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An overview of national and international seed quality assurance systems and strategies for energizing seed production chain of field crops in India

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ABSTRACT

Quality seeds are inevitable to meet the challenges of ever increasing population and food security. Being the carrier of technology, seed over the period of time evolved as the trade commodity. India being the 5th largest player in global seed market and a wide range of crop seed being produced under varied agro-climatic condition, there is a scope for up-scaling revenues through seed export. Seed quality assurance in India comes under the jurisdiction of the Seeds Act 1966, wherein quality seed must satisfy the requirements of Indian Minimum Seed Certification Standards (IMSCS), but under global scenario seed quality assurance system for seed export comes under the scope of Organization for Economic Cooperation and Development (OECD) standards and International Seed Testing Association (ISTA) methodology of seed testing. The present paper reviews the major discrepancies in standard operating procedures/methodologies of seed quality assurance system under IMSCS *vis-à-vis* ISTA international rules for seed testing and OECD seed scheme. Critical analysis of discrepancies suggests there is need to harmonize existing quality assurance system in India with OECD and ISTA standards for carving a special niche for Indian seed in international seed domain and to facilitate international seed trade. An attempt has also been made in the present paper to elucidate the issues prevalent in seed production with special emphasis on breeder seed production, regular erratic spans due to disruptive climate and strategies for energizing the quality seed production in field crops through production in off-season / alternate areas.

Key words: Breeder seed production, IMSCS, ISTA, OECD, Seed chain, Seed quality

Seed acts as a carrier of the genetic potential of varieties. Timely availability of good quality seed ensures high yield and economic returns to the farmers. Quality seed production follows efficient certification procedures. From a pre-dominantly public sector until the 1980's, the Indian seed sector has evolved gradually into a multi-faceted industry with involvement of about 500 seed companies/firms and increasing emphasis on research and development activities because of rapid growth under liberalized government policies (Chauhan *et al.* 2016). Seed, being a trade commodity, is subjected to bilateral and/or multilateral agreements at local, regional and international levels wherein seed quality is a more serious concern than quantity. In India, seed certification comes under the ambit of the Seeds Act 1966 and quality seed must satisfy standards as outlined in Indian Minimum Seed Certification Standards (IMSCS). Simplification and harmonization of testing and certification procedures between domestic and international bodies, viz. the International Seed Testing Association (ISTA), Switzerland, the Organization for Economic Co-operation and Development (OECD) Seed Schemes, France and Association of Official Seed Analysts (AOSA), USA are imperative for setting standards and regulations to provide enabling environment for seed industry in India to be competitive with international seed trade. Major disparities do exist in prevailing seed quality standards and regulatory mechanisms in India *vis-à-vis* ISTA and OECD. These disparities pertain to type, nature and specifications of certificate, range of crops, minimum lot size, standard operating procedure in physical purity analysis, viability testing, seed health testing, testing seed with weighed replicates, determination of other seed by number and seed vigour testing, modus operandi and seed crop standards (Tonapi *et al*. 2014, Kamble *et al*. 2015). Significant developments leading to harmonization of seed quality standards in India have been made since becoming signatory to OECD (Trivedi 2012). The paper reviews the prevalent seed systems in India, national and international quality regulations, breeder seed scenario and related issues and suggests strategy for energizing the seed production chain to manage the existing and emerging challenges in quality seed production of field crops.

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Seed production systems and supply chain in India

There are two types of seed system, i.e. informal and formal, prevalent in India. Formal seed system involves a chain of activities leading to clear products. Formal system generally consists of public sector research institutions, public and private sector agencies producing and marketing seeds, agencies responsible for seed certification and quality control (Fig. 1). The guiding principles in the formal system are maintenance of varietal identity, genetic purity and production of seed with optimal physical, physiological and sanitary quality (Reddy *et al.* 2007). In case of informal system, also known as village or farmer or local seed system, farmers themselves produce, disseminate and access seed directly from their own harvest, through exchange among friends, neighbours and relatives or through local grain markets. The varieties disseminated may be landrace or mixed races and likely to be heterogeneous mixture of different varieties. Both seed systems have their own limitations that need to be addressed through some innovative approaches (Table 1).

Indian seed quality assurance standards vis-à-vis ISTA Seed Testing Association Rules and OECD Seed Schemes

Seed quality assurance is a systematic and planned mechanism for ensuring the genetic, physical, physiological purity and health of seed. It is dynamic with emerging needs of global standards, including land requirement, field crop inspection, seed testing, pre- and post-control. In India, Seeds Act 1966, Seed Rules 1968, Seed (Control) Order 1983 and subsequent amendments define the certification standards and procedures wherein quality seed must

Table 1 Comparison between formal and informal seed systems (Lohr and Camacho 2015)

Formal	Informal
Difficult in addressing the diverse needs of small farmers in marginal areas as offers a limited range of varieties	Varietal integrity and genetic purity are not assured
Public sector formal seed system is unable to meet the huge demand of seeds especially of legumes and oilseeds	Often sub-optimal seed quality
Small farmers in remote rural areas are generally by-passed due to poor logistics in seed diffusion	Seed exchange is restricted to a geographical area and governed by cultural barriers
Reluctance of private sector to produce seeds of pure line varieties of high volume- low value crops	Crop failures or low yields have a tremendous effect on the availability of seed
Prohibitive seed prices	Mostly landraces and traditional varieties with low yield potential
Sensitive to natural disasters and socioeconomic manoeuvrings	Technology dissemination at slow pace

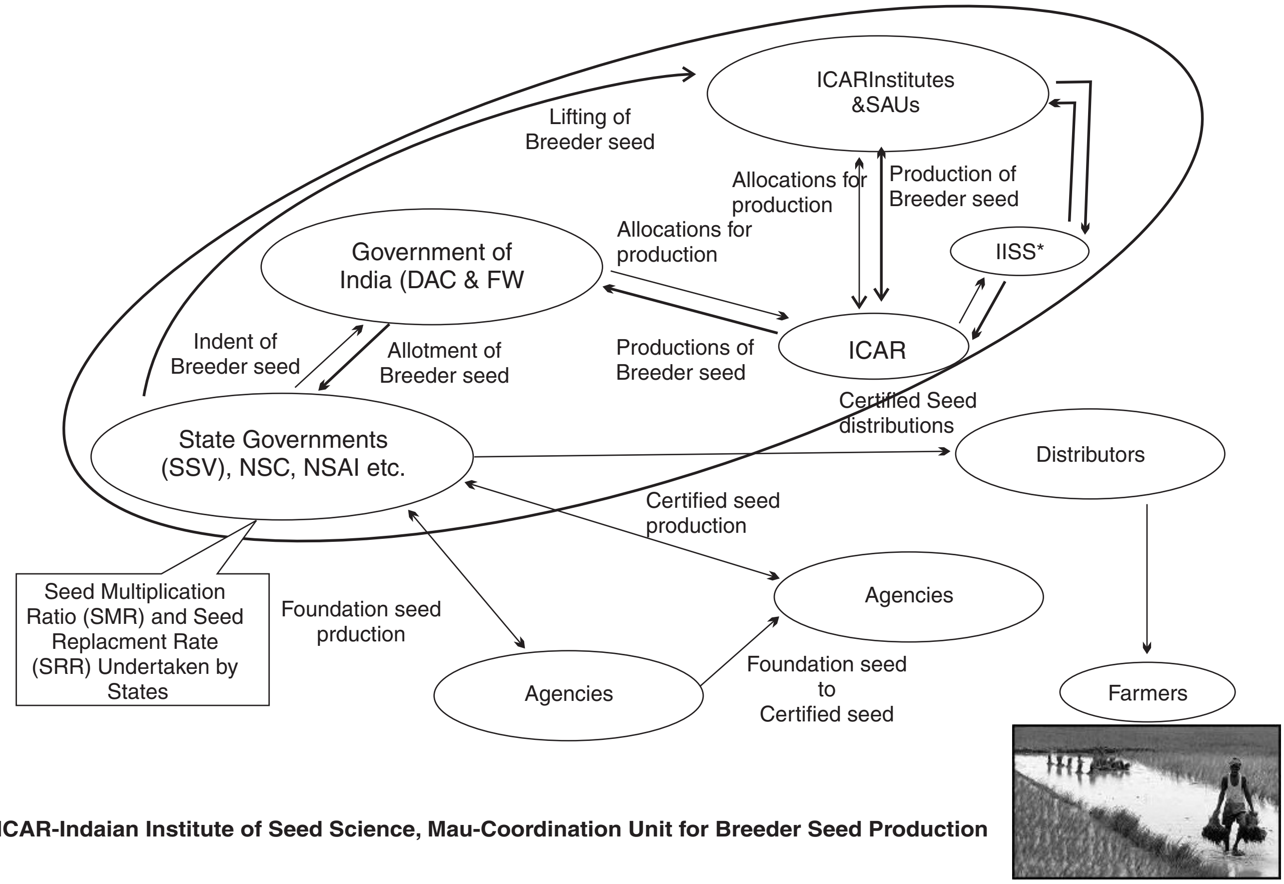

Fig 1 Seed production and supply chain in India (*Source:* http://seednet.gov.in)

satisfy IMSCS (Trivedi and Gunasakaran 2013). Several international bodies such as ISTA in 1924 in Switzerland; the International Plant Protection Convention (IPPC) in 1951 in Italy; the OECD Seed Schemes in 1953 in France and the International Union for the Protection of New Varieties of Plants (UPOV) in 1961 in Switzerland were created for setting standards and regulations that provided an enabling environment for the seed industry. In India, Protection of Plant Varieties and Farmer's Rights Act (PPV and FRA) in 2001 also enforces breeder's as well as farmer's rights in seed trading, but still in evolving phase (Chauhan *et al.* 2015). To augment the seed export, India became the member of OECD Seed schemes in 2008 to participate in multiplication of seeds abroad in order to play major role in international seed trade. The varieties/ hybrids of different crops developed and produced in India can be marketed in Asian and African countries falling within the same agro-eco-zones. The hybrid seeds of maize and rice can be marketed in SAARC and South East Asian countries, while seeds of sorghum and pearl millet can be exported to African countries. Similarly, India exported seeds worth US $ 67 million against global export of US $ 10 543 million during 2014-15 (http://apeda.gov.in / apedawebsite /six_head_product / floriculture. html). A comparative view on seed quality standards in India, ISTA's International Rules for Seed Testing and OECD seed schemes and scope to harmonize them for global competitive seed trade is presented hereunder.

Seed lot, submitted sample and working sample size

Seed size, in general, is the significant factor in determining the maximum seed lot size and the submitted sample is largely, in relation to working sample, based on the weight of 2 500 seeds. It is pertinent to note that the seed lot is rejected or accepted for sale, only on the basis of the tests conducted on the representative sample submitted to the seed testing laboratory. However, there exists a large variation in maximum seed lot size, minimum submitted sample and working sample size between IMSCS (2013) and ISTA International Rules (2015). Maximum weight of seed lot ranges between 10 000 - 20 000 kg (IMSCS) and 25 000 - 30 000 kg (ISTA international rules). In general, maximum weight of seed lot was higher by 25% (cotton) to 150% (safflower) as per ISTA rules than that of IMSCS (Trivedi and Gunasekaran 2013, Anonymous 2015). The minimum submitted and working sample size for purity analysis and assessing other seeds by number was invariably higher in ISTA rules (2015) for paddy, sunflower, cotton, jute, bird wood and buffel grass while lower for linseed, safflower, sweet clover, shaftal and Venezula grass (Table 2). The maximum submitted and working sample size for other crops were almost similar. There is no separate standard for pods and kernels of groundnut in ISTA rules (Table 2).

Non-coherence among the standards of genetic purity and other distinguishable varieties (ODVs) in IMSCS (2013)

Conventionally, genetic purity of hybrids/varieties is assessed by a grow-out test (GOT), which involves scoring distinct morphological traits for a given hybrid till maturity. There exists a balance between minimum genetic purity (%) and maximum permissible ODVs. GOT is not mandatory for all the crops, however, genetic purity for hybrids are 95%, in general. If we calculate the number of permissible off-type seeds to achieve 95% genetic purity, on the basis of test weight of the varieties and hybrids, it works out to be 2 143 seeds/kg of paddy, whereas permissible ODVs are 20/kg for certified seed (Table 3) that is distinguished only based on morphological markers, which is practically very difficult. Therefore, it is a time to revisit and raise standard for genetic purity. Further, we should also practice alternate methods of genetic purity testing such as DNA markers to minimize time and cost.

Inconsistency in standard operating protocols in seed testing vis-à-vis ISTA rules

ISTA produces internationally agreed rules for seed sampling and testing, accredits laboratories, promotes research, provides international seed analysis certificates and disseminates knowledge in seed science and technology. This ensures seed quality and facilitates national and international seed trade, and also contributes to food security. ISTA provides testing services for companies trading seed internationally. North American countries follow the Association of Official Seed Analysts (AOSA) rules, especially adapted for their market which, however, differs only in minor aspects from that of the ISTA. ISTA and the AOSA have a joint committee on the harmonization of rules. The OECD Seed Schemes provide a system for the assurance of varietal purity and identity for international seed trade, and are normally used in conjunction with ISTA seed lot certificates, which also carry the results of other quality tests. There are certain disparities between seed testing methods in India and ISTA (Table 4).

IMSCS (2013) vis-à-vis OECD seed schemes

The OECD Seed Schemes provide an international framework for the seed certification with an aim of facilitating the seed trade by reducing technical barriers. Rapidly growing seed trade, regulatory requirements in some countries, development of off-season production, the large breeding and production potential of exporting countries were the compelling factors for the establishment of seed scheme (Cortes 2009). The purpose of these schemes is to encourage the use of "quality-guaranteed" seed in participating countries (Trivedi 2012). The schemes authorize the use of labels and certificates for seed produced and processed for international trade according to agreed principles. They are based on two key criteria: varietal identity and purity. There are seven distinct and independent seed schemes and admission to each scheme is voluntary. Presently, India participates in five schemes namely, cereal, maize and sorghum, vegetable, grass and legume and crucifer and other oil or fiber species (Trivedi and Gunasekaran 2015).

Table 2 Comparison of minimum submitted and working sample size between IMSCS (2013) and ISTA Rules (2015)

Crop	IMSCS			ISTA		
	Minimum submitted sample (g)	Minimum working sample (g)		Minimum submitted sample (g)	Minimum working sample (g)	
		Purity analysis	Other species seed		Purity analysis	Other seeds by number
Cereals						
Paddy (*Oryza sativa* L.)	400	40	400	700	70	700
Pulses						
Blackgram (*Vigna mungo* L.)	1000	150	1000	1,000	700	1,000
Indian bean (*Lablab purpureus* L.)	1000	500	1000	1000	600	1,000
Oilseeds						
Castor (*Ricinus communis* L.)	1000	1000	1000	1000	500	1,000
Groundnut (*Arachis hypogaea* L.)						
Pods	1000	1000	1000	1000	1000	1000
Kernels	1000	600	1000			
Linseed (*Linum usitatissimum* L.)	300	30	300	150	15	150
Safflower (*Carthamus tinctorius* L.)	1,000	180	1000	900	90	900
Sunflower (*Helianthus annuus* L.)	250	125	250	1000	200	1000
Fibres						
Cotton (*Gossypium* spp.)	350	35	350	1000	350	1,000
Jute (*Corchorus* spp.)	100	10	100	150	15	150
Forages						
Birdwood grass (*Cenchrus setigerus* L.)	25	3	25	150	15	150
Blue panic (*Panicum antidotale* L.)	25	2	20	20	2	20
Buffel grass (*Cenchrus ciliaris* L.)	25	3	25	60	6	60
Doob (*Cynodon dactylon* L.)	25	1	10	10	1	10
Fenugreek (*Trigonella* spp.)	40	4	40	450	45	450
Guinea grass (*Panicum maximum* L.)	25	2	20	20	2	20
Sweet clover (*Melilotus indicus* L.)	100	10	100	50	5	50
Shaftal (*Trifolium resupinatum* L.)	25	2	20	20	2	20
Venezuela grass (*Melinis minutiflora* L.)	25	5	25	5	0.5	5

Table 3 Differences in permissible off-types and ODVs (IMSCS 2013) in paddy

Class of seed	Minimum genetic purity (%)	Reject number for sample size of		Permissible off-types (Maximum)	Permissible ODVs (Maximum)
		800	400		
Foundation	99	16	8	714 / kg	10 / kg
Certified					
Variety	98	24	12	1071 / kg	20 / kg
Hybrid	95	48	24	2143 / kg	20 /kg

Table 4 Comparison of seed testing methods in India and ISTA

Manual of seed testing, India	ISTA
Seed testing certificate	
Seed testing at State Seeds testing laboratories for assurance of seed quality standard and issuing foundation or certified seed tag to specific lots as the case there off	Two types of certificates, namely, Orange International Seed Lot Certificate when sampling and testing of samples are carried out in same country by accredited lab and Blue International Seed Sample Certificate when sampling is done by non-accredited laboratories/agencies but testing by ISTA accredited laboratory and quality assurance only for submitted sample tested in laboratory.
Range of crops	
Seed testing protocol as per manual of seed testing exist only for agricultural and horticultural crops excluding medicinal and aromatic crops.	Seed testing protocol has been standardized for agricultural and horticultural crops including medicinal and aromatic crops. Protocols for various herbaceous, tree species and seed mixtures were also included in the international rules for seed testing.
Physical purity analysis	
Purity component is divided into four classes (pure seed, other crop seeds, weed seeds and inert matter) but under IMSCS no such provision exists. For examinations of physical purity of grass seed samples, uniform blowing method is followed as per ISTA.	Purity component of submitted sample is divided into three component (pure seed, other seed including weed seeds/ other crops seeds and inert matter) Further, till date 63 pure seed definitions has been described for carrying out purity analysis.
Seed viability testing	
In manual of seed testing/IMSCS no such standard operating protocol exists.	Tetrazolium staining method has been standardized for diverse agricultural, horticultural and tree species. Further, excised embryo test has been specifically developed and adopted for viability testing in tree species.
Testing of coated seeds	
ISTA procedure.	Specific process for size of seed lot, obtaining primary sample, size of submitted sample, working sample size and method of obtaining working sample in case of coated seeds, viz. seed pellets, encrusted seeds, seed granules, seed tape, seed mats and treated seeds. Physical purity analysis can either be conducted upon pellets (pure pellets, unpelleted seeds and inert matter) or depelleted seeds (pure seed, other crop seeds and inert matter). Germination testing of pelleted seeds either by normal test (pure pellets without removing coating material) or additional/check test (pure seed after removing coating material).
Seed vigour testing	
No accepted protocol.	Four protocols have been standardized for soybean, maize, rapeseed- mustard, gardenpea.
Testing seeds by weighed replicates	
No provision exists.	Maximum germination potential of seed lot, has been standardized for *Eucalyptus, Betula* and *Chloris*
Seed health testing	
No accepted protocol.	28 seed health testing methods have been developed and validated for most of the economically important seed borne diseases along with specific sampling method and size of working sample.
Determination of other seeds by number	
No accepted protocol.	Other seeds refer to species other than those under test (other crop and weed seeds). The extent of the determination of other seeds shall be reported as complete, limited, reduced or reduced-limited test. • *A complete test* is one in which the whole working sample is searched for all other seeds. • *A limited test* is one in which the search is restricted to stated species in the whole working sample • *A reduced tes*t is one in which only part of the working sample is examined • A reduced-limited test is one in which less than the prescribed weight of seed for a working sample is examined for stated species only.

The IMSCS have been developed and adopted in 1988 and updated in 2013 to cater the needs of domestic seed certification system (Santhy *et al.* 2009, Trivedi and Gunasakaran 2013), whereas OECD seed certification are mainly meant to satisfy the needs of 59 member countries to meet the international seed standards and trade. IMSCS also satisfy many requirements of OECD rules and directions for field inspection to ensure varietal identity and purity. A seed crop when offers for OECD certification, then OECD rules and directions will be applied for field inspection and this process is well monitored through a comprehensive system of checks and balances. There exist wide differences in the modus operandi and standards in the two systems (Table 5). In India, there are five recognized classes of seed while in OECD scheme, there are six classes including two sub-classes within certified seed. The nucleus, breeder and foundation seed in IMSCS are equivalent to breeder's maintenance material, pre-basic and basic seed, respectively, of OECD seed schemes (Table 5). In India, varieties notified under Seeds Act 1966 will only qualify for seed certification but in OECD schemes, varieties included in the national list after checking against DUS characters or acceptable for Value for Cultivation and Use (VCU) in at least one country also qualify for certification.

In general, globally, the seed trade is one of the most regulated sectors, with a plethora of seed laws, testing and certification procedures (Singh *et al*. 2008). The simplification and harmonization of testing and

Table 5 Comparison of IMSCS (2013) and OECD seed schemes for varietal certification

IMSCS	OECD seed schemes
Classes and stages of seed multiplication	
Nucleus seed: Through maintenance breeding by the maintainers / breeders. Checked for varietal characters. Carries breeder's certificate and used for breeder seed multiplication.	*Breeders maintenance material:* Checked against DUS characters. Carries supplier's labels. Controlled and maintained by the maintainer / breeder. Used for pre-basic seed multiplication.
Breeder seed: Production monitored by expert team. Grow Out Test (GOT) is employed for certain crops. Used for Foundation Seed multiplication.	*Pre-basic seed:* Controlled by official certification authority [Designated Authority (DA)] + Maintainer. Undertake pre-controlled test. Cannot be commercialized and not for sale. Produced officially by the recognized institute/ organization.
Foundation seed: Controlled by official seed certification agency directly. *GOT* test is not compulsory but need based. Produced through registered seed producers/growers. Can be used for Foundation Stage-I to Foundation Stage-II multiplication in specific cases for the open pollinated varieties with specific approval from the Director of Seed Certification. Used for Certified Seed multiplication.	*Basic seed:* Controlled DA + Maintainer. Undertake pre-controlled test. Cannot be commercialized and not for sale. Produced officially by the recognized institute/organization.
Certified Seed: Controlled by official seed certification agency directly. GOT test is not compulsory and only need based. Produced through registered seed producers/growers. Can be used for Certified Stage-I to Certified Stage-II multiplication on specific cases for the open pollinated varieties with approval from the Director of Seed Certification.	*Certified seed:* Not under Breeder's/Maintainer's control however consulted for the number of multiplication. DA's and Controlling Authorities undertake the quality control including post control test + provision of patent royalty to the maintainers/breeders. Used for the commercial multiplication/sale.
Labeled Seed: Produced by the producer himself and no role of certification agencies. Producer himself is responsible for varietal purity and seed standards.	*Not finally certified seed:* Seed which is to be exported from the country of production after field approval, but before final certification as basic or certified seed, shall be identified in fastened containers by the special label.
	Standard seed: This category mainly exists in vegetable seed scheme. Seed that is declared by the supplier as being true to the variety and of satisfactory varietal purity. It must confirm to the appropriate conditions in the scheme.
Eligible varieties and parental constituents	
Only the varieties notified under Section 5 of the Seeds Act 1966 are eligible for certification.	Country shall have national list of varieties, which include only those varieties tested and listed to be Distinct, Uniform and Stable following internationally recognized guidelines and in case of agricultural species, varieties also found to have acceptable VCU in at least one country. Registered in National catalogue of varieties.
Control of the production of the seed	
Nucleus seed production is purely under the control of Breeder. Breeder seed is produced by breeder and monitored by a team comprising breeder, concerned Asst. Director of seed certification, a member from National Seed Corporation and a nominated member from farming community. Foundation and certified seeds are certified and labeled / tagged by Certification Agencies. Only official inspectors are allowed for seed certification.	The DA in the country of production of the seed is responsible for implementing the Scheme in relation to the production. Non-official inspectors are also allowed for certification of seeds.
Seed sampling	
By the officials of certification agency only.	DA is authorized to take seed lot sampling, fastening and labeling of container. The DA may authorize non-official persons to carry out such activities under official supervision.

Contd.

Table 5 (*Continued*)

IMSCS	OECD seed schemes
Seed analysis	
Seed quality analysis is carried out in Notified seed testing laboratories.	Seed quality testing is done as per the International Methods of Seed Testing recognized by the DA. The DA may authorize non-official laboratories to carry out seed analysis, but under official supervision.
Seed sample storage	
Guard samples of each seed lot shall be preserved for 2 years from the date of grant / extension of the certificate and 4 years in respect of rejected seed lots.	*Basic seed:* A third part of each sample shall be stored as long as possible for comparison in control plots with future test samples of Basic seed. *Certified seed:* A third part of each sample shall be stored for one year.
Pre-and post-control tests	
Seed certification agencies shall conduct a pre-requisite and / or need based GOT. No provision of pre- and post control tests.	Pre-control test is compulsory for pre-basic and basic seed. A part of every sample of basic seed and 5 to 10% of the certified seed shall be checked in a post-control test conducted immediately or in the season following the drawing of the sample.
Issue of certificates	
Release order (Form-II) issued by the officers of State Seed Certification Agency for foundation and certified class and for breeder seed by the concerned breeder/scientist.	The DA may issue certificates for each lot of pre-basic, basic and certified seed.
Blending of lots of same variety / re- packing and re-labeling in another country	
Bulking of unprocessed seed lots stocks are permitted provided the stocks meet certain requirements. No provision for re-packing and re-labeling in another place / country.	Two or more lots of certified seed of the same generation of one variety may be blended before or after export in accordance with the regulations of the country in which the seed is blended. Re-packing and re-labeling in another country allowed.
Reference numbers for certificates and seed lots	
There is no country code. Lot numbers need not be given in uniform digits. Continuous lot numbers are given for three years. (MAR 09-22-122-12) (harvest month and year-state code-unit code-lot number)	Lot numbers are assigned based on three letter country code as per ISO-3166-1 followed by initial letters of DA followed by reference number of the lot having uniform digits (for ex., 0001 to 9999) and a code letter used to indicate harvest year. The code number is given for a year.
Specifications for label or marking of seed containers	
Colour of labels • *Breeder seed:* Golden yellow • *Foundation seed:* White • *Certified seed:* Azure blue • *Labeled seed*: Opal green color Breeder seed label – 12 cm x 6 cm; Label size for foundation and certified is 15 cm x 7.5 cm, respectively. The label shall be made of durable material such as thick paper, paper with cloth lining, wax coated paper, plastic coated paper etc. There are differences in material, size and particulars furnished in the label.	*Type:* Labels may be either adhesive or non-adhesive. The information may be printed on one side only or on both sides. *Shape:* Labels shall be rectangular. **Color:** The colors of the labels shall be: *Pre-basic seed:* White with diagonal violet stripe *Basic seed:* White *Certified Seed :* 1stGeneration: Blue *2nd Generation or successive generations:* Red *Not finally certified seed:* Grey *Standard seed:* Dark yellow On all red and grey labels for certified seed of 2nd or further generation the appropriate generation number must be stated. One end of the label shall be overprinted black for a minimum distance of 3 cm leaving the rest of the label colored. *Material:* The material used must be strong enough to prevent damage in ordinary usage. Statement of re-packing and re- labeling is given if applicable. All information shall be given in either English or French except reference to the Scheme which must be in both English and French. Label no. is not given.
Specimen certificate and analysis results	
No such reference is specified. Tag numbers utilized for the lots are given in Indian system, certification tags / labels are issued.	Statement of re-packing and re-labeling is given additionally. Only number of containers and declared weight of the lot is given. ISTA orange certificate is given.

Contd.

Table 5 (*Continued*)

IMSCS	OECD seed schemes
Procedure for the extension of the scheme	
There is no provision.	Procedure for the extension of the scheme to include, for the purposes of field inspection, varieties under examination for registration on a national list.
Previous cropping	
Only in case of groundnut, the time interval between a seed crop and any other crop of the same species is two years, in sunflower one year, for other oilseeds and fibers no specification is given except the land shall be free from volunteer plants. As off-types of cotton are easily identifiable, the time interval may not be considered.	*Hybrids:* Hybrid seed may not be grown in the same field for successive years. *Varieties:* Grower requires furnishing particulars concerning the previous cropping in each seed field to the DA, Successive crops of the same variety and category of seed may be grown on the same field without any time interval provided that the satisfactory varietal purity is maintained. For the rest there shall be a minimum time interval between seed crops and any other crop of the same species as follows: Crucifer species: five years Other species: two years.
Isolation	
Depending upon the pollination behavior of crop, contamination nature, presence of wild species the distances vary for foundation and certified Seed. No modified isolation distance is permitted.	*Hybrids:* OP variety, hybrid, female parent prescribed distances from other variety of the same species except from a crop of male parent. Distances can be modified where there is sufficient protection from undesirable pollen or where the possibility of cross-fertilization is eliminated. *Varieties:* The seed crops of self-fertilizing species shall be isolated from other cereal crops by a definite barrier or a space sufficient to prevent mixture during harvest.
Weeds	
Maximum permitted objectionable weed plants: Foundation Seed: 0.01%; Certified Seed: 0.02%.	Maximum permitted objectionable weed plants: Foundation Seed: 0.01%; Certified Seed: 0.02%.
Number of harvest years	
No such specification.	The DA shall decide the number of harvest years to be permitted for a seed field, with particular attention when multiplying foreign varieties to the effects of changed ecological conditions on varietal purity.
Field inspection	
Varieties: Depending upon the crops, minimum two to four inspections from the time of flowering until harvest. *Hybrids:* Four inspections: 1st before flowering, 2nd, 3rd during flowering and 4th at maturity. Only one inspection is prescribed at the time of emergence of the inflorescence.	There shall be at least one field inspection of each seed crop after the emergence of the inflorescence. Control plots wherever possible are available for detailed examination at the time of field inspection of the seed plot. The DA shall decide whether or not approval can be given to the field following field inspections. For hybrids and parental lines three inspections.
Varietal purity in seed crop	
Foundation: Genetic purity is 99.0% Certified: 98.0%. Cotton hybrids: 90.0% Mustard hybrids : 85% All other hybrids: 95%.	Basic seed : 99.9%, Certified 1st generation and 2nd generation : 99.7% Depending upon the species: 95-99.9%
Field inspection of seed crops by authorized inspectors under official supervision.	
No non-official allowed for field inspection.	Official and non-official inspectors are allowed to conduct field inspection for seed certification.
Seed sampling (including fastening and labeling of containers) and seed analysis by authorized persons or laboratories under official supervision	
Seed sampling is done by seed certification officers and seed samples are analyzed by seed testing officers of notified laboratories. No non-official authorization	The DA may authorize persons who are not under its direct and exclusive authority to draw samples under official supervision (seed samplers). Laboratories may also be authorized to carry out seed analysis as required under the Schemes.

Contd.

Table 5 (*Concluded*)

IMSCS	OECD seed schemes
Seed lot sampling	
Sampling done by seed certification officers and supervised by supervising authority. Model label for container and printed information must be submitted for approval by DA.	• DA may authorize non-officials (samplers) to carry out seed sampling, fastening and labeling of container under official supervision (5%) and also non-official laboratory for seed analysis. • Model label for container and printed information must be submitted for approval to OECD. • White label for basic seed is not required if it is to be used in the same country
Seed analysis	
Seed samples are analyzed in notified laboratories as per the procedures given in Seed Testing Manual approved by Central Seed Committee.	Seed analysis is carried out in laboratories authorized by DA in accordance with current international methods. The laboratory shall be: • An independent laboratory • Laboratory belonging to a seed company. In the case samples referred to a laboratory belonging to a seed company, it may carry out seed testing only on seed lots produced on behalf of the said seed company, unless it has been otherwise agreed between the seed company, the applicant for certification and the DA.
Validity period	
No validity period is prescribed for breeder seed. For foundation and certified seed, the validity period shall be 9 months from the date of test at the time of initial certification that could be further extended for 6 months on retesting.	No validity period is mentioned for pre-basic, basic and certified seed.
Off-types in field	
Depending upon the crop / stage of multiplication, maximum permitted off-types: *Foundation seed* : 0.05% *Certified seed* : 0.20%	Maximum number of plants of the same species being not true to variety. *Basic seed* :1 in 30 sq m. *Certified seed* :1 in 10 sq m. The maximum permitted off-types Foundation: 0.075% Certified : 0.23% Considering plant geometry (45 x 15 cm), 1, 48,148 seed crop plants are there in one ha. Thus in basic seed,0.22% and certified seed, 0.67% off-types are permitted
Male sterile seed parent	
No such specification; follows 6:1 ratio according to crop.	Male sterile seed parent may be mixed with fully fertile seed parent in the ratio of 2:1.
Down-grading seed class	
If a seed field or seed lot is not found meeting the prescribed standards for the class for which it has been registered but conforms to the prescribed standards to the immediate lower class, the certification agency may accept such seed fields/seed lots for certification to the immediate lower class. However, downgrading shall not be applicable in case of hybrids and their parents.	No provision of downgrading seed class.

certification procedures helps to improve farmers' access to high-quality seed across the world. In Indian system, certification is carried out by a team consisting of officials from public sector organizations only at foundation and certified seed production stage while in OECD scheme, non-official inspectors are allowed for certification (Trivedi 2013). Further, it also allows non-official laboratories for seed analysis, while under Seeds Act 1966 it is carried out only by notified seed testing laboratories. Apart from other differences, in general, as well as crop specific standards, the major difference between IMSCS (2013) and OECD seed scheme is the involvement of non-official inspectors, laboratories and designated authority for seed sampling, seed analysis and issuance of certificates. In India, 10 State Seed Certification Agencies covering all the regions of the country were nominated as DA to carry out the varietal certification of the OECD Seed Schemes (Trivedi 2012).

Seed chain and varietal scenario

Breeder seed is the basic seed to initiate effective seed chain for ensuring production of desired quantity of quality seed. Indian Council of Agricultural Research (ICAR) is mandated to produce breeder seed of varieties released and notified in pursuance of Section 5 of Seeds Act 1966, as per the indent of Department of Agriculture, Cooperation and Farmers' Welfare (DAC&FW), Ministry of Agriculture and Farmers' Welfare, Government of India. The breeder seed indent for varieties notified for a specific state is directly submitted to the concerned State Agricultural Universities (SAUs)/organizations. The cut of date for placing indent with appropriate agency is 1st December for *kharif* crops and 1st May for *rabi* crops. Private seed companies also place the breeder seed indent by 15th January for *kharif* crops and 15th June for *rabi* crops through National Seeds Association of India or directly to DAC&FW (http://seednet.gov.in/PDFFILES/Breeder_Seed_Indent_Recommendation.pdf). The DAC&FW then consolidate the indents and provide to ICAR to produce breeder seed. Every year breeder seed of more than 1 100 varieties of 47 field crops comprising cereals, oilseeds, pulses, fibres and forages were produced (Table 6) by National Agricultural Research system comprising both ICAR institutes as well as SAUs. During 2015-16, 1 154 varieties were in the seed chain (http://seednet.gov.in/SMIS/SeedVariety Reports/wf_menu.aspx). The breeder seed produced is allotted by DAC&FW, for further use by public as well as private sector organizations for production of foundation, certified and truthfully labelled seeds.

Table 6 Varietal scenario in seed chain

Crop	Year			
	2012-13	2013-14	2014-15	2015-16
Cereals	583	549	511	562
Pulses	261	261	281	263
Oilseeds	251	238	225	225
Forages	70	59	68	58
Fibres	52	38	86	46
Grand total	1 217	1 145	1 171	1 154

Breeder seed production and issues

Breeder seed production of improved varieties with superior genetics and distribution is taking place at an incredibly faster pace, as witnessed in increased total breeder seed production under AICRP-NSP (Crops) and ICAR Seed Project of both national and state released varieties amounting to 128 312.8 q as against the indent of 112 152.1 q during 2014-15. The enhanced breeder seed production resulted in increased seed replacement rate (SRR) of various crops. Considering the overall indent and production levels, major breeder seed production centres were JNKVV, Jabalpur (53 22.2 tonnes); ANGRAU, Andhra Pradesh (1062.3 tonnes); GBPUAT, Pantnagar (664.1 tonnes); UAS, Dharwad (626.4 tonnes); RAU, Bikaner (560.0 tonnes) and PAU, Ludhiana (537.0 tonnes).

Declining breeder seed indent for national varieties

Consistent decline in the breeder seed indents for national varieties was observed since 2011-12 and decline was 13.8, 25.8, 31.6 and 33.6%, respectively, during 2012-13, 2013-14, 2014-15 and 2015-16 (Table 7). The analysis has shown that among the states during 2012-13 to 2015-16, increasing trend for breeder seed indents was observed only in Himachal Pradesh and Jharkhand, while the major states, viz. Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Gujarat, Maharashtra, Andhra Pradesh, Chhattisgarh and Odisha showed a declining trend for the breeder seed indents. This decline was mainly for rice, wheat, chickpea, mungbean, urdbean, groundnut, soybean, pigeonpea and fieldpea, which is a cause of serious concern.

Lack of congruence in data reporting

Since the organizations may place indents for breeder seed production either to DAC&FW for nationally released varieties and/or directly to the concerned SAUs for state released varieties, therefore, there could be a problem of reporting of production data. The DAC&FW consolidates the data only for centrally placed indents while a large amount of data remains unreported. The fact has been amply exemplified by the differences in the data from DAC&FW and ICAR-Indian Institute of Seed Science, Mau (Table 9). Actual indent and production were higher by 7.6-97.4% and 17.6-86.3%, respectively, except for the indent during 2011-12.

It appears that the requirement of breeder seed for the envisioned SRR on the basis of DAC&FW indents and production data do not reflect the real picture. In fact, there is possibility that enough breeder seed is being indented and produced even for those crops showing deficit breeder seed production. With the technological advances such as efficient crop management and new varieties, the seed multiplication ratio for different crops need to be reworked out, probably this could be an important factor resulting in to production of enough seeds even with declining indents. For wheat, with existing indents, a SRR up to 48% can be achieved with 100% conversion through efficient downstream seed multiplication. Similarly, even with present DAC&FW indents, for pulses (except lentil, field pea and lathyrus), oilseeds, fibres and forage crops the present level of breeder

Table 7 Breeder seed production (q) during the last six years

Year	Source			
	National varieties (DAC&FW)		National + state varieties (ICAR – IISS, Mau)	
	Indent	Production	Indent	Production
2010-11	83 880	98 419	90,266	115 867
2011-12	94 220	104 784	87 215	115 696
2012-13	81 193	89 437	90 577	117 827
2013-14	69 890	72 598	98 791	95 012
2014-15	62 222	65 180	112 152	128 312
2015-16	62 500	68 296	122 305	124 843

Table 8 Non-lifting of breeder seed (q) during the last three years

Crops	Year		
	2013-14	2014-15	2015-16
Cereals			
Paddy	289.2	212.7	515.2
Wheat	1782.2	2097.2	2418.6
Barley	26.3	63.0	48.7
Maize	3.2	44.8	70.8
Sorghum	1.0	13.4	9.5
Pearl millet	0.5	1.4	0.3
Pulses			
Pigeonpea	2.5	75.8	51.1
Chickpea	172.5	499.7	978.5
Mungbean	97.3	31.3	91.3
Urdbean	17.9	50.4	39.7
Lentil	3.6	58.6	40.0
Field Pea	10.9	133.9	35.0
Mash	1.4	10.7	3.3
Cowpea		7.0	5.8
Lathyrus			3.0
Oilseeds			
Indian Mustard	0.0	1.8	29.3
Toria	0.0	15.8	
Gobi Sarson	0.1		
Groundnut	0.0	780.2	1773.8
Soybean	3.1	578.2	820.4
Linseed		11.8	4.9
Sunflower			0.6
Sesame			4.8
Safflower		6.7	
Castor		2.4	
Fibres			
Cotton	9.0	1.9	3.2
Jute	8.6	13.2	0.7
Forages			
Berseem	6.5	5.7	4.4
Lucerne	0.0	0.5	
Oat	14.4	7.0	
Total	2450.1	4724.9	6952.9

seed indents has the capacity to meet the quality seed requirement even for higher SRR than the targeted one.

Non-lifting/partial lifting of breeder seed

Huge resources were infused for producing breeder seed of highest quality, hence non-lifting/partial lifting of allocated quantity by indenters is a serious concern. Further, in present scenario the cost of production is increasing and remunerations by such activity to BSP centres is also decreasing, so any act of non-lifting by indenting agencies will lead to huge monetary loss and also demotivates them from taking up this responsibility. In the year 2013-14, 2014-15 and 2015-16, 2450.1 q, 4800.2 q and 6952.7 q of breeder seed which were 2.6, 5.3 and 5.4% of total breeder seed production, respectively, among various crops were not lifted by indenting agencies (Table 8) comprising 6298 q and 1017q of wheat and paddy seed in cereals; 1650 q of chickpea and 179 q of fieldpea in pulses; 2554 q of groundnut and 1401q of soybean in oilseed; 16q of berseem and 21q of oats in fodder crops, by concerned state departments of Jharkhand, Rajasthan, Madhya Pradesh, Uttar Pradesh, Chhattisgarh, Sikkim, Meghalaya, Himachal Pradesh; state seed corporations of Uttar Pradesh, West Bengal and Odisha, national seed corporation and many private companies.

Disruptive climate vis-à-vis climate change

Seed quality comprises several parameters, viz. physical and genetic purity of seeds, seed germination, viability, vigour, seed health and appearance like size, shape, weight and colour. Each of these parameters depends on climatic variables prevailing during the crop growth period and subsequent seed processing. If climatic factors are adverse during crop growth, the resultant poor quality seeds fetch lower market value and causes economic loss to the farmers (Maity and Pramanik 2013). Deteriorating effects of climate change has already affected the seed production programmes in crop such as soybean, groundnut, chickpea and lentil. During 2013-14 and 2014-15, due to water stress coupled by sudden white fly outbreak drastically affected quality seed production in soybean. Consequently, a few breeder seed producing centres failed to meet the demand leading to major shortfall in soybean and chickpea. Climatic vagaries such as cyclones (*Hudhud*), untimely rains, hailstorms have also severely affected quality seed production activities in *rabi* crops during 2013-14 and 2014-15.

Perspectives

Despite a huge institutional framework for seed production both in the public and private sector, availability of good quality seeds continues to be a problem for the farmers. National Seed Plan-2002 targeted a benchmark of achieving 25 and 35% seed replacement rate (SRR) in self and cross pollinated crops, respectively, for realizing national food security (Anonymous 2002). Except groundnut, chickpea and pigeonpea, this benchmark SRR has been achieved by 2012-13 in most of the food crops. Now, the desired SRR is 33 and 50% for self- and cross-pollinated crops, respectively. Considering the national food and nutritional security, sustainable supply of quality a seed is most critical.

Energising breeder seed production

In majority of food and oilseed crops, indents are well above the required quantities for achieving target and envisioned SRR during 2019-20 and even sufficient for achieving 100% SRR covering total cropped area under quality seed in a few crops (Table 9). However, for crops like wheat, chickpea, soybean, sunflower and groundnut, current breeder seed indent / production is inadequate for maintaining the requisite SRR. The major reasons for deficit could be attributed to their low seed multiplication ratio (SMR), high seed rate/ unit area, less efficient seed production chain and aberrant climatic conditions. The level of indents is declining in many crops. Further, issues of non-lifting of seed needs to be seriously addressed as it can be the most important factor of de-motivation for breeder seed producing agencies for taking up such privileged activity. The breeder seed requirement is grossly over-estimated in several crops on account of two assumptions i.e. the seed replacement rate would be 100% and the entire area under a given crop is planted with improved varieties. Replacing altogether the land races, traditional cultivars and farmer's varieties would lead to irreparable loss of genetic variability so essential for mitigating challenges of climate change and prevailing as well as emerging biotic and abiotic stresses. Unrealistic indents of breeder seeds for some of the varieties coupled with sudden substantial fluctuations in varietal demands in quick spans is one of the reasons for inadequate or skewed availability of quality seed. The states are the major stakeholders in the seed chain as its initiation depends on their indents for the breeder seeds. They should prepare at least five year seed rolling plan (2017-22) phasing out old and obsolete varieties with latest released varieties. Then they should come up with crop wise/variety wise realistic indents to the concerned organization considering the expected gross cropped area, ideal seed replacement rate and gradual annual increase, at least three years in advance. Appropriate MoUs should be developed with the different stakeholders for firm commitments of procuring the seed thus mitigating the problem of non-lifting. Introduce bar / QR code is desirable for traceability of breeder seed source in multiplication chain for quality seed production. Development of variety specific molecular markers to enable rapid genetic purity testing, management of nucleus seed and its maintenance to either replace or supplement grow out test and a network on developing national database of crop varietal DNA profile (finger printing) should be created to facilitate quality breeder seed production is foremost.

Energising seed production and supply chain

Seed production chain, which involves several stakeholders, primarily the Departments of Agriculture of different States, State and National Seed Corporations, farmer producer organizations and private sector needs to be strengthened for efficient conversion of breeder seed into downstream classes to achieve higher

Table 9 Breeder seed actually required for existing SRR (2011-12) and targeted SRR during (2019-20) for major crops (Chauhan *et al.* 2016)

Crop	Gross cropped area (m ha)	Breeder seed required (q) @ 100% C.F.	Breeder seed produced (q) (2014-15)	Targeted SRR (2014-15)	Breeder seed required (q) for targeted SRR	Breeder seed Surplus/ deficit (q)	Actual SRR (2011-12)	Breeder seed required (q) as per actual SRR	Breeder seed Surplus/ deficit (q)	B/S required to be produced during 2016-17 to achieve 2019-20 target SRR		
										SRR* (2019-20)	Breeder seed (q)	Surplus/ deficit (q)
Paddy	45.5	1821.2	21299.0	35.0	637.4	20661.6	32.8	597.4	20701.7	48.8	888.8	20410.3
Wheat	30.6	76500.0	38058.9	35.0	26775.0	11283.9	35.5	27157.5	10901.4	51.5	39397.5	-1338.6
Maize	9.1	283.8	482.6	50.0	141.9	383.3	71.8	203.8	278.8	87.8	249.2	233.4
Pearl millet	9.6	11.9	60.4	50.0	6.0	56.2	53.6	6.4	54.0	69.6	8.3	52.1
Sorghum	8.3	48.6	322.7	35.0	17.0	305.7	40.1	19.5	303.2	56.1	27.3	295.4
Chickpea	9.6	34133.3	7072.3	35.0	11946.7	-4874.4	25.4	8669.9	-1597.6	41.4	14131.2	-7058.9
Pigeonpea	3.7	349.7	711.2	35.0	122.4	588.8	41.0	143.4	567.8	57.0	199.3	511.9
Mungbean	3.7	582.8	1091.4	35.0	204.0	887.4	23.6	137.5	953.9	39.6	230.8	860.6
Urdbean	3.2	498.4	652.0	35.0	174.4	477.6	30.3	151.0	501.0	46.3	230.8	421.2
Soybean	12.0	40000.0	11531.5	35.0	14000.0	-2468.5	30.5	12200.0	-668.5	46.5	18600.0	-7068.5
Groundnut	6.3	62900.0	11999.2	35.0	22015.0	-10015.8	23.7	14907.3	-2908.1	39.7	24971.3	-12972.1
Rapeseed-mustard	7.3	9.1	489.0	50.0	4.6	485.9	54.6	5.0	484.0	70.6	6.4	482.2

CF - Conversion Factor; SRR- Seed Replacement Rate. * SRR for 2019-20 was calculated with increment of 2% every year from the base year 2011-12.

output. In recent years, the climate changes had adversely affected agricultural production in the country and the seed production programme is not an exception, soybean and chickpea seed production were severely affected. Therefore, there is an urgent need to identify alternate areas or new niches in non-traditional season/areas for compensatory seed production. Institution of 'National Seed Grid' and identification of provenances for off-season seed production in oilseed and pulses will help in meeting the seed requirement and mitigating effects of climatic vagaries, viz., soybean- Maharashtra and Madhya Pradesh; groundnut- Gujarat and Andhra Pradesh; chickpea- Madhya Pradesh, Maharashtra and Andhra Pradesh; pigeonpea- Karnataka and Andhra Pradesh and lentil- Madhya Pradesh. Along with formulation of sustainable seed plan for contingency under natural calamities focus should also shift on harnessing the potential of rice-fallows for seed production of oilseed and pulses. ICAR-Indian Institute of Seed Science, Mau along with its collaborating centres in the states of Bihar, Madhya Pradesh, West Bengal and Tripura has initiated programme for seed production in rice-fallows to up-scale varietal and seed replacement rates at village level; capacity building of farmers especially women for quality seed production as a means of additional livelihood. The focus is on quality seed production of short-duration drought escaping varieties of *rabi* pulses and oilseeds such as chickpea, lentil, groundnut and rapeseed-mustard. Unemployed youths can be trained in the field of seed quality assurance and with financial support and seed quality assurance laboratories, *"seed clinic"* may be established in major seed growing areas.

Development of seed quality testing laboratories and strengthening them into seed quality assurance hubs will play an important role for energizing the quality seed production in the country. Besides state-of-art infrastructure, these laboratories should be staffed with qualified and well trained personnel. There is also need for regular updating the handbook on seed testing with all details like infrastructure needs such as construction, equipments, testing protocols /methods and stewardship in seed quality assurance. ISTA accreditated laboratories are authorized to issue orange and blue international seed analysis certificate which is indispensable for global seed trade. Seed testing laboratories in India should be motivated to participate in proficiency testing to assess competency. A number of laboratories issuing ISTA International Seed Analysis Certificates, which can be seen as a passport for international seed trade can serve as a promoter for seed industry (Masilamani and Murugesan 2012). As of now, 134 seed testing laboratories from 60 countries are accreditated to ISTA, which includes six laboratories from India (Chauhan *et al.* 2016) Building capacity and establishment of more ISTA accreditated laboratories for seed quality assurance will create an enabling environment for seed export. Development of seed-post-harvest technologies through dry chain concept needs special attention in order to assure long-term seed vigour and viability.

Establishing crop-wise advisory body/referral lab for implementation of quality control system and India, being one of the predominant players in South Asian Association for Regional Cooperation (SAARC) seed market, it should also explore feasibility of quality seed production of common varieties in other SAARC countries. In conclusion, strengthening the quality seed production chain in the era of climatic vagaries through off-season seed production and harnessing the inherent potential of rice fallow cropping systems especially for pulse and oilseed crops can usher the much awaited second green revolution. IMSCS standards were developed and adopted since 1974 to cater the needs of various stakeholders of Indian seed industry, whereas OECD seed schemes and ISTA standards are developed *per se* for promoting global seed business. As these are two different streams, certain variations in varietal certification procedures and standards exist, which needs to be addressed appropriately to open the Indian seed industry to global market. There are two options IMSCS, OECD and ISTA standards be harmonized to facilitate seed trade or OECD Rules and Guidelines applicable only whenever, a variety is being registered / offered for the OECD Seed Schemes and International varietal certification process has to be carried out. India being a participant since 2008 of OECD seed schemes; harmonizing seed standards, seed testing and establishment of ISTA accreditated seed testing laboratories seems to be appropriate to globalize fast emerging Indian seed market.

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