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Local varieties in India – New insights into adaptation patterns, performance and preferences over modern varieties of selected cereals among different seasons and regions

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ABSTRACT

The successful development and deployment of widely adapted, input responsive high yielding varieties (HYVs) in cereals along with required inputs have been widely adopted and consequently these HYVs replaced the specifically adapted local varieties (LVs). In this review, on the basis of 13 years data (2000–01 to 2012–13), attempts have been made to analyze the prevalence of local varieties (LVs), pattern of their adaptation, adoption and diffusion, yield including variability in the yield in cereals and coarse cereals in different regions and seasons in India. It was observed that HYVs did not replace LVs completely and LVs still cover significant area and are virtually grown in all regions and seasons in India. The adoption and adaptation pattern of HYVs was found to be highly asymmetrical. It was also revealed that under marginal conditions, the performance of LVs is comparable and even out yield HYVs, but under favorable environmental conditions with high input and better management conditions, HYVs performed extremely well and, therefore, highly responsive to inputs. The yield gains obtainable through HYVs over LVs, varies from season to season in the same region and in different regions in the same season. The variability in yield (CV) was always higher in LVs as compared to HYVs among all cereal crops as LVs are grown under marginal, sub optimal and low input management conditions. The significant negative association was observed between average yield and CV in case of rice HYVs, LVs of sorghum and in both HYVs and LVs in maize.

Key words: Farmers' varieties, High yielding varieties, Landraces , Variability in yield, Yield

Cereals are the major and cheapest source of calories and extremely important for securing food and nutritional security. During the Green Revolution (GR) period, the area under cereals crops increased very quickly due to the adoption of input responsive, high yielding varieties (HYVs) among cereal crops. Through genetic improvement a large number of improved high yielding varieties in virtually all major cereals have been released through All India Coordinated Research Improvement Programmes (AICRIPs). The successful development and deployment of widely adapted, photo-thermo insensitive and input responsive HYVs in cereals along with required inputs and favorable policy reforms turned India's position from not only food insecure and ship to mouth status to food secure to feed 1.35 billion population but also having surplus food-grains. These HYVs turned out to be miracle varieties and with their adoption and diffusion initially in the irrigated agro-ecosystem have led the phenomenon of green revolution and intensive agriculture in the country. The growth continued over the following decades making India the second largest producer of wheat and rice and third one in case of coarse cereals in the world. In India, since the onset of GR, during last fifty years (1965–66 to 2015–16) area coverage under rice, and wheat increased by 22.3%, and 140.5%, respectively, along with the combined area increase under these two cereals from 48 Mha (1965–66) to 73.6 Mha (2015–16) representing 53.25% area increase, while for coarse cereals the total area decreased (46.36%) from 44.34 Mha (1965–66) to 23.78 Mha (2015–16), and individual crop level, maximum area reduced in barley (73.5%) followed by sorghum (68%) and pearl millet (41.7%), but increased significantly in maize by 81% during the same period.

However, during the period of GR and thereafter, due to the introduction of input responsive, short stature, photothermo insensitive HYVs, large number of locally adapted farmers varieties/landraces/local varieties were replaced at faster pace and within a span of less than one decade in most of the rice growing regions of the country (Rahman *et al.* 2006), and by late 1990s, 74%

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area was planted with improved HYVs in rice (Katyal and Mruthyunjaya 2003). For coarse cereals, about 60% of maize, 53% of sorghum and 67% of pearl millet area was under HYVs or hybrids (Pray and Nagarajan 2012). Although, LVs have been replaced by HYVs but not displaced completely and voluminous literature exists on the adoption and replacement behavior of HYVs in the country. Furthermore, it has been speculated that LVs with desirable traits were ignored and are now rare in cultivation (Rekha *et al.* 2011). However, contrary to this, Singh *et al.* (2016) observed that LVs are still under cultivation in different states and seasons in the eastern region in case of rice, wheat and maize. In the review, attempts have been made to analyze the extent of prevalence of local varieties, pattern of their adaptation behavior, productivity performance in major cereal and coarse cereals specifically in different regions and seasons at all India level on the basis of 13 years (2000–01 to 2012–13) in order to draw logical conclusions and identification of unique trend, if any, including the dominance of different kind of varieties one over another in different seasons belonging to the same region in context of India.

Basis of selection of the states

The data regarding area coverage and yield obtained through HYVs and LVs in rice, wheat, maize, sorghum and pearl millet in various states have been compiled from various issues of "Agricultural Statistics at a Glance" published by the Directorate of Economics and Statistics under the Ministry of Agriculture and Farmers Welfare, New Delhi. The selection of different States was based on: (i) their contribution in terms of production share at least 1% in the total national production of the respective crop, (ii) to represent each growing region/zone, (iii) the availability of data with regard to both kind of varieties (HYVs and LVs), and (iv) whose data was available with regard to the productivity of HYVs and LVs of the respective crop grown during different seasons among different states for the period 2000–01 to 2012–13 and after 2012–13 data was not available with regard to area coverage and yield of these two kind of varieties. Moreover, the review is based on the 13 years data available which could be safely considered as sufficient time to embrace 'good' as well as 'bad' years (in terms of various abiotic and biotic stresses) for depicting the trends with respect to the productivity and adoption of a particular type of variety in a particular season and region in order to draw logical conclusions with regard to adoption and adaptation behavior including productivity performance of different types of varieties. The actual yield (kg/ha), mean yield (kg/ha), and the variability in yield was measured as coefficient of variation (CV) (% values). The correlation between average yield and variability in yield (CV) were also worked out in both kind of varieties.

Various trends observed under HYVs and LVs

Trends of area under HYVs and LVs among cereals and coarse cereals in different regions: The area including irrigated area in percentage, production and the average area (average of 13 years from 2000–01 to 2012–13) under HYVs and LVs of different cereals and coarse cereal crops among different regions (states) is mentioned in Table 1. In rice, the highest average area under LVs was found in Chhattisgarh (70.53%) followed by Bihar (45.54%) and Odisha (39.32%). In wheat in central region, Madhya Pradesh has maximum area under LVs (40.56%) followed by Bihar in eastern region and Rajasthan in the western region. Among coarse cereals, sorghum, pearl millet and maize are the dominant food, feed, fodder and fuel crops and grown predominantly under rainfed conditions in different regions and seasons of India. Sorghum grown in Western and Southern regions of the country and LVs in this crop covered significant area in Rajasthan (75.22%), followed by Maharashtra (71.17%), Gujarat (59.86%) and Karnataka (31.06%). Similarly, pearl millet is grown predominantly in Western region and the prevalence of LVs in pearl millet varied from one state to another with highest average area 54.49% covered in Rajasthan followed by Haryana. Maize is also grown across the country during different seasons and LVs occupied highest average area in Bihar (63.53%) followed by Rajasthan (53.52%) and Gujarat (39.85%). In all these crops, the average area under HYVs is irrigation dependent and states in which irrigated area under particular crop is high the HYVs occupy the maximum coverage and LVs grown under rainfed conditions with the exception in Bihar which has highest irrigated area (65.2%) under maize crop as well as area covered by LVs in this crop.

Productivity trends of HYVs and LVs in cereals in different seasons and regions: Rice is grown across the country (in different regions and seasons) under different ecologies (upland, lowland, rainfed, irrigated, and deep water), and also ~42% area covered by rice is rainfed in the country. Under different ecologies, different kind of varieties being high yielding, hybrids and local varieties are grown under diverse agro-ecosystems. In the Eastern region, rice is grown under highly diverse conditions and in Assam, Bihar, Odisha and West Bengal it is grown 2-4 times in a year. For example, in Assam, rice is grown in four different seasons (Sali, Ahu, Boro and Bao) and named according to its harvesting season. Similarly, in the Southern region in Tamil Nadu, Karnataka and Kerala rice is grown round the year while in the Western region (Gujarat state) it is grown during *kharif* and summer seasons while in Chhattisgarh (Eastern region) and Madhya Pradesh (Central region) in the crop is taken during *kharif* season only. Range, mean (2000-01 to 2012-13) yield kg/ha, variability in yield measured as coefficient of variability (% CV) of HYVs and LVs in cereal crops are mentioned in Table 2. Also, the superiority of HYVs over LVs is also presented. The average yield superiority of HYVs over LVs in rice was higher by 42.7%, while the variability in yield (CV) was found to be higher in LVs (25.4%) as compared to HYVs (18.6%) in rice. Highly significant negative association was observed between mean yield and variability in yield measured (CV) in HYVs (-0.528**) but non-significant in LVs (-0.056).

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

Region	State	Per cent irrigated area in 2012–13	Per cent average area under HYVs	Per cent average area under LVs
Rice				
Eastern	W. Bengal	48.2	90.17	9.83
	Odisha	33.8	60.68	39.32
	Bihar	62.4	54.46	45.54
	Chhattisgarh	35.3	29.47	70.53
Northern	Punjab	99.6	98.21	1.79
Southern	Karnataka	72.2	82.97	17.03
	Sub total			
	All India	58.3		
Wheat				
Eastern	Bihar	94.6	74.05	25.95
Western	Rajasthan	99.2	81.23	18.77
	Gujarat	90.8	91.20	8.80
	Maharashtra	73.9	94.43	5.57
Central	MP	90.8	59.44	40.56
Northern	Haryana	99.5	96.90	3.10
	Sub total			
	All India	93.4		
Sorghum				
Western	Maharashtra	9.5	28.83	71.17
	Rajasthan	0.2	24.78	75.22
	Gujarat	19.8	40.14	59.86
Southern	Karnataka	11.5	68.94	31.06
	Sub total			
	All India	9.6		
Pearl millet				
Western	Rajasthan	3.3	45.51	54.49
	Gujarat	22.2	95.03	4.97
	Maharashtra	5.0	93.09	6.91
Northern	Haryana	41.6	88.81	11.19
Southern	Karnataka	12.8	94.02	5.98
	Sub total			
	All India	9.1		
Maize				
Eastern	Bihar	65.2	36.47	63.53
Southern	Karnataka	36.0	98.02	1.98
Western	Rajasthan	0.9	46.48	53.52
	Gujarat	12.5	60.15	39.85
	Sub total			
	All India	25.4		

Source: Compiled from various issues of "Agricultural Statistics at a Glance" published by the Directorate of Economics and Statistics under the Ministry of Agriculture and Farmers Welfare, New Delhi.

Wheat, another important, cereal crop is grown only once in a year (during *rabi* season) in Eastern, Western and in Central regions. It is observed from Table 2 that in wheat, the average yield superiority of HYVs over LVs was higher by 35.1%, while the variability in yield (CV) was found to be higher in LVs (22%) as compared to HYVs (12.3%). The non- significant negative association was observed between mean yield and coefficient of variation in HYVs (-0.370) but non-significant positive in LVs (0.248).

Productivity trends of HYVs and LVs in coarse cereals in different regions and seasons: Coarse cereals are known for higher nutritional contents and having characteristics like drought tolerance, photo-insensitivity and resilient to climate change etc. The range, average yield (2000-01 to 2012-13), variability in yield measured as coefficient of variability (% CV) of HYVs and LVs in coarse cereal crops along with the superiority of HYVs over LVs are mentioned in Table 3. In maize, the average yield superiority of HYVs over LVs was higher by 31.5%, while the variability in yield (CV) was found to be higher in LVs (32%) as compared to HYVs (20.4%). The significant negative association was observed between mean yield and coefficient of variation in both HYVs (-0.717**) and LVs (-0.581*).

Millets are C_4 crops and hence are climate change compliant. Millets are drought, temperature and pest tolerant and hence are grains for the future in an environment of climate change and global warming (NAAS 2013). Sorghum for grain purposes in grown in all the regions except northern where this crop is grown only for fodder during *kharif* season, while in other regions it is grown for dual purposes. The average yield superiority of HYVs in sorghum over LVs was higher by 52.9%, while the variability in yield (CV) was found to be higher in LVs (27.3%) as compared to HYVs (21.7%). The non-significant negative association was observed between mean yield and CV in HYVs (-0.114) but highly significant in LVs (0.726**). In wheat, the average yield superiority of HYVs over LVs was higher by 31.4%, while the variability in yield (CV) was found to be higher in LVs (33.6%) as compared to HYVs (21.3%). The non-significant negative association was observed between mean yield and CV in HYVs (-0.673) but positively non-significant in LVs (0.071).

Asymmetrical adoption of HYVs: In wheat and rice, varieties developed in North-western and Southern regions respectively spread, adopted and diffused in Eastern region, thus reflecting the advantage of domestic spillover. Similarly, hybrid rice adoption has even taken place in rainfed areas of Eastern India that were not originally targeted for hybrids (Tripp *et al.* 2010). In these crops the poor performance of HYVs as compared to local varieties in low input environmental management system has been reported (Singh 2015, Singh *et al.* 2017). The extent and patterns of adoption of modern rice varieties vary among farmers and locations including the differential pattern of adoption of HYVs during different seasons in the same region (Pandey and Gauchan 2012). The classic examples are in case of rice in Odisha, during summer season while

Table 2 Range, average (2000–01 to 2012–13) yield (kg/ha), variability in yield (CV), association between average yield and CV among HYVs and LVs including the per cent superiority in yield of either kind of varieties over one-another among cereals grown in different regions and seasons in rice and wheat

Region	State	Season	Yield of HYVs (kg/ha)				Yield of LVs (kg/ha)				Per cent superiority of HYV over LVs
			Range		Mean (2000–01 to 2012–13)	CV (%)	Range		Mean (2000–01 to 2012–13)	CV (%)	
			Min	Max.			Min.	Max.			
					Rice						
Eastern	W Bengal	*Aus*	2132	4105	2636.9	28	1066	3024	1609.7	33	63.8
		Aman	2398	4381	2892.5	26	1409	3430	1993.7	28.7	45.1
		Summer	2821	5283	3573.7	25.3	1869	4891	2824.7	33.3	26.5
	Odisha+	Autumn	423	1878	1096.2	37.3	326	1360	763.5	34.3	43.6
		Winter	844	2878	1772.7	28.6	608	1585	1198.2	26.3	47.9
		Summer	2125	3165	2426.4	16.0	-	-	-	-	
	Bihar@	Bhadai	-	-	-	-	897	2006	1217.4	32.3	
		Garma	1502	2828	1894.4	21.5	1174	2366	1690.5	24.6	12.1
		Aghani	942	2850	1866.9	33.2	351	2235	1351.8	43.1	38.1
	Chhattisgarh		903	2709	1855.1	26.9	582	2075	1171.5	36.0	58.4
	Assam	Autumn	1452	2032	1771.1	9.4	665	1192	988.3	12.7	79.2
		Winter	1713	2554	2189.1	10.9	1223	1921	1527.6	11.7	43.3
		Summer	2126	3312	2545.7	12.7	1370	2392	1770.1	17.2	43.8
Northern	Punjab	*Kharif*	3246	4022	3783.6	6.6	1799	3369	3044.4	23.4	24.3
Southern	Tamil Nadu	K/K/S*	3347	4182	3728.8	8.4	3124	5271	2842.8	25.4	31.2
		S/T/P**	2648	3922	3108.8	13.3	593	2827	1894.9	34.5	64.1
		N/K***	3085	3923	3430.6	9.0	1613	3550	2770.9	21.0	23.8
	Karnataka++	*Kharif*	2503	3157	2851.0	5.9	880	1851	1501.0	21.9	89.9
		Rabi	2017	3550	2472.4	16.7	1507	2509	1957.4	15.7	26.3
		Summer	2094	4709	3269.1	19.4	1019	3179	2498.5	40.0	30.8
	Kerala	Autumn	2058	2571	2334.2	7.2	1426	1912	1595.8	11.2	46.3
		Winter	1875	2812	2455.4	9.2	1616	1944	1772.1	5.3	38.6
		Summer	2287	3161	2715.1	9.2	1309	2044	1646.2	12.0	64.9
Western	Gujarat	*Kharif*	1330	3210	2116.6	28.8	590	1564	1052.8	33.8	101.0
		Summer	2965	4764	3449.6	20.2	1879	4633	3115.6	25.8	10.7
Central	MP	*Kharif*	885	2909	1595.8	35.7	521	1436	919.3	32.6	73.6
Mean			1988.8	3394.7	2553.3	18.6	1176.6	2582.6	1788.7	25.4	42.7
Correlation coefficient (*r value*) between yield and CV					-0.528**				-0.056^{NS}		
					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
	Gujarat	*Rabi*	1974	3143	2649.1	13.1	697	2496	1587.3	32.6	66.9
	Maharashtra	*Rabi*	1201	1892	1507.5	13.3	695	1250	897.8	20.9	67.9
Central	MP	*Rabi*	1127	2387	2128.5	7.7	1077	1512	1275.1	9.7	66.9
Eastern	Bihar	*Rabi*	1442	3143	2188.3	21.2	1233	2778	1854.6	24.3	18.0
Mean			2037.8	3209.3	2626.1	12.3	1233.5	2721.8	1944.5	22.0	35.1
Correlation coefficient (*r value*) between yield and CV					-0.370^{NS}				0.248^{NS}		

@Rice grown in Bihar during Bhadai (Autumn rice known as 'Bhadai' in Bihar sown during May-June), Aghani (Winter rice/*Kharif* rice sown during June-July) and Garma (Summer rice/*Rabi* rice, also known as 'Garma' in Bihar. Sowing time is November to February) seasons.+ In Odisha rice is grown during Autumn, Winter and Summer season. ++ In Karnataka rice grown during *kharif, rabi* and Summer season. * Kar/Kuruvai/Somaveri (Early *kharif*), ** Samba/Thalady/Pishanam (Late *kharif*); *** Navarai/Koda. *Source:* Compiled from various issues of "Agricultural Statistics 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).

Table 3 Range, average (2000–01 to 2012–13) yield (kg/ha), variability in yield (CV), association between average yield and CV among HYVs and LVs including the percent superiority in yield of either kind of varieties over one-another among cereals grown in different regions and seasons in maize, sorghum and pearl millet

Region	State	Season	Yield of HYVs (kg/ha) Range Min.	Yield of HYVs (kg/ha) Range Max.	Yield of HYVs Mean (2000-01 to 2012-13)	Yield of HYVs CV (%)	Yield of LVs (kg/ha) Range Min.	Yield of LVs (kg/ha) Range Max.	Yield of LVs Mean (2000-01 to 2012-13)	Yield of LVs CV (%)	Superiority (%) of HYV over LVs
					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
		Rabi	-	-	-	-	2599	4522	3374.5	16.6	
	Odisha+	Autumn	1005	3734	1994.7	28.4	740	1514	966.7	19.8	106.3
		Winter	967	2738	1958.5	28.5	650	2472	1017.5	52.4	92.5
		Summer	1635	2912	2226.3	21.5	637	1945	1234.5	74.9	80.3
Southern	Karnataka++	*Kharif*	2125	3595	2865.7	16.2	877	2652	1882.7	26.9	52.2
		Rabi	2425	3659	3040.7	12.3	670	2781	2016.2	29.7	50.8
		Summer	2769	3822	3362.3	9.7	-	-	-	-	
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
Central	MP	*Kharif*	1337	2330	1583.3	21.7	331	1557	1094.9	33.8	44.6
Mean			1648.8	3081.5	2279.2	20.4	1093.6	2624.5	1733.7	32.0	31.5
Correlation coefficient (r value) between yield and CV					-0.717**				-0.581*		
					Sorghum (Jowar)						
Southern	AP	*Kharif*	1269	1872	1570.5	27.1	906	1241	1074.3	13.8	46.2
		Rabi	1126	2989	1966.8	44.1	1153	1505	1329.0	18.7	48.0
	Karnataka++	*Kharif*	1127	1867	1549.2	15.3	453	967	631.2	27.2	145.4
		Rabi	552	1224	934.5	21.0	136	1241	672.2	38.9	39.0
		Summer	1734	2496	2104.9	11.8	-	-	-	-	
	Tamil Nadu	*Kharif*	897	1755	1214.5	20.1	484	1394	790.1	31.0	53.7
Western	Gujarat++	*Kharif*	1048	1424	1311.2	9.3	425	1327	947.9	28.9	38.3
		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
	Rajasthan		250	1092	690.4	41.8	86	735	388.9	61.2	77.5
	Maharashtra		1127	1503	1296.7	11.2	341	1082	780.3	31.9	66.2
Eastern	Chhattisgarh		-	-	-	-	715	1125	863.1	16.5	
Central	MP	*Kharif*	1066	1439	1219.6	10.1	760	1197	999.0	14.2	22.1
Mean			950.7	1675.0	1314.6	21.7	570.1	1196.4	860.0	27.3	52.9
Correlation coefficient (*r value*) between yield and CV					-0.114^{NS}				-0.726**		
					Pearl millet (Bajra)						
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
	Rajasthan		288	1413	948.6	37.5	116	1158	532.1	58.7	78.3
	Maharashtra		614	1113	743.0	19.2	341	982	537.8	33.3	38.2
Southern	Karnataka		116	1097	741.2	31.6	300	734	461.0	29.0	60.8
Northern	Haryana		1160	1993	1691.0	14.7	756	2094	1376.9	28.1	22.8
Central	MP		964	1828	1511.0	16.5	486	1151	824.1	23.2	83.4
Mean			779.4	1609.3	1258.9	21.3	450.3	1519.6	957.9	33.6	31.4
Correlation coefficient (*r value*) between yield and CV					-0.673^{NS}				0.071^{NS}		

@Maize grown in Bihar during Bhadai, *Rabi* and Garma seasons, + Maize in Odisha grown during Autumn, winter & summer, ++ Grown during *Kharif, Rabi* and Summer season, ## Pearl millet in Gujarat is grown during Kharif and Summer. *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, New Delhi.

area is covered with HYVs while in other season autumn and winter local varieties play important role while in Bihar during *Bhadai* season only local varieties are grown. In maize crop both HYVs and LVs are grown during *Bhadai* and *Garma* season while during *rabi* season only LVs are predominantly being cultivated clearly indicating the importance of season which determine the prevalence of HYVs or LVs over one another. Similarly, the sorghum story in India witnessed by a major shift in production from the rainy to the post rainy season. The area shares between rainy season (62%) and post rainy season (38%) in the total cropped area in 1965-66 changed to 41.6% (rainy season) and 58.4% (post rainy season) by 2010-11 (Charyulu *et al.* 2013). In sorghum, more than 80% of the *rabi* sorghum area is still dominated by two important LVs namely, Maldandi a local landrace and M 35-1, a selection from Maldandi released eighty years ago in 1937 due to its premium grain quality. The adoption of HYVs in cereal and coarse cereals in fluctuated in less favorable environments and the main driver for adoption of HYVs are irrigation, socio-economic conditions and land reforms etc. Overall the adoption of HYVs in different regions and seasons of Indian states is highly asymmetrical. The findings of the present study are in agreement not only in case of maize but also for other crops like rice, sorghum and pearl millet too.

Variability in yield in different regions and seasons: Rice in India is grown under extreme diverse agro-ecological conditions ranging from an altitude of 10 feet below sea level to 7000 feet above sea level and annual rainfall ranging from 500 mm to 5000 mm of annual rainfall (Sathya 2013). As mentioned in Table 1, in India, about 42% area under rice is rainfed which contributes to less than 25% of the total rice production (Ellur *et al.* 2013). Rainfed upland rice constitute about 6.1 Mha area in India of which about 4.3 Mha falls under Eastern region with very low productivity of less than 1.0 tonne/ha (Lipi *et al.* 2010, Shetty *et al.* 2013). Sorghum and pearl millet grown under rainfed conditions and at national level >91% area covered by these crops is rainfed, while in maize about 75% area is rainfed. Overall, the variability in yield was found to be higher in case of LVs as compared to HYVs because they are being grown in marginal environmental conditions with low input management practices. The association between yield and variability in yield (CV) found to be negative significant in rice (only HYVs), maize (HYVs and LVs) and in sorghum only in case of LVs.

Yield variability for cereals in India is increasing relative to increases in average yield (higher coefficients of variation) at the national level (Mehra 1981). However, in case of sorghum, all-India mean yields were increasing and the coefficient of variation was decreasing gradually over a period of time. This clearly indicates that the increase in area under improved cultivars increases the yields and reduces the variability (Charyulu *et al.* 2013). Adoption of HYVs is positively correlated with, if not partially responsible for, increased sorghum and millet production variability (Walker 1989). Because in crops like maize, sorghum and pearl millet are open pollinated with commercial hybrids, the common practice of recycling seed. In states and/or cropping seasons in which use of hybrids is extensive, the majority of maize farmers replace their seed at the beginning of each cropping cycle. Replanting recycled F2 seed may well be rational when there is a high risk of crop failure, when the expected yield decline is low and/or when hybrid seed is expensive (Singh and Morris 1997).

The yield gains obtainable through HYVs over LVs, varies from season to season in the same region and in different regions in the same season including the variability in yield which also varies according to kind of varieties as well as seasons It is clearly demonstrated (Table2 and3), that the average yield superiority of rice HYV's in Bihar during *Garma* season (12.1%) and in maize during *Bhadai* (17.4%) as well as *Garma* season (17.5%), whereas HYV's of rice recorded higher yields over LV's during N/K (23.8%) in Tamil Nadu. Similarly, the average yield superiority of HYV's of pearl millet recorded in Gujarat was 3.6% (*Kharif*) and 8.5% (summer) only, whereas in case of maize MV's over LVs was only 1.6% (*Kharif*) in Gujarat and 5.1% (*Kharif*), but in Rajasthan the productivity of LVs was marginally superior over HYVs by only 1.2% (*Rabi*) and again HYVs superiority was seen over LVs during 11.6% (summer) in case of sorghum HV's. These examples reflect only marginal average yield gains in these states, stressing the fact that if LVs are cultivated with same levels of input and management as HYV's, comparable yield levels can be realized. Nevertheless, by the use of quality seed alone in case of LVs the gap between the two kind of varieties could easily be bridged up by increasing yield to the tune of 20-25% (Singh *et al.* 2018, Singh and Agarwal 2018). Moreover, large number of application for the protection of farmers varieties are being submitted in PPV&FR Authority for granting them PVP certificates (Singh and Agarwal 2019).

Conclusion

LVs being having specific adaptation and excellent source of traits for abiotic stress tolerance and resource efficiency are ideal candidates to be utilized for developing new varieties for adaptation and mitigation to adverse effects due to climate change, enhancing food and nutritional security. Farmers give importance to local genetic resources and utilize them as the farmers' varieties which emerged as farmers' selections from modern and LVs in market-oriented production systems. The adoption and diffusion of one kind of variety in a particular season and total absence of another kind in the same state, like in Odisha during summer season only HYVs of rice are grown, whereas in Bihar during *Bhada* (June-Nov) season only LVs are grown. In maize also, which is grown round the year in different seasons in Bihar where both HYVs and LVs are cultivated during *Bhadai* and *Garma* (Feb-May) seasons but cultivation of LVs during *rabi* (Nov-March) season indicates the adoption pattern of HYVs as highly asymmetrical in different seasons in same region and in different region in the same season. In upland rice, LVs are preferred over HYVs due to their resiliency to stress conditions, harvested in 70-80 days being extremely important for food and fodder security in the eastern region (Bihar, Odisha, Chhattisgarh, Jharkhand etc.) under rainfed upland conditions. Similarly, in western region during post rainy season sorghum LVs still dominate the scene. The yield gains obtainable through HYVs over LVs, varies from season to season in the same region. Variability in yield also varies according to kind of varieties grown along with input level and management conditions. Another interesting feature of the LVs is that almost all farmers varieties (FVs) are either photoperiod or temperature sensitive and could probably be both. This physiological phenomenon virtually exist in all cereals and coarse cereals and having specific adaptation and adoption patterns.

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