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The Extent and Rate of Adoption of Modern Cultivars in India

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Introduction

How quickly cultivars are replaced indicates how effectively the seeds of new cultivars are supplied and taken up by farmers. Many factors determine the rate of replacement, not least how cultivars are popularised by government agencies, how efficiently seed producers market new cultivars, and how superior the new cultivars are to the ones they should replace. Byerlee and Heisey, 1990 argue that if genetic gains in yield due to breeding are higher than the typical annual average of 1%, varietal replacement proceeds more quickly. For example, during the 1960s and 1970s, when annual genetic gains of 2% were achieved in semi-dwarf wheats, varietal replacement rates were higher. Higher replacement rates are also encouraged by high base yields, high deterioration in the seed quality of farmer-saved seed, and less expensive seed of improved varieties. Heisey and Brennan (1989) found that the price of seed purchased by farmers for sowing is a less important factor when base yields are high, and increases in the price of seed for sowing by farmers could even encourage higher replacement by stimulating seed production and its marketing.

Assessing varietal replacement is not easy, and many indices of varietal replacement have been proposed (Johnson and Gustafson, 1963; Brennan, 1984; and Brennan and Byerlee, 1989). Two indices were used by Byerlee and Heisey (1990):

- *The proportion of recent varieties grown in farmers' fields*. This index was proposed by Brennan (1984), and is an index of varietal newness. It is simply the percentage of area sown to varieties released within a specified period. For example, Byerlee and Heisey (1990) used a period of seven years to define a recent cultivar, allowing two years for seed to be multiplied after release and five years for the average longevity of a cultivar.
- *The weighted average age of varieties grown by farmers.* For this index, the varietal age is measured in years from varietal release and weighted by the proportion of area sown to each variety. A pre-selected target period is not required but more detailed information is needed to determine this index. It is an aggregate measure that equals a weighted mean of the replacement periods relating to individual farmers.

Both of these varietal replacement indices were used by Byerlee and Heisey (1990) for farmers' fields survey data, but these indices can also be obtained from statistics on the production of breeder or certified seed. For India, the data for breeder seed demand and production is the most centralised. Seed producers first submit written requisitions, termed 'indents', for breeder seed of released cultivars, to the Directorate of Seeds, Ministry of Agriculture and Co-operation. Statistics are also maintained on allocation and production of the breeder seed. All of these can be used to determine the average age of cultivars at the breeder seed production stage, and we used the data on breeder seed indents (see 'Methods of Analysis') to calculate weighted average age.

For a number of crops, statistics were obtained for certified seed production in Gujarat, Madhya Pradesh and Rajasthan. These data were analysed in the same way as those for breeder seed indents. Information, at the district level, is also available on the uptake of high yielding cultivars (HYVs). These data were used to see the extent of adoption of modern varieties by farmers and whether, as predicted by Byerlee and Heisey, 1990, this is related to the base yields that farmers achieve.

Are Resource-poor Farmers Growing Modern Cultivars?

The percentage adoption by area of high yielding varieties (HYVs) of rice was mapped for six states at a district level (Fig. 5.1). In many districts the adoption of HYVs was low; for example, in nearly all of the districts in MP, adoption was below 50% (Fig. 5.1). There was less than 50% adoption of HYVs in nearly half of all the districts, and these districts, with less than 50% adoption, accounted for a third of the area of production but only one fifth of the amount of production in the area examined (Table 5.1).

The mean yield in the districts where adoption of HYVs of rice is low is 1 t ha^{-1}, which is half that of the 2 t ha^{-1} yield in the districts where there is a high adoption of HYVs (Table 5.1). These highly significant differences ($P<0.001$) in average yield are too large to be explained only by genetic differences resulting from adoption or non-adoption of HYVs. The districts that have low adoption of HYVs have the most marginal agricultural environments where farmers use less inputs.

Table 5.1 Area and amount of production of rice in 149 districts in six states categorised by three levels of HYV adoption.

Extent of adoption of HYVs (% of area)	Number of districts	Area (million ha)	Production (million t)	Mean Yield (t ha^{-1})
0-50	62	5.00	4.90	0.98
50-75	34	3.25	5.58	1.71
75-100	53	6.28	12.78	2.04
Total	149	14.53	23.26	1.60

It is recognised that accurate data on percentage adoption of HYVs are difficult to collect as the complexity of the task causes error in data compilation. This is apparent from many obvious discrepancies in the data such as districts with more than 100% adoption[†], and districts with 0% adoption that not only have high average yields but border on others that have appreciable adoption of HYVs. Nonetheless, the data give an approximation to the real situation, allowing interesting comparisons across crops. For example, does the pattern shown for rice apply to other crops? Despite the very large differences in yield between districts categorised by adoption levels of HYVs, there was a fairly low, but significant, positive correlation between the district yields and district adoption levels in rice ($r^2 = 0.24$***) (Table 5.2). Given the inherent difficulties with these data, a correlation that accounts for about one quarter of the variation indicates an important relationship. Pearl millet and sorghum showed similar correlations (Table 5.2), but no correlation was found for maize or wheat. The data showing an absence of a correlation for maize is convincing. However, this is at variance to what might be expected—a positive correlation should emerge because of the adoption of long-duration hybrids in high potential areas and the low adoption of HYVs in marginal areas due to a lack of adapted early composites. In wheat, the lack of correlation is produced by many low-yielding districts having 100% adoption of HYVs. The reasons for this low yield are not clear but may be explained, in part, by low-yielding districts having a high proportion of HYVs of wheat grown under rainfed conditions.

[†] Such figures were adjusted to 100% in the analyses.

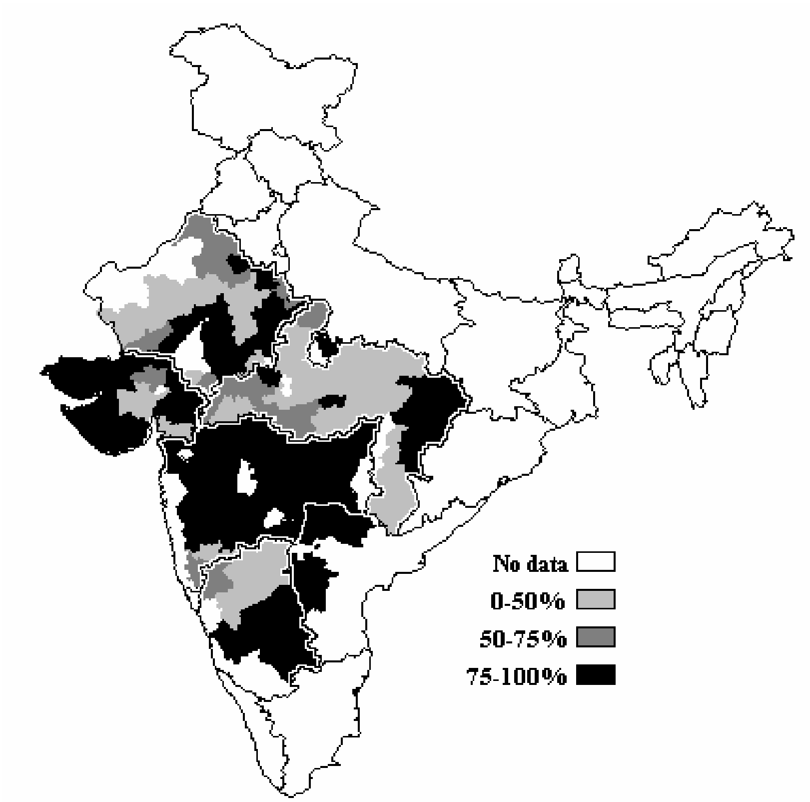

Fig. 5.1 **Percentage adoption of HYVs of rice in India in the districts of six states (Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Rajasthan) in 1983.** ***This is a rough sketch only and it does not purport to depict the political boundaries of India.***

Districts are still large areas that can contain a great diversity of land types varying from irrigated fertile tracts to marginal, hilly areas. What is required to obtain a definitive answer on the relation between extent of adoption of HYVs and land type, is an analysis of data at a level below that of district Unfortunately, such data were not available.

We conclude that in many crops, such as rice, pearl millet and sorghum, resource-poor farmers in marginal areas are benefiting less from HYVs than farmers in more favoured regions. However, as is argued elsewhere in this volume, there are HYVs suitable for marginal areas in many crops. Farmers in these marginal agricultural environments are not exploiting an enormous potential economic benefit from these cultivars. If, for example, another 50% of the farmers having average land holdings were to adopt HYVs of rice in the 62 districts that currently have less than 50% adoption of HYVs of rice, the increase in production would have an estimated value up to Rs. 2.5‡ billion. When all of India is considered, the economic returns from a higher adoption of HYVs is much greater, and still higher economic returns are expected when the value of increased production is considered for all crops.

We also conclude that after decades of formal plant breeding the adoption ceilings of HYVs is disappointing, not just for low resource farmers but in India as a whole. Although some districts have 100% adoption of HYVs in some crops, the overall adoption ceilings of HYVs in any crop are well below saturation. In the five crops studied, rice had the highest adoption rate (but still, on

‡ Assuming 50% of the farmers having typical land holdings change from landraces to HYVs in the area of production having a low adoption ceiling of HYVs (2.5 m ha in the 149 districts studied), and very conservatively assuming that there is a 20% increase in per hectare yield (0.2 t ha^{-1}) associated with adoption of HYVs with unchanged management costs. In this 2.5 m ha there will be an increase of 0.5 million tonnes in the amount of production. At a rate of £100 (Rs. 5000/-) per tonne, it will give an additional benefit of £50m (Rs. 2.5 billions).

average, only 64% of the area of rice was under HYVs), and in sorghum and maize only one third of the area is under HYVs (Table 5.2).

Table 5.2 Percentage adoption of HYVs for five crops in six states and the correlation between yield and adoption of HYVs.

Crop	Number of districts	Extent of adoption of HYVs (% of area)	Correlation between adoption % and district yield (r^2)
Rice	149	64	0.24**
Wheat	133	58	0.04
Pearl Millet	134	46	0.22**
Sorghum	160	33	0.24**
Maize	141	31	0.09

** significant at P<0.01

How Old are the Cultivars That are Being Grown?

Farmers quickly replace old cultivars when there is a continuous supply of new, superior cultivars (Cuevas-Perez *et al.*, 1995). Cultivar replacement rates are, therefore, a good index of success of the All India Coordinated Crop Improvement Programmes (AICCIPs) in releasing new cultivars and the extension agencies in popularising new cultivars. Different indices of varietal replacement were described in the introduction to this chapter. They can be calculated using data on:

- field surveys on the adoption of new varieties;
- certified seed production statistics, and
- statistics on breeder seed demand and supply.

Field surveys demand many resources, whereas good statistics are already available for India on the demand for breeder seed and on the production of breeder and certified seed. However, it is recognised that the age of cultivars under breeder seed production may not accurately reflect the age of cultivars grown by farmers:

- Indents for breeder seed are not perfectly related to the amounts of production of breeder, foundation and certified seed.
- Uncertified (truthfully labelled) seed is produced and sold that may have been produced from sources other than the breeder seed accounted for in the records (e.g. private seed companies).
- Seed of cultivars, both older or younger than average can spread from farmer to farmer.

All of these variables can give rise to both under- and over-estimates. It is, however, difficult to postulate reasons why such errors should be consistently in one direction. Hence, estimates made from breeder seed demand are assumed to be broadly accurate. This assumption was supported by the broad agreement between estimates made using either breeder seed indents or certified seed production statistics.

The weighted average age of cultivars, based on breeder seed indents, was determined for seven crops over 5 to 10 years (Fig. 5.2). The average age of the cultivars for which seed producers demand from the breeder varied from 6 years in pearl millet to 15-17 years in chickpea, sorghum and maize (Fig. 5.2). To see how these figures compare on an international basis, a comparison was made for wheat between India and the UK that has a highly developed and efficient system of varietal replacement. The average age of wheat cultivars for which breeder seed was indented in India was 9 years while the average age of wheat cultivars under certified seed production in the UK (in the period 1987-1993) was 3 years (Fig. 5.2). The real gap is more, since age should be compared at the same production stage—the breeder seed indents used for India underestimate the age of cultivars in certified seed production by 3 to 4 years.

State-level data for certified seed production were analysed for important crops in three states: from data obtained and reported for Gujarat by Jaisani (1995), for Madhya Pradesh by Upadhyaya (1995) and for Rajasthan by Vyas (1995). The certified seed production data confirmed the analysis from breeder seed indents—on average the cultivars are old. The crops with the oldest cultivars in certified seed production were maize (an average of 27 years) and chickpea (an average of 26 years). Apart from pearl millet, no crop had an average age below 10 years. The estimates on state level certified seed production were generally higher than those obtained using national indents for breeder seed (Fig. 5.2) and were often more than would be expected from adding the 3-4 years required from indenting for breeder seed to entering certified seed production (Fig. 5.3). This probably reflects differences between national-level breeder seed data and the state-level certified seed production data that is particular to the three states that were studied.

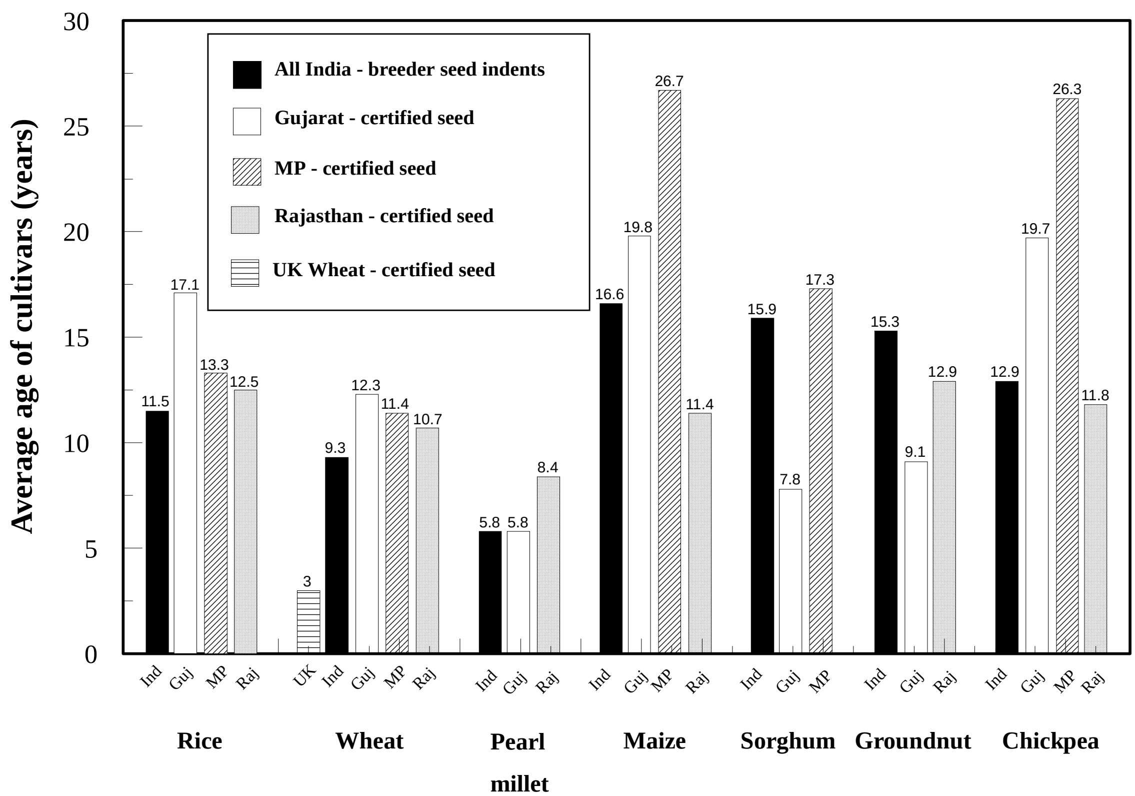

Fig. 5.2 **Comparison of weighted average age of cultivars of important crops estimated from breeder seed indents in India (1984-93), and certified seed production statistics in Gujarat (1992-93), Madhya Pradesh (1993-94) and Rajasthan (1992-93).**

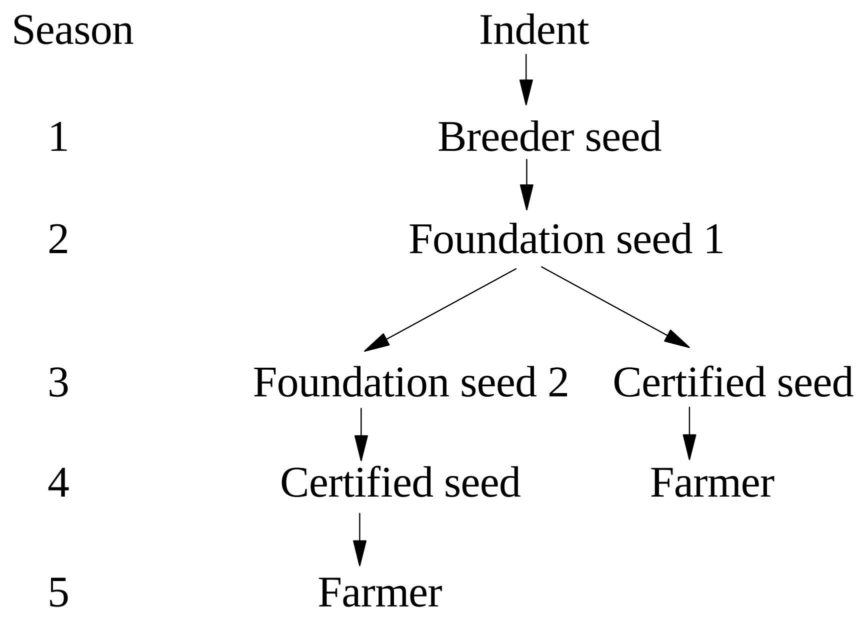

Fig. 5.3 **Steps between breeder seed indent and farmers' fields.**

The cultivars grown by farmers are much older than can be expected when an efficient system of variety popularisation and seed supply is in place. Cultivars are typically 10-20 years old whereas, in the highly efficient system for wheat in the UK, the average cultivar age was less than 3 years (Fig. 5.2). For each additional year in the weighted average age of the cultivars grown by farmers the opportunity is lost of benefiting from the genetic gains due to one year's progress in plant breeding. Byerlee and Heisey (1990) estimated this annual genetic gain to be 1%, while Fiddian (1973) estimated it as 1.3%. Somewhat higher estimates of 2% for the increases per annum due to genetic causes were obtained by Evans (1981) for Mexico, and Godden and Brennan (1987) for Australia and the UK. These estimates are comparable to the gains that were achieved in India during the green revolution period (1960's and 1970's) with semi-dwarf wheats.

The HYVs cultivated by farmers in India are about 15 years older than in a very efficient system. Although it is unrealistic to consider closing this gap entirely, even a halving of the gap would result in a 7-15% increase in yield for farmers growing modern HYVs, assuming a 1-2% genetic gain per annum. In reality, any efforts to close the gap would also result in a greater percentage of the cultivated area being devoted to HYVs so the potential gains are much greater. Over the whole of India, there is a tremendous loss of economic opportunity, as billions of Rupees in potential of increase in production are forgone. The situation is likely to be worse for resource-poor farmers, because the lower adoption ceilings that were found among this group of farmers are likely to be associated with farmers growing older than average HYVs.

Is the Situation Improving?

Trends over time were studied to see if the present situation is predicted to be better or worse than that found from the analysis of past data on the production of breeder and certified seed. The trend in rice, pearl millet, sorghum and groundnut was for the weighted age of breeder seed to increase significantly over time (Table 5.3). The rate of increase in weighted age of pearl millet cultivars and sorghum was high and equalled the increase in years, i.e., for each year the average age increases by a year. In rice and groundnut the weighted age of cultivars increases by about six months for each year ($b = 0.42 \pm 0.1^*$). The linear regressions were positive but a poor fit for wheat and chickpea, while there was no relationship at all in maize. The deteriorating situation in pearl millet has resulted in a three-fold increase in the average age of breeder seed from 1986 to 1993. However, this crop had the lowest average age caused by the rapid adoption of new cultivars in the late 1980s that were resistant to downy mildew, to replace cultivars susceptible to the disease. Replacement rates have subsequently slowed because many of the new cultivars have remained resistant to downy mildew.

Perhaps the situation is worsening in most crops because cultivar replacement has progressed beyond replacing landraces with modern varieties. Byerlee and Heisey (1990) argue that cultivar replacement rates are faster when genetic gains are higher. In the first stage of adoption, high yielding varieties have a large yield advantage over landraces and rapidly replace them. Once replacement of landraces is complete, adoption enters a second stage. In this stage, new HYVs have a smaller yield advantage over older HYVs than HYVs had over landraces. This reduced genetic advantage will, as argued by Byerlee and Heisey (1990), result in slower replacement rates.

Table 5.3 Regression of mean age of cultivars over years.

Crop	Source†	No. of years for analysis	Years	r^2	b ± se and significance of b^2
Rice	BSP	7	1986-1988, 1990-1993	0.76	0.42 ± 0.1*
Wheat	Report	10	1984-1993	0.27	0.31 ± 0.2
Pearl Millet	BSP	7	1986-1987, 1989-1993	0.81	0.96 ± 0.2**
Sorghum	Report	5	1987, 1990-1993	0.90	1.09 ± 0.3**
Groundnut	Report	8	1986-1993	0.51	0.59 ± 0.2*
Chickpea	Report	8	1985-1992	0.34	0.54 ± 0.3
Maize	Report	6	1987-1992	0.01	-0.02 ± 0.5

† BSP = Breeder seed production indent; Report = Annual report of the AICCIP.
‡ * = P< 0.05; ** = P<0.01.

Farmers' Choice: How Large, How New?

Rice and wheat

When the individual years are analysed it is clear that only a few varieties have a high seed demand (Table 5.4). IR36, released in 1981, is the most popular rice variety by far and has the highest breeder seed indent every year accounting for a quarter of the total seed indented for over the 7 year period. The oldest rice cultivar for which breeder seed is still demanded is IR8, released in 1966. There were five more rice varieties that accounted for more than 3% of the total breeder seed indent (Table 5.4) and all of them were more than 13 years old. Of these five varieties, only Kalinga III is an upland rice variety. The others are all irrigated lowland rice varieties.

The 10 wheat varieties in greatest demand accounted for 75% of the total breeder seed production over the 10 year period (Table 5.4). Of these, the varieties Sonalika (released 1967), HD 2285 (1982) and UP 262 (1977) were the most popular and they accounted for 40% of the total breeder seed production. The oldest variety of the 10 most demanded varieties was C 306 which was released in 1965 (Table 5.4).

Table 5.4 **Breeder seed indent of top ten varieties in major cereals as a percent of total indent over 7 years in rice and 10 years in wheat (see Table 2.3 for years analysed).**

Rice			Wheat		
Cultivar	Year released	Indent (%)	Cultivar	Year released	Indent (%)
IR36	1981	24.7	Sonalika	1967	17.5
Rasi	1977	6.5	HD 2285	1982	14.5
Mahsuri	1973	5.5	UP 262	1977	12.4
IR20	1970	5.4	HD 2329	1985	7.1
Kalinga III	1983	3.7	WH 147	1979	4.9
Jaya	1968	3.3	HD 2189	1979	4.5
Saket-4	1971	3.0	C 306	1965	4.0
Swarna	1982	3.0	PBW 226	1989	3.5
Ratna	1970	2.7	HP 1102	1979	3.4
Tellahamsa	1971	2.6	Lok-1	1981	3.2
Total		60.4	Total		75.0

Pearl millet and sorghum

Seed of hybrid parents of pearl millet constituted 70% of the total breeder seed indent. The most popular hybrid parents were those of ICMH 451 (81A x ICMP 451) which was released in 1986 and demand for their seed accounted for about 25% of the total indent. The most demanded open-pollinated variety was WC-C-75, released in 1982 (17% of the total indents) and the second most demanded was ICTP 8203, released in 1988 (9% of the total indent) (Table 5.5). The oldest pearl millet cultivar still popular was BK 560 (5141A x K560-230) released in 1975.

The most popular sorghum hybrids were CSH 5 (MS-2077 A x CS-3541) released in 1974 and CSH 9 (MS-296 A x CS-3541) released in 1981. The parents of these two hybrids accounted for 73% of the total breeder seed indent (Table 5.5). The oldest cultivar still popular is M-35-1, released in 1930 (5% of the total indent).

Table 5.5 **Breeder seed indent of top ten varieties in coarse grain cereals as a per cent of total indent over 7 years in pearl millet and 5 years in sorghum.**

Pearl Millet			Sorghum		
Cultivar	Year	Indent (%)	Cultivar	Year	Indent (%)
WC-C-75	1982	17.2	MS-296 A	1981	22.0
81A	1986	14.3	MS-296 B	1981	12.1
81B	1986	5.7	CS-3541	1974	20.6
ICTP 8203	1988	8.8	MS-2077 A	1974	12.3
K 560-230	1975	7.8	MS-2077 B	1974	5.7
ICMP 451	1986	7.4	M-35-1	1930	5.0
5141A	1975	6.0	MSCK-60 A	1964	2.5
5141B	1975	3.0	MSCK-60 B		
841A	1987	4.7	IS-84	1964	1.9
841B	1987	2.3	MS-2219 A	1970	1.9
			MS-2219 B		
			MR-750	1986	1.6
Total		77.2	Total		85.6

Groundnut and chickpea

The groundnut variety JL 24, released in 1978, alone accounted for 29 % of the total breeder seed indent (Table 5.6). The oldest varieties still popular are TMV 2 and AK 12-24, both released in 1940, and together they account for 14% of the total breeder seed indent.

The most popular chickpea variety was C-235, released in 1960, that accounted for 14% of the total breeder seed indent (Table 5.6). The oldest variety still indented for was Chaffa, released in 1940, but it accounted only for 1% of the total breeder seed indent.

Table 5.6 Breeder seed indent of top ten varieties in legumes as a per cent of total indent over 8 years in groundnut and chickpea.

Groundnut			Chickpea		
Cultivar	**Year**	**Indent (%)**	**Cultivar**	**Year**	**Indent (%)**
JL-24	1978	29.0	C-235	1960	13.6
TMV-2	1940	10.1	Radhey	1968	7.5
GG-2	1984	8.3	Phule G-5	1986	6.8
ICGS 11	1986	7.2	Annigeri-1	1978	6.8
ICGS 44	1988	6.7	Pusa-256	1985	6.7
SB-XI	1965	5.3	JG-315	1981	5.9
AK-12-24	1940	3.9	Avrodhi	1982	5.2
M-13	1977	2.9	H-208	1977	4.5
Girnar-1	1988	2.8	Ujjain-21	1955	4.2
GG-11	1985	2.3	Pusa-212	1982	4.0
Total		78.5	Total		65.2

Summary across crops

The amount of breeder seed indent accounted for by the top 10 cultivars varied from 60% in rice to 86% in groundnut (Tables 5.3, 5.4 and 5.5). Hence, in all crops a small number of cultivars account for most of the breeder seed production.

During 1993, seed producers placed indents for breeder seed of 20 varieties of rice, 32 of wheat, 8 of pearl millet (including parents of hybrids), 14 of sorghum (including parents of hybrids), 52 of groundnut, and 54 of chickpea. However, in every crop only a few of these varieties were in great demand and accounted for a large proportion of the total indent. A large proportion of the total quantity of seed demanded by seed producers was a few popular varieties (Tables 5.3 to 5.6). This proportion ranged from 29% in chickpea to more than half in sorghum. Only a few of the released cultivars become popular with farmers.

Apart from the average age of cultivars, the age of individual cultivars can also be examined. The unweighted age of the oldest cultivars for which there was a demand for breeder seed was high. Except for pearl millet, most of these oldest cultivars were older than 20 years. The oldest sorghum cultivar was released in 1930 (Table 5.5) and the oldest groundnut cultivar in 1940 (Table 5.6).

Seed producers are providing a small choice of varieties. To avoid risk, seed producers tend to estimate demand from farmers, who ask for the older cultivars that they already know, rather than promoting new cultivars that farmers do not know. This is consistent with the data on breeder seed indents, where there is a significant lag before seed producers place indents for new varieties. It takes many years following release before seed producers try new cultivars with farmers on a sufficient scale to create any significant demand from the farmers. Limited choice has a greater adverse effect on resource-poor farmers since they have diverse environments that require several or many environment-specific cultivars.

Pearl millet variety ICMV 221 is a recent example. It was released in 1993 and is a replacement for the bold-grained and early maturing variety ICTP 8203 released in 1988. In spite of its significantly higher grain and fodder yield in AICPMIP trials over many years, seed producers took at least three years before they began to undertake its seed production, on a smaller scale than desired, and they continue with the large-scale seed production of ICTP 8203.

Discussion

The All India Coordinated Crop Improvement Projects (AICCIPs) of the Indian Council of Agricultural Research, that started with the establishment of the maize project in 1957, now form one of the largest and best research networks in the developing world (ICAR, 1992). One of the primary objectives of the AICCIPs is to provide improved genetic material to farmers. However, despite considerable success in breeding improved cultivars they are not reaching farmers in a timely fashion. They are already quite old by the time they enter the initial stages of seed multiplication. By the time the final, certified seed multiplication stage is reached the situation is generally more serious, at least in the three states that were studied. The full benefits of the research are thus not being realised as old varieties continue to be cultivated for much longer periods than desirable.

New varieties do not enter into the seed production process for many seasons. Normally, there is a delay of 4 to 6 years between the official notification of a variety and its commercial cultivation (Vyas, 1995). Seed producers often do not place indents for new varieties immediately. To avoid risk, they tend to estimate demand for seed by asking farmers who demand older, well-established cultivars, rather than promoting new cultivars which are not familiar to them. It takes several years after release before any significant extension activities are taken up by extension workers and seed producers. Hence, the demand necessary for a new cultivar to be successful is greatly delayed.

The studies on Gujarat, Rajasthan and MP, reported in later chapters in this volume, showed that extension workers and seed producers do very little to promote new cultivars until several years after their release. In part, this is due to poor provision of information to seed producers and, particularly, to extension workers. For example, at the national level, the only centrally published description of varieties is by Tunwar and Singh (1985). Thereafter, a catalogue of varieties was produced (Govt. of India, 1993), but it does not describe varietal characteristics. Varietal descriptions, post 1985, are only available in the minutes of the Central Sub-Committee on Crop Standards, Notification and Release, more popularly known as the Central Varietal Release Committee (CVRC) (Ministry of Agriculture and Cooperation, 1985-1993) in more crop-specific publications (AICPMIP, 1988; CRRI, 1992). The minutes of the CVRC are neither circulated widely nor are they freely accessible, and do not reach many of the field-level workers in the extension services or seed sector. Because costs are prohibitive, the print runs of crop specific publications are limited. There are no computerised databases of released cultivars available that would help overcome the costs of printing catalogues.

Information about the release of new varieties and their characteristics is often not available in the annual coordinated project reports. Hence, even breeders and crop scientists involved with them may not become aware of new varieties and their characteristics.

The information channel from the Central Sub-Committee on Crop Standards, Notification and Release of Varieties to seed producers and extension agencies and finally to farmers is very long. There is little organised effort to deliver the message about new varieties to farmers. Unaware of new releases, state departments of agriculture and farm science centres, *Krishi Vigyan Kendras* (KVKs) continue their extension activities with old cultivars. They do not experiment with newly released cultivars from other states because they do not appear on the list recommended by their own state (Jaisani, 1995; Upadhyaya, 1995; Vyas, 1995). There should be a greater exchange of material between states and a greater adoption of national releases at the state level. In essence, ‘free trade’ of cultivars is required by the removal of non-tariff barriers in the shape of a regulatory framework that encourages the selective promotion of state releases within their own states. To enable this freer exchange of germplasm of released cultivars across states, information on new varieties released at a national and state level needs to be quickly and widely disseminated. SAUs, KVKs, and NGOs should then be encouraged to test these new varieties with farmers. However, there is no central procurement mechanism for small quantities of seeds of released varieties, and no central requirement to place the seed of newly released cultivars in designated long term stores. For example, Joshi and Witcombe, 1995) experienced a great difficulty in procuring seed of several released rice cultivars for farmer participatory trials; the seed of some of them could not be obtained for several years.

We have argued above that one of the major reasons for low adoption ceilings and replacement rates is poor popularisation. However, sometimes it may be because breeders have not yet produced superior material. For example, the continuing popularity of the very old sorghum cultivar, M-35-1, is almost certainly because new superior alternatives have not yet been developed. Other cases of very old but still popular cultivars, such as Sonalika wheat (1967), JL-24 groundnut (1978) and C-235 chickpea (1960), may be for the same reason. However, for most of the crops considered, the evidence does not suggest that new varieties are failing to replace old ones because they lack superiority. On the contrary, often their superiority is demonstrated as they replace old cultivars but this replacement takes place too slowly. Analysis of AICCIP data show that new cultivars do have a yield superiority and, in many cases, improved resistance to diseases and pests. In some countries, popular cultivars such as IR36 have already been largely replaced by IR64 and IR72. These cultivars have also been released in India but are not yet popular.

Participatory varietal selection schemes reveal that new cultivars are preferred to old ones and lack of uptake has been due to farmers not being given an adequate choice of cultivars (Joshi and Witcombe, 1995 and Chapter 3.2). In the cases of M-35-1 sorghum, Sonalika wheat, JL-24 groundnut and C-235 chickpea discussed above, farmer participatory varietal selection programmes should be conducted by farmers that have continued to grow them. Would these farmers, when exposed to newer cultivars that are carefully pre-selected to be appropriate to their needs, adopt them or not?

The evidence presented in this chapter clearly indicates the need for a greater flow in the number of new varieties that are released, produced and adopted by the farmers. To feed an ever increasing population, methods must be devised that give a higher uptake of modern cultivars and a faster rate of replacement of older cultivars in farmers' fields. Farmer participatory approaches should be particularly effective in achieving this goal.

Methods Used

Adoption of HYVs

Except for a few states for which district level data are published, statistics on the areas under modern varieties, which are always described as High Yielding Varieties (HYVs), are only obtainable from Directorates of Agriculture, and Bureau of Economics and Statistics in each state. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has obtained such data for seven states, and Dr ML Whitaker of ICRISAT has kindly provided us with them. As an example, we examined the percentage uptake of HYVs of rice in 149 districts of Andhra Pradesh, Madhya Pradesh (MP), Tamil Nadu, Karnataka, Maharashtra, Gujarat and Rajasthan. These were all of the districts for which ICRISAT obtained data for 1983. These data were mapped after exporting them to the IDRISI Geographic Information System (Eastman, 1992). An analysis of district level data was done for a further four crops: wheat, pearl millet, sorghum and maize. The data are reported as area under HYVs. When this area was higher than the total area devoted to that crop then it was assumed that adoption levels were 100%. An analysis of the maps showed that, in general, the data revealed clear geographical trends of uptake. Nonetheless, the data is not completely reliable as there are anomalous districts that show very different adoption amounts to neighbouring ones. In part, this is due to the large size of the districts, as adoption amounts are certainly not uniform within districts.

Breeder seed and certified seed statistics

Seed producers first submit written requisitions termed indents, for breeder seed of released cultivars to the Directorate of Seeds, Ministry of Agriculture and Co-operation. Statistics are maintained on allocations and production of the breeder seed and they can be used to determine the average age of cultivars at the breeder seed production stage. We used statistics on breeder seed indents from two sources, the Directorate of Seeds, Government of India and AICCIP annual project reports (Table 5.7). In pearl millet and sorghum, we indirectly assessed the age of hybrid cultivars from the indents for breeder seed of their parental lines. Using the allocations for breeder seed, the age (years from release to the study year) of cultivars under demand was determined for six crops. The average age of the cultivars for which seed was indented, weighted by the quantity of indent, was computed to provide an estimate of the average age of the cultivars that are under breeder seed production. In pearl millet, breeder seed is produced for open-pollinated varieties and for parental lines of hybrids. The age of hybrid cultivars was therefore indirectly assessed by the age of the parental lines.

Table 5.7 Data analysed in the study.

Crop	Source Government of India	Coordinated Project Annual Report
Rice	1986-88, 1990-93	-†
Wheat	1986, 89	1984-93
Pearl millet	1986-87, 1989-93	-†
Sorghum	1987, 1990-93	1989-93
Groundnut	1988-92	1986-93
Chickpea	1988, 90, 92-94	1985-92
Maize	1987-92	-†

† - = not available.

To estimate age of cultivars, we used the index of Byerlee and Heisey (1990). This index was used for field-survey data using the proportion of area sown to each variety. Instead of area sown, we used the proportion of the total indent.

In any year of seed production Y_s, the age of a cultivar A_t is the number of years since its release Y_r, *i.e.* $A_t = Y_s - Y_r$. This age was weighted by W_i the proportion of the total indent in that year accounted for by that cultivar. Thus the weight, W_i = the amount of seed indented for a variety/total seed indent of all varieties in a year. The total of these weighted breeder seed indents, $\Sigma\ A_t.W_i$, in any year gives the average age of the cultivars for which seed has been indented in that year. This analysis was repeated over years for the various crops. The ages presented in Fig. 3.2.1 are the averages over all of the individual years that were analysed separately.

For comparative purposes, we estimated the age of wheat cultivars in a developed country. Data for certified seed production of wheat varieties from the UK (1987-1993) were extracted from several publications of the National Institute of Agricultural Botany (NIAB). These publications from 1987 to 1993 were: "*Seed Production in Cereals in England and Wales*", "*NIAB Summary Guide to Cereal Varieties*", "*Classified List of Cereal Varieties in England and Wales*", "*Farmers Leaflet for Recommended Varieties of Cereals*" and "*Cereal Variety Hand book*" published in various years.

State-level data for certified seed production for important crops were extracted from consultants reports for Gujarat (Jaisani, 1995), Madhya Pradesh (Upadhyaya, 1995) and Rajasthan (Vyas, 1995).

Using the same technique of weighted average age, we have also estimated the age of cultivars for certified seed production in Gujarat, Madhya Pradesh and Rajasthan for various crops. These can be compared to the age estimates for breeder seed production at the national level to test the validity of the method.

The contribution of individual varieties to the average age of cultivars was also studied.

Assumptions in the methods used

All methods of estimating cultivar age are subject to error. We have used statistics on breeder seed indents as it is a cost-effective. We also used data on certified seed production to check on its validity. It is clear from the discussion below that various factors that lead to both under- and over-estimates, but it is probable that there effect is broadly neutral so that the overall estimates are reasonable.

We estimated the average age of cultivars for which breeder seed has been indented and this is referred to as the "age of cultivars" below. The index used by Byerlee and Heisey (1990), however, uses the proportion of actual area under a variety for calculating the weighted average age. Since our method involves the first stage of seed multiplication it gives a conservative estimate of the weighted average of a cultivar. The indents are placed at least one season before the actual breeder seed production which has to be followed by foundation and certified seed multiplication. Hence breeder seed indent statistics underestimate the age of cultivars grown by farmers by about 4 to 5 seasons (Fig. 2.3). Normally, foundation and certified seed is only grown in the dry season because higher quality seed can be produced in this season, so often the delay of 4-5 seasons represents a delay of 4-5 years.

A factor that may lead to inaccuracies in estimating the age of cultivars under breeder seed production is if the indented seed is not taken up by the indentor or when, for whatever reason, indents for breeder seed do not relate to breeder, foundation or certified seed production. This can lead to both under- and over-estimates depending on which cultivars are concerned. The sale of uncertified or truthfully labelled seed of some varieties by state agricultural universities, state farms and private sector, and seed movement between states through other agencies may lead to errors, but estimates of these sales are often not available. Only for those crops that have high private sector involvement (pearl millet and sorghum) is this likely to lead to an under-estimate of cultivar age. It is likely that the age of purchased certified seed will be less than the age of cultivars grown by farmers, leading to an under-estimate of age, because farmers can grow old cultivars from farm-saved seed, but have to purchase seed of new cultivars. However, once cultivars are grown by farmers, farmer-to-farmer spread will vary with cultivar age, and we can assume the spread is higher with newer cultivars resulting in a compensating over-estimation of the age of cultivars.