India's Experience of Plant Variety Protection: Trends, Determinants and Impact

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India's Experience of Plant Variety Protection: Trends, Determinants and Impact

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Plant variety protection (PVP) is a recent development in the developing countries, and there is not adequate evidence on the response of the seed industry to this policy change. This paper examines the trends in PVP in India, protection behaviour and early impact on seed industry. The results showed a significant growth in PVP attracting participation of both the public and private sectors. However, there is some degree of crop segmentation with private sector mostly concentrated on vegetables and cotton, while public sector on foodgrains. Furthermore, 55 per cent of the applications from private sector were for the new varieties, whereas 85 per cent of the public sector applications were for the extant varieties. The results of logit model revealed that yield, adaptability, institute origin and variety traits were the major factors which influenced the PVP decisions of breeders. The hedonic pricing model indicated a price premium of 11-15 per cent for seeds of the protected varieties. The trends in exchange of germplasm, number of varieties released, breeder and quality seeds produced, seed replacement rate and number of public-private partnerships, indicate the growth of the Indian seed industry and its confidence in the PVP mechanism. The study concluded that initial impact of PVP on seed industry and farmers' accessibility to quality seeds is positive.

Key words: Plant variety protection**,** protection behaviour, hedonic pricing, impact of PVP, India.

JEL Classification: O31, O34, Q18

Introduction

Breeding of new plant varieties and supply of seeds were mainly in public domain until the 1970s when organised seed sector was taking shape in India (Spielman *et al.*, 2011). The diversification process of the seed industry started with the expansion of seed market, which further got steam with implementation of the New Policy on Seed Development in 1988 (Pray *et al*., 2001). The diversification process was noticed across the different stages of the seed system, *viz.*, development of plant varieties and multiplication and distribution of seeds (Morris *et al*., 1998) Now large number of private seed companies (500 in 2011) are active in India and most of them are having their own R&D and investing about 5-20 per cent of their sales revenue in R&D (Dravid, 2011). However, private seed companies have shown interest in developing low-volume and high-value seed, such as those of vegetables, cotton, sunflower, maize or other hybrid dominated crops (Anonymous, 2012). Since most of these companies were using public material, protection was not a major issue and wherever needed biological protection provided by hybrids was adequate. But now it is quite likely that biological protection of hybrids may not be adequate, especially for single-cross hybrids, and some form of legal

protection will be needed to protect the interest of private plant breeding. Besides, India as a signatory country of Trade Related Intellectual Property Rights (TRIPs) agreement under World Trade Organisation (WTO), it is bound to provide patent or protection or combination thereof for plant varieties. Therefore, India has adopted the protection of plant varieties in 2001.

The literature suggests that the impact of IPRs is not uniform across the countries and also there is no consensus among the economists. Proponents argued that IPRs provide incentives to innovators to invest in R&D which result in development of new varieties and increases availability of improved varieties to farmers (Kanwar and Evenson, 2003; Kolady and Lesser, 2009). Further, it facilitates the flow of genetic material and new varieties across the countries as licensing and royalty agreements are widespread world over (Wijk, 1996). However, opponents contented that IPRs have not played any role in stimulating R&D investment and development of new varieties (Leger, 2005; Drew, 2010); and the stronger protection may even cut the global rate of innovation (Grossman and Helpman, 1991). In particular, IPRs in developing countries has not provided the expected results, especially in the transfer of technologies from developed countries, because weak R&D infrastructure in developing countries hinders adoption of new technologies (Correa, 2001). In this context, the case of India is somewhat different, in the sense that it has a well-developed scientific infrastructure and a diversified seed industry. The question now arises how public and private breeding programmes are responding to this policy change. In particular, which organisations, public or private are seeking protection, and which crops are witnessing more protection activities. Has there been an increase in the development of plant varieties and their delivery to farmers after the new IPRs regime? This paper addresses these questions. It specifically provides evidence on the trends in plant variety development and their protection behaviour, and price premium of the protected varieties and impacts by analysing trends in the development and protection, exchange of germplasm and changes in the commercial seed market.

Indian Plant Variety Protection

The main objective of the Protection of Plant Varieties and Farmers' Rights (PPV&FR) Act, 2001 is the development of seed industry by protecting interest of the breeders, seed agencies and

farmers by providing an effective mechanism for protection of plant varieties and rights of the farmers. Three types of rights are provided under the Act. First, breeders' rights which give exclusive rights to produce, sell, market, distribute, import or export the seeds of the protected variety. Second, researcher's rights which allow a researcher to use a protected variety for conducting experiment or research and use the variety as initial source for the purpose of development of another variety. Third, farmers' rights which is unique in the Indian system in the sense that these recognize the rights of farmers as breeders (who has bred or developed a new variety), as conservator (who is engaged in the conservation of genetic resources of land races and wild relatives of economic plants) and as users (who can save, use, sow, re-sow, exchange and share or sell his farm produce including seed (unbranded) of a protected variety). In India, besides protection the new and essentially derived varieties (EDV) like in other countries, extant variety (EV) and farmers' variety (FV) can also be protected (http://plantauthority.gov.in).

Data and Methodology

The detailed information on the PVP applications and registration of varieties in India was collected from published and unpublished reports of the PPV&FR Authority. Trends in these varieties for different crops were analysed in this paper using simple tabular analysis. Few studies have focussed on the determinants (the factors which are considered by breeders) of PVP. Larger market size and stronger IPRs regimes were found to be associated with PVP grants across the countries (Srinivasan,*et al*., 2002). In China, institute origin of the variety, quality characteristics, adaptability of the variety and age of the varieties were major determinants of PVP applications (Hu *et al*, 2006). Most of the studies applied logit model for analysing the adoption behaviour (*Adeogun et al*., 2008; Farid *et al*, 2010). Following a similar approach, we applied the logit model to study the determinants of PVP behaviour of the industry with following explanatory variables.

$$Y = f(X_1, X_2, D_1, D_2, D_3, D_4, D_5, D_6, D_7, D_8, D_9)$$

where: Y= 1 for protected variety, 0 for otherwise; X_1= Yield of a variety (kg/ha); X_2= Number of years after release of a variety; D_1= 1 for public sector variety, 0 for otherwise; D_2= 1 for hybrid, 0 for otherwise; D_3= 1 for short duration variety, 0 for otherwise; D_4= 1 for state variety, 0 for

otherwise; D_5= 1 for regional variety, 0 for otherwise; D_6= 1 for variety is resistant to pest or disease or both, 0 for otherwise; D_7= 1 for maize variety, 0 otherwise; D_8= 1 for cotton variety, 0 for otherwise and D_9= 1 for mean fibre length of the cotton more than 23 mm, 0 for otherwise.

A strong economic logic exists for higher probability of protection for a high yielding variety as compared to a low yielding variety of the same crop. The Indian Council of Agricultural Research-IPR (ICAR-IPR) guidelines suggests that all the extant varieties of ICAR which have not completed 15 years from the date of notification can be taken up for protection under the PPV&FRA as a priority activity (ICAR, 2006). Obviously, the varieties which are in demand are likely to be protected in this category. The private sector varieties are guided by profit motive in opting for the protection. A marked difference in the protection status can thus arise depending on whether the variety was developed by the public institution or private sector. It was also expected that parent lines of hybrids having higher seed sale and probability are likely to be protected. Further, as cost of R&D involved in bringing out a hybrid is higher in comparison to open pollinated variety, it is expected that the probability of protection of hybrids is high.

For the purpose of analysis, a distinction was made between varieties based on the extent of geographical area where the variety can be cultivated. A variety recommended for more than five states is classified as a national variety, two to five states as a regional variety and one state as a state variety. The national variety can have a higher market share and profit compared to the regional and state varieties is expected to reflect in their protection status. Similarly, varieties with additional features like pest and disease resistance, abiotic stress resistance, quality traits etc are more likely to be protected. Since the model contains dichotomous dependent variable, the maximum likelihood estimation method was used to estimate the logit model. Three crops, namely rice, maize and cotton varieties were selected for the analysis based on their commercial importance and protection coverage of varieties. In each crop, based on availability and accessibility of complete required information, sample size was fixed as 30 for protected varieties. And equal number of unprotected varieties was also randomly selected from the varieties which are recently released and eligible for protection. In total, 180 varieties (60 varieties from each crop) were selected for analysis out of which 111 varieties

were from public sector and 69 were from private sector. Data regarding the information about the varieties was compiled from published government reports (Rani *et al*., 2011; Kaul and Kumar, 2011; Shanmugam and Gunasekaran, 2007) and private seed companies' products catalogue and website.

Economic benefits of protected varieties such as premium price, better bargaining power and market share are likely to stimulate the investment in plant breeding and therefore promote the growth of seed industry. Availability and accessibility of the data limits the measurement of these benefits, however, the economic value of plant variety rights (premium price) was effectively measured through hedonic pricing models in the past studies. The hedonic pricing model is mainly developed for explaining the relationship between price and quality characteristics of the commodity. Some studies have established the relationship between seed price of a plant variety and its quality characteristics by using hedonic pricing model and estimated the economic value of each characteristic of a variety (Dalton,2004; Lambert and Wilson, 2003; Lesser,1994; Drew, 2010). By adopting Lesser's approach, premium price for protected plant varieties were estimated. The hedonic pricing model was applied to three major crops (rice, maize and cotton) and estimated the equation for three crops by fitting the model separately. A pooled model for all the three crops was also estimated to assess consistency of the results. It is hypothesised that farmers pay certain amount for desirable characters of the variety, and the price of a variety will be sum of marginal value of different characteristics of the variety. Regressing seed prices of the varieties on characteristics gives an estimate of the contributions of the variety characteristics to the price, that is, the implicit price of the attributes. Retail seed price of selected crop varieties collected through survey was used as dependent variable. The semi-log linear form of the hedonic pricing model with following variables was estimated.

$$\ln Y = f(X_1, D_1, D_2, D_3, D_4, D_5, D_6, D_7, D_8)$$

where; lnY= Natural log of seed price of a variety (Rs/kg); X_1= Yield of a variety (kg/ha); D_1= 1 for protected variety, 0 for otherwise; D_2= 1 for public sector variety, 0 for otherwise; D_3= 1 for variety is resistant to pest and/ or disease, 0 for otherwise; D_4= 1 for maize variety, 0 for rice; D_5= 1

for cotton variety, 0 for rice; D_6= 1 for mean fibre length of the cotton more than 23 mm, 0 for otherwise.

Quantifying the impact of PVP on the Indian seed industry is a challenging task. This study has examined the initial impact by assessing the changes that occurred in the seed industry based on four quantitative indicators. First, the export and import of germplasm were estimated to capture the international flow of new varieties. Second, the decadal growth in the number of varieties was worked out to reckon the availability of improved varieties in the market. Third, the trend in breeder seed production and distribution of quality seeds was measured to assess the availability of quality seeds to farmers. Further changes in public and private shares in quality seed distribution and improvement in seed replacement rate (SRR) of selected crops were also studied. Fourth, the number of public-private partnerships (PPP) was studied to analyse the changes in marketing channel in dissemination of new technology and revenue generation by the public sector through PPP. The export and import of seed germplasm information was compiled from various annual reports of National Bureau of Plant Genetic Resources (NBPGR). Details of notified varieties were compiled from the website of Ministry of Agriculture (Seednet, 2012), breeder seed production was compiled from the annual reports of the AICRP-National Seed Project (NSP) and the data on PPP in commercialisation of new varieties or new seed technologies were compiled from National Seed Association of India (NSAI, 2011).

Results and Discussion

Trend in PVP Application and Certification

Since 2006, the PPV&FR authority started regular functioning, and initially the Authority invited applications for only 12 genera and species of the major food crops under the Act. Gradually, it had expanded its coverage in other crops and in total 54 genera and species in 2011, which include cereals (8), pulses (7), oil seeds (11) vegetables (7), spices (5), fibre crops (6), flower crops (6), medicinal plants (4) and other crops (3). The PVP applications started to be received by PPV&FRA from 2007 onwards. It is evident from Table 1 that within 6 years, number of applications increased about three times, i.e. from 432 in 2007 to 1361 in 2011. In total, 4268 applications have been filed till 2012, out

of this; the highest numbers of applications were filed in the EV category followed by FV, and NV. The number of new varieties was nearly doubled from 2007 to 2012, and their share varied from 12 to 81 per cent in the last five years. There was substantial increase in the farmers' varieties from two in 2007 to 939 in 2011. However, in FV category there were very high fluctuations over the years. In 2011, a large number of PVP applications for FV category were received (939) and just in the preceding year, only four applications were received. It might be due to the enhancement in the awareness level among farmers about the protection of plant varieties.

Although the number of private companies applied for the protection in the PPV&FRA is very low (12) in the initial year, within a short span of time the Authority could build the confidence in the Indian seed industry and number of the companies applying nearly doubled in the last six years. Although total applications have been reasonably good in number, only about 13 per cent of them were issued the protection certificate. Out of 546 certificates issued, 91 per cent were for EVs, followed by eight per cent in NVs and one per cent in FVs category. The variation among these categories might be due to the difference in the registration procedure followed. For instance, the EV will have to go for one year DUS testing and in case of NV the testing is for two years.

Table 1. Trend in PVP applications and titles issued under PPV&FRA in India

Year	Crop genera& species covered	No. of private seed companies	Applications filed by all sectors					Titles issued	
			EV	NV	EDV	FV	Total	EV	Total
2007	18	13	355	75	0	2	432	-	-
2008	18	20	389	153	0	5	547	-	-
2009	21	20	385	176	0	127	688	163	168†
2010	45	30	96	440	1	4	541	60	60
2011	54	27	257	164	1	939	1361	91	106‡
2012	57	34	260	137	0	302	699	182	212*
Total	-	-	1742	1145	2	1379	4268	496	546
(%)	-	-	40.8	26.8	0	32.3	100	90.8	100.0

Note: EV=extant variety; NV=new variety; EDV= essentially derived variety; FV =Farmers variety; variety includes hybrid also; † includes 2 NV and 3 FV: ‡ includes 15 NV; includes 26 NV, 3 FV and1EDV.*

Institutions and Crop Focus of PVP Applications

The composition of varieties filed by different institutions show that about 55 per cent of the total applications filed by private sector were in NV category, which indicated their preference for protection of new varieties over the older varieties. The concentration of applications was the highest in cotton, followed by cereals, vegetables, and relatively low in oilseeds and least in pulse crops (Table 2). It revealed that private companies focussed on the major crops, which have the high market demand. In farmers' variety, almost 100 per cent applications were filed for cereal crops, particularly rice and negligible applications were for pulses and oilseeds. Interestingly, four applications had been filed under the NV category by farmers.

Table 2. Composition of varieties filed by different sectors (2007-2012)

Crop	Private sector			Farmer	Public sector			Total			
	EV	NV	Total	FV	EV	NV	Total	EV	NV	FV	Total
Cereals	252	358	610	1352‡	478	110	588	730	472	1348	2550
(%)	41.3	58.7	100	-	81.3	18.7	100	28.6	18.5	52.9	100
Pulses	5	19	24	22	187	30	217	192	49	22	263
(%)	20.8	79.2	100	73.3	86.2	13.8	100	73.0	18.6	8.4	100
Oilseeds	41	51	92	3	53	3	56	94	54	3	151
(%)	44.6	55.4	100	-	94.6	5.4	100	62.3	35.8	2.0	100
Vegetables	161	215	376	1	44	1	45	205	216	1	422
(%)	42.8	57.2	100	-	97.8	2.2	100	48.6	51.2	0.2	100
Fibres	349†	329	678	0	112	18	130	461	347	0	808
(%)	51.5	48.5	100	-	86.2	13.8	100	57.1	42.9	0.0	100
Others	2	0	2	5	60	7	67	62	7	5	74
(%)	100.0	0.0	100	-	89.6	10.4	100	83.8	9.5	6.8	100
Total	810	972	1782	1383	934	169	1103	1744	1145	1379	4268
(%)	45.5	54.5	100	-	84.7	15.3	100	40.9	26.8	32.3	100

† includes one essentially derived variety; ‡includes 4 new varieties from farmers.

The public sector had mostly filed under the EV category, i.e. more than 84 per cent of the applications across the groups. These public varieties were dominated by cereals and pulses and to some extent to fibre crops. When compared to public sector, except pulses and spices, private sector dominated all other groups. Similar types of findings were reported by Hu *et al* (2006) for China. Public sector was protecting their the extant varieties, perhaps to see in opportunity of benefit sharing in case these are used in breeding programs of private sector. It is also observed that private sector has

given less attention to the crops, where public sector R&D is high. This finding is in line with other study conducted for UPOV-member countries where it was found that concentration of PVP certificates is less in the case of crops where public sector or co-operative institutions have played substantial role in plant breeding (Srinivasan, 2003).

Determinants of PVP

The results of the estimation of the logit model are presented in Table 3. The high value of R^2 shows that the determinant model fits the data reasonably well. The pooled regression estimates also conform to the results of individual crop equation estimates. A positive coefficient for explanatory variables increases the probability of success. Most of the variables are significant and have expected signs. Yield, as assumed, has a positive influence on the protection. Odds ratio indicated that for one quintal increase in the yield, there is almost equal chance for a variety being protected or unprotected. It might be due to the fact that companies will protect all the varieties beyond a particular yield level.

Institute origin of the variety has revealed mixed result. If a variety belongs to public sector, odds ratio in favour of protection was high for rice and maize. It implied that compared to the private varieties, public varieties are more likely to be protected. In case of cotton, the picture was just reverse. If a variety belongs to public sector, it had a lesser chance for protection as compared to private sector varieties. It might be due to the fact that private sector played a major role in cotton research and varietal development, especially after introduction of *Bt* cotton in the country, and the PVP application analysis also confirmed the private sector domination in cotton. Interestingly, age, type and duration of the variety are non-significant and did not influence the protection behaviour. It shows that industry does not differentiate the characteristics such as variety and hybrid, long duration and short duration and age of variety while making decisions regarding protection. During the survey, private companies' personnel also mentioned that they were forced to apply for protection in order to prevent illegal claim of ownership or copying the variety by the competitors. As expected, adaptability of a variety was positive and significant in determining the protection behaviour of the industry and the varieties with the national coverage were more likely to be protected.

Table 3. Determinants of PVP behaviour of seed industry

	Rice (N=60)			Maize (N=60)			Cotton (N=60)			Pooled (N=180)		
Parameters	Coeff.	SE	Exp(B)	Coeff.	SE	Exp(B)	Coeff.	SE	Exp(B)	Coeff.	SE	Exp(B)
Response variable: Protection status of a variety (1= PVP; 0=otherwise)												
Intercept	3.21	2.57	24.68	5.39	3.28	218.14	5.70	2.24	299.49	5.52	1.38	249.27
X_1 (Yield)	-0.001***	0.00	0.99	0.001***	0.00	0.99	0.001*	0.00	0.99	-0.001***	0.00	0.99
X_2 (Age)	0.22	0.15	1.25	-0.15	0.14	0.86	-0.06	0.11	0.94	-0.07	0.05	0.93
D_1 (Origin)	2.30**	0.99	9.94	2.98***	1.02	19.61	-2.57*	1.38	0.08	1.07**	0.47	2.92
D_2 (Type)	1.28	1.16	3.59	1.27	1.58	3.55	0.03	0.92	1.03	0.45	0.52	1.57
D_3 (Short duration)	0.11	1.10	1.11	-0.22	1.23	0.80	0.70	0.88	2.02	0.04	.048	1.04
D_4 (State variety)	-2.01*	1.08	0.13	-2.91**	1.32	0.05	-3.29**	1.40	0.04	-2.19***	0.54	0.12
D_5 (Regional variety)	-0.23	1.15	0.79	-0.74*	1.43	0.48	-3.13**	1.60	0.04	-0.94*	0.58	0.39
D_6 (Resistant variety)	1.39*	0.80	4.03	2.42***	1.08	11.27	1.66**	0.86	5.27	1.725***	0.42	5.61
D_7 (Maize variety)	-	-	-	-	-	-	-	-	-	0.006	0.58	1.01
D_8 (Cotton variety)	-	-	-	-	-	-	-	-	-	-2.92***	0.93	0.05
D_9 (Long-staple cotton variety)	-	-	-	-	-	-	2.35**	1.11	10.44	-	-	-
-2Loglikelihood		48.46			34.14			46.68			166.17	
Cox & Snell R^2		0.44			0.56			0.46			0.37	
Nagelkerke R^2		0.59			0.74			0.61			0.49	

Note: ***, ** and * indicate significance at 1%, 5% and 10% respectively.

Pest and disease resistance traits also have expected influence and high odds ratio for varietal protection. The odds ratio for resistant variety for maize was the highest (11.27) followed by cotton (5.27) and rice (4.03). The odds ratio for resistant variety for maize was the highest (11.27) followed by cotton (5.27) and rice (4.03). It indicates a resistant variety would have 11 times higher chance for protection than a non-resistant variety. Similarly, quality parameters also favourably influenced the protection decision in case of cotton varieties. It implied that varieties with better product quality are more likely to be protected (10 times higher) than other varieties.

Valuation of Plant Variety Protection

The hedonic model explains more than 73 per cent of the variation in the seed prices for all the three crops (Table 4). As expected, protection status of the variety influenced the price positively and significantly. Protected varieties had a premium price of 11 to 15 percent over the unprotected varieties. This is considerably higher than that reported by Lesser (1994) for soybean in USA (2.3 percent), but lower than that of ornamental crops (23 percent) reported by Drew (2010). The pooled regression estimate in our case shows very high premium price (39 percent) for the protected varieties, it may be possible due to wide price differences among the crop varieties ranging from Rs 22 to 100 /kg for rice and Rs 320 to 1300/ packet for cotton in 2011-12. It is worthy to note that premium price should be within the range of farmers' affordability, otherwise small and marginal farmers will be deprived from access to new and improved varieties. Yield, pest and disease resistance and quality variables significantly and positively influenced the seed price. There was an increase in price about 2 per cent for both rice and maize and 10 per cent for cotton for a unit increase in yield and those varieties, which possessed resistance characteristics priced higher. Institute origin of the variety negatively influenced the price. It indicated that the price of private varieties was on an average 10 per cent higher than public sector varieties.

Table 4 . Valuation of premium price for protected varieties through hedonic pricing model

	Rice (N=60)		Maize (N=60)		Cotton (N=60)		Pooled (N=180)	
Variable	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Response variable: ln price of varieties								
Intercept	2.75	0.06	3.11	0.12	5.64	0.09	3.19***	0.16
X_1 (Yield)	0.002***	0.00	0.002***	0.00	0.001***	0.00	0.001***	0.00
D_1 (Protected variety)	0.11**	0.02	0.16*	0.07	0.13*	0.05	0.39***	0.07
D_2 (Origin)	-0.11*	0.06	-0.12**	0.06	-0.09**	0.05	-0.08	0.07
D_3 (Resistant variety)	0.09	0.01	0.11**	0.06	0.10**	0.04	0.21***	0.07
D_4 (Maize variety)	-	-	-	-	-	-	0.56***	0.12
D_5 (Cotton variety)	-	-	-	-	-	-	3.25***	0.16
D_6(Long-staple cotton variety)	-	-	-	-	0.09*	0.05	-	0.09
R^2	0.81		0.73		0.87		0.94	

Note: ***, ** and * are significance level at 1%, 5% and 10% respectively

Early Impact of PVP on Indian Seed Industry

Promotion of varietal development and improving accessibility of quality seed to farmers were the major objectives of the PPV&FR Act**.** Therefore, data on exchange of planting materials, release of notified varieties, seed production, seed replacement rate and public-private partnerships (PPP) are examined to ascertain the early impact of PVP on Indian seed industry. Export and import of seed germplasm were assumed as a proxy for the actual material exchange. It shows that import of annual germplasm accessions increased manifold from a mere 7,816 per year in 1995 to 37,018 in 2012 (Figure 1). A notable change witnessed in the later half of 2000s and import indent was mostly from private companies which indicate increase in private plant breeding intensity in India. The changes occurred in the flow of new plant materials and research activities could be attributed to new IPRs regime. Table 5 presents the decadal growth in the number of notified varieties and shows a significant increase in the varietal releases of major crops during the recent decade (2000-2010) as compared to in the previous two decades (1980-2000). It should be noted that the negative growth was observed in release of notified varieties in pre-PVP decade (1990-2000) for all crop groups, except vegetables.

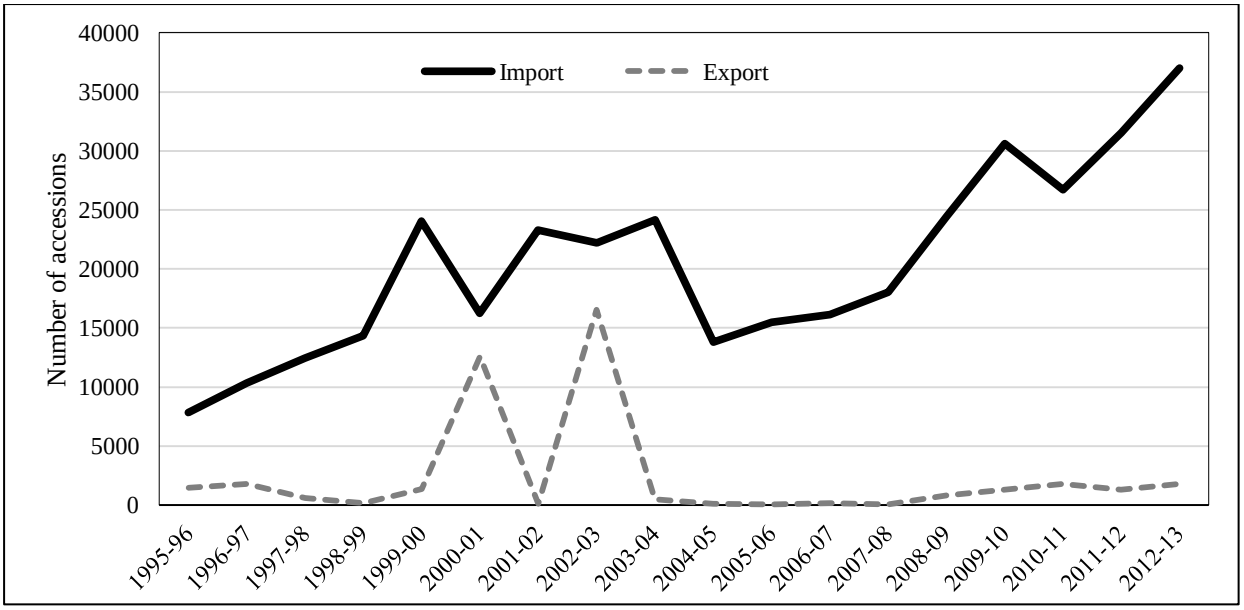

Figure 1. Exchange of germplasm: 1995-2012

Table 5. Crop-wise decadal growth in the number of notified varieties: 1980-2010

Crop	1981-1990	1991-2000	2001-2010	Crop	1981-1990	1991-2000	2001-2010
Cereals				**Oilseeds**			
Paddy	206	197	282	Groundnut	42	39	60
Wheat	75	68	103	Mustard	9	6	53
Maize	46	61	111	Soybean	26	24	32
Sorghum	61	50	46	Sesame	24	15	26
Pearl millet	41	42	48	Sunflower	10	20	28
Sub-total	429	418 (-3)	590 (41)	Linseed	19	7	20
				Castor	11	14	12
				Sub-total	141	125(-11)	231 (85)
Pulses				**Vegetables**			
Chick pea	42	37	62	Bhendi	6	7	13
Green gram	37	32	44	Brinjal	20	25	22
Pigeon pea	38	27	30	Cauliflower	3	6	9
Black gram	18	27	26	Onion	7	4	10
Field pea	15	17	25	Potato	3	8	13
Lentil	10	13	19	Tomato	15	13	28
French bean	6	5	9	Sub-total	54	63 (17)	95(51)
Sub-total	166	158 (-5)	215 (36)	**Cotton**	76	81 (7)	85 (5)

Source: Compiled by authors from http://seednet.gov.in
Note: Figures in parentheses indicate percentage change over previous decade

In the case of cereals, major cereals (rice, wheat and maize) recorded a higher growth in the recent decade; however, a sluggish growth was observed in pearl millet and a declining trend in sorghum. It shows that commercially important crops like maize received more attention. The varietal

growth in pulses was also higher during the recent decade as compared to in the previous decades, except for pigeon pea and black gram and the oilseed sector has also witnessed as same trend, except castor. Mustard crop has recorded an impressive growth in the recent decade, more than five-time increase in the release of notified varieties as compared to that in the previous decades. A gradual and steady trend has been found in the case of vegetables, whereas in cotton, it is almost stagnant. It could be due to the fact that cotton and vegetables are mostly dominated by the private sector and all their varieties might not have been notified under the Seed Act.

Overall, a higher decadal growth in the number of varieties for the majority of crops was recorded in the post-PPVFRA period. There could be many reasons for this significant growth in varietal development like availability of improved breeding tools, advances in Science &Technology such as better identification methods, increased availability of genetic materials (germplasm, inbred lines). Besides, strengthening of plant breeding capacity in public sector through varietal development programmes like All India Co-ordinated Research Project (AICRP) for various crops (ICAR, 2008) increased breeding intensity of private seed companies, but one cannot rule out the possibility of breeders' response to the incentives offered by PVP. This finding is in consonance with the study of Naseem *et al.* (2005), who have reported that PVP has led to the development of more varieties of cotton in the USA. Similar findings were reported by Diez (2002) and Srinivasan (2004). They have argued that plant breeders' rights in the Europe have increased the incentives for private firms to develop new crop varieties. Kolady and Lesser (2009) have also found that implementation of PVP attracted private investment in wheat in the USA and provided high-yielding varieties of these crops in higher numbers from both public and private sectors.

Production of Breeder and Quality Seeds

In India**,** the breeder seeds are produced by different ICAR institutes and state agricultural universities (SAUs). The seed indents are submitted by the public sector institutes and private seed companies across the country, and each breeding centre is allocated the production targets. It is assumed that the changes in breeder seed production may indicate the response of seed industry to the policy changes in the country. The production of breeder seeds has consistently increased for all the

crops, except cotton (Table 6). The trend analysis has also indicated that there was a tremendous increase in seed production of cereals and oilseeds after 2002. Surprisingly, the breeder seed production in cotton declined after 2003. It may be due to the introduction of *Bt* cotton in the country during this period. After the introduction of *Bt* cotton, the cotton seed sector is mainly dominated by the private seed companies. The pattern of distribution of quality seeds has also shown a considerable change. During 1995-96 to 2011-12, it has increased by about two-times for cereals and by about four-times for pulses and oilseeds. In the pulses seed distribution hovered around 5 lakh quintals during 1995-2001, but after that it got momentum and reached a maximum of about 21 lakh quintals in 2010-11. The study has also found that there was no impact on the fibre crops (cotton) and seed production remained stagnated at around 2.5 lakh quintals throughout this period. It could be because it reached a high seed replacement rate (SRR) in as early as 2000. It may be mentioned here that the ICAR had launched a seed project in 2005-06 with a financial outlay of about Rs 20 million, covering 86 centres throughout the country, which increased the capacity for quality seed production of crops and played a major role in changing the seed production scenario in the country (Prasad *et al.*, 2011)

Table 6. Trends in breeder seed production and quality seed distribution in India: 1995-2011

	Breeder seed production (in tonnes)				Quality seed distribution (in '000 quintals)			
Year	Cereals	Pulses	Oilseeds	Fibres	Cereals	Pulses	Oilseeds	Fibres
1995-96	2645	339	992	19	4400	360	1260	260
1998-99	1874	416	595	25	5730	410	1380	290
2001-02	2154	579	1234	39	6560	470	1210	290
2004-05	3189	870	1927	33	8140	740	2340	280
2008-09	4833	1505	2676	20	14740	1450	3990	260
2009-10	5959	1995	3511	22	16520	1970	5070	270
2010-11	6167	1562	3729	80	18260	2080	5060	260
2011-12	6282	1428	3871	51	18450	1920	5840	340

Source: Compiled by authors from annual reports of AICRP-NSP (Crops) for different years and from www.indiastat.com

Seed Replacement Rate

The trend in seed replacement rate indicates the reach of quality seeds in the farmers' field and changes could indicate a better accessibility of quality seeds by the farmers. The Government of India while preparing the National Seed Plan has specified the desirable seed replacement rate (SRR) to achieve the higher productivity based on pollination type of crops, viz. 25 per cent for self-

pollinated crops, 35 per cent for OPVs of cross pollinated crops and 100 percent for hybrids. The trend in SRR shows that during early 2000s, SRR was in the range of 10-20 per cent for majority of crops, except pearl millet and rapeseed and mustard, which has increased to 20-40 per cent in 2011-12 (Table 7). The increase in SRR was higher in the last five years (2006-12). The SRR is much higher than the desirable rate in paddy (40 percent) and wheat (33 percent), but it is quite low for pulses and groundnut. The hybrid dominated crops like pearl millet, cotton and maize recorded higher SRR because hybrid seed is replaced every year. Therefore, one can say that diversification of the seed industry has increased availability of quality seed to farmers. Of course, there have been concentrated efforts by the state line departments to promote new varieties and seed under various schemes like Rashtriya Krishi Vikas Yojana and National Food Security Mission.

Table 7. Seed replacement rate for major crops in India

Crop	2001-02	2006-07	2011-12
Wheat	13	22	33
Paddy	19	22	40
Maize	21	44	57
Sorghum	18	19	24
Pear millet	46	55	60
Bengal gram	4	9	19
Red gram	9	12	22
Groundnut	5	10	23
Rapeseed and Mustard	38	61	79
Soybean	12	28	53
Cotton	21	20	33/100*

*Note: * indicates SRR for hybrids*

Public-Private Partnerships

It is evident from Figure 2 that a noticeable change in PPPs occurred after 2006. The number of PPPs was around 5 per year till 2005 and it increased to about 30 per year and the highest of (42 per year) was noticed in 2011. A total of 174 Memoranda of Agreement (MoAs) were signed between the public institutes and private companies during 2003-2011, which involved 75 private companies, 28 public institutes (ICAR and SAUs) and 4 institutes of Consultative Group on International Agricultural Research (CGIAR). This trend clearly indicates the positive impact of PVP on public-private partnerships.

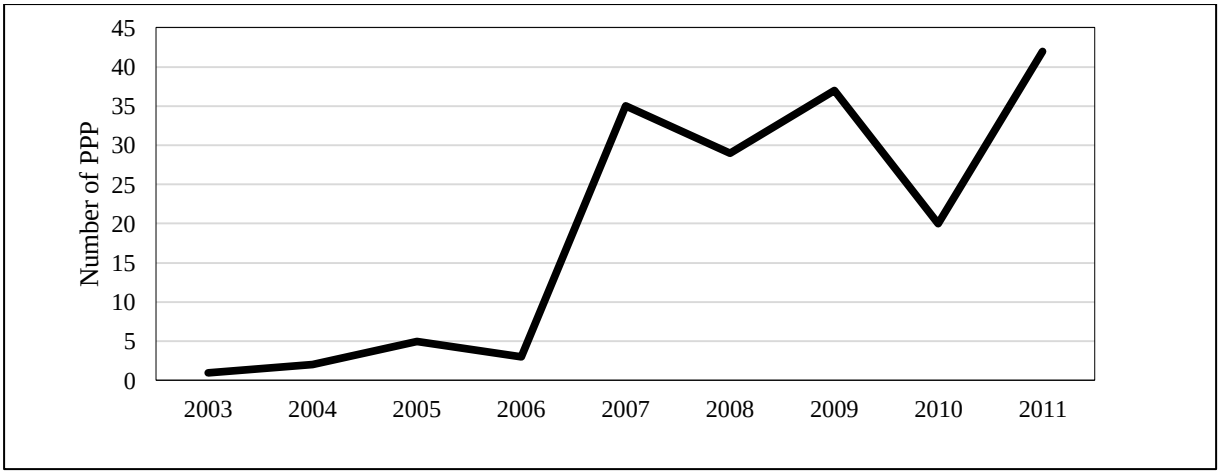

Figure 2. Trend in public-private partnerships (PPP) in seed sector: 2003-2011

Summary and Conclusions

In conclusion, there was a positive response to PVP reform from all the stakeholders and the number of PVP applications filed steadily increased over time. The ownership rights have been issued to 13 per cent of the applications within a short period of the establishment of the PPV&FRA. The trend analysis clearly explains the pattern of concentration of PVP applications across the crops and sectors. Both public and private sectors were active players in PVP, and the former dominated for the extant varieties, whereas it was for the new varieties by the latter. The private sector mostly concentrated on commercial crops, especially vegetables and cotton, while public sector remains active in food crops, i.e. cereals and pulses. The PVP applications from farmers were mainly for rice. The varieties with higher yield and large market were likely to be got protected as there was 11-15 per cent price premium for the protected varieties. This implies that protection of plant varieties may also pave the way for surge in seed prices in India. Therefore, suitable policy measures should be taken to monitor the trend in the seed market and take appropriate measures to ensure farmers' access to protected varieties at affordable price.

There has been an increasing trend in the import of germplasm in the country which indicates high access to international genetic material. It has also been observed that growth in the number of notified varieties in the recent decade (2001-2010) has increased for most of the crops. An increase has also been found in breeder seed production and distribution of quality seed in the country. The

SRR has increased about three-times for the major crops in recent years. A discernible increase in public-private partnerships has been recorded after 2006. Therefore, the available evidence suggests that initial response of the industry to PVP is optimistic. However, there is a need for monitoring these trends in the seed industry, and as more data accumulate over the years, a better understanding of the impact of PVP on the seed industry can be established.

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