations is to prevent misrepresentation of the seeds, to ensure good seed quality with agreed-upon testing standards and to check and prevent the spread of weeds/diseases/pests. Ultimately, it is to protect the right of the sellers (breeders, innovators and companies) and buyers (farmers and commercial entities). Hence, the laws include clauses for punishing false representation with penalties and seizure. The national rules and regulations align with international standards and requirements. Additional agreements can also be drawn up separately between individual exporting and importing countries to align with the specific requirements defined by the importing country.

USA, as the longest-leading producer of soybean in the past 70 years, instituted a complete set of rules, regulations and systems before 1940. The national seed law is publicized in the U.S. Code of Federal Regulations (CFR), Title 7, Part 201: Federal Seed Act Requirements [38] with periodic updates. It defines the roles and responsibilities of the regulatory and governing bodies and sets the regulatory framework for seed-production recording, testing, certifying and labeling. Soybean-producing states within the USA comply with the federal laws and could also develop their own detailed practices and standards. The seed laws and regulations in Brazil, Argentina and India follow a similar road map. The regulations in these four countries emphasize seed certification and label information accuracy (USA mandates label accuracy but leaves certification voluntary). China is the only major soybean-producing country that uses an administrative approval/confirmation/permit system with quality data on the label. Verification is performed by spot-check sampling. However, a seed certification system has recently been designed following the OECD seed scheme. Ten selected Chinese provinces tested the draft system with a good outcome. The system is anticipated to be formally implemented in the near future [39][40][41].

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