Indian Journal of Agricultural Sciences **91** (8): 1107–16, August 2021/Review Article
https://doi.org/10.56093/ijas.v91i8.115747

Research Review Article

Farmers' varieties to increase nutritional security, eco-system resiliency and farmers' income

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Received: 05 February 2020; Accepted: 13 July 2021

ABSTRACT

The successful development and deployment of widely adapted, photo-thermo insensitive and input responsive high yielding varieties (HYVs) in cereals along with required inputs and favorable policy reforms heralded green revolution (GR) in the country which changed India's status from food unsecured food secured and food surplus nation. However, HYVs displaced the locally adapted, climate resilient and resource efficient, but low yielding farmer's varieties (FVs) initially from the irrigated areas and later on from the risk prone, low input, marginal and rainfed areas but the HYVs/ hybrids could not replace FVs completely and FVs still occupy significant areas in different low input marginal areas and still providing valuable ecosystem's provisioning, regulating and cultural services. India being member of the World Trade Organization (WTO) adopted and implemented Trade Related Intellectual Property Rights (TRIPS) in the form of Protection of Plant Varieties and Farmers' Rights (PPV&FR) Act (2001) and Geographical Indications of Goods (Registration and Protection) Act (1999) known GIs to protect even FVs by providing PVP certificates and registered as Goods respectively by these legislations. FVs are also known to have special nutritional/medicinal/ therapeutic value in addition to adaptive traits have been protected either through PPV&FR Act or through GIs as Goods. Moreover, under GIs registration and protection FVs being having the heritage varietal status supposed to have high commercial values for trade like several kinds of Rice. Interestingly, in both legislative protections, Rice FVs dominate the scene. Virtually, the economical produce of FVs as Goods under GIs have domestic as well as international market and receive the premium prices. The FVs with special nutritional/aroma/medicinal traits with distinct identity and protected under PPV&FR Act, should also get higher economic returns if there is policy support by the Government. Currently, to mitigate the adverse effects due to climate change, breeding new varieties with specific instead of wide adaptation is advocated and the FVs by virtue of having specific adaptive traits as well as increased resource efficiency present themselves as ideal candidates for using as donors. The FVs can also be used for enhanced nutritional security as well as promoting agricultural trade to increase farmers' income.

Keywords: Crop improvement, Ecosystem services, Farmers varieties, Geographical indications, Specific adaptation

Cereals are the major and cheapest source of energy as compared to other food items and are vital for food and nutritional security. The technologies in the form of high yielding varieties (HYVs) (characterized by their semi-dwarf nature, photo-thermo insensitive behavior, and input responsivity) along with the assured supply of quality seed of these varieties with other inputs such as irrigation, fertilizers, farm power and machineries required for intensive agriculture along with policy reforms in the form of input subsidies and minimum support prices (MSPs) successfully led to the establishment of green revolution (GR) in India (Baranski 2015). The GR in India has completed golden jubilee in 2015–16 and the achievement could be judged by overall food-grains productivity increase by a factor of 3.24 times (from meager 629–2042 kg/ha) and overall food-grains production increased by 3.48 times (from 72.35 MMT in 1965-66 to 251.37 MMT in 2015-16) with marginal area increase (7% only) from 115.1 Mha to 123.22 Mha during the period of reference in India. The adoption and diffusion of HYVs in the form of open pollinated varieties (OPVs)/ hybrids in many crops under mostly rainfed conditions has occurred since the early 1980s (Evenson and Gollin 2003, Pender 2008). The very essence of the GR in India is the development and diffusion of a series of modern HYVs in irrigated and favorably rainfed areas and subsequent acceleration in public sector investments in complementary infrastructures in terms of seed, fertilizers, farm machineries, irrigation as well as institutions (Hazell 2009).

The long-term trend of rising temperatures, declining

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average precipitation, and increase in extreme precipitation events have been observed and long-term weather patterns predict that climate change could reduce annual agricultural incomes in the range of 15% to 18% on average, and up to 20–25% for rainfed areas (Economic Survey 2017-18). The increased frequency, intensity, power, duration and scale of extreme events caused by climate change are certain to intensify in future due to ever increasing level of global warming due to enhanced anthropogenic activities in the form of greenhouse gas (GHGs) emissions. Therefore, serious issues related to climate change, agro-biodiversity loss and food and nutritional security are continuously haunting to the researchers as well as policy planners. Moreover, the central challenge before Indian agriculture is low productivity coupled with high variability in yield and yield gaps. The volatile agricultural growth in India seriously questioned the sustainability of agriculture and in the Economic Survey of India, in 2016 it was categorically emphasized that "Indian agriculture, is in a way, a victim of its own success, which over time is posing to be a major threat" (Economic Survey 2015-16). The very first two sustainable development goals (SDGs) of the United Nations, related to end poverty and hunger are to be achieved completely by 2030 by all signatory Nations. Similarly, 12 of the 17 SDGs emphasize on the nutrition linked indicators which reflect the increased concerns of the global community.

Although, modern HYVs having wide adaptation, covered large areas and these varieties displaced farmers' varieties (FVs) but couldn't replace them completely. Under unfavorable conditions however, farmers' varieties (also known as landrace or traditional/local varieties) being climate resilient and having specific adaptation performed well and therefore, the adoption and diffusion of one kind (improved HYVs vs local/farmers) of variety in a particular season and total absence of another kind in the same region/state (Singh and Agrawal 2019). Farmers grow different kind of varieties depending upon the season and resource availability. The farmers' varieties still cover significant area and virtually grown in all regions and seasons in India. Therefore, highly asymmetrical adoption pattern of HYVs in different seasons in same region and in different regions in the same season do exists (Singh *et al*. 2016, Singh *et al*. 2017, Singh *et al*. 2018a). Moreover, the yield gains obtainable through HYVs over FVs, 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 (Singh and Agrawal 2020a, Singh and Agrawal 2020b). The FVs in literature are shown to have comparatively higher nutritional contents as compared to HYVs, in addition to the specific adaptation and climate resiliency. The present article review the critical role of legislatively protected FVs for enhancing food and nutritional security, ecosystem's resiliency, crop improvements and increasing farmers' income local level in relation to climate change and in mitigating its adverse effects.

Legislatively protected varieties developed through Informal Seed Systems (FVs) in India

Since the dawn of civilization, farmers practicised selection in favor of relatively better performing crops and plants at local level, developed specifically adapted varieties, maintained and conserved these FVs. A perfect harmony was maintained through natural and farmer's selection and different varieties had been the part of the expression of art, culture and indigenous traditional knowledge (ITKs). Local environments also played significant role in the forms of fixing the trails and identity through photoperiod and/or thermo sensitivity. Over the generations, this practice resulted in ever increasing quantities of locally adapted varieties known as the landraces, folk varieties, heirloom varieties, traditional varieties, local varieties, or farmers varieties etc. Seed travelled across the continents and countries into the new environments where both natural selection and farmers selections crafted and drafted varieties for increasing local adaptations and ultimately enhanced productivity (Singh 2017). Over the time most of the farmers' varieties were known based upon their geographical identity and became popular such as basmati rice. Globally, to promote agricultural trade through the World Trade Organization (WTO), it is obligatory by the member countries to adopt intellectual property rights (IPRs) on plant varieties through legislations. For plant varieties, two kinds of IPRs were implemented in India in accordance to WTO such as the Protection of Plant Varieties and Farmers' Rights (PPV&FR) Act (2001) for the protection of varieties and the Geographical Indications of Goods (Registration and Protection) Act (1999) to protect the goods of known identity with associated indigenous traditional knowledge. The status of these two kinds of protection is described briefly in the following sections.

(I) Protection of Plant Varieties and Farmers' Rights (PPV&FR) Act (2001): India has enacted law known as the PPV&FR Act (2001) in order to comply the obligations under Trade Related Intellectual Property Rights (TRIPs) agreement of the World Trade Organization (WTO). The PPV&FR Act is a *sui generis* legislation and a unique one worldwide because it combines plant breeders' rights with elements of the Article 8(j) of the United Nations Convention on Biological Diversity (CBD) and Article 9 of the FAO's 'International Treaty on Plant Genetic Resources for Food and Agriculture' (ITPGRFA), also known as (Seed Treaty), wherein farmers' claims as stewards of plant genetic resources (PGR) are enshrined. The Indian *sui-generis* system of PVP is unique, because under this act a variety can be registered as new variety, essentially derived variety (EDVs), extant variety and farmers' variety (FVs). The PPV&FR Act (2001) defines farmers' variety under section 2(l) as a variety which (*i*) has been traditionally cultivated and evolved by the farmers in their fields; or (*ii*) is a wild relative or land race of a variety about which the farmers possess the common knowledge. Data showed that (Table 1) maximum number of FVs have been protected in case of food crops which are extremely important for food security

(rice and wheat) and that too FVs belong to self-pollinated crops and relatively only a few FVs have been protected in cross pollinated crops. Although the yield capacity of traditional varieties is limited but it is compensated by other appreciable characters such as high nutritional value, good cooking qualities including pleasurable aroma, and sufficient volume of cooked meal with less quantity of raw rice.

Nutritional/medicinal/therapeutic value and adaptive traits of protected FVs: Rahman *et al.* (2006) reported that a large number of FVs in rice with high nutritional and medicinal value are still grown by tribal's and small farmers in some eastern states. Similarly, Deb *et al.* (2015) demonstrated that a considerable number of rice landraces are capable of taking up micronutrients like Fe, Cu, Zn and Mn. Many of these landraces contain up to 13-fold greater concentration of Fe and Zn than transgenic metal-fortified rice. On comparison, at least 67 folk landraces from their sample contain >20 mg/kg iron. Farmers rice varieties have enormously high potential of remedying dietary iron and zinc deficiencies in the country. FVs are known to have adaptive traits as well as excellent nutritional/medicinal/therapeutic attributes in addition to their higher economic returns as compared to HYVs. The list of rice FVs including the legislatively protected ones with their nutritional/medicinal/therapeutic properties along with the adaptive traits have been provided by Singh and Agrawal (2020b). In addition, the number of rice FVs protected through PPV&FR Act (2001) from States in Eastern India has also been mentioned by these authors (Singh and Agrawal 2020b).

(II) Status of GIs protected FVs in various field crops: The Geographical Indications of Goods (Registration and Protection) Act (1999) came into force on September 15, 2003. Section 2(e) of the Act defines the term geographical indication as an indication which identifies such goods as agricultural goods, natural goods or manufactured goods as originating, or manufactured in the territory of a country, or a region or locality in that territory, where a given quality, reputation or other characteristic of such goods is essentially attributable to its geographical origin. The Act has established a registry known as the GI registry, to facilitate registration of GIs in India. Goods as per sec 2(f) of GI Act 1999 to be protected include handicraft, manufactured, food stuff, natural goods, and agricultural goods. As on 10 September, 2019, 361 Goods were registered with GI Registry. This also includes 15 foreign GIs. Out of this, 108 were agricultural Goods including 19 FVs of field crops which were protected through GIs. Overall, Maharashtra (25) lead the tally in GIs registered Goods followed by Karnataka (22), Kerala (16), Tamil Nadu (9). Most of the registered GIs Goods belong to high value crops namely fruits, condiments and species, beverage, aromatics, flowers, vegetables and jaggery etc. Summing this, horticultural and other high value crops have lion's share (≥ 82%) among the registered GIs Goods so far. Moreover, out of 19 FVs, among field crops, 15 FVs belonged to rice only, while 2 FVs were protected in pigeon pea and one each in wheat and sorghum (Table 2).

These FVs are being grown in farmers' fields throughout centuries altogether in the regions of their origin and maintained identity. The legislatively protected FVs through GIs describe the produce of heritage farmers' varieties (FVs) and the associated traditional knowledge (ITKs) for centuries altogether such as Navara rice, Pokkali and Kaipad rice in Kerala. Similarly, 'Basmati Rice' belongs to a unique varietal group which has separated itself due to combined natural and human selection, and recognized widely as a specialty rice. The Basmati has attained heritage rice status as it is considered as farmers variety being maintained and grown by farmers of north-western region of India for more than 250 years. These virtues of Basmati rice command them premium price in domestic and international markets (Siddiq *et al*. 2012). Some of the FVs even have been protected through PPV&FR Act as FVs and through GIs as Goods, such as Kalanamak another heritage variety of rice from eastern Uttar Pradesh. The specific adaptation is the hallmark of all the legislatively (either through PPV&FR Act (2001) or protected FVs.

Ecosystem services through HYVs and FVs: Modern HYVs are bred to suit for agricultural intensification (high input-high output) and in turn these varieties do provide high provisioning services in terms of higher yield while Ficiciyan and others (2018) have reported other important services like regulating -resistance against pests and diseases appear to often become lost during breeding for HYVs (Ficiciyan *et al*. 2018). Similarly, for extremely important abiotic stress like drought which is mainly responsible for high yield gap as well as high variability in yield and in this regard the similar kind of observation recorded by Sandhu and Kumar (2017) by mentioning that the Modern high yielding varieties although do possesses high yield potential, but are highly vulnerable to abiotic stresses such as drought and in the course of post GR breeding unknowingly, the drought tolerance contributing alleles of traditional cultivars have not been properly retained/maintained in the modern cultivars (Sandhu and Kumar 2017). Nevertheless, the ecosystem's resiliency depends upon the diversity at species level, variety level and gene level but wide use of improved HYVs has led to a genetic bottleneck, resulting in the loss of crop, variety and allele diversity (Peroni *et al*. 2002; Tsegaye and Berg 2007). Similarly, the modern HYVs are mainly responsible for declining of provisioning, regulating, and cultural ecosystem services and this observation was made in none other than Millennium Ecosystem Assessment (MEA 2005) with regard to the various kind of ecosystem services provided by HYVs and FVs and their comparative roles are mentioned in Table 3.

The current process of agricultural intensification system is the single most important threat to biodiversity (Gept 2006). FVs are known to possess traits for local adaptation, stress tolerance, yield stability, and nutrition. Moreover, rice FVs such as 'Pokkali' are excellent source of salt tolerance as salt stress adversely affect rice yield in rainfed and irrigated agro-ecosystems (Dwivedi *et al*. 2016).

Farmers varieties for future crop improvement: Climate

Table 1 Status of legislatively (PPV&FR Act, 2001) protected varieties of formal and informal seed sectors in India (up to 15 Oct, 2019)[@]

Crop	Registered HYVs formal seed sector	Registered FVs informal seed sector	Total	Crop	Registered HYVs formal seed sector	Registered FVs inormal seed sector	Total
Cereals and Coarse Cereals				*Fiber Crops*			
Rice	321	1527	1848	Tetraploid cotton	281	1	282
Wheat	146	23	169	Diploid cotton	43		43
Durum wheat	16	1	17	Jute	17		17
Dicoccum wheat	5		5	Sub total	341	1	342
Barley	15		15	*Condiments and Spices*			
Maize	260	6	266	Small cardamom	3	6	9
Sorghum	130	4	134	Black pepper	3	3	6
Pearl millet	127		127	Garlic	7		7
				Turmeric	4		4
Finger millet	6		6	Sub total	**17**	**9**	**26**
Foxtail millet	1		1	*Vegetables and melons*			
Little millet	1		1	Bitter gourd	1		1
Sub total	1028	1561	2589	Bottle gourd	3		3
Pulses				Brinjal	40		40
Pigeon pea		7	7	Cabbage	1		1
Greengram	31	2	33	Cauliflower	5		5
Chickpea	48	2	50	Chilli	7		7
Blackgram	19	1	20	Potato	25		25
Field pea	27		27	Pumpkin	3		3
Kidney bean	10		10	Coriander	1		1
Pigeonpea	31		31	Cucumber	2		2
Lentil	12		12	Musk melon	2		2
Sub Total	178	12	190	Okra	36		36
Oilseeds				Onion	8		8
Indian mustard (Sarso)	62	6	68	Rapeseed (gobhi sarso)	6		6
Rapeseed (Toria)	7	6	13	Indian mustard (Karan Rai)	2		2
Sesame	10	1	11	Ridge gourd	1		1
Castor	10		10	Spinach beet	1		1
Soybean	34		34	Tomato	41		41
Sunflower	56		56	Veg. amaranth	1		1
Groundnut	31		31	Sub total	186		186
Linseed	5		5	*Plantation*			
Safflower	6		6	Coconut	6		6
Sub total	221	13	234	Sugarcane	48		48
				Sub total	54		54
Flowers							
Rose	1		1	Grand total	2026	1596	3622

@: PPV&FRA, New Delhi

Table 2 Protected FVs as Goods in India through the Geographical Indications of Goods (Registration and Protection) Act (1999)@

State/GI region	Crop	Farmers' variety	Remarks*
Kerala	Rice	Navara Rice	Indigenous medicinal plant of Kerala. It has unique medicinal characteristics and widely used in Ayurvedic treatments.
		Palakkadan Matta Rice	Coarse bold and red in color. Unique taste
		Pokkali Rice	Unique saline tolerant rice variety cultivated in organic way in the water-logged coastal regions
		Wayanad Jeerakasala Rice	Scented, non-basmati rice is famous for its characteristic fragrance and aroma.
		Wayanad Gandhakasala Rice	Scented, non-basmati rice is famous for its characteristic fragrance and aroma is known for its natural fragrance of sandal
		Kaipad Rice	Sticky nature, red kernel with delicious taste
Maharashtra		Ajara Ghansal Rice	Famous for its taste, aroma and nutritive value
		Ambemohar Rice	Used for religious and marriage ceremonies. Taste of this rice variety is sweet. Used for making the traditional food 'Vapholya' during Makarsankranti festival. It has strong fragrance reminiscent of mango blossoms, which is noticeable when the rice is cooked
	Sorghum	Mangalwedha jowar (Photoperiod sensitive)	Famous for its sweet taste and nutritional value
	Pigonpea	Navapur tur dal	Unique taste and aroma, high nutritional contents
Uttar Pradesh (UP)	Rice	Kalanamak (Photoperiod sensitive, tall traditional)	Heritage rice black-husked, short-grained rice superior to "Basmati" in aroma and taste.
Assam		Joha Rice (Photoperiod sensitive, tall traditional)	Unique in aroma and grain characteristics and distinct from other aromatic rice like Basmati in biochemical and other quality attributes.
		Boka Chaul Rice	Zero-cooking identity
Gujarat	Wheat	Bhalia Wheat	Bhalia Wheat is rich in gluten, a type of amino acid. It is also rich in protein.
Punjab, Haryana, Delhi, HP, Uttarakhand, Parts of western UP and J&K	Rice	Basmati (Tall, photoperiod and temperature sensitive behavior)	Extra-long slender grain, lengthwise excessive elongation on cooking, soft and fluffy texture of cooked rice, and pleasant aroma. In addition to unique cooking quality, Basmati rice is also reported to have low glycemic index (Foster-Powell *et al.* 2002) and is micronutrient rich especially for iron and zinc (Gregorio 2002).
Bihar	Rice	Katarni Rice (photo-sensitive)	Famous fine grain quality with scent
West Bengal	Rice	Govinda Bhog (photo-sensitive)	Short grain white aromatic, sticky rice having a sweet buttery flavor.
		Tulaipanji (67/2016)	Pleasant, strong and stable aroma. One of its distinct features is that aroma has been found stable and strong in the parboiled rice grain even up to one year.
Karnataka	Pigeonpea	Gulbarga Tur Dal	Unique taste, aroma and shelf-life which is due to the richness of calcium (Ca) and potassium (K) in the soils of the region. The milling quality of the dal is high due to the spherical nature of the dal grains which make it a premier quality dal, called "patka dal".

Source: @ the GIs registered agricultural Goods (FVs) list downloaded from http://www.ipindia.nic.in/registered-gls.htm , * Adapted from various issues of Geographical Indications Journals (GOI).

Table 3 Comparison of HYVs and FVs in relation to Ecosystem Services

Ecosystem service	Performance indicator	High yielding vs Farmers varieties
Provisioning services	Yield	FVs yield equally or higher under harsh conditions (Yadav 2010, Brocke *et al.* 2014, Li *et al.* 2012); HYVs exhibit higher yield, but input costs may be also high, even counterbalancing the benefit from higher yields (Li *et al.*2012); HYVs under low input marginal condition record high variability in yield as well as higher yield gaps (Singh and Agarwal 2020a); F/LVs provide much needed yield stability under extreme and adverse condition (Singh and Reddy 2013).
	Resource use efficiency	FVs tend to deliver more stable yields under limited environments (Sangabriel-Conde *et al.* 2014); FVs are sources of traits (increased nutrient-use efficiency, enhanced radiation use -(photosynthetic) efficiency—which are very important for sustainable intensification (Singh and Agrawal 2020c).
	Crop storability	Higher storability of FVs with lower levels of storage losses to insects (Maggs-Kolling and Christiansen 2003, Moreno *et al.* 2006).
Regulating services	Resilience to climate change effects	FVs are often better adapted to drought stress (Annicchiarico 2006, Mazvimbakupa *et al.* 2015, Munoz-Perea *et al.* 2007); FVs may be more pest resistant (Olson *et al.* 2012); FVs are better adapted to local climate conditions (Singh *et al.* 2011, Singh *et al.* 2013, Singh *et al.* 2015, Fenzi *et al.* 2017).
	Biological pest and disease control	FVs maintain high levels of resistance against pest and disease (Tamiru *et al.* 2011, Sánchez-Martín *et al.* 2017, Patil *et al.* 2014); FVs are sources of host-plant resistance and abiotic stress tolerance genes (Newton *et al.* 2010).
	Pollination	Declining pollinators (intensified land use, climate change, alien species, and the spread of pests and pathogens (Kearns *et al*. 1998, Potts *et al*. 2010); this has serious implications for human food security and health, and ecosystem function (Vanbergen 2013).
	Biodiversity richness	Up to 75% of plant genetic diversity has been lost due to the rapid expansion of industrial agriculture and large-scale adoption of monoculture farming (Jacques and Jacques 2012).
Cultural services	Tradition, cooking quality, nutritional values, taste and color, aesthetic, medicinal and cultural significance	FVs are passed over generations together with recipes (Montes-Hernandez *et al.* 2005); FVs are sources of phytonutrients with desired micronutrient concentrations that alleviate human aging-related and chronic diseases (Newton *et al.* 2010).

change is a realty now and on the basis of long-term data (six decades) on temperature, rainfall and crop production a long-term trend of rising temperatures, declining average precipitation, and increase in extreme precipitation events have been observed and long-term weather patterns implies that climate change could reduce annual agricultural incomes in the range of 15–18% on average, and up to 20–25% for rainfed areas (Economic Survey 2017-18). In India, climate variability has increased both spatially and temporally over the past 50 years (Davis *et al*. 2019**)**. Therefore, to adapt and mitigate adverse effects of climate change the climate resilient as well as resource efficient varieties need to be developed. FVs being climate resilient and resource efficient have greater role to play as these varieties do posses the adaptive traits required to breed abiotic stress tolerance varieties (Singh 2017a, Singh 2020). The development of multiple abiotic stress tolerance such as heat and drought is crucial to mitigate the extreme and adverse conditions due to increased climatic variability under marginal low input conditions (Singh *et al.* 2011, Singh 2014). In addition, FVs do have comparatively higher nutritional contents in delicately balanced way and high yielding varieties along with higher nutritional contents is the need of the day as micronutrient malnutrition problems. Moreover, the efforts needed to develop varieties with improved nutritional value but ignored for so long and warrant immediate attention (Singh and Agarwal 2020b, Singh and Agarwal 2020c). Development, deployment and the diffusion of climate resilient improved varieties are required to adapt and mitigate the adverse affects due to climate change (Singh *et al.* 2020), also the huge gaps still exist in formal seed systems highlighting poor seed and varietal replacement ratio particularly in developing nations where a few widely adapted and aged varieties in almost all crops still dominate the scene and even have the status of mega star varieties (Singh 2015, Singh and Singh 2016)

FVs are known to possess the adaptive traits, for example gene for submergence tolerance in rice has been transferred from a farmer's variety Swarna which became megastar variety (Swarna Sub-1) in eastern India (Singh 2018) covering around 30% area in eastern region and neighboring countries. Similarly Evenson *et al.* (1998)

reported that while a rice variety released in the 1960s had on an average 3 landraces in its pedigree while in more recent releases have 25 or more, and the average number of distinct landraces found in bread wheat pedigrees grew from about 20 in the mid-1960s to about 50 in 1990s (Smale 1997). With respect to rice breeding for grain quality, the popular basmati rice variety 'Karnal Local' which possesses better grain and cooking quality, was a selection from the traditional Basmati rice collection in Karnal district of Haryana later released as Taraori Basmati in 1996 (Singh *et al*. 2004). It was widely used parents by rice breeders for grain, cooking and eating characteristics. The International Rice Research Institute (IRRI), Philippines used it in as many as 249 crosses (Singh *et al*. 2018b). Kalanamak a heritage rice from eastern Uttar Pradesh is under cultivation since millennia and using it as a parent, a new variety was released as Kalanamak 3 (KN3) for cultivation in eastern Uttar Pradesh, India. Subsequently, several semi-dwarf breeding lines, developed through hybridization or induced mutation, outyielded KN3 by 40% (Chaudhary *et al*. 2012). A first semi-dwarf, non-black husk cultivar, Bauna Kalanamak 102, with comparable cooking quality and aroma to "KN3," has been released for cultivation (Chaudhary *et al*. 2012, Dwivedi *et al*. 2019).

Trade of legislatively protected (GIs) Goods: Most celebrated agricultural Goods of international Geographical Indication from India is Darjeeling tea and Basmati rice. The 77 districts spreading in seven states namely Punjab, Haryana, Delhi, Himachal Pradesh, J&K, Uttarakhand and parts of western Uttar Pradesh from north west region of India has been earmarked as the Geographical Indication (GI) for Basmati rice and the GI status has been conferred to Basmati rice in 2016 (GI No. 145 of the Geographical Indication Registry, Government of India, vide certificate No. 238 dated 15.02.2016). Later on 13 districts of Madhya Pradesh have also been included in Basmati growing area for GI by the order of High Court of Delhi during 2019. Over one half of Basmati rice is exported as Sela (parboiled) to the Gulf countries particularly Saudi Arabia followed by Kuwait and UAE as well as UK and USA (Siddiq *et al*. 2012). The annual foreign exchange earning of Basmati rice has surged during 2013–14 to US$ 4.87 billion (Singh *et al.* 2018b). With respect to the trading of GIs Goods from India, Jena and Grote (2010) found that adoption of GI for Basmati rice led to increase in margins of the producers and higher returns for certified (organic) GIs Basmati than non-certified rice. Furthermore, consumers are willing to pay a higher price because they were distinct and of good quality GI protected guaranteed agricultural products (Vinayan 2015, Kishore 2018). In India, GI registration has increased in popularity, but a lack of GI knowledge among producers has led to registration of products with low potential for success (Vinayan 2017). Some of the GIs Goods such as Navara Rice is even more useful for socio-economic upliftment of the community as a whole as this rice is used in medicine and therefore there is a continuous demand for it.

Policy intervention

Presently, large number of FVs and GIs protected varieties are grown by farmers and realizing their importance their quality seed need to be produced locally in order to increase yield by the use of quality seed. However, in India, formal seed sector produce and supply the seed of varieties notified as per Seed Act (1966) only while FVs are left behind and therefore this is in addition to the inherent weakness (poor seed and varietal replacement ratios) of formal seed sector (Singh 2013), and further warrant strengthening of local seed system particularly in marginal environments to include even the seed production of crops of local importance (Singh 2016) to increase food and nutritional security which is possible through participatory approach (Singh 2012, Singh 2017a) in order to enhance the adoption and diffusion of even varieties developed through formal seed system (Singh *et al.* 2020). Integration and commercialization of FVs could be made under sub-optimal environments for securing food and nutritional security, promoting sustainable agriculture through sustainable intensification and agro-biodiversity conservation (Singh 2018, Singh *et al.* 2018a). Moreover, semi-formal method of seed certification may be employed to resolve the issue. Such a system such as Quality Declared Seed (QDS) system developed by the Food and Agriculture organization of the United Nations may be considered. The farmers varieties could be commercialized by adopting and implementing the FAO policy of Quality declared seed system in parallel to increase diverse seed access by marginal and small holders in India at local level in order to improve seed systems resiliency in parallel to normal seed regulatory system for protecting varietal diversity and ensuring food security in India (Singh and Agrawal 2018).

Conclusion

Through quality seed the yield improvement of 20–25% could easily be obtained. In rainfed areas and other low input marginal environments, marginal and small farmers operate in complex, diverse and risk-prone (CDR) environments with minimum or no external inputs. In such environments, farmers managed seed systems representing informal seed system which is the only means on which resourced constrained farmers rely. Moreover, due to the presence of various seed and/or airborne pathogens and storage pests the quality of FSS of rice is not according to Indian minimum seed certification standards (IMSCSs) which ultimately culminate in poor germination and poor crop plant stand particularly, in rainfed/marginal conditions and thus significantly effecting yield and quality. Also, the seed health status of FSS not found at par in accordance with IMSCSs. Therefore, to improve the quality of FSS, some other equally good but less stringent procedures like Quality Declared Seed (QDS) system developed by the Food and Agriculture Organization of the United Nations may be considered. QDS system, being semi-formal, cost effective and less stringent in comparison to the conventional seed certification with focusing for ensuring the availability of

quality seed in adequate quantity of the locally adapted varieties at local level. Moreover, through this system the full advantage of the rich genetic diversity in the form of FVs, an alternative registration and certification system is advocated to channelize and commercialize FVs using formal system.

The economic benefits through registered GIs Goods are higher as compared to PVP by PPV&FR Act (2001) and in both cases the FVs of distinct nature, origin and values are involved. Therefore, in order to extend the benefit to farmers, the PPV&FR Authority should take lead for the profiling of the PVP protected FVs in order to capture the nutritional/medicinal/therapeutic values to commercialize the produce of FVs. Also, the PPV&FR Authority should facilitate for ensuring the availability of quality seed of the identified FVs at local level. As listed, some of the FVs are popular for their unique nutritional/medicinal/therapeutic values and farmers need to be encouraged to produce them organically in order to get the premium price. Also, linkage need to be established with star rated hotels and big hospitals to market the product of legally protected FVs for the continuous demand and supply.

REFERENCES

Annicchiarico P. 2006. Diversity, genetic structure, distinctness and agronomic value of Italian lucerne (*Medicago sativa* L.) landraces. *Euphytica* **148**(3): 269–82.

Baranski M R. 2015. Wide adaptation of Green Revolution wheat: International roots and the Indian context of a new plant breeding ideal, 1960–70. *Studies in History and Philosophy of Biological and Biomedical Sciences* **50**: 41–50.

Brocke K V, Trouche G, Weltzien E, Kondombo-Barro C P, Sidibe A, Zougmore R and Goze E. 2014. Helping farmers adapt to climate and cropping system change through increased access to sorghum genetic resources adapted to prevalent sorghum cropping systems in Burkina Faso. *Experimental Agriculture* **50**: 284–305.

Chaudhary R C, Mishra S B, Yadav S K and Ali J. 2012. Extinction to distinction: Current status of Kalanamak, the heritage rice of eastern Uttar Pradesh and its likely role in farmers' prosperity. *LMA Convention Journal* **8**(1): 7–14.

Davis K F, Chhatre A, Rao N D, Singh D and DeFries R. 2019. Sensitivity of grain yields to historical climate variability in India. *Environmental Research Letters* **14**(6): 064013.

Deb D, Sengupta S and Pradeep T. 2015. A profile of heavy metals in rice (*Oryza sativa* ssp. *indica*) landraces. *Current Science* **109**(3): 407–09.

Dwivedi S L, Ceccarelli S, Blair M W, Upadhyaya H D, Are A K and Ortiz R. 2016. Landrace germplasm for improving yield and abiotic stress adaptation. *Trends in Plant Science* **21**(1): 31–42.

Dwivedi S, Goldman I and Ortiz R. 2019. Pursuing the potential of heirloom cultivars to improve adaptation, nutritional, and culinary features of food crops. *Agronomy* 9(8): 441.

Economic Survey 2015–16. Agriculture: More from less-Chapter 04. 68–85 pp.

Economic Survey 2017–18. *Climate, Climate Change, and Agriculture,* Vol (1). Chapter **6**, pp 82–101.

Evenson R E and Gollin D. 2003. Assessing the Impact of the Green Revolution, 1960 to 2000. *Science* **300**(5620): 758–62.

Evenson R E, Gollin D and Santaniello V. 1998. Introduction and overview: Agricultural values of plant genetic resources. (*In*) *Agricultural Values of Plant Genetic Resources,* R E Evenson, D Gollin and V Santaniello (Eds). CAB International. pp 1-25.

Ficiciyan A, Loos J, Sievers-Glotzbach S and Tscharntke T. 2018. More than yield; Ecosystem services of traditional versus modern crop varieties revisited. *Sustainability* **10**(8): 2834.

Foster-Powell K, Holt S H A and Brand-Miller J C. 2002. International table of glycemic index and glycemic load values. *American Journal of Clinical Nutrition* **76**(1):5–56.

Gept P. 2006. Plant genetic resources conservation and utilization: The accomplishments and future of a societal insurance policy. *Crop Science* **46**(5): 2278–92.

Gregorio G B. 2002. Progress in breeding for trace minerals in staple crops symposium: plant breeding: a new tool for fighting micronutrient malnutrition. *Journal of Nutrition* **132**(3): 5005–25.

Hazell P B R. 2009. The Asian Green Revolution: IFPRI Discussion Paper 00911, IFPRI, p 40.

Jacques P J and Jacques J R. 2012. Monocropping cultures into ruin: The loss of food varieties and cultural diversity. *Sustainability* **4**: 2970–97.

Kearns C A, Inouye D W and Waser N M. 1998. Endangered mutualisms: the conservation of plant–pollinator interactions. *Annual Review of Ecology and Systematics* **29**(1): 83–112.

Kishore K. 2018. Geographical Indications. An Indian prospective. *Journal of Intellectual Property Rights* **23**(4-5): 159–66.

Li J, van Bueren E T L, Jiggins J and Leeuwis C. 2012. Farmers' adoption of maize (*Zea mays* L.) hybrids and the persistence of landraces in Southwest China: Implications for policy and breeding. *Genetic Resources and Crop Evolution* **59**: 1147–60.

Maggs-Kolling G L and Christiansen J L. 2003. Variability in Namibian landraces of watermelon (*Citrullus lanatus*). *Euphytica* **132**: 251–58.

Mazvimbakupa F, Modi A T and Mabhaudhi T. 2015. Seed quality and water use characteristics of maize landraces compared with selected commercial hybrids. *Chilean Journal of Agricultural Research* **75**(1): 13–20.

Montes-Hernandez S, Merrick L C and Eguiarte L E. 2005. Maintenance of squash (*Cucurbita* spp.) landrace diversity by farmers' activities in Mexico. *Genetic Resources and Crop Evolution* **52**: 697–07.

Moreno L L, Tuxill J, Moo E Y, Reyes L A, Alejo J C and Jarvis D I. 2006. Traditional maize storage methods of mayan farmers in Yucatan, Mexico: Implications for seed selection and crop diversity. *Biodiversity Conservation* **15**: 1771–95.

Munoz-Perea C G, Allen R G, Westermann D T, Wright J L and Singh S P. 2007. Water use efficiency among dry bean landraces and cultivars in drought-stressed and non-stressed environments. *Euphytica* **155**(3): 393–402.

Newton A C, Akar T and Baresel J P. 2010. Cereal landraces for sustainable agriculture. A review. *Agronomy for Sustainable Development* **30**(2): 237–69.

Olson M B, Morris K S and Mendez V E. 2012. Cultivation of maize landraces by small-scale shade coffee farmers in western El Salvador. *Agricultural Systems* **111**: 63–74.

Patil J V, Reddy P S, Prabhakar; Umakanth A V, Gomashe S and Ganapathy K N. 2014. History of post-rainy season sorghum research in India and strategies for breaking the yield plateau. *Indian Journal of Genetics and Plant Breeding* **74**(3): 271–85.

Pender J. 2008. Agricultural technology choices for poor farmers in less-favoured Areas of South and East Asia. Occasional Papers, Knowledge for development effectiveness by the International Fund for Agricultural Development (IFAD), 82 p.

Peroni N and Hanazaki N. 2002. Current and lost diversity of cultivated varieties, especially cassava, under swidden cultivation systems in the Brazilian Atlantic Forest. *Agriculture, Ecosystems & Environment* **92**(2/3): 171–83.

Potts S G, Biesmeijer J C and Kremen C. 2010. Global pollinator declines: trends, impacts and drivers. *Trends in Ecology and Evolution* **25**(6): 345–53.

Rahman S, Sharma M P and Sahai S. 2006. Nutritional and medicinal values of some indigenous rice varieties. *Indian Journal of Traditional Knowledge* **5**(4): 454–58.

Sánchez-Martín J, Rispail N, Flores F, Emeran A A, Sillero J C, Rubiales D and Prats E. 2017. Higher rust resistance and similar yield of oat landraces versus cultivars under high temperature and drought. *Agronomy for Sustainable Development* **37**(1).

Sandhu N and Kumar A. 2017. Bridging the Rice Yield Gaps under Drought: QTLs, Genes, and their use in breeding programs. *Agronomy* 7: 27.

Sangabriel-Conde W, Negrete-Yankelevich S, Eduardo Maldonado-Mendoza I and Trejo-Aguilar D. 2014. Native maize landraces from Los Tuxtlas, Mexico show varying mycorrhizal dependency for P uptake. *Biology and Fertility of Soils* **50**: 405–14.

Siddiq E A, Vemireddy L R and Nagaraju J. 2012. Basmati Rices: Genetics, Breeding and Trade. *Agricultural Research* **1**(1): 25–36.

Singh R P, Prasad P V V, Sharma A K and Reddy K R. 2011. Impacts of high-temperature stress and potential opportunities for breeding. In: *Crops Adaptation to Climate Change,* pp. 166-185. Shyam Singh Yadav, Robert Redden, Jerry Hatfield, and Hermann Lotze – Campen (Eds). Wiley – Blackwell, USA, ISBN: 978-0-8138-2016-3.

Singh R P. 2012. Enhancing food and seed security through participatory approach in the Eastern region to mitigate the climate change impact. *Journal of Research*. (BAU): **24**(1): 1–12.

Singh R P. 2013. Issues and strategies to correct missing links in seed sector of India. *Journal of Research (BAU)*: **25**(1): 1–15.

Singh R P and Reddy K R 2013. Impact of climate change and farm management. *Climate Change and Environmental Sustainability* 1(1): 53–72.

Singh R P, Prasad P V V and Reddy K R. 2013. Impacts of changing climate and climate variability on seed production and seed industry. *Advances in Agronomy* **118**: 49–110.

Singh R P. 2014. Effect of heat and drought in crops under rainfed/marginal environments and mitigation strategies through breeding for tolerance: A Review. *Climate Change and Environmental Sustainability* **2**(1): 10–29.

Singh R P. 2015. Varietal replacement rates among field crops: current status, constraints, impact, challenges and opportunities for the Indian seed industry. *Seed Times* **7**(3&4): 71–89.

Singh R P, Prasad P V V and Reddy K R. 2015 . Climate change: Implications for stakeholders in genetic resources and seed sector. *Advances in Agronomy* **129**: 117–80.

Singh R P. 2016. Local seed system strengthening in marginal environments to mitigate climate change effects *vis-a-vis* ensuring food security in India. *Climate Change and Environmental Sustainability* **4**(2): 158–177.

Singh R P and Singh S. 2016. Optimizing seed replacement rates in Jharkhand: Present scenario, challenges and opportunities. *Jharkhand Journal of Development and Management Studies* **14**(2): 6987–7007.

Singh R P, Kumar A and Pal S K. 2016. The prevalence, productivity and protection of traditional varieties vis-à-vis modern varieties in Eastern India: An appraisal. Special Issue - Seed biotechnology and Eastern India's "New Green Revolution": Issues and Challenges. *Jharkhand Journal of Development and Management Studies* **14**(2): 6955–70.

Singh R P. 2017. Seed: An ambassador of science, technology, trade and agrarian revolution. Invited paper for the thematic issue on Journey of seed. *Seed Times* **10**(2): 16–23.

Singh R P. 2017a. Improving seed systems resiliency at local level through participatory approach for adaptation to climate change. *Adv Plants Agric Res (USA)* **6**(1):15-16.

Singh R P, Agarwal D K, Prasad R S V, Kumar S K and Jeevan S P. 2017. Varietal and seed replacement in the era of climate change. ICAR-IISS, Mau, Uttar Pradesh, India. pp 156 ISBN: 978-81-925128-2-6

Singh R P. 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 Science* **3**(2):65–67.

Singh R P and Agrawal R C. 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 Science* **3**(6): 387–91.

Singh R P, Singh S and Lal S K. 2018a. Channelizing protected farmer's varieties through semi-formal seed systems for effective utilization and conservation of agro-biodiversity: An Overview. *Seed Research* **46**(2): 87–97.

Singh R P and Agarwal R C. 2019. Farmer's Varieties in India-Factors affecting their preferential prevalence and the current status of their legal protection. *Indian Journal of Agricultural Sciences* 89(9): 1371–82.

Singh R P. 2020. Ensuring food security by good seed governance: A case study from Jharkhand. (Chapter 21) (In) *Ecological and Practical Applications for Sustainable Agriculture*. Bauddh K, Kumar S, Singh R, Korstad J (Eds), pp 445–70. Springer, Singapore.

Singh R P and Agarwal R C. 2020a. Local varieties in India- New insights into adaptation patterns, performance and preferences over modern varieties of selected cereals among different seasons and regions. *Indian Journal of Agricultural Sciences* **90**(3): 470–76.

Singh R P and Agrawal R C. 2020b. Farmers' varieties and ecosystem services with reference to eastern India (Chapter, 20). (In) *Ecological and Practical Applications for Sustainable Agriculture*. Bauddh K, Kumar S, Singh R, Korstad J (eds), pp. 421–44. Springer, Singapore.

Singh R P and Agrawal R C. 2020c. Role of Indian seed industry in promoting food and nutritional security and agricultural sustainability (Chapter, 19). (In) *Ecological and Practical Applications for Sustainable Agriculture,* Bauddh K, Kumar S, Singh R, Korstad J (Eds), pp 411–20. Springer, Singapore.

Singh R P, Chintagunta A D, Agarwal D K, Kureel R S and Jeevan Kumar S P. 2020. Varietal replacement rate: Prospects and challenges for global food security. *Global Food Security* **25**: 100324.

Singh V P, Pratik S, Gopala Krishnan S and Singh A K. 2004. Role

of Indian Agricultural Research Institute in genetic improvement of rice varieties in India. (In) *Genetic improvement of rice varieties in India*, Sharma S D, Rao P (eds), pp. 141–87. Today and Tomorrow's printers and publications, India.

Singh V P, Singh A K, Mohapatra T, Krishnan G and Ellur R K. 2018b. Pusa Basmati 1121 – a rice variety with exceptional kernel elongation and volume expansion after cooking. *Rice* **11**: **(**19).

Smale M. 1997. The Green Revolution and wheat genetic diversity: dome unfounded assumptions. *World Development* **25**(8): 1257–69.

Tamiru A, Bruce T J A, Woodcock C M, Caulfield J C, Midega C A O, Ogol C K P O, Mayon P, Birkett M A, Pickett J A and Khan Z R 2011. Maize landraces recruit egg and larval parasitoids in response to egg deposition by a herbivore. *Ecology Letters* **14**(11): 1075–83.

Tsegaye B and Berg T. 2007. Utilization of durum wheat landraces in East Shewa, central Ethiopia: Are home uses an incentive for on-farm conservation? *Agriculture and Human Values* **24**: 219–30.

Vanbergen A J. 2013. Threats to an ecosystem service: pressures on pollinators. *Frontiers in ecology and environment* **11**(5): 251–59.

Vinayan S. 2015. Willingness to pay for GI products in India: The case of Darjeeling tea and Pochampally Ikat. *Hyderabad Social Development Papers* **3**(1-3): 1–21.

Vinayan S. 2017. Geographical indications in India: Issues and challenges—An overview. *Journal of World Intellect Property* **20**(3-4): 119–32

Yadav O P. 2010. Drought response of pearl millet landrace-based populations and their crosses with elite composites. *Field Crops Research* **118**(1): 51–56.