Matthew P. Reynolds
Hans-Joachim Braun *Editors*

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Chapter 14
Seed Systems to Support Rapid Adoption of Improved Varieties in Wheat

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Arun Kumar Joshi and Hans-Joachim Braun

Abstract New varieties of crops are developed to provide farmers seeds of cultivars that are acquainted with specific environmental or management conditions to realize best yield and quality. Seed is the carrier of genetic potential for the performance of a crop, hence is considered the most vital input in agriculture. Wheat being self-pollinated, it is not necessary to buy seed every year as in case of hybrids. Seeds are multiplied through an informal or formal approach. In most developing countries, informal wheat seed sector is dominant. Seed production follows well defined steps wherein a particular class of seed is grown to deliver another class of seed to the farmer. In general, there are four classes of seeds in wheat – nucleus, breeder, foundation and certified, although in some cases registered seed is also produced. The strength of the seed sector varies across countries – strong in developed countries but moderate to weak in the Global South. In most countries seed production and its marketing is regulated and both public and private sectors are involved. In counties with a not so strong seed sector, a fast track approach for varietal release and seed dissemination has been advocated to meet the challenges of climate change and transboundary diseases.

Keywords Improved seed · Seed system · Pre-release · Policy · Training · Participatory

14.1 Learning Objectives

- Improved seed is key for food and nutritional security.
- Seed system is within breeding process.
- Fast track release and dissemination is important.
- Policy change and capacity building are required.

A. K. Joshi (✉)
International Maize and Wheat Improvement Center (CIMMYT), New Delhi, India

Borlaug Institute for South Asia (BISA), Ludhiana, Punjab, India
e-mail: a.k.joshi@cgiar.org

H.-J. Braun
International Maize and Wheat Improvement Center (CIMMYT), Texcoco, Mexico

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14.2 Introduction: Need for Efficient Wheat Seed System and Issues That Affect Its Functioning

High yielding varieties with better quality and nutrition, that are adapted to a particular environment, increase the choice of healthy and nutritious food while generating a viable income for farmers [1] (For history of wheat breeding, see Chap. 2). In a self-pollinated crop like wheat, traditionally it takes about 15–20 crop cycles starting from crossing, testing and then to finally release a variety. Combining fast track breeding systems with fast track testing and release can bring this down in spring wheat to 6 (most extreme) to 10 crop cycles (more realistically). For a long time, shuttle breeding has been used at CIMMYT for spring wheat in which two breeding cycles are managed in a year, to reduce time to develop a variety in the breeding process and improve adaptation of breeding lines (For details, see Chap. 7).

New varieties, if not delivered to farmers on time may become susceptible to new races of pathogens and may not remain useful [2, 3]. Like breeding, seed dissemination in farmers fields may also take considerable time [4, 5]. The speed of seed dissemination is much faster in developed countries where there is abundance of private companies compared to the developing world [3]. There are several reasons of slow rate of variety turnover. A major challenge is the requirement of high seeding rate, 80–120 kg in spring wheat and about 180 kg in winter wheat. This demands a huge amount of seed to be produced and marketed which makes it quite challenging compared to other major cereal crops like maize and rice which require low (about 1/5th to 1/10th) seed rate. Since it is not necessary to purchase seed every year for a self-pollinated crop like wheat, it has a weaker economic business model compared to hybrid crops. Another factor is the low degree of commercialization in developing countries where majority of farmers are small holders [6].

Most countries require that as a pre-requisite for a variety to be admitted to the national list, it must meet the criteria if DUS (Distinctiveness from other varieties, Uniformity and Stability). DUS determines whether a newly bred variety is distinct (D) compared to existing varieties within the same species, whether the characteristics are expressed uniformly (U) and that these characteristics are stable (S), and do not change over subsequent generations [7]. For agricultural plant varieties incl. wheat, value for cultivation and use is often also required. A variety is considered to have value for cultivation and use if its qualities taken as a whole offer a clear improvement for cultivation, for use of the harvest or use of products derived from the harvest compared to comparable listed varieties. The value features of a variety are determined by properties shown in cultivation testing and laboratory testing relating to cultivation, resistance, yield, quality and it must be distinctly different from other varieties [8].

A seed production program can not compromise on the three issues: (1) the nature of improved variety, (2) seed purity (both physical and genetic) and, (3) seed germination. In addition, the seed must be made available in required quantities before the optimum sowing date at a reasonable cost. Thus, seed production involves

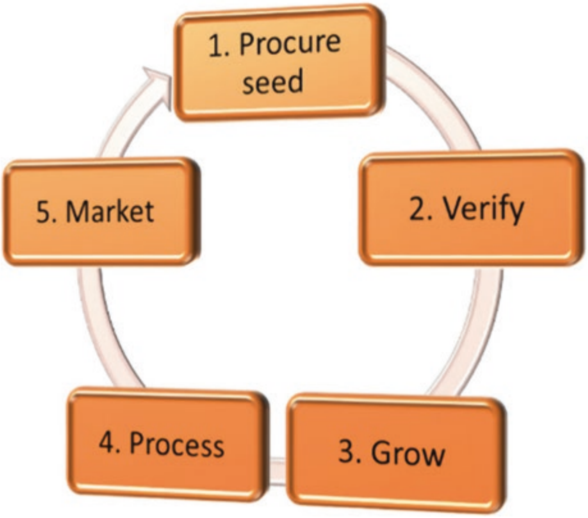

Fig. 14.1 Seed-to-Seed cycle in seed production

all those stages that fall between the procurement of right class of seed for initiating seed production and the distribution of the next class of seed to the grower. In other words, seed production is achieved through a "Seed-to-Seed" cycle (Fig. 14.1) and hence, is different from commercial crop production, where focus of production is the grain for consumption or the market.

14.3 Importance of Quality Seed in Modern Agriculture

Seed is considered the most cost efficient means of increasing agricultural production since it carries genetic potential to express best yields in a given environment. Agronomic interventions and policy decisions also play a key role. However, efficacy of other agricultural inputs in enhancing productivity and production, such as fertilizers, pesticides and irrigation is largely determined by the quality of seed. Food security is therefore dependent upon the seed security of farming communities [9]. Not only improved seed is necessary to realize yield potential, but promotion of varieties with different resistance genes enhance genetic diversity in farmers' fields and reduce the risk of pandemics.

The value of quality seed in obtaining optimum production and productivity has been proven in numerous studies of different crops including wheat [10]. Good seed is also important to keep farmers in good confidence and living without fear from losses due to diseases and abiotic stresses. During sudden emergence of a new virulence or a disease, seed of resistant varieties work just like a vaccine and save farmers from crop failure (Dr. Alison Bentley, personal communication, April 14, 2021).

14.4 Systems of Deed Dissemination

Since wheat is sown in large areas with high seeding rates, most seed is produced close to seed markets where wheat is grown. In other crops having low seed rate, seed can be imported from different regions, but not in wheat due to high transportation costs. In general, there exist two broad systems of seed dissemination and adoption: formal (organized) and informal (unorganized) [11].

14.4.1 Formal and Informal Seed Dissemination

The formal seed system involves an organized way of seed business in which improved varieties are developed and seed of a particular class is produced and marketed. In contrast, in the informal system, farmers themselves produce and disseminate from their own harvest following farmer to farmer exchange. The informal system is mostly observed in the Global South, where farmer to farmer seed dissemination is well known in countries like Afghanistan, Bangladesh, Ethiopia, Nepal, Pakistan and in some parts of India [3, 12]. The formal sector dominates in high income countries. However, both formal and informal seed systems may exist in developing countries. Among high income countries, the public wheat sector is strong in North America, while Australia, West and Central Europe and in the Southern cone of Latin America the formal private sector prevails.

In view of significant informal seed sector, countries like Nepal implemented participatory research program as an official way of varietal selection and seed dissemination. Much earlier, participatory research [13, 14] with farmers was recognized as a way of varietal selection and promoting seed dissemination. The approach of participatory varietal selection (PVS), in which new pipeline varieties are tested in farmers fields, has inherent ability to fast track the dissemination of seeds of new varieties since pipeline varieties enter seed production on the day 1 of their introduction to farmers fields which happens much before their official release [15, 16].

14.4.2 Seed System in Developed Countries and UPOV

The global private spending on agricultural R&D (excluding R&D by food industries) has increased from about $5.1billion in 1990 to $15.6billion by 2014 [17]. In wheat and small grains, the total spending on R&D in 2014 was $1 billion [17]. Since farmers can save and reproduce their own wheat seed, seed royalties and consequent return of investments used to be limited. This limitation was recognized in developed countries and attempts were made to strengthen property rights of plant breeder over time. One such effort was the International Union for the Protection of

Plant Varieties (UPOV) which is an international agreement that attempts to create a common approach to plant breeders rights [18]. UPOV was established by the International Convention for the Protection of New Varieties of Plants that was adopted in Paris in 1961 and revised in 1972, 1978 and 1991. UPOV's mission is to provide and promote an effective system of plant variety protection, with the aim of encouraging the development of new varieties of plants, for the benefit of society [18].

There are currently 75 members of UPOV, 57 countries have legislation to implement the UPOV 1991 convention. The implementation of UPOV 1991 in different countries was done in different years. For example, USA (1994), Germany (1998), UK (1999), Australia (2001), European Union (2005), France (2012) and Canada (2015). Major wheat producing countries that are not member of UPOV are India, Pakistan, Nepal, Iran, Afghanistan, Kazakhstan and Ethiopia. A well-functioning royalty collection system is in Australia. The interesting component of the Australian system is that royalties are collected when commercial grain is delivered to the elevator. Breeding companies have therefore no incentive to invest in large seed production programs. They give seed of their varieties to seed producing farmers who make their money on selling seed. Thus seed farmers become the seed promoters. The Australian model is suitable for countries where most wheat is exported i.e., grain delivered to an elevator where variety is determined and royalty payments can be calculated. It could be a model for wheat exporting countries like Canada, Kazakhstan, Ukraine and Argentina.

14.4.3 Pre-release Seed Multiplication

Pre-release seed multiplication means multiplication of the seed of a variety before its formal release. This assures sufficient seed is available for large scale multiplication. Due to production costs, in many developing countries, the amount of breeder seed available at the time of varietal release is about one ton only. This amount is too small to allow rapid dissemination. Moreover, as soon as farmers learn about release of a new variety there is demand, but no seed is available. This leads to multiple consequences, such as dissatisfaction among farmers, slow rate of adoption and sometimes may lead to black marketing of seed or sale of spurious seed. The benefits of pre-release seed multiplication, as explained in Sect. 14.5, are of immense value during outbreak of a new disease like Ug99 [4] or wheat blast [19].

14.5 Type of Varieties in Wheat and Classes of Quality Seed

Seed production methodology is influenced by the type of the variety being pursued. A brief concept is explained below.

14.5.1 Land Race, Pure Line Varieties and Hybrid Varieties

14.5.1.1 Land Race

Cultivars that are under cultivation in farmers fields for a long time beyond the records of organized breeding are termed land races. They are grown sparsely and are generally observed in far flung areas where new alternatives are not available. Land races are mostly heterogeneous and hence their seed production is done by bulking seeds of similar looking plants.

14.5.1.2 Pure Line Varieties

Pure line varieties are the advanced generations of the progenies of single plants selected from a heterogeneous population generated through an organized crossing and breeding program. Therefore, pure line varieties are highly homozygous and homogeneous and do not change their genetic makeup from generation to generation except though outcrossing and/or mutations. Therefore seed production needs simple steps with focus on purity through use of pure source seed, rouging, avoiding seed mixture etc.

14.5.1.3 Hybrid Varieties

A hybrid variety is the first generation seed derived from cross between genetically unrelated parents. Their seed production involves development and crossing of generally two parents (inbreds/pure lines). Therefore, maintenance of inbreds/pure lines is essential. Hybrid seed production program involves use of male sterility or chemical hybridizing agents. Seed of hybrid varieties when grown more than once, show reduced expression of yield and other traits due to inbreeding depression. Hence their seed need to be purchased every year.

As of today, most released wheat varieties are pure lines and hybrid wheat is globally insignificant. Producing hybrid seed is much more complex than pure line seed. This chapter focuses on seed production of pure line varieties.

14.5.2 Classes of Improved Seed

Seeds of high yielding varieties, that are genetically and physically pure and carry high germination (%) are called Improved Seed. There are different classes of seeds recognized in different countries (Table 14.1). However, for easy understanding, there are four recognized classes: Nucleus seed (NS), Breeder Seed (BS), Foundation Seed (FS) and Certified Seed (CS) (Fig. 14.2). The last two classes of seed fall under

Table 14.1 Wheat seed classes nomenclature in some countries

Class of seed	S. Asia (India, Nepal, Bangladesh, Pakistan)	OECD	AOSCA	Ethiopia	Egypt
First seed available	Nucleus seed	Nucleus seed	Nucleus seed	Nucleus seed	Nucleus seed
1st generation supplied by plant breeders	Breeder	Breeder	Breeder	Breeder	Breeder
2nd generation	Foundation	Pre-basic	Foundation	Pre-basic	Foundation
3rd generation	Certified	Basic	Registered	Basic	Registered
4th generation		Certified 1	Certified	Certified 1	Certified
5th generation		Certified 2	–	Certified 2	–

Modified with permission from Ref. [2]
OECD includes European countries; AOSCA is Association of Official Seed Certifying Agencies. AOSCA's membership includes Seed Certifying Agencies across the US, and Global membership including Canada, Argentina, Brazil, Chile, Australia, New Zealand, and South Africa
For all classes, stage I and stage II are permitted in most countries when quality seed is in short supply

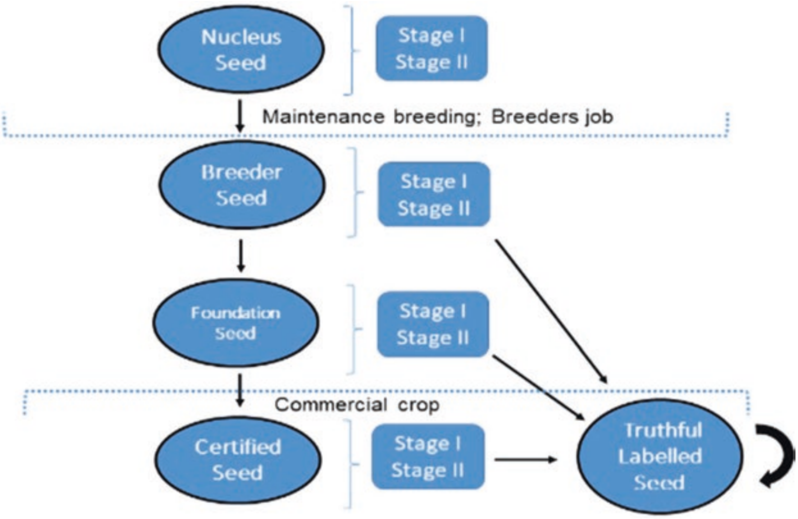

Fig. 14.2 Classes of improved seed and their general status during seed production

certified seed category and are generally certified by a government designated certification agency. In some countries, another class of seed (Registered Seed) is designated between foundation and certified seed class. Each class of seed may be reproduced again from same type of seed and are classified as stage I and Stage II. For instance Breeder seed stage I and Breeder seed stage II. The stage II class is allowed (from stage I of the same class) only under emergency situations when a particular class of seed is in extremely short supply. There is another class of seed

Fig. 14.3 Nucleus seed production in wheat by progeny rows of single spikes at BISA Ludhiana, India

called Truthful Labelled (TL) seed. This seed can be produced from any class of seed and is not certified by any certification agency, but quality assurance is given by the producer/company.

14.5.2.1 Nucleus Seed

Nucleus Seed (NS) is the first seed available when a variety is produced. It is generally produced by the breeding institution which owns the variety. It is considered 100% pure – both genetically and physically. Nucleus seed is produced by growing progeny rows using seeds collected from a number of single spikes (Fig. 14.3). Off type single rows are removed and only rows having characteristic traits of the variety are harvested and bulked.

14.5.2.2 Breeder Seed

BS is the progeny of nucleus seed and is produced by the breeder/sponsored breeder or the original institute where the variety was developed. The BS crop is monitored by an Inspection Team comprising of plant breeders and officials designated by government.

14.5.2.3 Foundation Seed

FS is the progeny of BS and is used to produce the next class of seed i.e., certified seed. This seed is not used for commercial cultivation. Foundation seed is also certified by a certifying agency for minimum seed standards. Production of FS is done under the control of government designated agencies (Seed Certification Agency).

14.5.2.4 Certified Seed

CS, the last category of seed, is the progeny of foundation seed. Certified seed is given to farmers for commercial cultivation. Production of CS is also done under the control of a government designated agencies (Seed Certification Agency).

14.5.2.5 Truthful Labelled Seed

As per Seeds Act prevailing in various countries, *certification is voluntary* but *labelling is compulsory*. It means presence of proper labelling in seed bags is necessary. As a result, there is another class of seed called Truthfully Labelled (TL) seed where there is no involvement of Certification Agency, but labelling is done. TL seed can be produced from any class of seed.

14.6 How to Judge the Quality of Seed

Seed quality is judged by seed testing. Seed testing refers to an evaluation of seed quality parameters to ensure that the seed conforms to the 'Minimum Seed Standards'. Seed testing involves tests that are meant to verify the following three parameters: (1) Physical and genetic purity, (2) moisture content and (3) seed germination. The information obtained from seed testing is printed on the seed tags attached to the seed bags or packets.

Seed testing as a science and standard procedure has developed during the nineteenth century. The first seed-testing laboratory was established in 1869 in Saxony, Germany while in 1876 in USA and in 1961 in India. Presently, seed testing laboratories are present in almost all countries and are regulated by both government and private sectors. The procedure for seed testing is based on guidelines from International Seed Testing Association [7] and other publications of the host country issued in support of the standard procedure. The standard procedure for seed testing involve, seed sampling, purity analysis, germination test, moisture test and test for seed health.

14.7 Steps Involved in Seed Production and Minimum Seed Standards

A seed production program must ensure attainment of the defined genetic constitution of the aggregate of seed being produced.

14.7.1 Steps in Seed Production

Quality seed of wheat is produced in a step wise fashion. Each class of seed is produced under strict supervision and must meet minimum seed quality standards [2]. In general, seed multiplication of a variety involves the following five steps: (1) Procurement of a class of seed, (2) Reporting to monitoring/certification agency, (3) Seed production in the field, (4) Seed processing, (5) Delivering seed to market (Fig. 14.4).

14.7.2 Minimum Seed Standards

Each class of seed must conform to certain level of quality standards, termed minimum seed standards. These standards mainly reflect two things – the performance of the seed crop in the field and the characteristics of the seed being made available to the consumers. Seed standards are very stringent in case of the nucleus and breeder seed compared to the foundation and certified. The major parameters that define minimum seed standards are based on field and seed standards.

14.7.2.1 Field Standards

Isolation distance is considered the most important field standard in a seed production program. The isolation distance includes distance of the seed production field from the fields of other varieties of wheat and from same variety not conforming to the purity standards. It also includes distance of the seed field from the field carrying infection of certain air borne diseases such as loose smut. In most countries, the isolation distance in case of pure line varieties is only 3m, however, if there is a

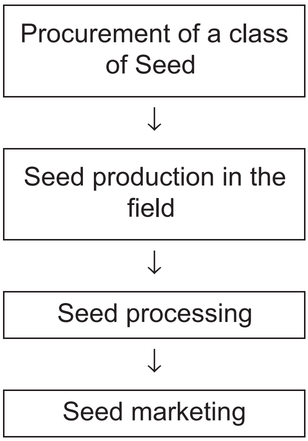

Fig. 14.4 Steps in quality seed production of wheat

loose smut infected field, the isolation distance shall be 150 m. Outcrossing in wheat, for most varieties, is between 0% and 1%, though there are varieties which show, depending on the year, outcrossing rates of up to 9% [20].

14.7.2.2 Seed Standards

Among seed standards, genetic purity is of utmost importance. However, appropriate germination and physical purity are equally important. A genetically pure seed without proper germination will lead to crop failure, hence is of little value. Physical impurities may also impair crop performance by leading to lesser plant population or by causing unwanted infestation by weeds. Likewise, moisture percent below a threshold helps in maintaining seed life and vigor during transportation or storage. For wheat, the minimum germination for certified seed is 85%, while moisture should be <12%. (Tables 14.2 and 14.3).

14.8 Need for Rapid Seed Dissemination and Challenges to Support Rapid Adoption of New Varieties

A major bottle neck in realizing the impact of improved wheat varieties in many countries is the long time gap between identification of a variety through yield trials and the time the variety is available for cultivation in farmers' fields. This takes usually from 5 to 8 years, since seed multiplication usually starts only when a variety is registered or released. Initiating seed multiplication at the time a variety enters registration trials can shorten the period by three years, but more importantly will provide farmers three years earlier protection from air borne diseases like rusts (For details on wheat rusts, see Chap. 8). Thus there are solid justifications for the need of rapid seed dissemination through pre-release seed multiplication. However, pre-release seed multiplication is often not done, since there is the risk that a line will be dropped from registration trials due to poor performance, which converts expensive breeder seed into commercial grain. This means, pre-release seed multiplication can be economically risky for a seed producer and therefore private companies will only do pre-release seed production when they are sure that there will be significant demand for the new variety. If the public sector produces seed by this approach and shares with private sector, the risk will be carried by Government institutions. This approach of using government institutions for pre-release seed multiplication was successfully implemented for the fast track release and dissemination of U99 resistant wheat varieties in six countries of Asia and Africa [4].

Table 14.2 Minimum seed certification standards for foundation (F) and certified (C) seed of pure line varieties in wheat and other cereals as applicable in India and South Asia

No.	Parameter – need for all parameter units	Wheat		Paddy		Barley		Triticale	
		F	C	F	C	F	C	F	C
	General requirements								
1.	Distance to fields of other varieties (M)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
2.	Distance to fields of the same variety not conforming to varietal purity requirements for certification (M)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
3.	Distance to field of varieties with infection of disease in excess of 0.10% and 0.50% in Foundation and Certified seed respectively. (M)	150	150	–	–	150	150	150	150
4.	Off types %	0.05	0.20	0.05	0.20	0.05	0.20	0.05	0.20
5.	Inseparable other crop plants	0.01	0.05	0.01	0.02	0.010	0.050	0.01	0.05
6.	Plants affected by seed borne disease	0.10	0.50	–	–	0.10[e]	0.50[e]	0.10[f]	0.50[f]
7.	Objectionable weed plant (Max.)	–	–	0.01[c]	0.02[c]	–	–	–	–
8.	Plant effect by ergot disease	–	–	–	–	–	–	0.02[g]	0.04[g]
9.	Pure seed % (Mini.)	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0
10.	Inert matter % (Max.)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
11.	No other crop seeds/Kg (Max.)	10.0	20.0	10.0	20.0	10.0	20.0	10.0	20.0
12.	Germination % (Mini.)	85.0	85.0	80.0	80.0	85.0	85.0	85.0	85.0
13.	Moisture % (Max.)	12.0	12.0	13.0	13.0	12.0	12.0	12.0	12.0
14.	For-vapor-proof containers % (Max.)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
15.	No Total weed seeds/kg (Max.)	10.0	20.0	10.0	20.0	10.0	20.0	10.0	20.0
16.	Other distinguishable varieties/ Kg (Max.)	–	–	10.0	20.0	10.0	20.0	–	–
17.	No Objectionable weed seeds/kg (Max.)	2.0[a]	5.0[a]	2.0[c]	5.0[c]	–	–	2.0[h]	5.0[h]
18.	Seed infested % (Mini.)	None[b]	None[b]	0.10[d]	0.50[d]	–	–	0.05[i]	0.25[i]
19.	Husk less seeds % (Max.)	–	–	2.0	2.0	–	–	–	–

[a]*Hirankhuri* (Convolvulus arvensis L.), Gulli danda (*Phalaris minor Retz*)
[b]Nematode galls of Ear-cockle (*Anguina tritici Milne*.), *Tundu* (*Corynebacterium michiganense*)
[c]Wild rice (*Oryza sativa* L. var. fatua Prain (Syn. O. Sativa L.f. spontanea Rosch)
[d]Seed infested by paddy bunt (*Neovossia horroda* (Tak)
[e]Loose smut (*Ustilago nuda*)
[f]Loose smut disease (*Ustilago tritici*)
[g]Ergot disease
[h]Wild morning glory (Hirankhuri, Gulli danda)
[i]Karnal bunt (KB – *Neovossia* indica); There is zero tolerance for KB in KB free countries

Table 14.3 Minimum seed certification standards for foundation (F) and certified (C) seed of hybrid varieties in wheat and other cereals as applicable in India

No.	Parameter	Wheat		Paddy		Barley	
		F	C	F	C	F	C
	General requirements						
1.	Fields of other varieties including commercial hybrid of the same variety	200	100	200	100	200	100
2.	Fields of the same hybrid (code designation) not conforming to varietal purity requirements for certification.	200	100	200	100	200	100
3.	Field of same varieties with infection of loose smut disease in excess of 0.10% and 0.50% in Foundation and Certified seed respectively.	200	150	–	–	200	150
4.	Off types in seed parent	0.05	0.20	0.05	0.20	0.05	0.50
5.	Off types in pollinator	0.05	0.20	0.05	0.20	0.05	0.50
6.	Pollen shedding ear heads in seed parent	0.05	0.10	0.05	0.10	0.05	1.00
7.	Inseparable other crop plants	0.01	0.05	–	–	0.01	
8.	Plants affected by disease	0.10	0.50			0.10[f]	0.50
9.	Pure seed % (mini.)	98.0	98.0	98.0	98.0	98.0	98.0
10.	Inert matter % (maxi.)	2.0	2.0	2.0	2.0	2.0	2.00
11.	Other crop seeds/kg (maxi)	10/kg	20.0	10.0	20.0	10.0	None
12.	Germination % (mini.)	85.0	85.0	80.0	80.0	85.0	85.0
13.	Moisture % (maxi.)	12.0	12.0	13.0	13.0	12.0	12.0
14.	For-vapor-proof containers %(maxi.)	8.0	8.0	8.0	8.0	8.0	8.0
15.	Other distinguishable varieties/kg (maxi.)	–	–	10.0	20.0	10.0	20.0
16.	Total Weed seed/kg (maxi.)	10.0	20.0	10.0[d]	20.0[d]	10.0	10g
17.	Objectionable weed seed/kg (maxi.)	2.0[b]	5.0[b]	2.0	5.0	–	None
18.	Seed infested (%)	None[c]	None[c]	0.10[e]	0.50[e]	–	None
19.	Seed infested by Karnal bunt[a]	0.05	0.025	–	–	–	–
20.	Husk less seeds % (maxi.)	–	–	2.0	2.0	–	2.0

[a]Karnal bunt (KB – *Neovossia indica*); There is zero tolerance for KB in KB free countries
[b]*Hirankhuri* (*Convolvulus arvensis L.*), Gulli danda (*Phalaris minor Retz*)
[c]Seed infested with Nematode galls of ear- cockle
[d]Wild rice (*Oryza sativa* L. var. fatua Prain (Syn. O. Sativa L.f. spontanea Rosch).
[e]Paddy bunt (*neovossia horrida*)
[f]Loose smut (*Ustilago nuda*)

14.9 Case Studies of Rapid Seed Dissemination

Development of seed of high yielding, stress tolerant varieties that can adapt to unfavorable climatic conditions and have capacity to thwart the hazard posed by a range of pests and diseases are at the forefront of the agriculture industry of different countries [21]. Some examples of rapid variety release and seed dissemination are described in Sects. 14.9.1 and 14.9.2.

14.9.1 Thwarting the Threat of Stem Rust Race UG99

In the beginning of this century it was found that stem rust race caused by *Puccinia graminis* f. sp. *tritici*, in particular race Ug99 and its derivatives [22] were virulent on about 90% wheat varieties of the world [23] (See Chap. 8). The consultative group centers (CIMMYT and ICARDA) and BGRI, in collaboration with national research centers from countries under threat, developed high yielding Ug99 resistant varieties and disseminated rapidly in the most threatened areas [4]. Rapid seed multiplication and dissemination of Ug99 resistant varieties was initiated in Nepal, Bangladesh, Afghanistan, Pakistan, Egypt, Ethiopia, Iran and India [4]. In Nepal [4] and Bangladesh [15], PVS was used aggressively. The objective was to ensure that Ug99 resistant varieties must occupy about 5% of the area sown to wheat in each country to ensure sufficient seed to displace current popular varieties. Approaches used for rapid multiplication and distribution included pre-release seed multiplication, while resistant varieties were released in a fast track manner [4].

14.9.2 Case of Wheat Blast in South Asia

The emergence of wheat blast caused by Magnaporthe oryzae pathotype triticum (MoT) in year 2016 in Bangladesh [19, 24], its first occurrence outside Latin America, raised alarm bells in whole of South Asia [25, 26] (See Chap. 9). Wheat blast is exemplary for the benefits of global testing and consequent data sharing for entries in International Screening Nurseries and Yield Trials, which are distributed by CIMMYT worldwide. When wheat blast was detected in Bangladesh, data from Bolivia allowed to identify lines that were resistant and had good agronomic performance in Bangladesh. These lines were tested in Bangladesh under local environment and management system in the crop season 2016–2017. Side by side a pre-release seed multiplication was also initiated. Bangladesh Agricultural Research Institute (BARI) released wheat blast resistant variety (BARI Gom 33) in 2017 [19] (Fig. 14.5). The same approach was used for testing lines for other countries of South Asia (India, Nepal and Pakistan) where wheat blast represents a potential threat for future wheat production. In 2020, Borlaug 100 was released in Bangladesh (as WMRI 3) as well as in Nepal (as NL 1307). So far, more than two dozen wheat blast resistant varieties have been released in India (Dr. G.P. Singh, Director ICAR-IIWBR, Karnal, personal communication, June 24, 2021).

14.10 Future Need of Rapid Seed Dissemination

Due to increasing demand for wheat and the emergence of new challenges, the need of rapid breeding and seed dissemination appears to be of a higher necessity in future [3]. There are considerable number of challenges that may become more serious and unpredictable just like COVID-19 (Coronavirus disease) in case of human

Fig. 14.5 BARI Gom 33, a Zinc-enriched, blast resistant variety released in Bangladesh

beings. Some of the current and future issues that need rapid seed dissemination are: biotic stresses (wheat blast, new virulences of wheat rusts, aphid), abiotic stresses (high temperature and reduced availability of water) and biofortified varieties to address malnutrition (For details on biotic and abiotic stresses, see Chaps. 8, 9, 10 and 12).

Recently, Atlin et al. [3] proposed seven steps that should be taken by different countries to speed up varietal turnover: (i) Quick identification of new promising varieties supported by reliable data; (ii) A robust demonstration in place for promoting these varieties; (iii) De-certification of obsolete varieties to ensure promotion of new ones; (iv) Withdrawal of seed subsidies of old varieties; (v) No support of funding for the production of seed of obsolete varieties; (vi) Setting targets for the average varietal age in seed production and in farmers' fields; (vii) Establishing a simple variety release processes to encourage private sector.

14.11 Policy Changes by Countries to Ensure Rapid Seed Dissemination

The importance of improved seed or food security and environmental sustainability places high importance to the policies through which a strong seed system can be built and sustained. Countries having similar socio-economic and infrastructural facilities may share common policies and learn from one another [27].

Seed policy changes can play effective role in supporting entire agriculture operations of a country. For example, policy change in Turkey in the mid-1980s that allowed foreign investment led to major change in their seed sector. The private sector became strong in Turkey by another policy change in which government pays 60% of price difference between certified and commercial grain back to a farmer against submission of an invoice that farmer had purchased certified seed. With this introduction, the seed sector in Turkey completely changed and there are now many private companies producing seed and variety replacement rate has increased considerably. The success of this policy is dependent upon subsidies.

Countries like India also introduced a new seed policy in 1988 which allowed farmers to obtain best planting materials available [28]. Another policy change (2003) in India promoted participatory seed production in farmers' fields. A recent policy change among South and Southeast Asian countries occurred between 2013 and 2018. Three agreements were made:

(i) Between Government of Bangladesh and India in 2013 for rice by which it was agreed that they can release varieties of one country in to another.
(ii) The agreement between Bangladesh and India on rice was extended to Nepal in 2014.
(iii) In 2017, the agreement extended to other cereals, pulses, oil seeds, vegetables and fiber crops, was made among five countries (India, Nepal, Bangladesh, Sri Lanka and Cambodia) with the provision that variety released in a country can be released in any other by using the data of the country of release.

14.12 Seed System Is Within the Breeding Process – Conservation and Sustainable Use of Crop Genetic Resources

Seed is an inherent part of the entire breeding process which involves the entire range of activities involved in the conservation, pre-breeding, breeding or genetic improvement, testing, release and delivery to farmers through seed systems (Fig. 14.6). In informal seed systems, seed may be obtained through farmer to farmer exchange and the seed may come from a land race. But whether formal or informal, seed system falls within the breeding process since it depends on a number of varieties developed over a given period, which in long term is dependent upon conservation and sustainable use of crop genetic resources.

Formal seed systems are highly regulated. The seed of a variety is the part of scientific and technical network, both on its upstream and downstream. The upstream is the entire breeding process which starts on the day first cross is made to develop a variety. This cross becomes possible since there is collection of diverse genotypes having a range of genes for agronomic, stress tolerance and quality traits. Therefore investment in germplasm conservation and breeding research is necessary to ensure a strong seed system in place (For details on genetic resources, see Chap. 16). On the downstream, a seed of a variety will be of value if it is maintained as it is and is liked by farmers. This requires a standard way of producing high quality of seed with an efficient marketing system. To maintain purity of a released variety, fundamentals of maintenance breeding must be applied. Through genetic purity, productivity gains achieved are maintained and do not deteriorate over time. Maintenance research may not be profitable [29] since it will not lead to a measurable increase in production, but is important to realize actual genetic potential of a variety over a given period of time [30].

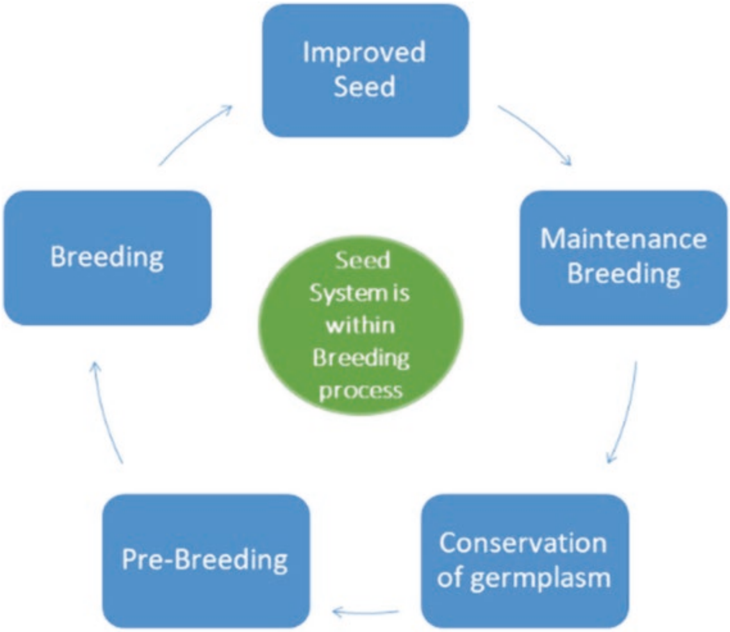

Fig. 14.6 Relationship of improved seed and the breeding process

14.13 Building Capacity in Seed Assurance in Developing Countries

The strengthening of the seed sector will require high class capacity building to have enough people trained in a country or region to support this system. A seed delivery system is like a value chain composed of interlinked components – from the development of well-adapted and nutritious varieties and their adoption by farmers, through the production and distribution, including sales, of quality seeds and planting materials, to on-farm utilization of recommended inputs by farmers [9]. The effective functioning of the value chain depends on the extent to which the stakeholders are able to put into practical use the relevant knowledge and skills required for producing quality seeds and planting materials [31].

To support capacity building in wheat seed system, almost all national research systems and international institutions like that in CGIAR (mainly CIMMYT, ICARDA), organize regular training programs. CIMMYT has been organizing a wheat improvement course since 1968 which includes components of maintenance breeding and seed production (CIMMYT, 2021). ICARDA's seed unit conducts courses focusing on seed production. Likewise, FAO assists member countries in carrying out a number of capacity building activities [9]. In addition to this, FAO has developed a Seeds Toolkit [31] to support capacity building of seed practitioners for the whole value chain of seed.

14.14 Key Concepts

Rapid seed system is necessary for rapid adoption of new varieties and to address new challenges. Strong seed systems are key to achieve food and nutritional security, environmental sustainability and carry immense potential to achieve the United Nations Millennium Development Goals. Large number of varieties are released across the world, but many do not reach small holder farmers who are in majority in the developing world. Whenever improved seeds have reached to farmers at large scale, as was the case during the Green Revolution, significant changes were observed. Many other examples showed the importance of rapid seed dissemination. This is more urgent today since problems are surmounting due to climate change, dwindling water resources, soil fatigue and a number of transboundary insect-pests and diseases. However, seed system is not so strong in most of the developing countries where wheat is grown. There is urgent need to invest in this system.

14.15 Conclusions

Rapid seed dissemination is key to adoption of new varieties and thus is crucial to whole plant breeding efforts and benefit to global agriculture.

An efficient seed system is integrated with in an efficient breeding system. The key to good seed is a good plant breeding program including pre-breeding that generates valuable genetic stocks. A seed system can be formal or informal and involves well defined steps of seed production. The objective of a seed system is to ensure absence of crop failure in the fields of farmers, especially small holders and marginal. This could be possible when both variety and seed is of desired level and is produced and delivered when it is needed the most. Any delay in seed delivery will be wastage of the efforts put into breeding a variety. Rapid seed dissemination is key to adoption of new varieties and is crucial to whole plant breeding efforts and benefit to global agriculture.

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