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Channelizing Protected Farmer's Varieties through Semi-Formal Seed Systems for Effective Utilization and Conservation of Agro-biodiversity: An Overview

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ABSTRACT: The paradigm of agricultural development based on maximizing grain yield in major cereal crops led to increased production of high-yielding wheat, and rice and replacement of other more nutrient-rich coarse cereals. The circulation of seed among farmers is central to agro-biodiversity conservation and dynamics. The local varieties (LVs) still cover significant area and virtually grown in all regions and seasons in India; the performance of farmers varieties (FVs)/ LVs is comparable under marginal conditions and even these varieties can out yield high yielding varieties (HYVs) under certain marginal environmental conditions. However, HYVs performed extremely well under favorable environmental conditions with high input and better management conditions and therefore, highly responsive to inputs. The low yield of FVs/LVs over modern varieties (MV's) can be increased by a margin up to 20-25% by supplying quality seed of FVs alone. In the legal instrument (PPV&FR Act, 2001), farmers have been treated at par with formal breeders but the varieties developed by the former face difficulty to qualify for distinctiveness, uniformity and stability (DUS) tests, particularly in cross pollinated crops and therefore being marginalized. To take the full advantage of the rich genetic diversity in the form of FVs, an alternative registration and certification system developed by the food and agriculture organization of the United Nations known as Quality Declared Seed (QDS) system is advocated to channelize and commercialize FVs using formal system. The QDS is an alternative way to reach small and marginal farmers, who have limited access to certified seed for crop production; this system being semi-formal is less stringent and inexpensive as compared to conventional seed certification with the focus on local seed market. The semi formal seed systems are the needs of the day to provide the quality seed of FVs and indigenous/ under-utilized crops at local level in order to increase the resilience of the seed system for effective utilization and maintenance of agro biodiversity which is depleting at a faster pace. The semi-formal seed system may also serve as a bridge between formal and informal seed systems.

Keywords: Farmers/ local varieties, Modern varieties, Plant variety protection, Quality declared seed, Semi-formal seed system

The paradigm of agricultural development based on maximizing grain yield in major cereal crops led to increased production of high-yielding wheat, and rice and replacement of other more nutrient-rich coarse cereals. During the green revolution phase due to the release of the high yielding varieties (HYVs), traditional/ local/ farmers varieties/ landraces were replaced within less than one decade in most of the rice growing regions of the country [1]. The area planted under HYVs of cereal crops was <100 hectare in 1964-65, which increased to 18 Mha in 1971-72 and 45 Mha by 1980-81; it was an unprecedented and unparalleled diffusion compared to any innovation anywhere in the world of the time. Furthermore, during the sixth five -year plan of the country, 56 Mha was brought under the HYVs, by 1984-85, and by that time 75% of the area under wheat, 40% of the area under rice and an equal proportion of the area under maize was planted with the HYVs. Millions of peasants had adopted it, and many of them used only a fraction of the recommended package of inputs [2]. Overall by the late 1990s, 74% area was planted with HYVs/improved or modern varieties (MVs) in rice [3]. For coarse cereals, 60% of maize, 53% in sorghum and in pearl millet 67% of area was under HYVs or hybrids [4]. Furthermore, it was observed that the traditional varieties with desirable traits were ignored and are now rarely in cultivation [5].

However, contrary to the observations made by various researchers including mentioned here, currently, farmers

are cultivating a range of varieties and HYVs have not been able to replace the local varieties completely. Nevertheless, on this issue, contemporary literature was reviewed and on the basis of meta-analysis, these researchers identified four main limitations with respect to local/farmers varieties such as (i). Local crop genetic diversity does not exist or is not in sufficient quantities within the production system (ii). Local crop genetic diversity exists but is not accessible to farmers (iii). Farmers do not value and use local crop genetic resources and (iv). Farmers do not benefit from the use of local crop genetic diversity [6, 7]. The present publication attempts to find answer to the above mentioned concerns and would certainly help the policy planners, administrators, researchers and agro-biodiversity conservators aiming for adaptation and mitigation the challenges posed by climate change in order to ensure food, nutritional and livelihood security *vis-a-vis* agro- biodiversity conservation for securing a natural resource base for future generations.

Extent of Area under Farmers' Varieties (FVs)

The area, including irritated area in percentage and the average area (average of thirteen years i.e. from 2000-01 to 2012-13) under high yielding varieties (HYVs) and farmers/ local varieties (F/LVs) of different cereals and coarse cereal crops among different regions (states) are mentioned in table 1. Rice is grown throughout length and breadth of the country under different ecologies, but the states which recorded area under both HYVs and LVs have been taken into consideration. Rice crop in Eastern region cover a significant area in West Bengal (5.43 Mha), Orissa (4.03 Mha), Chhattisgarh (3.78 Mha), Bihar (3.25 Mha), whereas Punjab and Southern state, Karnataka counts for 2.85 Mha and 1.27 Mha area under cultivation, respectively. Altogether, these six states covered 20.61 Mha, representing 48.58% of total area in the country under the crop during 2012-13. The irrigated area at the national level was 58.3% area in 2012-13, which varies among states - Orissa (33.8%), Chhattisgarh (35.3%), West Bengal (48.2%), Bihar (62.4%), Karnataka (72.2%) and Punjab (99.6%). The LVs covered just 1.79% average area under rice in Punjab, but the highest average area under LVs was found in Chhattisgarh (70.53%), followed by Bihar (45.54%), Orissa (39.3%), Karnataka (17.03%) and West Bengal (9.83%). Unlike rice, wheat is predominantly grown in all regions, except southern India and altogether six states covered 14.48 Mha (48.84% of all India wheat area) in 2012-13 (Table 1). The irrigated area under wheat at national level during 2012-13 was 93.4%; Haryana and Punjab accounted for >99% area, 94.6% in Bihar to 90.8% each in the two states Gujarat and MP, whereas it was the lowest in Maharashtra (73.9%). The area under LVs varied among different wheat growing states as; 3.1% (Haryana), 5.57% (Maharashtra), 8.8% (Gujarat), 18.77% (Rajasthan), 25.95% (Bihar) and 40.56% (MP).

Among coarse cereals; Sorghum, Pearl millet and Maize are the dominant crops important for food, feed, fodder and fuel purposes and grown predominantly under rain-fed conditions in different regions and seasons of India. Sorghum is grown in western and southern regions of the country and four states namely, Maharashtra, Rajasthan, Gujarat and Karnataka covered 5.13 Mha (out of total area of 6.21 Mha) under the crop in India, representing a share of 83% by these states in 2012-13. The irrigated area under sorghum at national level was only 9.6% and ranged among different sorghum growing states as 0.2% (Rajasthan), 9.5% (Maharashtra), Karnataka (11.5%), and Gujarat (19.8%). The LVs of sorghum covered significant area in Rajasthan (75.22%), followed by Maharashtra (71.17%), Gujarat (59.86%) and Karnataka (31.06%). Pearl millet is another important coarse cereal crop, popularly grown in arid and semi-arid regions of the country and predominantly in Western region, except in Haryana (Northern state) and Karnataka (Southern region). These five states, namely; Haryana, Rajasthan, Gujarat, Maharashtra and Karnataka jointly covered 5.59 Mha areas in 2012-13 and altogether represented 82.67% area of the country. This crop virtually had the lowest irrigated area (9.1%) in India but it varied state-wise i.e. Rajasthan (3.3%), Maharashtra (5%), Karnataka (12.8%) and Gujarat (22.2%). Among the different states, the maximum irrigated area under pearl millet was reported in Haryana (41.6%). The prevalence of LVs in case of pearl millet also varied from one state to another as Gujarat (4.97%), Karnataka (5.98%), Maharashtra (6.91%), Haryana (11.19%), but the highest average area was reported in Rajasthan (54.49%).

Like rice, maize is also grown across the country during different seasons and four states namely, Karnataka, Rajasthan, Bihar and Gujarat jointly covered 3.47 Mha (34.84%) in 2012-13. Among coarse cereal crops, maize

Table 1. Area, irrigated area (percentage) and average (2000-01 to 2012-13) coverage area under HYVs and F/LVs in cereals in different regions/states of India

Region	State	Area (Mha)-2012-13	Percent (area) to all India-2012-13	Irrigation (%) in 2012-13	Average area (2000-01 to 2012-13) under HYVs (%)	Average area (2000-01 to 2012-13) under local var. (%)
				Rice		
Eastern	W. Bengal	5.43	12.80	48.2	90.17	9.83
	Orissa	4.03	9.50	33.8	60.68	39.32
	Bihar	3.25	7.66	62.4	54.46	45.54
	Chhattisgarh	3.78	8.91	35.3	29.47	70.53
Northern	Punjab	2.85	6.72	99.6	98.21	1.79
Southern	Karnataka	1.27	2.99	72.2	82.97	17.03
	Sub total	20.61	48.58			
	All India	42.75	100.00	58.3		
				Wheat		
Eastern	Bihar	2.22	7.49	94.6	74.05	25.95
Western	Rajasthan	2.82	9.51	99.2	81.23	18.77
	Gujarat	1.05	3.54	90.8	91.20	8.80
	Maharashtra	0.59	1.99	73.9	94.43	5.57
Central	MP	5.30	17.88	90.8	59.44	40.56
Northern	Haryana	2.50	8.43	99.5	96.90	3.10
	Sub total	14.48	48.84			
	All India	30.00	100.00	93.4		
				Sorghum		
Western	Maharashtra	3.04	49.19	9.5	28.83	71.17
	Rajasthan	0.68	11.00	0.2	24.78	75.22
	Gujarat	0.09	1.46	19.8	40.14	59.86
Southern	Karnataka	1.32	21.36	11.5	68.94	31.06
	Sub total	5.13	83.01			
	All India	6.21	100.00	9.6		
				Pearl millet		
Western	Rajasthan	3.99	55.42	3.3	45.51	54.49
	Gujarat	0.62	8.61	22.2	95.03	4.97
	Maharashtra	0.62	8.61	5.0	93.09	6.91
Northern	Haryana	0.41	5.69	41.6	88.81	11.19
Southern	Karnataka	0.31	4.34	12.8	94.02	5.98
	Sub total	5.95	82.67			
	All India	7.30	100.00	9.1		
				Maize		
Eastern	Bihar	0.69	7.92	65.2	36.47	63.53
Southern	Karnataka	1.31	15.04	36.0	98.02	1.98
Western	Rajasthan	0.99	11.37	0.9	46.48	53.52
	Gujarat	0.48	5.51	12.5	60.15	39.85
	Sub total	3.47	39.84			
	All India	8.67	100.00	25.4		

Source: Compiled from various issues of Agricultural Statics at a Glance Published by the Directorate of Economics and Statistics under the Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Cooperation & Farmers Welfare (Government of India).

accounted for the highest area under irrigation at national level (25.4%), but it varied significantly among the different states, from just 0.9% in Rajasthan, Gujarat (12.5%) and Karnataka (36%). Similarly, variation in average area occupied by LVs in maize among different states was observed i.e. Karnataka (1.98%), Gujarat (39.85%) and Rajasthan (53.5%). Interestingly, LVs occupied highest average area (63.53%) in Bihar, as this state also recorded highest irrigated area (65.2%) under maize crop.

Adoption of High Yielding Varieties

Adoption of high yielding varieties in different regions and seasons has been asymmetrical. As per rules of thumb, it is assumed that improved varieties and improved management practices each contribute about 50% to observed yield gains in cereal crops [8, 9]. The extent and patterns of adoption of modern rice varieties vary among farmers and locations [10]. The adoption rate of MVs in different states in different seasons varies significantly and the low adoption rate of improved cultivars in rain-fed rice environments in eastern India is mainly due to undulated topography and lack of assured irrigation [11]. Moreover, a differential pattern of adoption of MVs during different seasons in the same region was observed. The classic examples are in case of rice crop in Orissa; whereas MVs covered the major rice area during summer season, local varieties play important roler autumn and winter season. Similarly, only local varieties are grown during Bhadai season in Bihar. Likewise, both MVs and LVs are grown during Bhadai and Garma season under maize crop, whereas only LVs are predominantly being cultivated during *rabi* season, clearly indicating the importance of season which decide of MVs or LVs over one another. Similarly, sorghum is grown during two seasons in India i.e. mainly as a rain-fed crop in the rainy season and under residual soil moisture /limited-irrigated conditions in the post rainy season [12, 13].

Adoption of MV's and FV's

The estimated yield gains in wheat during the first and second phases of technical change in the Green Revolution [14]. They proposed that the first phase of adoption of modern varieties, which involved the replacement of taller varieties by semi-dwarf varieties, as a one-time increase in productivity. They estimated that yield gains in this phase were 25 per cent in irrigated areas, 20 per cent in wetter rain-fed areas, and 10 per cent in dry areas. The next phase of genetic technical change occurred when farmers replaced the already adopted modern varieties with newer modern varieties. This second type of genetic technical change stabilized yield levels against evolving diseases and steadily improved yield potential [15]. Similarly, for maize, it was concluded that the productivity gains attributable to MV adoption are best estimated on a case-by-case basis, taking into account the specific circumstances, including the type of germplasm involved, the production environment, farmers' seed and crop management practices [16]. However, in the absence of location-specific data on incremental yield gains attributable to adoption of MV, they suggested and recommended the yield gains through (i), Improved OPV replacing a land race - an average of 25% yield gain (ii) Improved OPV replacing an older improved OPV - an average of 15% yield gain (iii) Hybrid replacing a land race - an average of 50% yield gain (iv) Hybrid replacing an improved OPV - an average of 25% yield gain and (v) Hybrid replacing another hybrid - an average of 15% yield gain to compare the yield performance of different kind of varieties. These assumptions also holds good for sorghum and pearl millet crops.

Marginal superiority of MV's over FV's in different region(s) and season(s) has been recorded. The superiority of one kind of variety over another with regard to yield varies from one season to another. By accepting the above mentioned assumptions in the present study, it is very clear that the productivity levels of LV's are comparable to that of MV's in different crops in different regions as well as in different seasons. Since MV's are grown under high input management conditions as compared to LV's, the superiority of MV's over F/LV'S by a margin of just ~10% seem to be negligible Although, MVs clearly demonstrated their yield superiority over LVs in almost all the seasons and regions but wherever the margin of superiority of MVs over LVs was $\leq$ 25%, have been considered here and the data is presented in table 2 with the assumption that by the use of quality seed of FVs the gap between the two kind of varieties could easily be bridged up as by the use of quality seed alone the yield could be increased by 20-25%. It is clearly demonstrated that the average yield superiority of rice MV's in Bihar was 12.1% during Garma season, whereas it was 23.8% (in Tamil Nadu during N/K. Further, MV's recorded higher maize yields to the level of 17.4 and 17.5 percent in the Bihar state during Bhadai and Garma season, respectively. Similarly, the average yield superiority of MV's of pearl millet over LVs recorded in Gujarat was 3.6% (kharif) and 8.5% (summer) only, whereas in case of maize, it was only 1.6% (kharif) in Gujarat and 5.1% (kharif) in Rajasthan and to the tune of -1.2% (rabi) and 11.6% (summer) in sorghum. These examples reflect only marginal average yield gains in these states, stressing the fact that if F/LVs are cultivated with same levels of input and management as MV's, comparable yield levels can be realized.

Table 2. Average yield (2000-01 to 2012-13) superiority (marginal ≤25%) of HYVs over F/LVs among cereals and coarse cereals crops in different regions and seasons.

Region	State	Season	Yield of high yielding varieties (kg/ha)				Yield of local varieties (kg/ha)				Percent superiority of MVs over F/LVs
			Range		Mean (2000-01 to 2012-13)	CV (%)	Range		Mean (2000-01 to 2012-13)	CV (%)	
			Low	High			Low	High			
					Rice						
Eastern	Bihar@	Garma	1502	2828	1894.4	21.5	1174	2366	1690.5	24.6	12.1
Northern	Punjab	Kharif	3246	4022	3783.6	6.6	1799	3369	3044.4	23.4	24.3
Southern	T.N.	N/K***	3085	3923	3430.6	9.0	1613	3550	2770.9	21.0	23.8
Western	Gujarat	Summer	2965	4764	3449.6	20.2	1879	4633	3115.6	25.8	10.7
					Wheat						
Northern	Haryana	Rabi	3887	5185	4332.7	9.3	2240	4931	3567.9	25.1	21.4
Western	Rajasthan	Rabi	2596	3506	2950.4	9.3	1459	3364	2484.4	19.4	18.8
Eastern	Bihar	Rabi	1442	3143	2188.3	21.2	1233	2778	1854.6	24.3	18.0
					Maize						
Eastern	Bihar@@	Bhadai	1297	3737	2020.6	29.6	768	3423	1721.0	37.7	17.4
		Garma	2427	4084	3088.0	15.2	2467	2953	2627.9	7.9	17.5
Northern	Himachal	Kharif	2368	3292	2786.5	14.2	1670	2559	2251.6	12.6	23.8
	J&K	Kharif	1343	2043	1840.3	9.7	1199	3779	1577.5	42.8	16.7
Western	Rajasthan	Kharif	962	2136	1414.1	31.3	875	1867	1346.0	30.4	5.1
	Gujarat	Kharif	774	1978	1448.9	26.4	734	2095	1426.5	30.6	1.6
					Jowar (Sorghum)						
Western	Gujarat++	Rabi	750	1353	1080.0	23.5	876	1611	1093.4	27.4	-1.2
		Summer	462	1086	837.3	25.3	506	932	750.1	18.4	11.6
Central	MP	Kharif	1066	1439	1219.6	10.1	760	1197	999.0	14.2	22.1
					Bajra (Pearlmillet)						
Western	Gujarat##	Kharif	666	1297	1026.6	17.5	695	1320	990.9	16.1	3.6
		Summer	1648	2524	2150.7	12.3	458	3198	1982.4	46.5	8.5

@ Rice grown in Bihar during Bhadai, Aghani and Garma seasons
*** Navarai/Koda
@@ Maize grown in Bihar during Bhadai, Rabi and Garma seasons
++ Grown during Kharif, Rabi and Summer season
Pearlmillet in Gujarat is grown during kharif and Summer

Current Status of Legislative Protection of FVs in India

The PPV & FR Act, 2001 protects the farmers' rights and recognizes a farmer as a '*breeder*,' as a *'conservator*', and as a *'user'* who is entitled to save, use, sow, re-sow, exchange and share or sell his farm produce, including seed of a variety protected under this Act, just as he was entitled before the enforcement of this Act, provided that the farmer shall not be entitled to sell branded seeds of a variety protected under this Act. Also, the sui-*generis* system of plant variety protection is unique in India, because a variety can be registered as per the provisions of this Act under either of four categories: new variety, essentially derived varieties (EDVs), extant variety and farmers' variety. The first farmers' varieties to obtain registration under the PPV & FR Act were three varieties of rice in 2009 – 'Tilak Chandan', 'Indrasan' and 'Hansraj'. Three more varieties were registered during 2012, which consisted of one variety of rice ('Dadaji HMT') and two of bread wheat ('Kudrat 9' and 'Wheat Ravi No.1'). Until 2012, only six farmers' varieties registered being extremely low. The pace of farmers' variety registration picked up since 2013. One of the main critiques of the PPV&FR legislation is that farmers' varieties must fulfill the same criteria (distinctiveness, uniformity and stability, or DUS) as developed for commercial varieties. This is quite challenging, since commercial cultivars presuppose a high level of genetic uniformity and stability, neither

observed nor considered desirable in case of farmers' varieties, mostly bred for diversity and resilience. The criteria have been modified for farmers' varieties, whereby farmers submit half the quantity of seed material required for a commercial variety and the number of 'off types' (any seed or plant that deviates in one or more characteristics from the variety as described) cannot exceed double the number of off-types specified for a new variety [17]. However, these relaxations still do not resolve the underlying problem of the inadequacy of DUS criteria for farmers' varieties [18]. From the present study also, it is clear that the PVP certificates granted to farmers varieties in case of coarse cereals (maize, pearl millet, sorghum etc) are very low, in spite of the fact that large number of farmers' varieties in these crops are still being grown in different states and at the same time virtually they cover significant crop area during different regions and seasons. A simiiliar situation does exist for farmers' varieties in vegetable and cash crops and therefore, warrant further amendments in the act. The dynamic and heterogeneous nature of farmers' varieties is better suited because they can adapt these varieties to specific local conditions, production and agro-ecosystem resilience [19, 20].

While summarizing the status of farmers' varieties protection through legal instrument known as PPV & FR Act 2001, the share with regard to varietal proposals submitted by farmers and other stakeholders for granting PVP certificate by the PPV & FR Authority, since inception and till Feb. 15, 2017 under the act and also the percent share of PVP certificates granted to them in different crop groups by the authority during 2007 - 2016 is presented in table 3 & 4. It is clear that the farmers

Table 3. Share of varietal proposals submitted by farmers, public & private sector seeking PVP certificates in different crops and protection granted under PPV&FR Act-2001 (up to Feb. 15, 2017)

S.No.	Crop Group	No. of applications submitted for granting of PVP certificate under PPV&FR Act 2001				Percent share of applications by different stakeholders		
		Farmers	Pvt. sector	Public sector	Total	Farmers	Private	Public
1	Cereals & Coarse cereals	5447	1229	875	7551	72.1	16.3	11.6
2	Pulses	721	34	251	1006	71.7	3.4	25.0
3	Oilseed	422	177	168	785	53.8	22.5	21.4
4	Cash crop	85	1030	243	1360	6.3	75.7	17.9
5	Plantation crop	51	0	20	71	71.8	0.0	28.2
6	Condiments & spices	344	0	31	375	91.7	0.0	8.3
7	Vegetables	603	961	135	1699	35.5	56.6	7.9
8	Fruits	494	5	24	523	94.5	1.0	4.6
9	Ornamentals	21	10	22	53	39.6	18.9	41.5
10	Aromatic & medicinal plants	20	0	2	22	90.9	0.0	9.1
	G. Total	8208	3446	1771	13445	61.0	25.6	13.2

Table 4. Percent share of PVP certificates granted to farmers, private and public sector varieties in different crops under PPV&FR Act-2001 (2007 - 2016)

S.N.	Crop Group	No. of PVP certificate granted under the PPV&FR Act 2001				Percent share of PVP certificates obtained by different stakeholders		
		Farmers	Pvt. sector	Public sector	Total	Farmers varieties	Pvt. Sec.	Public Sec.
1	Cereals & Coarse cereals	872	350	497	1719	50.7	20.4	28.9
2	Pulses	6	8	176	190	3.2	4.3	92.6
3	Oilseed	6	64	148	218	2.8	29.4	67.9
4	Cash crop	-	113	145	258	-	43.8	56.2
5	Plantation crop	-	-	6	6	-	-	100.0
6	Condiments & spices	8	-	7	15	53.3	-	46.7
7	Vegetables	-	19	40	59	-	32.2	67.8
8	Ornamental	-	1	-	1	-	100.0	-
	G. Total	892	555	1019	2466	36.2	22.5	41.3

varieties occupied first rank with respect to PVP proposals seeking protection through legislation in case of fruit crops group (94.5%), followed by 91.7% in Condiments and Spices, 90.9% in Aromatic & Medicinal Plants groups, 72.1% in Cereals and Coarse cereal group and almost equal share in both pulse and plantation crops group (71.8%) and 53.8% in oilseed crops group, recognizing the fact that farmers have virtually developed varieties in almost all crops, ranging from food and nutritional security point of view to even ornamentals and aesthetic value. Nevertheless, farmers varieties ranked foremost with regard to getting PVP protection under the act in case of cereals and coarse cereals group (50.7%) and Condiments & spices (53.3%), but lagging far behind in pulse group (3.2%) and oilseed crops (2.8%) as compared to public and private sector. Overall, FVs ranked second (36.2%), subsequent to 41.3% by public sector varietal protection. Likewise, the public sector also worked on the varietal development and placed major emphasis on the crops for food and nutritional security, while private sector played an important role to develop varieties among crops in which hybrid vigor was exploitable and therefore concentrated primarily on hybrid variety development.

With respect to the right to claims of benefit sharing, if their registered varieties and land races have been used for deriving new varieties, one such case that has received public attention illustrates the problem with benefit-sharing. It was argued that "Conservation biology is the biology of scarcity"; in contrast, agro-biodiversity conservation is the "biology of farm productivity" [21]. Without supporting and maintaining human interest in the productive capacity of agro ecosystems, genetic diversity will not survive on-farm [22]. The public sector institutes/organizations can play a significant role by facilitating farmers for the registration of their varieties (farmers') in order to get them protected legally; the Krishi Vigyan Kendras (KVKs) of Jharkhand have been closely associated with local farmers in this endeavor and have played a pivotal role in conservation of area specific farmers' plant varieties.

Channelizing of FVs through Semi-formal Seed System

In India, despite the introduction of mono cropping during the Green Revolution, farmers still maintain many of their traditions of nurturing biodiversity of wild and cultivated food crops and medicinal plants. Similarly, farmers maintain different varieties of cereal, coarse cereal, pulses, and minor millets crops. Farmers often recognize the attractive features of modern varieties (MVs), such as novel resistance, and identify characters that are not appreciated, especially regarding taste, processing qualities, and resilience under less optimal growing conditions [23]. Unlike irrigated areas, which are homogenous for intensive cropping systems, the rain-fed areas are more diverse and heterogeneous, which harbor a great deal of biodiversity [24]. The term 'seed system' refers to the totality of processes that are part of the development, maintenance, production, storage and diffusion of varieties [25]. Given the challenges facing agriculture resulting from climate-induced stresses, building resilience is a priority. Seed systems are important for enhancing such resilience as seed security has direct links to food security and resilient livelihoods, in general [26]. Regardless of the virtues or weaknesses of informal seed systems, it is unrealistic and undesirable to have a formal seed sector that is capable of supplying 100 percent of the seeds of all crops planted [27]. The estimated contribution of seeds in the productivity is considered to be about 15-20 %. In India, the formal seed sector accounts for about 30-35 per cent of the total seeds distributed in the country, while the informal seed sector, comprising mainly farm-saved seeds (FSS), accounts for the remaining 65-70% [28] stressing the need to strengthen the seed system's resilience at the local level.

Strategies for Channelizing FVs through Regulatory Measures

In India, considering the importance of FVs, these varieties need to be popularized as well as maintained through maintenance breeding, thus ensuring their seed production and distribution at local level to channelize and commercialize the protected FVs in order to provide resilience of agro ecosystems vis~a~vis adaptation and mitigation of adverse effects on account of climate change.

Rationalizing regulatory mechanisms

In the National Seeds Policy (2002), the provisions have been made for an appropriate climate for the seed industry to utilize available and prospective opportunities, safeguarding the interests of Indian farmers and the conservation of agro-biodiversity. While PVP focuses on new plant varieties, *sui generis* regimes may cover other categories of varieties that are not necessarily novel or that do not comply with one or more of the requirements

under the UPOV Convention. Sui generis system may not apply to one or more of the NDUS requirements. For instance, the Indian PPVFR Act allows for the registration of extant and farmers' varieties that are not novel, but it requires that they conform to the DUS criteria. Doing away with the novelty requirement (which is essential under PVP legislation) may significantly expand the range of varieties eligible for protection, since those varieties that have been offered for sale or commercialized at any time before an application for protection is filed, are eligible for protection. Generally, in the informal seed sector, only varieties qualifying distinctness, uniformity and stability (DUS) and value for cultivation and use (VCU) criteria and duly released and notified as per Seed Act, 1966 are inducted into seed production chain. However, FVs are generally unable to meet the DUS requirements. In pursuance of this, PPV & FR act 2001 Act has amended for furtherance of its implementation, stipulating that uniformity standards for could be relaxed to allow double the number of off-types, as otherwise permitted for the registration of other categories of varieties under that Act [30]. The most important barrier to the commercialization of FVs (farmer varieties) is the seed regulatory system, which either due to design or implication, exclude farmer varieties from organized seed sector activity. In India, a variety cannot be marketed until it has been released and/or notified officially and thereafter, it is introduced into the formal seed system. The variety registration and protection system is based on the DUS plus VCU criteria to identity a variety. To accommodate the farmers' varieties in formal seed systems, it has been suggested that farmer variety should be accommodated within variety registration system by adopting "looser" identifiability criteria [31]. Nevertheless, it was pointed out the very genetically heterogeneous nature of OPVs is an asset for farmers because they can adapt these varieties according to specific local conditions and production objectives and advocacy for farmer OPVs should receive more support through social and regulatory recognition [32].

Adoption of quality declared seed (QDS) system side-by-side

The FAO/ Swedish International Development Cooperation Agency (SIDA) Technical Conference on Improved Seed Production (Kenya 1981) and at the Expert Consultation on Interstate Movement of Seeds (Rome 1986) identified the concept of Quality Declared Seed as a strategy to increase the availability of quality seed for the agricultural community. QDS is a relatively open scheme, which meets the needs of farmers in a flexible way but without compromising basic standards of seed quality. It may, therefore, contribute to the wider policy objective of diversifying the seed supply system so that farmers may have wider choice. Under India's National Food Security Mission (NFSM), consideration for QDS finds mention. Importantly, QDS systems can be less costly than conventional certification systems [33].

Integration of formal and informal seed systems via semi-formal seed system

It was reported that the Koraput district of Odisha, India, recognized for its rich diversity in Asian cultivated rice, is known to be one of the centres of origin of these varieties [34]. Smallholder farm families in the region cultivate landraces to fulfill their economic, social and cultural needs using traditional practices, which contribute significantly to maintaining *in situ* on-farm diversity and sustainability. Yet, lack of support mechanisms and relevant training to enhance their skills in the seed selection process, common in the formal seed sector, are constraining the needed scale of quality seed production. Smallholder farmers operate in complex, risk-prone, and diverse environments and it is difficult to use only one seed system in such environments. Hence, a diversity of approaches will be more consistent in this context. To deal with such situations efficiently and to take the advantage of both formal and informal seed systems, a new concept called Integrated Seed System Development (ISSD) was designed to support the development of programs and policies coherent with the local realities of farmers with the objective to create a useful conceptual framework for developing coherence among seed practices, programs, and policies. The system is intended to integrate both the conventional seed system and local traditional seed systems at the technical and institutional levels [29, 35]. A critical analysis of strengths and weaknesses of both informal and formal seed sector [36, 37] is represented in table 5.

At the same time, the weaknesses may serve as opportunities to improve the informal seed sector, particularly since the formal sector does have a comparative advantage with respect to those aspects. These opportunities can be considered as a basket of

Table 5. Complementarily of weaknesses and strengths of informal and formal Seed Sector

S.No.	Criteria	Informal seed sector (Farmers' seed supply)	Formal seed sector (Public and private seed agents)
A.	Seed technology		
1	Seed technology	-	+ + +
2	Local adaptation seed technology	+ + +	±
3	Timely supply	+ + +	-
4	Costs/efficiency	+, -	- -, +
B.	Varieties		
1	Seed of local varieties (LVs)	++	- -
2	Seed of modern varieties (MVs)	-	+ + +
3	Access exotic genes	- - -	+ + +
4	Recombination of genes	-	+ + +
5	Adaptation of gene combinations	+ + +	- -
6	Maintaining/supplying diversity	+ +	-
C.	Seed diffusion		
1	Local (within localities/regions)	+ +	-
2	Inter-regional/continental	±	+ + +
3	Equity of access	-	+ ±
D.	Knowledge		
1	Local conditions	+ + ±	- -
2	Modern technology	- -	+ +
E.	Outreach (scale)*	Wide	Limited
F.	Quality and relevance of information provided*#	High	Limited

Source: Almekinders [36] and * Christinck *et al.* [37] extracts, #from a farmer's perspective

options that may or may not be relevant, selected for implementation at the local farmers' level. The recognition of complementarities opens up the possibility of defining and structuring a formal seed sector that can operate effectively to meet the seed requirements of local farmers. Building on the strengths of the farmers' seed systems and considering farmers as important suppliers of seed, it offers opportunities to the formal sector to focus on the key-activities of national seed supply, for which they have expertise and are well equipped [36,37].

In India also, there are numerous examples of varieties that were widely diffused via farmer-to-farmer exchange, such as the rice variety Mahsuri that became most popular variety in India. In the late 1960s, a rice variety (Mahsuri) was rejected but because of its local diffusion and demand for seed, this variety was eventually officially released [36]. By the 1980s, it was the third most widely grown rice variety in India [3]. Moreover, this variety was also included in further breeding programmes and in the parentage of large number of rice varieties. Another mega variety, 'Swarna' (MTU 7029), a selection from Mahsuri in the early 1980s in India, is one of the most popular varieties grown in the rain-fed low lands of several Indian states [3]. These examples clearly reflect the critical roles of formal and informal seed sectors and their integration increased the efficiency in time and space and also further advocates the integration of the two is needed in order to mitigate the supply crisis effectively [39]. Moreover, the semi-formal seed systems can also serve well as a bridge between formal and informal seed systems by correcting the weaknesses of both the systems.

CONCLUSION

It is very clear that LVs still occupy significant area under almost all crops. Also, it became clear that differential pattern of adoption do exist with respect to MVs during different seasons in the same region.. MV's are grown under high input management conditions as compared to LV's and the superiority of MV's over LV's by a margin up to 20-25% can be overcome by supplying quality seed of FVs alone. As indicated, the very genetically heterogeneous nature of OPVs is an asset for providing resilience to the seed systems in order to provide adaptation and mitigation at local level due to the adverse effects of climate change. With regard to the protection of FVs, in case of food grains crops (cereals and pulses), almost all farmers' varieties certificates have been

provided for self pollinated crops, which have relatively low seed replacement rate. From the present study also, it is clear that in case of coarse cereals, vegetable and cash crops, the PVP certificates granted to farmers' varieties are very low in spite of the fact that a large number of farmers' varieties of these crops are still being grown in different states and virtually occupying a significant crop area. The major bottleneck for granting PVP certificates appears to be distinctiveness, uniformity and stability (DUS) requirements according to the provisions the PPV & FR Act, as FVs/ landraces are much more heterogeneous by virtue of their genetic makeup and pollination behavior. Therefore, the act requires further amendments in order to protect FVs in a legal manner. To take the full advantage of the rich genetic diversity in the form of FVs, an alternative registration and certification system developed by the Food and Agriculture organization of the United Nations known as Quality Declared Seed (QDS) system is advocated to channelize and commercialize FVs using formal system. The QDS is an alternative way to reach marginal and small farmers in remote/ unreached areas, who have relatively less access to certified seed for crop production. The semi-formal seed systems are the need of the hour for ensuring the availability of quality seed of FVs, and indigenous/ under-utilized crops at local level in order to increase the resilience of the seed systems for effective utilization and maintenance of agro biodiversity, which is depleting at a faster pace. Finally, by channelizing the FVs /LVs into mainstream agriculture instead of placing them in marginal environments would not only enhance sustainability of the agro ecosystems but also ensure the food and much required nutritional security, ultimately resulting in compliance with the Sustainable Development Goals (SDGs) for reducing Poverty and attaining Zero hunger.

REFERENCES

1. RAHMAN S, MP SHARMA AND S SAHAI (2006). Nutritional and medicinal values of some indigenous rice varieties. *Indian Journal of Traditional Knowledge*, **5**(4), 454-458.
2. DOGRA B (1983). India: The new seeds. A disaster in the making as pests have a field- day with the high yield varieties. *Ecologist*, **13**(6): 222-223.
3. KATYAL JC AND MRUTHYUNJAYA (2003). The CGIAR at 31: An Independent Meta-Evaluation of the Consultative Group on International Agricultural Research CGIAR Effectiveness - A NARS Perspective from India.
4. PRAY CE AND L NAGARAJAN (2012). Innovation and research by private agribusiness in India. International Food Policy Research Institute (IFPRI) discussion paper 1181. Washington DC.
5. REKHA T, KP MARTIN, VB SREEKUMAR AND J MADASSERY (2011). Genetic diversity assessment of rarely cultivated traditional indica rice (*Oryza sativa* L.) varieties. *Biotechnology Research International*, pp: 7. doi:10.4061/2011/784719.
6. JARVIS DI, T HODGKIN, BR STHAPIT, C FADDA AND I LOPEZ-NORIEGA (2011). An heuristic framework for identifying multiple ways of supporting the conservation and use of traditional crop varieties within the agricultural production system. *Critical Reviews in Plant Science*, **30**(1&2), 125-176.
7. FRISON E AND T HODGKIN (2016). Strategic opportunities to strengthen community based approaches to seed agro biodiversity. Opportunities Report IN; The Future of Food: Seeds of Resilience, A Compendium of Perspectives on Agricultural Biodiversity from Around the World. Global Alliance for the Future of Food,(2016) 25-53 available at https://futureoffood.org/wp-content/uploads/2016/12/Seeds-of-Resilience_Full-Compendium.pdf.
8. BELL MA, RA FISCHER, DB YERLEE AND K SAYRE (1995). Genetic and agronomic contributions to yield gains: A case study for wheat. *Field Crops Research,* **44**: 55-65.
9. FUGLIE K, N BALLENGER, KDRUBENSTEIN, C KLOTZ, MOLLINGER, J REILLY, U VASAVADA AND J YEE (1996).Agricultural Research and Development: Public and Private Investments Under Alternative Markets and Institutions. Agricultural Economic Report No. 735. Washington, DC: *Economic Research Service*, USDA. pp: 7.
10. PANDEY S AND D GAUCHAN (2012). Synthesis of key results and implications In: Patterns of adoption of improved rice varieties and farm-level impacts in stress-prone rain-fed areas in South Asia. Pandey S, Gauchan D, Malabayabas M, Bool-Emerick M, Hardy B. (Eds.) Los Baños (Philippines): International Rice Research Institute, pp. 1-18.
11. FUWA N, N EDMONDS AND P BANIK (2007). Are small-scale rice farmers in eastern India really inefficient? Examining the effects of microtopography on technical efficiency estimates. *Agricultural Economics,* **36**: 335-346.
12. SINGH RP, A KUMAR AND SK PAL (2016). The prevalence, productivity and protection of traditional varieties vis-à-vis modern varieties in Eastern India: An appraisal. *Jharkhand Journal of Development and Management Studies*, **14**(2): 6955-6970.
13. SINGH, RP, DK AGARWAL, SR PRASAD, KV SRIPATHYAND SP JEEVAN KUMAR (2017). Varietal and seed replacement in the era of climate change. Pp: 156 ISBN: 978-81-925128-2-6 published by Indian Council of Agricultural Research - Indian Institute of Seed Science (ICAR-IISS), Mau, U.P, India.
14. BYERLEE D AND G TRAXLER (1995). National and international research in the post-green revolution period: evolution and impacts. *American Journal of Agricultural Economics,* **77**: 268-278.
15. SMALE M, J SINGH, SD FALCO AND P ZAMBRANO (2008). Wheat breeding, productivity and slow variety change: evidence from the Punjab of India after the Green Revolution. *The Australian Journal of Agricultural and Resource Economics*, **52**: 419–432.

16. MORRIS ML, J RISOPOULOS AND D BECK (1999). Genetic Change in Farmer-Recycled Maize Seed: A Review of the Evidence. CIMMYT Economics Working Paper No. 99-07. Mexico, D.F.: CIMMYT, ISSN: 0258-8587.

17. ANONYMOUS (2009). Government of India, The Gazette of India Extraordinary. Part II, Section 3, Sub-section (i). G.S.R. 452 (E). June 30, 2009.

18. PESCHARD K (2017). Seed wars and farmers' rights: comparative perspectives from Brazil and India. *The Journal of Peasant Studies*, **44**(1): 144-168.

19. SINGH RP (2018). Integration and commercialization of local varieties under sub-optimal environments for food security, promoting sustainable agriculture and agro-biodiversity conservation. *MOJ Ecology and Environmental Sciences,* **3**(2): 65-67.

20. SINGH RP AND RC AGRAWAL (2018). Improving efficiency of seed system by appropriating farmer's rights in India through adoption and implementation of policy of quality declared seed schemes in parallel. *MOJ Ecology and Environmental Sciences*, **3**(6): 387-391.

21. PLUCKNETT DL AND ME HORNE (1992). Conservation of genetic resources. *Agriculture, Ecosystems and Environment,* **42:** 75-92.

22. WOOD D AND JM LENNE (1997). The conservation of agro-biodiversity on-farm: questioning the emerging paradigm. *Biodiversity and Conservation*, **6**(1): 109-129.

23. SALAZAR R, NP LOUWAARS AND B VISSER (2006). On Protecting Farmers' New Varieties: New Approaches to Rights on Collective Innovations in Plant Genetic Resources. CAPRi Working Paper # 45. International Food Policy Research Institute (IFPRI) 2033 K Street, N.W. Washington, D C, U.S.A.

24. SRINIVASA RAO C, R LAL, JVNS PRASAD, KA GOPINATH, R SINGH, VS JAKKULA, KL SAHRAWAT, B VENKATESWARLU, AK SIKKA, SM VIRMANI (2015). Potential and Challenges of Rain-fed Farming in India. In: Sparks, D.L. (Ed.). *Advances in Agronomy*, **133**: 113-181.

25. TRIPP R (1997). New seed and old laws. Regulatory reform and the diversification of national seed systems. Intermediate Technology Publications on behalf of the Overseas Development Institute, London, pp: 259.

26. KANSIIME MK AND A MASTENBROEK (2016). Enhancing resilience of farmer seed system to climate-induced stresses: Insights from a case study in West Nile region, Uganda. *Journal of Rural Studies*, **47**: 220-230.

27. LOUWAARS N (2002). Seed policy, legislation and law: Widening a narrow focus (ed.). Binghamton: Food Products Press.

28. ANONYMOUS (2016). State of Indian Agriculture 2015-16. Government of India Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation & Farmers Welfare Directorate of Economics and Statistics New Delhi, 2016. Retrieved from eands.dacnet.nic.in/PDF/ State of Indian Agriculture, 2015-16.

29. LOUWAARS N (1994). Integrated seed supply, a flexible approach. In: Seed production by smallholder farmers. Proceedings of the ILCA/ICARDA research planning workshop, Hanson J (Ed.). International Livestock Centre for Africa, Addis Ababa, 39-56.

30. ANONYMOUS (2009). Government of India, The Gazette of India Extraordinary. Part II, Section 3, Sub-section (i). G.S.R. 452 (E). June 30, 2009.

31. SRINIVASAN SC (2016). Institutional capacity and implementation issues in farmers' rights. In: Halewood, H. (Eds.), Farmers' crop varieties and farmers' rights: Challenges in taxonomy and law. Issues in Agricultural Biodiversity, 249-281.

32. SERPOLAY-BESSON E, S GIULIANO, N SCHERMANN AND V CHABLE (2014). Evaluation of Evolution and Diversity of Maize Open-Pollinated Varieties Cultivated under Contrasted Environmental and Farmers' Selection Pressures: A Phenotypical Approach, *Open Journal of Genetics*, **4**: 125-145.

33. SPIELMAN DJ AND M SMALE (2017).Policy Options to accelerate Variety Change among Smallholder Farmers in South Asia and Africa South of the Sahara, Environment and Production Technology Division. IFPRI Discussion Paper 01666, pp: 68.

34. MISHRA S, SS CHAUDHURY AND VA NAMBI (2012). Strengthening of traditional paddy seed selection practices of tribal farm families with improved knowledge and skills in Koraput district, Odisha. *Indian Journal of Traditional Knowledge*, **11**(3): 461-470.

35. DE BOEF WS, NP LOUWAARS AND CJM ALMEKINDERS (1997). Methodology issues in strengthening farmers' research and technology development. New frontiers in participatory research and gender analysis for technology development. Proceedings of the 1996 International Seminar on Participatory Research and Gender Analysis for Technology Development in Cali, Colombia. International Centre for Tropical Agriculture, Cali, 1997: 87-100.

36. ALMEKINDERS C (2000). The importance of informal seed sector and its relation with the legislative framework, Paper presented at GTZ-Eschborn, July 4-5, 2000. Retrieved from citeseerx.ist.psu.edu/viewdoc/.

37. CHRISTINCK A, M DIARRA AND G HORNEBER (2014). Innovations in Seed Systems. Commissioned by The McKnight Foundation, pp: 75.

38. MAURY D (1989). The innovative approach of Indian farmers. In: Chambers R, Pacey A, Thrupp L, (eds). Farmer first: farmer innovation and agricultural research. London (UK): Intermediate Technology Publications.

39. SINGH RP, PVV PRASAD AND K RREDDY (2015). Climate Change: Implications for Stakeholders in Genetic Resources and Seed Sector. *Advances in Agronomy*, **129**: 117-180.