ICRISAT VILLAGE LEVEL STUDIES:

ACCELERATING THE ADOPTION OF MARUTI PIGEONPEA

[1]D Kumara Charyulu[*], John Mullen[**], D Moses Shyam[*],

MCS Bantilan[*] and CV Sameer Kumar[**]

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[1] Corresponding author email: d.kumaracharyulu@cgiar.org
* Scientist, Special Project Scientist, Program Director of RP-MIP respectively from ICRISAT, Hyderabad
** Consultant and Pigeonpea Breeder respectively at ICRISAT, Hyderabad

ABSTRACT

Pigeonpea is an important leguminous crop in Semi-Arid Tropics of South Asia and sub-Saharan-Africa. It is a rich source of protein in diets and also sustains soil productivity by fixing environmental nitrogen. The adoption of pigeonpea improved cultivars not only enhances the farmers' income but also ensures household nutritional security. Pigeonpea is one among five mandated crops of ICRISAT's research and has been working for its crop improvement since 1972. Availability of high yielding cultivars, susceptibility to Fusarium wilt and sterility mosaic diseases are major constraints limiting the pigeonpea production and productivity in India. Over the last four decades, ICRISAT has released several medium-long duration cultivars resistant to Fusarium wilt disease in targeted states of India in collaboration with NARS partners. Among those, 'Maruti (ICP 8863)' is the most prominent one released in 1986 in Karnataka state of India. The extent of adoption of this cultivar reached its peak (around 70%) by end of 20th century. But, its spread has continued through neighboring states (Maharashtra, Andhra Pradesh and Madhya Pradesh) through farmer to farmer networks from early 1990s itself. The Agro-biological studies conducted by ICRISAT under VLS project during mid 80s in Maharashtra villages[2] have further accelerated the pigeonpea technology adoption process in the state. Even though Maruti has not released formally in the state, the farmer to farmer exchange of seed got spread quickly in Akola initially and later to surrounded districts of Buldhana, Yeotmal, Amravathi and Wardha. The pigeonpea growers in the state benefitted significantly through enhanced adoption as well as prevention of yield losses due to wilt. The present paper make systematic efforts to document its adoption pathway and quantify the contribution of the VLS village infrastructure to the more rapid adoption of Maruti in the state.

[2] Refer Walker and Ryan (1990) for more detail.

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Introduction

One of the most well-known projects at the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) has been the Village Level Studies (VLS) project now known as the Village Dynamic Studies of South Asia (VDSA) project. The first generation of this project began in 1975 with 6 villages and 240 households in the semi-arid tropic (SAT) region of India.

The direct outputs from the VLS activities were a unique dataset with times series and cross section dimensions allowing the tracking of changes in income, consumption and wealth across years and an environment in the villages which allowed for the simulation and testing of new farming system technologies, community development projects and special purpose surveys.

These outputs were extended to a range of next users which led after further investment by them to five classes of intermediate outcomes including:

- Capacity building through formal and informal training in the VLS project ;
- New methods and theories in the analysis of panel data where volatility of income streams, risk, is pervasive;
- Some guidance in priority setting at ICRISAT and elsewhere;
- Tracking poverty and simulating the impact of rural policy;
- Accelerated adaptation and adoption of ICRISAT farm technologies.

Our focus is on the last of these outcomes. An important output from the VLS project has been the close spirit of cooperation between the VLS households, the resident investigators and other members of the VLS team which has given rise to an environment and infrastructure where other scientists can test the feasibility of new farm technologies. As a result of this environment, where there is interaction between farmers and scientists over several seasons, it is plausible that farm technologies that enhance the welfare of rural households have been identified earlier and adapted and adopted more quickly than otherwise. Viewing these technologies from the viewpoint of rural households, a whole farm (household) perspective in other words, rather than from the more limited perspective of an enterprise, also increases the relevance of the experiments and accelerates adoption.

Our objective in this paper has been to provide some evidence of the value of this environment for accelerated technology development and adoption through a case study of the adoption of Maruti pigeonpea in eastern Maharashtra. Maruti (ICP 8863) was an improved pigeonpea cultivar formally released by ICRISAT in collaboration with NARS partners in Karnataka state during 1986-87. It was resistant to soil borne bacterial wilt which has a devastating impact on the yield of pigeonpea. The incidence of this disease was very rampant in Karnataka during eighties and was endemic in parts of Maharashtra, Andhra Pradesh and Madhya Pradesh. However, ICP 8863 was not officially released, except in Karnataka, and efforts to popularize its spread did not receive any support from the formal seed sector or public extension agencies in the other states.

From discussions with VLS farmers in Kanzara (Maharashtra) an ICRISAT pigeonpea breeder recognised that Maruti had the characteristics sought by the farmers. He gave 5 kg of Maruti to the VLS resident investigator who distributed the seed to five village farmers. This was in 1987 before the start of the rainy season. The use of Maruti spread very quickly over the next five years from Kanzara throughout the district of Akola and then to neighbouring districts of Buldhana, Yeotmal, Amravathi and Wardha (Padmaja, 2012, p.173) mainly through kinship relations (either by blood or marriage), caste group affiliations, friends etc. Padmaja (p.173) noted that Maruti was still the dominant variety of pigeonpea in 2009. Had this opportunity not been provided by the VLS project, the spread of Maruti in Maharashtra would likely have been much slower and hence farmers would have experienced losses from Fusarium wilt for much longer.

More specifically, our objective has been to value the gains for farmers in Maharashtra from this more rapid adoption of Maruti and to relate these gains to the investment made by the VLS project allowing this. According to Padmaja (2012) while Maruti was released in Karnataka (1986) there were no efforts by the formal seed sector or extension agencies in other states to introduce this variety elsewhere. Later in 1996-97 Maruti was released by the state seed company and was adopted throughout Maharashtra but we have chosen a narrower focus where the VLS project was likely to have been influential. We have collected data on cropping systems and returns and the adoption of Maruti from four villages as the basis for our assessment of the economic gains from the more rapid adoption of Maruti first in Akola and then in the four neighbouring districts.

Pigeonpea Industry in India and major states

Pigeonpea (*Cajanus cajan*) is particularly important pulse crop in India where it is consumed as dahl by many families. It has often been grown as a subsistence crop for home consumption but significant areas as now grown as commercial crops. It is a source of protein in diets and sustains soil productivity by fixing nitrogen. Since 1951 both area sown and production of pigeonpea have almost doubled in India (Figure 1).

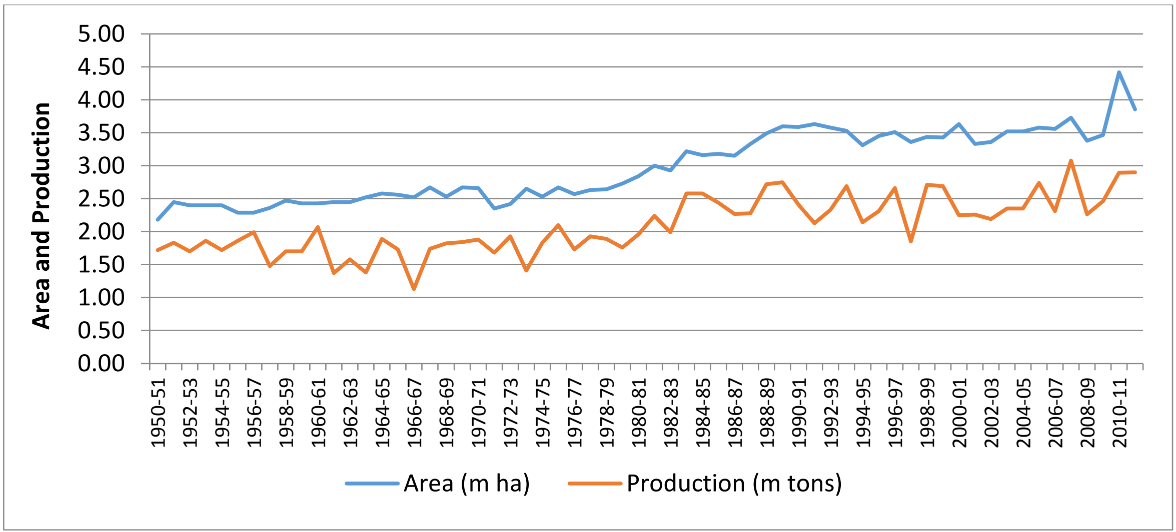

Figure 1: Pigeonpea area and production for India, 1950-2011

Maharashtra is the leading state for pigeonpea cultivation with about 1.2 m ha followed by Karnataka, 0.7 m ha, Andhra Pradesh, 0.5 m ha and Madhya Pradesh 0.4 m ha (Figure 2) (average for 2009-11). Maharashtra contributes the lion share (35%) in the total pigeonpea production in the country followed by Karnataka (15%), Madhya Pradesh (10%) and Andhra Pradesh (8%).

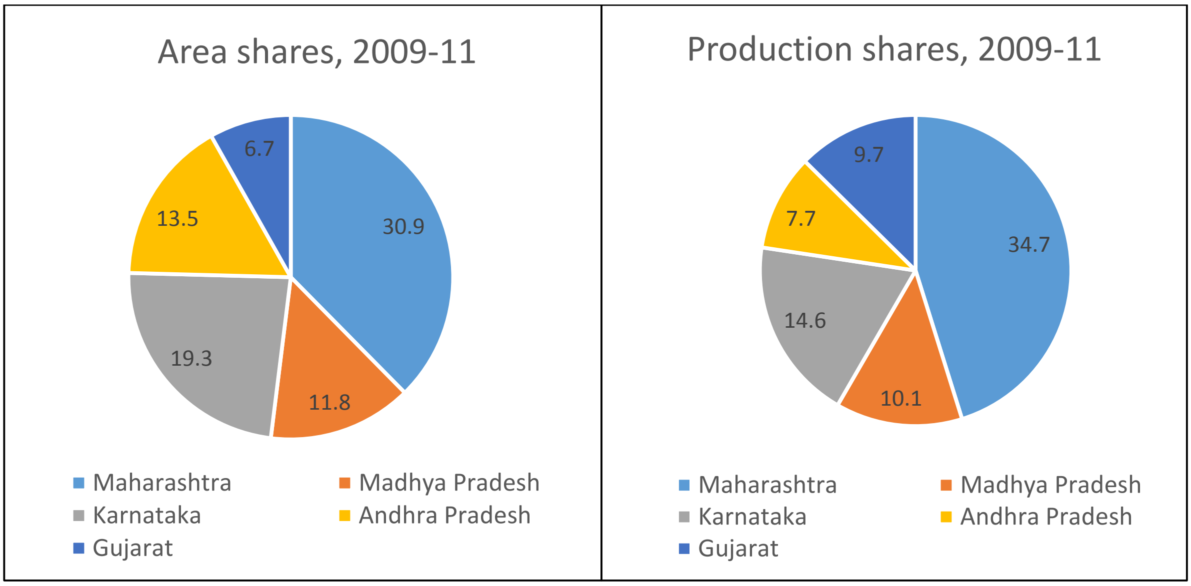

Figure 2: Area and production shares across major states, 2009-11

Our focus in this paper is on Maharashtra. As for India, the area sown to pigeonpea in the state has almost doubled but production has grown more strongly, by almost 3 times since 1980 (Figure 3). This implies that yield has been growing and this can be seen from Figure 4 where yield in Maharashtra has increased from just over 500 kgs/ha in 1980 to just over 700 kgs/ha in 2011.

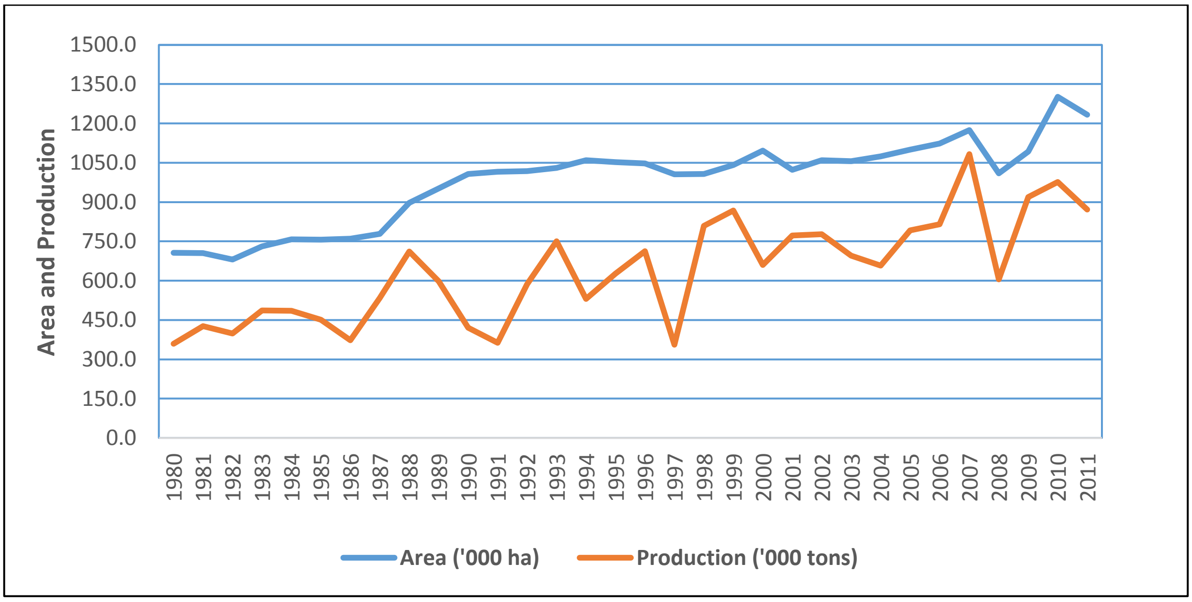

Figure 3: Pigeonpea area and production scenario in Maharashtra, 1980-2011

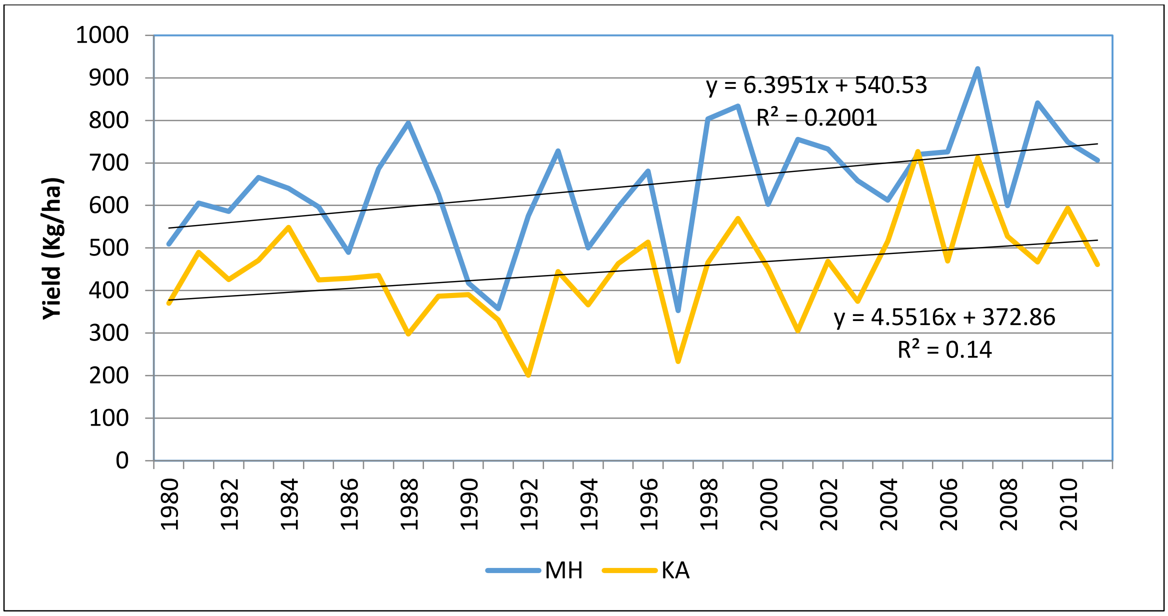

Fig 4: Pigeonpea yield growth in Maharashtra and Karnataka states, 1980-2011

The performance of pigeonpea in major Maruti growing districts of Maharashtra is presented in Table 1 for the triennium period 2008-2011. The largest areas pigeonpea were in Yeotmal and Amravathi districts followed by Buldhana, Wardha and Akola. However, the average yields higher in Akola, Amravathi and Buldhana followed by Wardha and Yeotmal districts. Figure 5 depicts the growth in yield in Akola district between 1990 and 2010. On average, yield has increased at the rate of 9 kg per annum during the last two decades. The peak yields during late 1990s might be due to introduction of wilt resistant pigeonpea cultivars in the district.

District	Area ('000 ha)	Production ('000 tons)	Yield (Kg/ha)
Akola	54.0	42.9	786.1
Buldhana	66.2	48.2	738.8
Yeotmal	109.7	74.8	678.1
Amravathi	105.4	80.9	783.4
Wardha	65.9	45.9	680.9

Table 1: Performance of pigeonpea in major Maruti growing districts of Maharashtra, 2008-2011

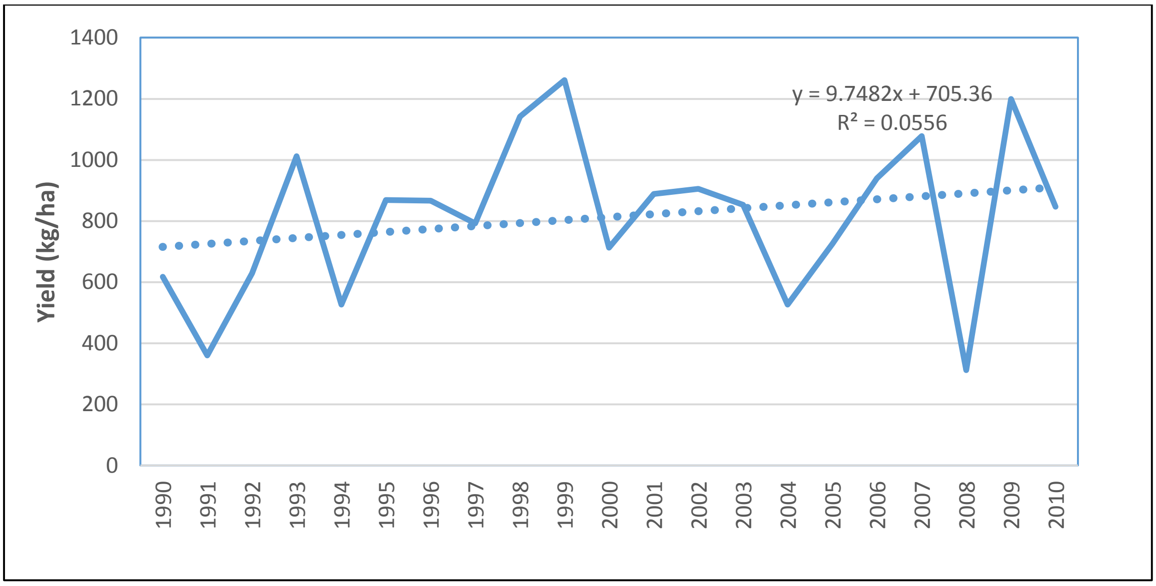

Figure 5: Pigeonpea yield in Akola district, 1990-2010

The price of pigeonpea has risen strongly. In nominal terms it has risen from about 500 Rupees/100kg in 1970s to about 3,500 Rs in the most recent years (Figure 6). Since mid 1990s, there was a significant increase in price through strong policy support which encouraged pigeonpea growers in the state. It was again significantly revised during late 21st century.

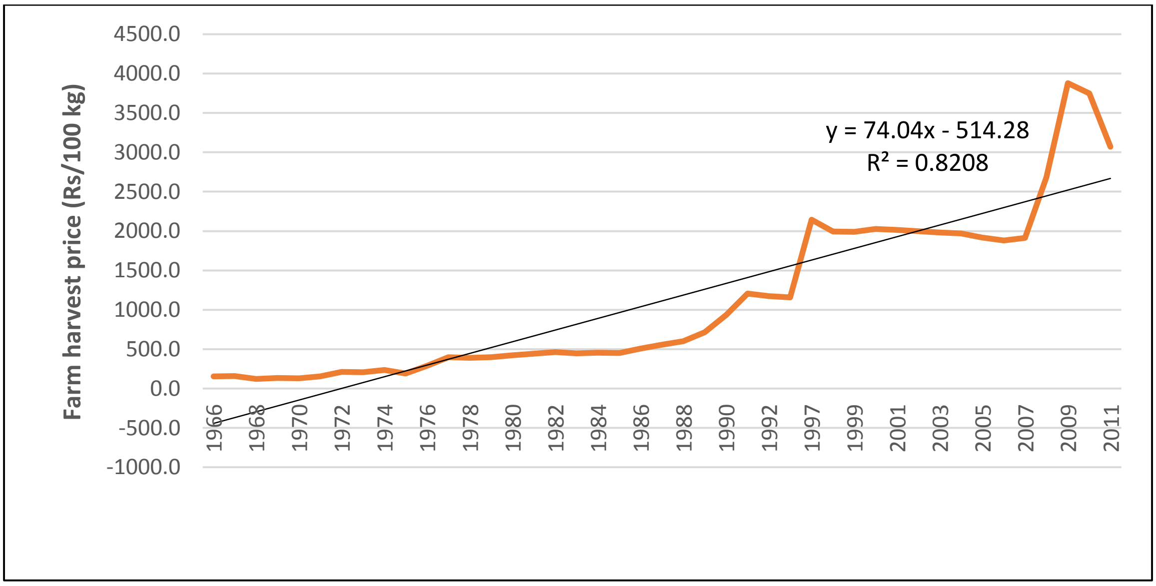

Figure 6: Farm harvest price (Rs/100 kg) of pigeonpea in Maharashtra, 1966-2011

Pigeonpea Breeding at ICRISAT

In recent decades pigeonpea breeding programs at ICRISAT and elsewhere have bred pigeonpea varieties with a range of maturity and disease resistance characteristics suitable for a wide variety of rainfall, farming system and soil type situations.

Fusarium wilt was a major constraint to growing pigeonpea and local varieties yielded 400 kg/ha or less. In 1986, Maruti (ICP 8863) with 160 days duration was released and by 2000 accounted for about 60 – 70% of total area in Akola and neighbouring districts. Maruti took about 10 years to develop at ICRISAT. Even though ICRISAT started its pigeonpea breeding research at 1972, the first 5 years spent on collection of wider source of germplasms. Research on wilt started in about 1974/75. It took 2-3 seasons to develop the 'sick' plots and then screening of germplasm in these sick plots took about 5 years. For a further five years potential resistant lines were field tested in different regions. It was first released in 1986 in Karnataka. A more precise time line for development can be found in Bantilan and Joshi (1996, Table 1 page 5).

Cultivar	Release year	Description of the variety
Hyderabad-185	1956	Released from Nagpur station for rainfed cultivation.
BDN 1	1976	Long duration variety (260-270 days) released for Maharashtra and Madhya Pradesh states. Selection from local land race 'Bari 192-42'
BDN 2	1979	White seeded variety and tolerance to wilt (150-160 days). The genotype is developed by selection from the base population of Bari II-132-A-1.
TAT 10	1985	Produced from PDKV, Akola and BARC, Trombay. TT 2 x TT8 pedigree. 100-115 days maturity and medium bold seeded type.
Maruti (ICP 8863)	1985	Selection from land race and developed by ICRISAT. Maturity: 160-170. Resistant to Fusarium wilt and tolerant to water logging. Released in Karnataka and spread over to Maharashtra and Andhra Pradesh states.
BSMR 175	1991	First genotype having combine resistance for sterility mosaic and wilt. White seeded type with good dhal quality. Maturity:165-170 days. Pedigree: (Pant A 3 x ICP 7035) x BDN 2
BSMR 736	1996	Having combine resistance for sterility mosaic and wilt. Highly responsive to agronomic management (spacing and irrigation) practices and red seeded type. Maturity: 180-185 days. Pedigree: ICP 7217-4-1 x No.148
AKT 8811	2000	145-150 duration variety released from PDKV, Akola. Selection *enmasse*from several crosses viz., (ICPL 6 x DA 6), (ICPL 6 x AL 57), (ICPL 84008 x AL 57), (ICPL 95 x H 80-110)
BSMR 853	2001	Sterility mosaic and wilt resistant, white seeded type Pedigree: (ICP 7336 x BDN 1) x BDN 2
BDN 708	2006	Early maturing (160-165 days) variety suitable for low rainfall and medium soils. Pedigree: BDN 2 x ICPL 87119
Vipula	2007	Early maturing variety released from MPKV, Rahuri
BDN 711	2011	The variety (150-155) is moderately resistant to wilt and sterility mosaic disease. Highly suitable for low rainfall and light to medium soils.

Table 2 Major pigeonpea releases in Maharashtra

Maruti is not resistant to sterility mosaic disease (SMD) and so is now less widely used in some pigeonpea growing areas (Western Maharashtra and Marathwada regions). 'Asha' a long duration variety has this resistance and has slowly replaced Maruti in the SMD susceptible regions. A number of other new varieties (see Table 2) are growing in popularity and they too have similar crop durations (early to medium). SMD is not a problem in the area around Akola and neighbouring districts (Buldhana, Yeotmal, Amravathi and Wardha), the focus area of this study, but wilt is a serious problem, and so Maruti has remained a dominant variety in this area (the Vidarbha region).

Bantilan and Joshi (1996) evaluated the initial economic impact of breeding programs at ICRISAT and Indian NARS which developed Maruti[3]. They reported that fusarium wilt was one of the most widespread and destructive diseases of pigeonpea. A high incidence of wilt was found in Maharashtra (23%), Bihar (18%) and Uttar Pradesh (15%) (Kannaiyan et al. 1984). The disease had the potential to reduce yields by up to 50% and so losses from the disease were often large.

Pigeonpea cropping systems in Maharashtra

Inter-cropping is a key element of traditional farming systems in India especially on small farms. Pigeonpea is often grown as part of an intercropping rotation. Jodha (1979), using data from the VLS villages, pointed to the importance of intercropping. His findings on the extent of and profitability of intercropping and his call for agronomic research in an intercropping context likely had some influence on the direction of crop research at ICRISAT.

Traditional intercropping systems are complex. Numerous crop combinations are used in a single village. Intercropping, besides effectively meeting the needs of subsistence farmers, plays an important role as insurance against risk.

Traditionally, pigeonpea is a rainy season crop sown in June-July with the onset of the monsoon. Pigeonpea as a sole crop is relatively inefficient because of its low initial growth rate and harvest index (Willey et al. 1980). The tall, spreading and long duration varieties of pigeonpea are still grown as a mono crop mainly in dryland areas. However, these are being gradually replaced by early and medium maturing varieties, which escape drought and frost during the reproductive phase. Development of early and extra early varieties of pigeonpea has provided ample opportunity to use pigeonpea in various intensive cropping systems (Ahlawat et al. 1986).

The important intercrops grown in Maharashtra with pigeonpea can be grouped into three broad categories:

1. *Cereals* viz., sorghum, maize, pearl millet and minor millets
2. *Legumes* viz., soybean, groundnut, mungbean and urdbean
3. *Cash crops* viz., cotton and sugarcane

[3] There have been economic analysis of other dimensions of ICRISAT's pigeonpea breeding program including those by Bantilan and Parthasarathy (1997, 1999), Ryan (1998) and Gordon and Chadwick (2007).

There are many factors that influence the choice of companion crop with pigeonpea. Relative prices are important. However soil type is also important because of its impact on water holding capacity. The deep vertisols favour longer duration cash crops like cotton and sorghum. The presence of soil borne diseases influences the variety of pigeonpea chosen. If farmers have access to some irrigation then they might choose a shorter duration crop like soybean so that they can double crop with a cereal like wheat. The challenge is to choose a combination of crops and a row spacing such that the yield losses from intercropping the individual crops is more than offset by the total revenue from the system.

Sorghum + pigeonpea was the most predominant intercropping system in Maharashtra until early 1990s. In general, the yield of pigeonpea when intercropped with cereals is always adversely affected. Due to this, pigeonpea intercropping with cereals like sorghum have reduced significantly in Maharashtra during 1990s. Sorghum was been replaced with cotton (10:1 ratio) due to its remunerative price and high yields. But cotton is a risky crop and farmers slowly replaced cotton with soybean. Soybean + pigeonpea intercropping (6:1 ratio) become is the preferred system due to its short duration, suitability to mechanical cultivation and higher profits per ha. Photos of the pigeonpea + soybean and pigeonpea + cotton rotations are shown as Figures 7 and 8.

In the early 80's the main crops around Kanzara, ordered by area, were cotton, sorghum, green gram and pigeonpea (Padmaja, 2012, Figure 6.1, p.172). Pigeonpea had been more important that greengram (mung bean) during the 70s but production fell in the early 80s perhaps because of increasing losses from Fusarium wilt. Since early 2000s the production of cotton has fallen dramatically while that of soybean has increased just as naturally. Pigeonpea remains third in importance and while wheat and chickpea are close competitors during post-rainy season.

Now farmers around Kanzara typically intercrop pigeonpea with soybean (about 65% of area) although cotton is preferred on good soils (about 30%) and there are small areas (less than 5%) of other crops like sorghum and mungbean (depending on relative prices). Sowing occurs after the rains in July. The cash crops like soybean are harvested in September and pigeonpea by December. The land then lies fallow until June.

Wherever the farmers have access to some irrigation, they plant wheat after the soybean is harvested, effectively double cropping soybean with wheat while intercropping with pigeonpea. Sometimes farmers rotate the system with soybean followed by chickpea (double legume crop) instead of soybean + pigeonpea intercropping. Access to irrigation and market prices is the prime determinants for choosing between soybean + pigeonpea or cotton + pigeonpea cropping systems. There are no strong agronomic reasons to change crops in the following year and so relative crop prices are likely to influence the choice.

Figure 7: Soybean + pigeonpea followed by wheat (after harvesting soybean rows)

Figure 8: Cotton + Pigeonpea intercropping system (10:1 ratio)

Methodology for Assessing the Gains from Maruti

Our objective has been to estimate the gains from the contribution of the VLS project to hastening the rate of adoption of Maruti in Akola and its surrounding districts of Buldhana, Yeotmal, Amravathi and Wardha. In developing a methodology we have been careful to avoid attributing to the VLS project, economic benefits that are rightly attributable to the pigeonpea breeding program. There have also been gains in the productivity of the other crops that pigeonpea is grown with and again our intention has been to avoid attributing to the VLS project, gains more rightly attributable to other crop breeding and nutrition programs. Our intent is to isolate the benefits farmers received from adopting Maruti more quickly than otherwise would have occurred because of the VLS village research environment.

The traditional approach is evaluating the economic welfare associated with a new crop variety has been to estimate the reduction in per unit production costs, k, arising from the new variety. This estimate of k, *bc* in figure 9, is an estimate of the vertical shift in the supply of Maruti and is the basis for estimates of the changes in the price and quantity produced of pigeonpea and associated changes in consumer (area *abfe*) and producer (area *efcd*) surplus using a standard model of the pigeonpea market. Typically this change in potential total welfare over the target population is then scaled through time by the rate of adoption and an estimate of net present value is derived using discounting techniques.

This approach was also used by Bantilan and Joshi (1996). This approach is most sound when the technology has an impact on one enterprise which is unrelated in production with other enterprises.

Evaluating the impact of a new variety of pigeonpea like Maruti is made difficult by the complex farming system it is part of. In the Akola district, pigeonpea is usually intercropped with soybean or cotton. Moreover as a pulse it contributes nitrogen to following crops. In this situation, a single enterprise market model such as represented by figure 9 is a crude approximation of what is actually occurring.

An alternative approach, and our starting point here, is to estimate the change in net income from using Maruti in inter-cropping systems including pigeonpea. This change in net profit, for say, a soybean + pigeonpea system, can be estimated from a gross margin budget (income less variable costs) for a hectare of the soybean/pigeon pea system and then scaled to the target area.

Effectively this estimate of the change in net income is area *abcd* in Figure 9, the change in unit costs, k, times Q, the size of the industry. It underestimates total welfare gains by the triangle, *bfc* which are potential gains as pigeonpea systems, now more profitable because of Maruti, are grown more widely by farmers at the expense of cropping systems that do not include pigeonpea. The area *abcd* are the total industry gains enjoyed by consumers and producers. If the price of pigeonpea does not fall much (demand is highly elastic), then most of the gains accrue to farmers.

There are a number of steps in evaluating the VLS contribution to the adoption of Maruti in our study area. First we estimated the area of pigeonpea intercropping systems in the five districts, then we estimated the adoption of Maruti within these systems. The change in profit from the use of Maruti on a per hectare basis has to be estimated and then scaled up to the gains from Maruti in the districts by applying the area of pigeonpea systems and the adoption of Maruti. This gives a total gain from Maruti in these districts. Finally the acceleration in the rate of adoption of Maruti attributable to the VLS project has to be estimated and applied to these estimates of total gains to arrive at an estimate of the contribution of the VLS project. These steps are discussed in turn.

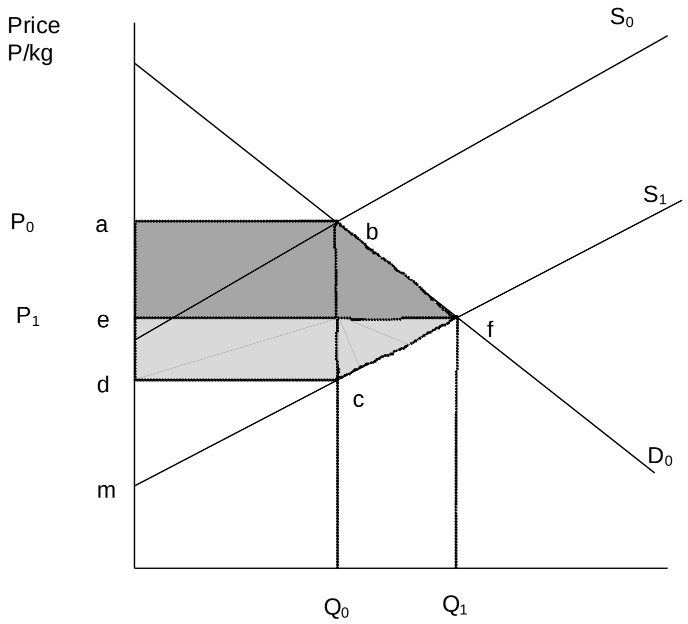

Figure 9: The welfare gains from shifting the supply of Maruti

This is an ex-post study so estimates of these parameters were required over a time period beginning in 1985. A difficulty with an ex-post review is that the changes in farm practice over the observation period arise not only from the new technology but also from other changes in the economic environment in which the farm operates (and perhaps in social and environmental factors conditions as well). This creates significant attribution problems.

There are also difficult recall problems in assembling data and budgets extending back to 1985. Our starting point has been 2013-14. Crop budgets were prepared for 2013 and all prices are in 2013-14 Rs. One of the assumptions involved in this estimation process is that the relative profitability of the alternative cropping systems reflected in the 2013-14 budgets has not changed but it may have been different in early years of the adoption process.

The data on Maruti adoption rates, areas sown to pigeonpea and shares of total pigeonpea area accounted for by the alternative pigeonpea systems and the net gain budgets were obtained from interviews with farmers in the villages, the VLS databases and from scientists and economists. Focus group meetings with farmers were held in the villages of Kanzara, Kinkheda, Lasanpur and Nimbha. Field reconnaissance surveys were extensively conducted to validate adoption information at Akola and neighbouring districts. Secondary data were also collected from Directorate of Economics and Statistics, Akola and Maharashtra State Seeds Corporation/Mahabeej (MSSC) to complement the focus group meetings.

Many parameter estimates were at five year intervals. To form a continuous time series we linearly interpolated these parameters between each fifth year observation. We focused on estimating the benefits in Akola and the other four districts as a group. Our expectation has been that because Maruti was first introduced in Akola, adoption was earlier there than in the other districts. The budgets for the 4 villages in Akola were the basis for estimates of net gains from Maruti for all five districts.

The area of pigeonpea cropping systems and adoption of Maruti in the five districts

Village	Cropping Pattern	Unit	1985	1990	1995	2000	2005	2010	2013
Kanjara	Sole pigeonpea	% s	90	0	0	0	0	0	0
	Cotton + PP	% s	0	60	60	15	0	0	0
	Sorghum + PP	% s	0	20	20	0	0	0	0
	Soybean + PP	% s	10	0	5	70	80	90	100
	BG+GG+PP	% s	0	20	15	15	20	10	0
	area of PP	ha	81.0	91.1	121.5	101.2	91.1	81.0	81.0
Lasanpur	Sole pigeonpea	% s	0	0	0	0	0	0	0
	Cotton + PP	% s	50	60	65	65	60	25	10
	Soybean + PP	% s	0	0	0	0	0	75	90
	Green Gram + PP	% s	25	20	15	20	30	0	0
	Sorghum + PP	% s	25	20	20	15	10	0	0
	area of PP	ha	60.7	70.9	101.2	81.0	101.2	81.0	60.7
Nimbha	Sole pigeonpea	% s	0	0	0	0	0	0	0
	Cotton + PP	% s	100	100	100	60	20	20	10
	Soybean + PP	% s	0	0	0	40	80	80	90
	area of PP	ha	101.2	91.1	81.0	91.1	81.0	85.0	101.2
Kinkheda	Sole pigeonpea	% s	0	0	0	0	0	0	0
	Cotton + PP	% s	50	50	50	50	25	20	5
	Sorghum + PP	% s	45	45	45	45	30	0	0
	Green Gram + PP	% s	5	5	5	5	5	0	0
	Soybean + PP	% s	0	0	0	0	40	80	95
	area of PP	ha	182.2	161.9	141.7	121.5	111.3	81.0	81.0
Akola	Sole pigeonpea	% s	5	3	2	2	1	1	1
	Cotton + PP	% s	55	56	62	56	41	34	30
	Soybean + PP	% s	0	1.000	4	17	38	55	65
	Sorghum + PP	% s	40	40	32	25	20	10	4
	area of PP	ha	62000	76000	77000	88000	108000	101000	98000
Other districts#	Sole pigeonpea	% s	3	2	2	1	1	1	1
	Cotton + PP	% s	60	59	63	55	44	43	40
	Soybean + PP	% s	0	4	11	22	39	48	54
	Sorghum + PP	% s	37	35	24	22	16	8	5
	area of PP	ha	213000	274000	340000	330000	338000	331000	321000

 # includes Buldhana, Yeotmal, Amravathi and Wardha districts

Note: '%s' indicates % sown area under each cropping system

Table 3: The proportion of common alternative cropping systems in the villages

The changes in pigeonpea intercropping systems since 1985 are described in Figure 3 (see also Table 3). As already noted the soybean + pigeonpea system has become popular but at the expense of the sorghum + pigeonpea rotation. The area for cotton + pigeonpea remains important but gone down over time.

The adoption pathways for Maruti in each of the four villages are displayed in Table 4a and for Akola and the other four districts in Table 4b. The adoption of Maruti was rapid once it became available and it remains the dominant variety in the study region. As we anticipated, the adoption of Maruti began sooner in Kanzara after farmers in the village got initial access to seed. It has taken a steep pathway and reached ceiling level of adoption (100%) by 2005 much ahead of neighbouring villages (Figure 10). Even in 2013, the area occupied by Maruti variety was almost 90 per cent.

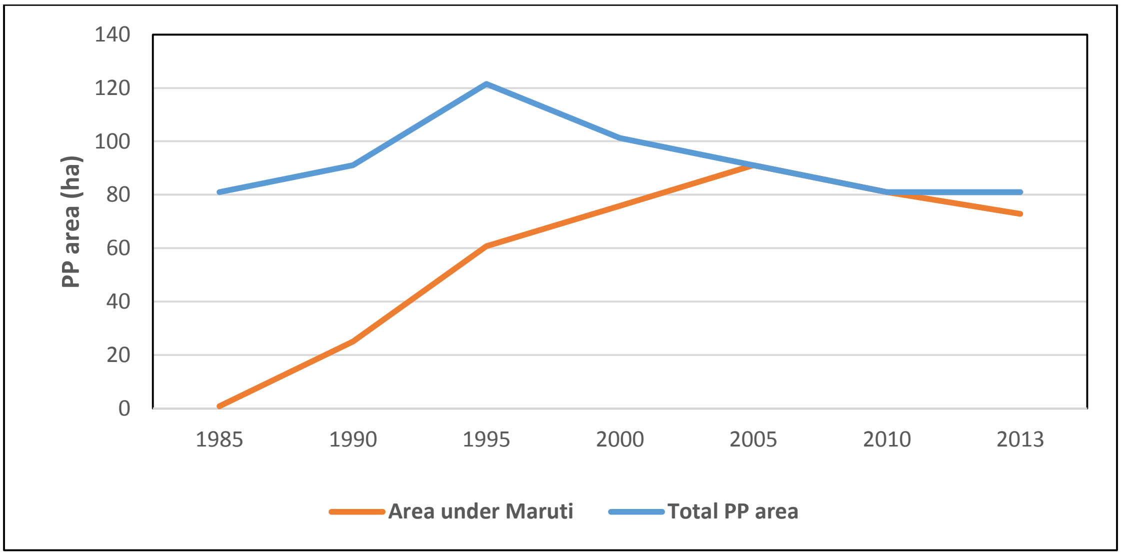

Figure 10: Adoption pathway of Maruti in Kanzara village, 1985-2013

In case of Kinkheda, the companion village of Kanzara, adoption was slower until 1995 and then grew rapidly reaching a ceiling level of adoption of 95% by 2005. It is still a dominant variety in Kinkheda. Lasanpur and Nimbha (non-VLS villages) followed exactly the Kanzara adoption pathway but with a lag of 3-5 years.

Village	Cultivar Name	1985	1990*	1995	2000**	2005	2010	2013
Kanjara	Gavruni (local)	50.0	35.0	20.0	10.0	0.0	0.0	0.0
	Gajara	40.0	30.0	20.0	10.0	0.0	0.0	0.0
	Maruti	1.0	27.5	50.0	75.0	100.0	100.0	90.0
	Local (Black type)	5.0	7.5	10.0	5.0	0.0	0.0	3.0
	Nirmal	0.0	0.0	0.0	0.0	0.0	0.0	2.0
	Ganesh	0.0	0.0	0.0	0.0	0.0	0.0	2.5
	Asha	0.0	0.0	0.0	0.0	0.0	0.0	2.5
Lasanpur	Local	100.0	55.0	10.0	5.0	0.0	0.0	0.0
	Maruti	0.0	15.0	40.0	60.0	95.0	95.0	100.0
	Asha	0.0	0.0	0.0	2.5	5.0	5.0	0.0
Nimbha	Gajara	100.0	85.0	70.0	35.0	0.0	0.0	0.0
	Maruti	0.0	15.0	30.0	60.0	90.0	90.0	80.0
	Asha	0.0	0.0	0.0	5.0	10.0	10.0	20.0
Kinkheda	Local	90.0	77.5	65.0	35.0	5.0	0.0	0.0
	Mahabeej	10.0	20.0	30.0	15.0	0.0	0.0	0.0
	Maruti	0.0	2.5	5.0	50.0	95.0	95.0	90.0
	Asha	0.0	0.0	0.0	0.0	0.0	5.0	5.0
	Tara	0.0	0.0	0.0	0.0	0.0	0.0	2.5
	Ganesh	0.0	0.0	0.0	0.0	0.0	0.0	2.5

** averaged from 1985 and 1995 values; ** averaged from 1995 and 2005 values*

Table 4a: Adoption of pigeonpea by variety in the study villages

District	Cultivar Name	1985	1990*	1995	2000**	2005	2010	2013
Akola	Local	80	70	60	50	20	10	5
	Maruti	0	5	19	24	45	70	50
	Asha	0	0	1	3	5	7	10
	PVK Tara	0	0	0	1	2	3	5
	Others	20	25	20	22	28	10	30
Other districts#	Local	80	70	60	50	20	10	5
	Maruti	0	2	13	24	45	60	45
	Asha	0	0	1	3	5	7	10
	PVK Tara	0	0	0	1	2	5	8
	Others	20	25	20	22	28	18	32

 # includes Buldhana, Yeotmal, Amravathi and Wardha districts

Table 4b: Adoption of pigeonpea by variety in the study districts

From Akola, Maruti spread neighbouring districts like Buldhana, Yeotmal, Amravathi and Wardha through kinship networks (Figure 11). The pattern of adoption in Akola and the other districts is displayed in Figures 12 and 13.

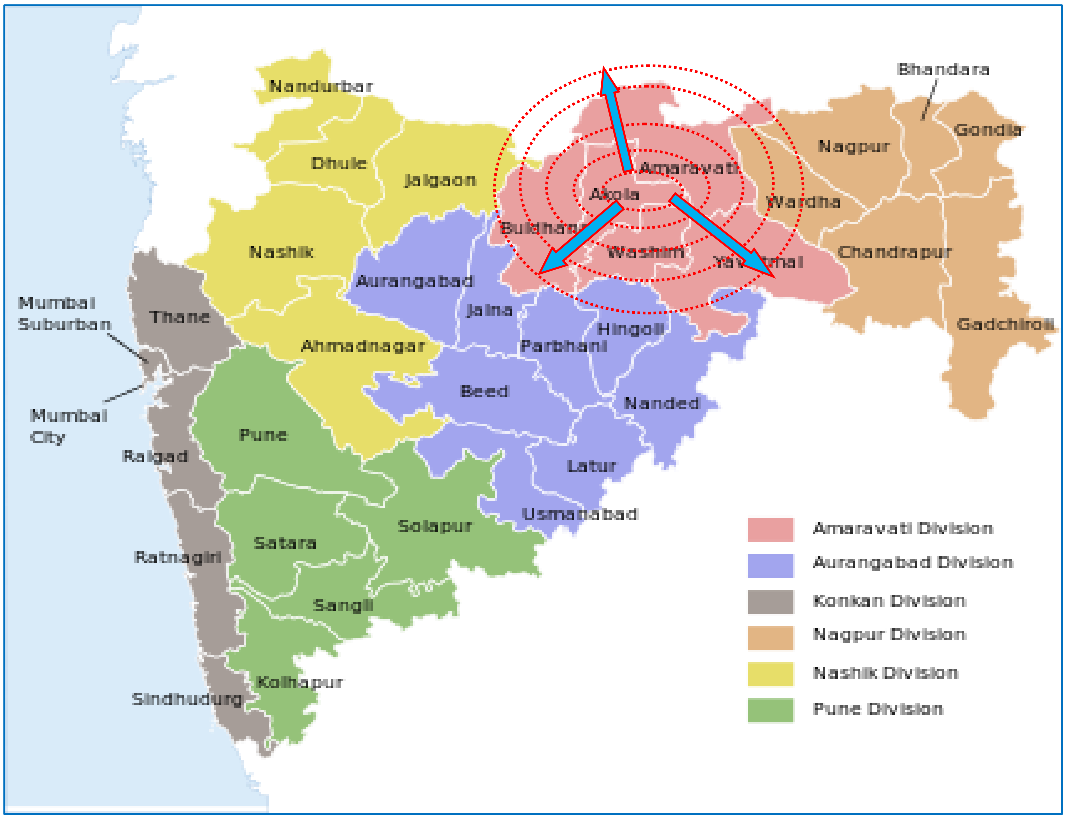

Figure 11: Pattern of diffusion of Maruti in Akola and surrounding districts

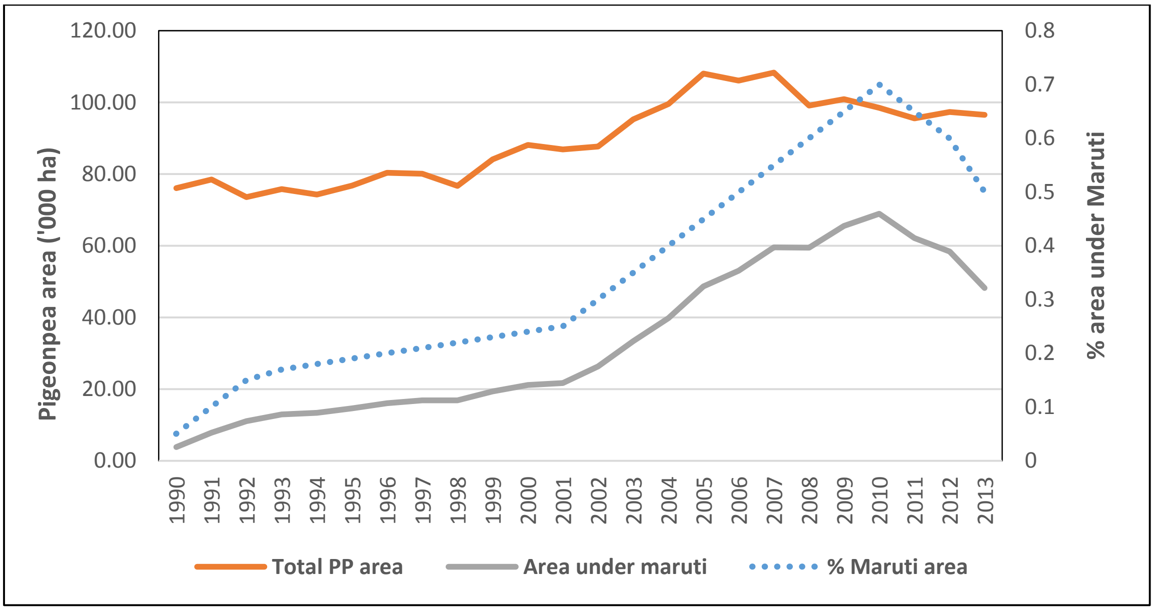

Figure 12: Adoption pathway of Maruti in Akola district, 1990-2013

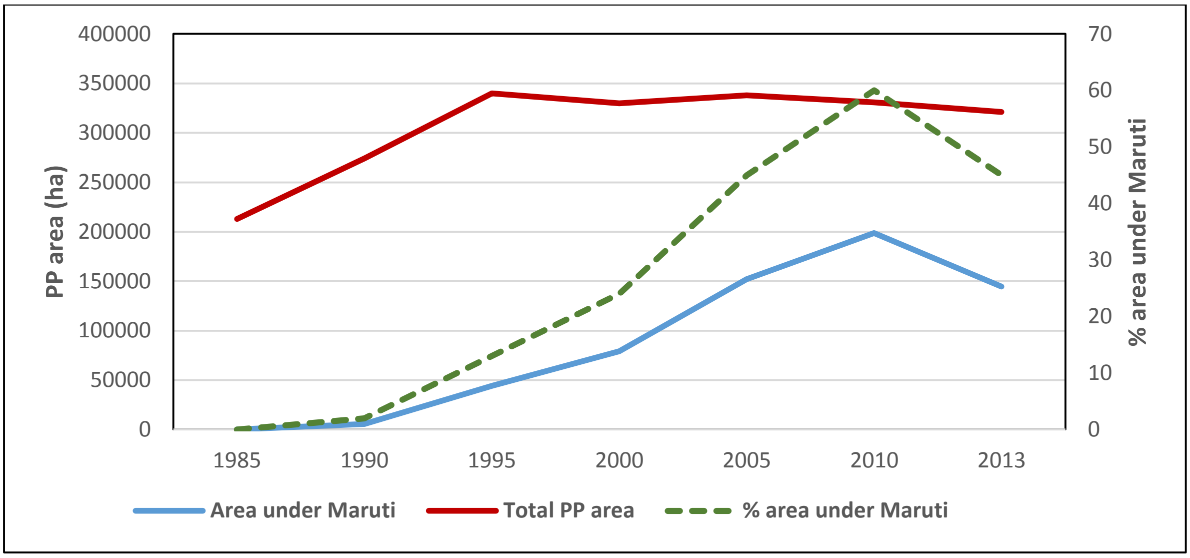

Figure 13: Adoption pathway of Maruti in other targeted districts (Buldhana, Yeotmal, Amravathi and Wardha) of Maharashtra state

Tables 3 and 4 allow us to estimate in any year the area of Maruti pigeonpea systems. For example, in Akola the total area of the Maruti pigeonpea and soybean system in 2013 can be estimated as the total area of pigeonpea, 98,000 hectares, times the share of the pigeonpea/soybean system, 65%, times the level of adoption of Maruti, 50%, giving 31,850 hectares. This process is repeated for each pigeonpea system for Akola and the other districts.

The Net Gains from Maruti pigeonpea technology

The next step is to estimate the net gains from Maruti over the varieties used in 1985 in each of the main pigeonpea intercropping systems. Some of the difficulties of doing this from the viewpoint of 2013 have already been discussed. We estimated the variable costs and income based on technology in 2013 for one hectare of each of the soybean and cotton intercropped with pigeonpea systems, the main systems operating in 2013. For each system we prepared one budget based on Maruti and one based on the pre-Maruti variety most often used before Maruti became available. The difference in net income was the net gains from Maruti. Crop budgets of this nature from the mid 80s were not available and it would tax the memories of those who helped us to construct budgets for that time. Moreover had budgets based on historical data had been available we would have had to express them in 2013 Rs. Of course our budgets have required some speculation about the technology for the pre-Maruti varieties although there is data on yields at that time. Our objective has been as nearly as possible to hold the technology constant in all regards except for Maruti variety. However different varieties have different fertilizer, seed and plant protection costs and these also vary between villages.

In preparing the net gain budgets, the increase in yield of pigeonpea from the switch to Maruti was estimated. Recall that Bantilan and Joshi suggested that the losses from wilt were up to 50% and that the area in Maharashtra suffering from wilt was about 23%. After discussions with farmers and scientists our approach has been to discount present Maruti yields more conservatively by 10%.

Our estimates of benefits are likely to be highly sensitive to this assumption. Our implied 'without' Maruti scenario has been the yield of other improved varieties which are not as successful as Maruti.

The only costs that change are those that arise from the change to Maruti. Few costs changed and the income from the companion crop did not change. The objective is to isolate the changes caused by the switch to Maruti. Budgets for the main intercropped pigeonpea systems are set out in Table 5a and 5b. These budgets are for the VLS villages of Kanzara and Kinkheda and the non-VLS villages of Nimbha and Lasanpur, all in Akola.

The budgets (Table 5a &5b) show a marked advantage from the use of wilt resistant Maruti. The annual gains/hectare for the pigeonpea + cotton rotation ranged from Rs.4,224 in Kanzara village to Rs.3,520 in Lasanpur and Nimbha villages. Similarly, for the pigeonpea + soybean rotation the gains/ha ranged from Rs.4,928 in Kanzara village to Rs. 3,661 in Kinkheda village. Since the mid 80s there have been changes in the 'popularity' of the alternative rotations (Table 3). In particular the pigeonpea+sorghum rotation is now rarely used. The reasons for this include low demand for sorghum, its long-duration and highly labour incentive nature. We do not have a current budget for this rotation. Even though sorghum is a cereal and soybean a legume, it seems that they fill a similar role in the rotation and relative profitability, which has changed over this period, guides the choice. We could have chosen not the value the net gain from Maruti in the pigeonpea+sorghum system which would have underestimated gains. Our approach has been to assume that the net gains from this system were the same as the net gains from the soybean + pigeonpea rotation which replaced it. The benefits derived from Maruti adoption in sole pigeonpea crop and other rotations (Pigeonpea + greengram; Pigeonpea + greengram + blackgram) were not included in total VLS gains because lack of sufficient data and because the areas involved were small.

The net gains for each system were averaged over the four villages and applied to the Akola district and to the aggregate of the other four districts. For example the net gains from Maruti in the soybean + pigeonpea system in Akola are 4,329 Rs in 2013. We have assumed the same level of net gains for this system each year since 1985. Recall that in 2013 there were 31,850 ha of this system in Akola. So the net gain from Maruti was Rs.137,887,966. Similarly the gains from the adoption of Maruti in the cotton system in Akola and for both the soybean and cotton systems in other districts were estimated.

Item	Kanjara				Kinkheda			
	Soybean + PP*		Cotton + PP**		Soybean + PP*		Cotton + PP**	
	Pre-Maruti	*Maruti*	*Pre-Maruti*	*Maruti*	*Pre-Maruti*	*Maruti*	*Pre-Maruti*	*Maruti*
Total variable costs	38038	38038	51623	51623	37235	37235	48535	48535
Gross revenue	88253	93181	141308	145532	74181	77842	111960	115621
Net profits	50215	55143	89685	93909	36946	40607	63425	67086
Increase in net profits due to maruti		4928		4224		3661		3661
** grown in 6:1 row proportion ** grown in 10:1 row proportion*								

Table 5a.Farm level impact of Maruti (Rs per ha) in VLS villages

Item	Lasanpur				Nimbha			
	Soybean+PP*		Cotton+PP**		Soybean+PP*		Cotton+PP**	
	Pre-Maruti	Maruti	Pre-Maruti	Maruti	Pre-Maruti	Maruti	Pre-Maruti	Maruti
Total variable costs	37668	37668	51129	51129	35934	35934	48288	48288
Gross revenue	82451	86956	126698	130218	80806	85030	121240	124760
Net profits	44783	49288	75569	79089	44872	49096	72952	76472
Increase in net profits due to maruti		4505		3520		4224		3520
** grown in 6:1 row proportion ** grown in 10:1 row proportion*								

Table 5b.Farm level impact of Maruti (Rs per ha) in non-VLS villages

Following these processes the gains from the adoption of Maruti in the Akola and the other districts were estimated from 1985 to 2013. These two streams of net gains are in 2013 Rs. To aggregate a compounding rate of 5% was applied to give the total benefits in 2013 present value terms. The total gains in Akola were estimated to be 4.6 b Rs and in the other districts, 14.9 b Rs or 19.5 b Rs in total, $US 325 m at an exchange rate of 1,000 Rs to $US 16.67.

Estimating the VLS Share of total Maruti gains

So far we have focussed on estimating the gains from the adoption of Maruti. The next step is to attribute some of these gains to the VLS project. The rationale for why Maruti was adopted earlier in Kanzara and other villages in eastern Maharashtra when it had not been officially released in Maharashtra was proposed above. While we have some observations on the spread of Maruti once it was introduced in Kanzara, the number of years it would have taken for Maruti to spread to Kanzara without the VLS environment is conjectural. Perhaps one or more families in Kanzara might have visited relatives or friends growing Maruti in Karnataka in 1986-87 and brought home some seeds. Perhaps it might have taken several years more particularly if the rate of adoption near the Karnataka border had not yet taken off. One of the farmers we visited who was one of the first users of Maruti suggested it might have been five years before he used Maruti but for the meeting with the ICRISAT breeder.

We have examined scenarios of 1,2 and 3 year lags but only present here the results for a one year lag. From the adoption data in Bantilan and Joshi it seems that despite the late start to adoption of Maruti in Maharashtra, adoption rates were pretty similar from 1995 and so no further benefits were attributed to the VLS program from then. The streams of benefits can be found in Table 6. In Akola the benefits attributable to the VLS is the lag is one year amount to 103 m Rs or $US 1.7 m and in the other districts they total 398 m Rs or $US 6.6 m or $US 8.3 m in total. This is about 2.56% of the total gains from the introduction of wilt resistant Maruti in Akola and the other four districts.

Year	Total benefits to Akola district (Rs)	Benefits gained due to one year advance in Akola (Rs)	Total benefits to other districts(Rs)	Benefits gained due to one year advance in other districts (Rs)
1985	-	-	-	-
1986	6,051,143	6,051,143	15,916,040	15,916,040
1987	11,525,987	5,762,994	30,316,267	15,158,133
1988	16,465,696	5,488,565	43,308,953	14,436,318
1989	20,908,820	5,227,205	54,995,496	13,748,874
1990	24,891,453	4,978,291	65,470,828	13,094,166
1991	44,096,326	20,390,180	149,847,921	87,494,752
1992	61,415,720	19,419,219	226,040,641	83,328,335
1993	76,985,657	18,494,495	294,637,120	79,360,319
1994	90,933,478	17,613,805	356,188,037	75,581,256
1995	103,378,364	-	411,208,851	-
1996	115,408,533	-	456,959,599	-
1997	126,058,554	-	497,420,687	-
1998	135,432,590	-	532,992,149	-
1999	143,628,013	-	564,047,914	-
2000	150,735,817	-	590,937,388	-
2001	178,475,196	-	669,999,124	-
2002	203,230,925	-	740,191,177	-
2003	225,224,260	-	802,179,001	-
2004	244,662,151	-	856,584,784	-
2005	261,738,101	-	903,990,064	-
2006	283,876,340	-	913,918,820	-
2007	303,312,665	-	920,852,117	-
2008	320,254,201	-	925,052,721	-
2009	334,894,473	-	926,765,168	-
2010	347,414,234	-	926,216,899	-
2011	302,658,213	-	802,892,503	-
2012	261,376,883	-	689,213,023	-
2013	223,340,809	-	584,539,542	-
Total (USD)*	76,988,305	1,724,110	249,261,223	6,636,630
* Indian Rupees converted USD $ during 2014 at an exchange rate of 1,000 Rs to $US 16.67				

Table 6 Benefits due to VLS accelerated technology adoption (US $)

A graph of showing the area of gains attributable to the VLS is displayed in Figure 14. It is the area between the two graphs.

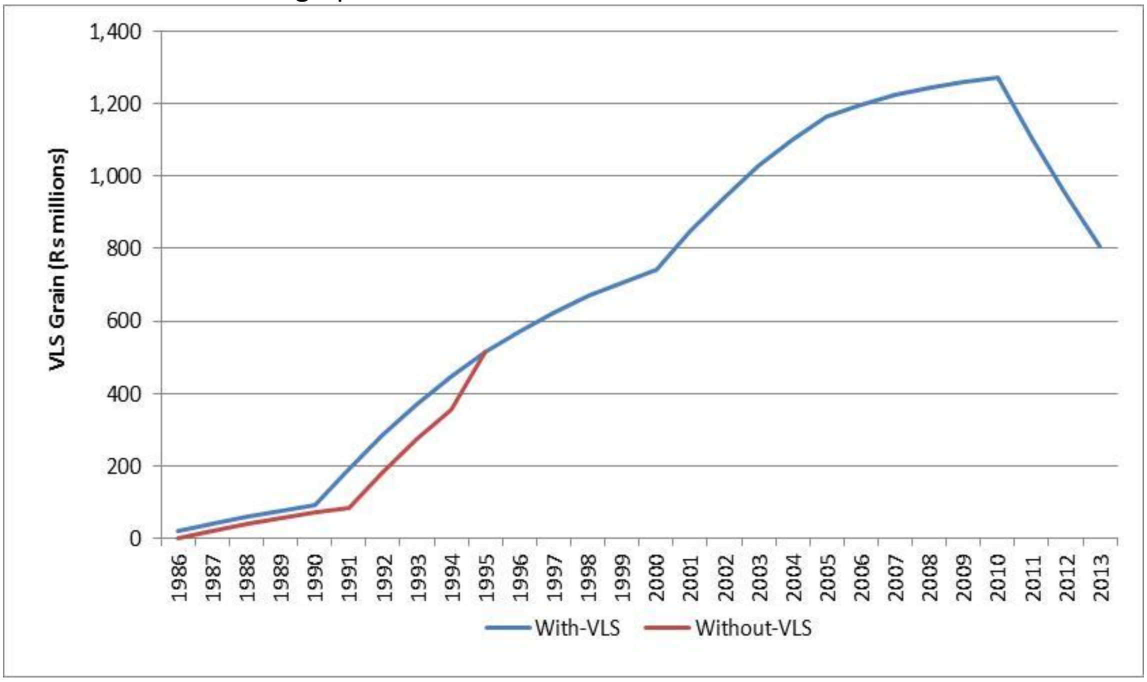

Figure 14: Annual Welfare benefits (Rs) due to accelerated technology adoption

Returns to the VLS investment

The variable costs of achieving the faster rate of adoption in Akola and the four neighbouring districts was very small and were not identified in financial records. We made an estimate of these costs by budgeting the time of ICRISAT staff who involved in research and extension activities in the study region and valuing time spent at nominal salaries in those years converted to 2013 Rs using the GDP deflator for India and then compounded forward at 5%. The present value of the total investment in 2014 Rs was 9.2 m or $US 152,814.

Year	Present value in 2014 (Rs)
1985	0
1986	1,192,530
1987	1,241,684
1988	1,279,910
1989	1,321,804
1990	1,393,160
1991	503,093
1992	522,092
1993	546,266
1994	572,175
1995	594,314
Total	9,167,028

Table 7 Stream of research investments in Maruti diffusion in Akola

These variable costs are very small relative to the total benefits from the more rapid adoption of Maruti. However no account has been taken of the 'overhead' costs of setting up the VLS databases and the village infrastructure that made it easy for this advance in the rate of adoption of Maruti to be achieved. Mullen (forthcoming 2015) has estimated that these overhead costs amounted to $US 14.7m in 2014 present value terms.

The VLS presence and efforts were in the villages of Kanjara and Kinkheda in Akola. A conservative approach would be to attribute only the benefits from more rapid adoption of Maruti in Akola, $US 1.7m, to the VLS project. Another more generous scenario recognises that Maruti spread to the other 4 districts from Akola through kinship relationships even though VLS resources were not used to induce this spread. The benefits in the other 4 districts from the more rapid adoption of Maruti were estimated to be $US 6.6m.

If the Akola benefits are related to the variable costs incurred (Table 7) the benefit cost ratio is 11.1:1 but no allowance has been made for a share of overhead costs of $US14.7m. The benefit cost ratio increases to 54:1 across the five districts.

Another approach to investment analysis would involve estimating the benefits attributable to the VLS projects from a range of activities until the sum of benefits from these activities comfortably exceeds the investment in the VLS project. Some of these issues are discussed in Mullen (2015, forthcoming).

Conclusions

Maruti pigeonpea was bred by ICRISAT (and partners) and released in Karnataka in 1986. Wilt is a major disease of pigeonpea in many areas of India. Maruti is wilt resistant and so was widely adopted. It was not immediately released in the Maharashtra. From discussions with VLS farmers in Kanzara (Maharashtra) an ICRISAT pigeonpea breeder recognised that Maruti had the characteristics sought by the farmers. He gave 5 kg of Maruti to the VLS resident investigator who distributed the seed to five village farmers. This was in 1987 before the start of the rainy season. The use of Maruti spread very quickly over the next five years from Kanzara throughout the district of Akola and then to four neighbouring districts of mainly through kinship relations (either by blood or marriage), caste group affiliations, friends etc. Had this opportunity not been provided by the VLS project, the spread of Maruti in Maharashtra would likely have been much slower and hence farmers would have experienced losses from Fusarium wilt for much longer.

Pigeonpea is usually intercropped with other crops including soybean, cotton and sorghum and so estimating the gains from a new variety such as Maruti is best done in terms of the change in net income (gross margin) for the cropping system not just for Maruti as a sole crop. Our approach has been to estimate the change in net income for the main pigeonpea systems and aggregate these benefits according to the areas of each system and the adoption of Maruti. This approach is equivalent to estimating the benefits from Maruti as the change in net income by the area and overlooks the deadweight loss triangle in traditional economic surplus welfare analysis although the area of pigeonpea systems increased.

The contribution of the VLS project was to advance the rate of adoption of Maruti in Akola and perhaps the four neighbouring districts. This adoption parameter is most uncertain. One of the VLS farmers who first used Maruti said that it may have been a further five years before they got Maruti. We have assumed a lag of only one year and hence the benefits attributable to the VLS project were estimated by lagging the stream of benefits to Maruti by one year and taking the difference. We further assumed that the rate of adoption would have been the same from 1995 and hence no further benefits were attributed to the VLS project from then. The benefits attributable to the VLS projects were just over 2% of the total benefits from the adoption of Maruti.

All estimation was based on budgets expressed in 2013 rupees and the stream of benefits from 1986 was compounded forward at 5% to arrive at a 2013 present value. The variable VLS costs were based on time spent in nominal rupees converted to 2013 real rupees using the GDP deflator for India and compounded forward to present value terms.

The variable costs amounted to $US 152,814. The VLS presence and efforts were in the villages of Kanjara and Kinkheda in Akola. A conservative approach would be to attribute only the benefits from more rapid adoption of Maruti in Akola, $US 1.7m, to the VLS project. If the Akola benefits are related to the variable costs incurred the benefit cost ratio is 11.1:1 but no allowance has been made for a share of overhead costs of the VLS projects of $US14.7m. The benefit cost ratio increased to 54:1 across the five districts.

Another approach to investment analysis would involve estimating the benefits attributable to the VLS projects from a range of activities until the sum of benefits from these activities comfortably exceeds the investment in the VLS project. Further assessments of the impact of VLS/VDSA activities are planned.

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