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ARTICLES

Perceptions and Adoption Decisions of Farmers in Cultivation of Improved Pearl Millet Cultivars - A Study in Tamil Nadu[@]

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INTRODUCTION

Pearl millet is grown in about 10 million hectares in India producing 7 million tonnes of grains (Government of India, 1996). It is grown in most of the states in India but is found to have concentrated in nine states, namely, Rajasthan, Gujarat, Haryana, Maharashtra, Uttar Pradesh, Tamil Nadu, Karnataka, Andhra Pradesh and Madhya Pradesh, thus showing its adaptability not only across physio-geographic but also across socio-economic environments and its resilience to grow in most unfavourable environments such as parts of Rajasthan.[1] The key feature, however, is that the crop is largely grown in dry and marginal lands, on which the poor depend for their livelihood. Increasing the production of this coarse cereal means ensuring food security to the millions of poor who largely live in backward and resource-poor regions of India.

Tamil Nadu ranks sixth among Indian states both in area planted to and production of pearl millet. Though it is produced in most of the districts, its major presence is felt in seven districts with varying agro-climatic and socio-economic environments.[2] Temporally, the area sown to pearl millet in Tamil Nadu has shown a secular decline. Between the triennium ending 1972 and 1995, it lost nearly half of its area from 4.51 lakh to 2.12 lakh hectares (Government of Tamil Nadu, 1996). Two reasons for the shrinkage in area which could be discerned are: (a) changing food habits of the people primarily made possible by supply of subsidised rice and wheat (superior cereals) under the public distribution system which has shifted the demand curve for pearl millet to the far left (Krishnamoorthy and Selvaraj, 1997) and (b) competitiveness of more profitable crops such as groundnut, sunflower, pulses and maize. One redeeming feature, however, is the sustained growth in the productivity of pearl millet which has almost doubled from 650 kg/ha in the early 1970s to 1,200 kg/ha in the triennium ending 1995 which helped to maintain the production level. It is more likely that the area under pearl millet may either remain at the present level or decelerate further. Thus productivity enhancement would be the key strategy to increase pearl millet production in Tamil Nadu. Large scale adoption of improved cultivars (ICs) of pearl millet will be the winning strategy for enhancing its production.

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A quick look-back will reveal that improved ICs[3] of pearl millet have been cultivated in Tamil Nadu for the past three decades. This has been made possible by the development of ICs of pearl millet by the public (national and international) and private research systems.[4] Through Tamil Nadu state public research system, so far, 14 pearl millet cultivars have been developed. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has bred several cultivars, of which WC-C 75, ICMS 7703 and ICMV 221 have made significant impact in Tamil Nadu. In addition, a continuous flow of a number of hybrids from the private seed sector has transformed the cultivation of pearl millet in the state. While ICs developed by public sector research, both national and international, have formally been released by the State Variety Release Committee, the private sector marketed their hybrids without formal approval. The hybrids such as HB 1, HB 2 and HB 3 which were developed through a crash programme by the public sector and grown in the early 1970s were to be discontinued later due to incidence of downy mildew.[5] The recent decade has witnessed a large scale growing of ICs of pearl millet spanning the entire Tamil Nadu (Government of Tamil Nadu, 1996).

But there are issues which emerged concurrently need detailed scrutiny. Despite a wider consensus on adoption of ICs of pearl millet, no scientifically based results are available indicating the precise measurement of spread of ICs and their composition. An understanding of the farmers' perceptions about new technologies in pearl millet production is critical to improve them further. This gives a feedback to the researchers to fine-tune the existing technologies and design new technologies which will meet the precise needs of the farmers. Further, a study of the farmers' behaviour in adoption of technology will help the policy makers to design the right kind of policies to facilitate rapid spread of new technologies.

Studies such as the current one will throw light on the constraints which discourage the adoption of improved cultivars of pearl millet. Secondly, it is reported by the field functionaries that adoption rates and varietal composition considerably vary across production environments (such as agro-climatic zones) which may cause differential impact on income distribution. Thirdly, the area under pearl millet in Tamil Nadu is showing a secular decline as indicated elsewhere. Fourthly, research products from the private sector appear to be taking over the products of the public sector research accomplished both by Indian National Agricultural Research System and ICRISAT. This has implications for agricultural research investment and prioritisation. Lastly, what are the traits of ICs which seem to have met the requirements of the pearl millet growers ? These issues unambiguously warrant a scientific investigation to understand the problems with better perspectives and more insights to design the right kind of policies to promote pearl millet production. This paper attempts to achieve this objective. The specific aims of the study are: (i) to study the composition and scale of adoption of ICs of pearl millet in Tamil Nadu temporally and spatially and to specifically examine the adoption of ICs developed by different agencies, (ii) to identify the determinants of adoption of ICs of pearl millet and quantify their influence and (iii) to know the perceptions of pearl millet farmers on the constraints which inhibit increased adoption of ICs.

DATABASE AND METHODOLOGY

Sampling Framework

The study area constitutes seven millet growing districts of Tamil Nadu (see note 2). Firstly, in order to get preliminary insights on the adoption of production technologies and constraints faced by them in pearl millet cultivation, Participatory Rural Appraisal (PRA) was conducted in seven of the sample villages (one village in each district) representing seven districts. Further, in each district two top ranking blocks in terms of pearl millet area were selected. This was followed by the selection of 28 villages from the 14 blocks at the rate of two villages per block, again considering their top position in terms of pearl millet area. Ultimately 336 pearl millet growing farm households equally distributed across the 28 villages, constituted the sampling units. The sample farmers represent all agro-climatic and production environments under which pearl millet is cultivated in Tamil Nadu. The survey data pertained to the year 1996-97. Besides household level survey, a detailed discussion with leading farmers, agricultural extension personnel, researchers, seed producers and agricultural policy makers in the state was made to understand the issues precisely. In addition, secondary data relating to area, production and seed distribution of pearl millet were collected from the offices of the Joint Director of Agriculture, located at district the level.

Analytical Framework

In order to have better insights into the adoption process, cultivar-wise (or a group of cultivars) analysis was attempted. The farmers adopt ICs of pearl millet which are bred by various agencies, viz., (i) Public-National Agricultural Research System (NARS) which includes Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs), (ii) Private National Agricultural Research System - wherein private seed producing companies run their own R & D, and (iii) International Agricultural Research Centres (IARCs) and in the present case, it is ICRISAT. A disaggregated analysis provides the contribution of each research agency to pearl millet improvement. The analysis also looks at temporal adoption pattern of agency-wise cultivars from 1989-90 to 1994-95. In order to analyse the seed replacement and economic life of cultivars, information was elicited from individual farmers on these aspects. And then, simple percentage analysis was done to examine replacement of seeds of different cultivars and the information was documented and analysed. An attempt was also made to study the adoption rate of individual cultivars developed by each agency. Spatial comparison of adoption of pearl millet cultivars across the seven districts formed part of the analysis.

Tobit Model

It is critical to precisely measure the degree of influence of variables which determine the adoption. The literature on adoption lists out a set of variables, viz., farm size, availability of family labour, proximity to market, human resource, capital availability, input prices, agricultural information, production uncertainity and risk (Shakya and Flinn, 1985; Adesina and Zinnah, 1993; Rauniyar and Goode, 1996). Fedar *et al.* (1985) and Byerlee (1996) provide a detailed review of adoption models. Particularly, limited dependent variable

model provides a good framework to study the adoption behaviour of agricultural technology. Some of the most appropriate models are Probit, Logit and Tobit. In the present paper, an advanced version of Tobit model (Tobin, 1958) proposed by Rosett and Nelson (1975)[6] was considered more appropriate as it measures not only the probability that a pearl millet farmer will adopt an improved cultivar but also its intensity of adoption. The functional form of Tobit model is given below.

$$Y_i = X_i\beta \quad \text{if } i_i^* = X_i\beta + \mu_i > T$$
$$(\text{or}) = 0 \quad \text{if } i_i^* = X_i\beta + \mu_i \leq T \qquad \ldots(1)$$

where Y_i is the probability of adopting (and the intensity of use of) improved cultivars; i^* is a non-observable latent variable; and T is a non-observable threshold level; μ_i is an independently normally distributed error term with zero mean and constant variance σ^2. The above equation is a simultaneous and stochastic decision model. If the non-observed latent variable i* is greater than T, the observed qualitative variable Y_i that indexes adoption becomes a continuous function of the explanatory variables and zero otherwise. In the present case, there are large number of farmers who have completely adopted the technology. The Tobit model has the flexibility of accommodating a lower limit and an upper limit of a variable or any one of them in econometric estimation and it uses maximum likelihood method to estimate the coefficients of the equation. The regression coefficients are asymptotically efficient, unbiased and normally distributed. The Tobit model has the additional merit of determining the effect of a change in the i-th variable on changes in the probability of adopting and the expected use intensity of the improved cultivar. The total effect of an explanatory variable can be decomposed using McDonald and Moffitt (1980) procedure to quantify the two effects and are shown in terms of elasticities. The total elasticity consists of two effects, viz., (a) the change in probability of the expected level of use intensity of the improved cultivars for those farmers who are already adopters and (b) the change in the elasticity of the probability of being an adopter.

The empirical model assumes that the dependent variable, proportion of area under ICs to total area under pearl millet depends on the variables: education, non-farm income, farm size, irrigation, market distance, existence of NARS-Private companies and district/regional characteristics. The adoption behavioural model (Leagnes, 1979) suggests that education, a personal variable; farm size, a socio-economic variable; and irrigation, a bio-physical variable; all primarily in the farmer's environment would affect adoption of a technology. Non-farm income was hypothesised to be positively related to adoption as the farmer will have adequate resources to invest on modern technology. Similarly, distance to factor and product markets was expected to negatively affect adoption. Further, the farmer's perceptions of technology-specific characteristics significantly condition technology adoption decisions. The omission of technology-specific attributes may bias the results of factors conditioning adoption choices (Adesina and Zinnah, 1993). The major three attributes of ICs which attracted the farmers are 'bold grain size', 'uniform maturity' and 'downy mildew resistance'. Bold grain size, besides adding to the yield, fetches higher price as industrial raw material to poultry feed manufacturers. Uniform maturity facilitates harvesting at one stroke against the staggered harvesting in the case of traditional varieties wherein maturity

of crop is not uniform. ICs which are currently cultivated possess downy mildew resistance character which the pearl millet growers value very much. As the data showed that NARS-Private is capturing more share over the years, it was hypothesised that the presence of private companies through their sales network may push up the adoption and so it has been included in the model. District dummies were included to understand the fact whether the spatial changes in adoption could be attributed to the region specific agro-climatic characteristics, viz., soil, temperature, rainfall, etc. The model variables along with their units of measurement are as follows:

ADOPTION : Proportion of area under ICs to total pearl millet area.
EDUCATION : Farmers' education in years of schooling.
NON-FARM INCOME : Annual income earned from other than agricultural sources, measured as binary variables: 1 if the farmer has non-agricultural income, 0 otherwise.
FARM SIZE : Farm size measured in hectares.
IRRIGATION : Binary variable; 1 if the farmer irrigates pearl millet, 0 otherwise.
MARKET DIST : Distance to the market measured in kilometres.
PRIV SEED : Presence of private seed sector, identified with the use of private seeds in the farm; measured as a binary variable; 1 if the private seed sector exists in the area, 0 otherwise.
HARV : Measured as binary variable; 1, if the farmer thought of harvesting at one stroke as crop maturity is uniform which is superior to staggered harvesting in traditional varieties.
GRAIN : Bold grain size. Measured as binary variable; 1, if the farmer thought of bold grain size was superior to the local varieties in terms of adding to grain and fetching better price in the market; 0 otherwise.
DOWNY : Downy mildew resistance. Measured as binary variable; 1, if the farmer thought of the IC downy mildew resistance as against the susceptability of earlier varieties; 0 otherwise, and
DISTRICT DUM : Measured as binary variable with the base district Kadalur, value 1 for representing district, 0 otherwise.

RESULTS

Adoption of Improved Cultivars (ICs)

The percentage of sample farmers who have adopted ICs and the percentage of area under different cultivars during 1994-95 are shown in Table 1. It may be seen that NARS-Private cultivars are dominant both in terms of area and number of farmers. The share of ICRISAT in the number of adopters and the area under ICs was about 25 and 23 per cent respectively, thus occupying the second place. The corresponding figures for NARS-Public were 20 per cent and 12 per cent. Local varieties are found among 27 per cent of the sample farmers and in 23 per cent of the pearl millet area. Of the three ICRISAT cultivars, WC-C 75 covers about 50 per cent of the total area under these cultivars. ICMS 7703 is the second important

among ICRISAT bred cultivars. Among NARS-Private cultivars, Pioneer hybrid dominates with two-thirds of the total area under private sector cultivars. Pioneer is followed by Eknath and MAHYCO. Most of these private sector companies used germplasms and resistance materials from ICRISAT and NARS in their hybrids. The leading cultivars among NARS-Public are CO 7 and KM 2. The widespread adoption of ICs may be attributed to the important benefits such as higher yield, resistance to diseases, improved marketability of grains, etc.

TABLE 1. ADOPTION PATTERN OF IMPROVED PEARL MILLET CULTIVARS : SAMPLE RESULTS

Institutions	Cultivars	Farmers (per cent)	Proportion to total pearl millet area (per cent)
(1)	(2)	(3)	(4)
ICRISAT	ICMS 7703	9.32	6.23
	ICMV 221	3.67	4.59
	WC-C 75	11.58	11.79
	Sub-total	24.57	22.61
NARS-PRIVATE			
	EKNATH	1.69	6.59
	HLL	0.28	0.41
	MAHYCO	3.38	3.26
	MBH 110	1.12	1.47
	PBH 3	0.28	0.15
	PG 5822	1.00	0.56
	PG 5877	0.56	0.20
	PIONEER	19.20	29.23
	PLANTGENE	0.56	1.22
	Sub-total	28.07	43.09
NARS-PUBLIC			
	CO 3	0.28	0.15
	CO 7	9.03	5.02
	KM 2	9.32	4.98
	KM 3	0.85	0.20
	X 5	0.56	1.22
	Sub-total	20.04	11.57
LOCAL	Traditional	27.32	22.73
		100.00	100.00

(i) *Temporal Performance*

The adoption pattern during the period from 1989-90 to 1994-95 is presented in Table 2. The adoption of ICs in Tamil Nadu began in the early 1980s and picked up momentum from the mid-1980s. However, the collapse of pearl millet hybrids in the early 1970s due to the incidence of downy mildew is still lingering in the minds of the farmers. The share of ICRISAT cultivars in total pearl millet area has declined from 38 per cent in 1989-90 to 23 per cent in 1994-95. Over the five year period, NARS-Public has expanded area under its cultivars but the proportion of area has declined from 15 to 11 per cent. The major share of area came under NARS-Private cultivars in recent years, whose area in the sample farms increased sharply during the period, 1989-90 to 1994-95. As regards ICRISAT cultivars, WC-C 75 was dominating the whole period under purview. It was the major variety which

had the trait of resistance to downy mildew; it had a 2.4 per cent disease incidence only; and at the same time showed higher yield. In the 1980s, it was the most popular variety in all pearl millet growing states in India. The cultivar suited both irrigated and rainfed conditions. It was widely grown as open-pollinated variety in the country. During the period 1984-92, it was sown annually on an estimated 0.6 - 1.2 million ha without any significant decline in downy mildew resistance (Rai and Hash Jr., 1994). However, ICMV 221 is picking up in recent years mainly in southern districts where drought occurrence is relatively more. Among NARS-Public cultivars, CO 7 and KM 2 emerged significant all along. Among private cultivars, Pioneer hybrids emerged strong over the years. The presence of traditional varieties in 23 per cent of the area provides evidence that the diffusion process of ICs is still incomplete.

TABLE 2. TEMPORAL ADOPTION PATTERN OF IMPROVED PEARL MILLET CULTIVARS

(per cent)

Cultivars (1)	1989-90 (2)	1990-91 (3)	1991-92 (4)	1992-93 (5)	1993-94 (6)	1994-95 (7)
ICRISAT						
ICMS 7703	2.41	7.49	9.40	7.21	7.04	6.23
ICMV 221					1.84	4.59
WC-C 75	35.90	31.85	23.85	16.31	15.64	11.79
Sub-total	38.31	39.34	33.25	23.52	24.52	22.61
NARS-PUBLIC						
CO 7	3.57	3.22	5.00	4.36	6.29	5.02
KM 2	10.81	9.23	6.25	5.94	6.10	4.98
OTHERS[a]	0.98	0.90	0.51	1.15	2.09	1.57
Sub-total	15.36	13.35	11.76	11.45	14.48	11.57
NARS-PRIVATE						
PIONEER	3.56	7.25	16.93	28.12	18.23	29.23
EKNATH	-	-	1.44	5.70	8.12	6.59
OTHERS[b]	1.24	3.46	5.91	4.41	5.21	6.05
Sub-total	4.80	10.71	24.28	38.23	31.56	41.87
Local	41.53	36.60	30.71	26.80	29.44	23.95
Grand total	100.00	100.00	100.00	100.00	100.00	100.00

a. Others include CO 3, KM 3, KM 8 and X 5.
b. Others include HLL, MAHYCO, MBH 110, PBH 3, PG 5822 and PLANTGENE.

(ii) *Spatial Performance*

The spread of ICs across study districts in Tamil Nadu is shown in Table 3. The ICRISAT cultivars are seen to be significant in Thiruvannamalai, Virudhunagar and Thoothukudi districts even though their share has declined in the latter two districts over time. The highest proportion of area under NARS-Public cultivars could be seen in Salem district with 44.60 per cent. It is followed by Thiruvannamalai (43.71 per cent), Kadalur (35.90 per cent), and Perambalur (31.87 per cent) districts. Over the years, NARS-Public cultivars have sharply declined and finally disappeared from Kadalur and Thoothukudi districts. NARS-Private

appears to be increasingly important in Kadalur, Virudhunagar, Thoothukudi and Vizhuppuram districts. Private cultivars are yet to make their presence in Perambalur, Salem and Thiruvannamalai districts. This mixed presence of different cultivars over space may be attributed to the interplay of various factors. Mostly, the suitability of cultivars and the role of different agencies in promoting the cultivars do appear to determine the pattern across districts. One of the reasons for wider acceptance of ICs of pearl millet is its suitability in sustaining the cropping systems. Their indirect contribution through land-saving is most important.

TABLE 3. SPATIAL PERFORMANCE OF IMPROVED CULTIVARS OF PEARL MILLET IN TAMIL NADU

(per cent)

Districts (1)	Cultivars (2)	1988-89 (3)	1989-90 (4)	1990-91 (5)	1991-92 (6)	1992-93 (7)	1993-94 (8)	1994-95 (9)
Kadalur	ICRISAT	15.37	13.44	14.50	20.07	4.27	2.38	2.56
	NARS-PUBLIC	35.90	43.78	33.90	11.04	2.89	0	0
	NARS-PRIVATE	0	10.36	24.00	41.68	68.65	77.17	80.08
	LOCAL	48.73	32.42	27.60	27.21	24.19	20.45	17.36
Perambalur	ICRISAT	21.61	7.22	13.37	23.51	22.43	13.75	10.15
	NARS-PUBLIC	31.87	30.56	24.38	35.94	26.61	31.59	34.38
	NARS-PRIVATE	0	0	0	0	0	0	0
	LOCAL	46.52	62.22	62.25	40.55	50.96	54.66	55.47
Salem	ICRISAT	0	3.43	18.47	23.52	14.45	6.50	6.32
	NARS-PUBLIC	44.60	47.29	37.55	49.25	66.36	74.29	73.89
	NARS-PRIVATE	0	0	0	0	0	0	0
	LOCAL	55.40	49.28	43.98	27.23	19.19	19.21	19.79
Thiruvannamalai	ICRISAT	29.58	31.37	42.75	59.54	60.50	66.06	62.21
	NARS-PUBLIC	43.71	35.41	36.85	22.11	27.10	23.75	25.58
	NARS-PRIVATE	0	0	3.10	2.42	0	2.13	2.46
	LOCAL	26.71	33.22	17.30	15.93	12.40	8.06	9.75
Thoothukudi	ICRISAT	60.38	40.71	62.24	43.94	26.74	29.45	34.33
	NARS-PUBLIC	1.47	6.80	1.35	0.95	0.45	0.38	0
	NARS-PRIVATE	0	17.25	12.14	27.17	56.70	58.44	58.97
	LOCAL	38.15	35.24	24.27	27.94	16.11	11.73	6.70
Virudhunagar	ICRISAT	44.63	64.27	52.10	27.90	27.93	20.20	18.92
	NARS-PUBLIC	0	1.61	0	1.26	3.14	3.40	3.62
	NARS-PRIVATE	5.85	5.62	18.30	54.86	59.25	71.04	70.59
	LOCAL	49.52	28.50	29.60	15.98	9.68	5.36	6.87
Vizhuppuram	ICRISAT	41.87	46.98	45.30	49.12	22.88	26.01	10.17
	NARS-PUBLIC	3.50	6.08	8.10	9.87	15.30	15.28	21.97
	NARS-PRIVATE	0	0	0	5.43	16.61	25.62	32.80
	LOCAL	54.63	46.94	46.60	35.58	45.21	33.09	35.06

(iii) *Influence of Farm Size*

Table 4 presents details of farm size of adopters and non-adopters. Among pearl millet growers land leasing was almost absent. In fact, operated land area was mostly owned land only. The average operated farm size of adopters and non-adopters was 3.80 ha and 2.45 ha respectively. One may suspect that farm size exerts a positive influence on adoption of

ICs of pearl millet because large farm generates more income, which provides a better capital base, and risk bearing capacity. This appears to be true as the average farm size of adopters is larger by 1.35 ha over the non-adopters. One factor which boosts the farm size for adopters is the presence of larger size of drylands comprised in the southern districts, viz., Virudhunagar and Thoothukudi where pearl millet is grown mostly as a rainfed crop. The larger farm size of adopters is in general contributed by the presence of drylands. The average size of drylands is higher by 1.28 ha among adopters. This is reinforced by the fact that the size of irrigated land is almost similar among adopters and non-adopters. Also, the average area planted to pearl millet is higher in the adopter category with 0.97 ha as against 0.89 ha in the non-adopter category. The significance of farm size will however be known from Tobit model results which are presented in a later section.

TABLE 4. FARM SIZE - ADOPTERS VS. NON-ADOPTERS

(ha)

Particulars	Adopters			Non-adopters		
	Irrigated	Dry	Total	Irrigated	Dry	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Owned	0.96	2.97	3.93	0.89	1.66	2.55
Leased-in	0.04	0.12	0.16	0.01	0.01	0.02
Leased-out	0.01	0.01	0.02	0.01	0.08	0.02
Current fallow	0.02	0.21	0.23	0.01	0.02	0.03
Permanent fallow	0.02	0.02	0.04	0	0	0
Operated land	0.95	2.85	3.80	0.88	1.57	2.45
Pearl millet area	0.21	0.76	0.97	0.11	0.68	0.79

(iv) *Influence of Education and Income*

Universally, education is observed to be a fundamental factor for economic and social changes (Myrdal, 1968). Education helps an individual to acquire knowledge. Is formal education always a pre-requisite for technology adoption? An analysis of education defined in terms of number of years of formal schooling as related to adoption of improved cultivars of pearl millet is given from Table 5. Differences in the level of education between adopters

TABLE 5. LEVEL OF EDUCATION AND SOURCES OF INCOME OF THE SAMPLE HOUSEHOLDS

(per cent)

Particulars	Adopters	Non-adopters
(1)	(2)	(3)
Educational status		
Illiterate	15.32	22.78
Primary	26.38	27.72
Secondary	45.96	42.57
Collegiate	12.34	6.93
Total	100.00	100.00
Source of income		
Crop	74.28	68.57
Trade	7.91	15.69
Labour	9.83	10.69
Livestock	1.96	0.84
Others	6.02	4.21
Total	100.00	100.00

and non-adopters appear to be less significant. The adopters look better at the collegiate level of education. Illiterates are higher by one-third among non-adopters. Obviously, the present level of modernisation in communication and infrastructure might help even the less educated farmers in the adoption of ICs.

Crop production offers the largest slice of household income both to the adopter and non-adopter households (Table 5). While income from crop production alone accounted for about three-fourths of the total income among adopters, its share for non-adopters constituted two-thirds. Non-adopters earned about 16 per cent through trade which was only 8 per cent for adopters. The share of labour earnings is similar across the two groups. The influence of non-farm income on adoption is also examined using the Tobit model and the results are presented in a later section.

(v) *Sources of Seed and Information*

Sources of information and seed are central to the spread of improved cultivars. Easy availability of information and of seeds may help the new cultivar to reach more farmers in a given time. Sources of information and seed for ICs of pearl millet are shown in Table 6. The details are given for three ICRISAT cultivars and seven private cultivars. The State Department of Agriculture is seen to be the major source of information for ICRISAT cultivars. Other farmers and relatives put together play a notable role in spreading the new cultivars. Interestingly, private hybrids are known to farmers through more than one source. The Department of Agriculture plays a minor role while seed shops play a larger role in the distribution of all private sector cultivars, excepting Hindustan Lever seeds. The implication that emerges out of this analysis is that all the agents (private, public sector agencies, farmers and relatives) have to play an increasing and complementary role in the spread of ICs to the farmers.

TABLE 6. SOURCES OF SEED AND INFORMATION

(per cent)

Particulars	ICRISAT cultivars			Private cultivars					
	WC-C 75	ICMS 7703	ICMV 221	HLL	MAHYCO	MBH 110	PBH 13	PG 5877	PIONEER
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Seed									
Department of Agriculture	85.47	82.22	75.00	100.00	-	-	-	20.00	1.32
Seed shop	7.01	17.78	8.34	-	100.00	100.00	100.00	80.00	98.68
Others	7.52	-	16.66	-	-	-	-	-	-
Information									
Department of Agriculture	73.50	80.00	58.33	100.00	-	25.00	-	20.00	10.52
Seed shop	3.42	4.44	8.33	-	33.33	-	50.00	60.00	18.43
Others	23.08	15.56	33.34	-	66.67	75.00	50.00	20.00	71.05

Note: Others include other farmers, relatives, co-operative credit society and university outreach programmes.

(vi) *Preference for Improved Cultivars*

Reconnaissance survey and interaction with extension workers, private seed shops and the agricultural scientists working on pearl millet facilitated to identify 18 different technology traits and factors which may induce the farmers to prefer ICs of pearl millet. The factors and the extent of their influence are shown in Table 7.

TABLE 7. REASONS FOR ADOPTION OF IMPROVED CULTIVARS

(per cent)

Reasons	Kadalur	Salem	Thiruvannamalai	Perambalur	Thoothukudi	Virudhunagar	Vizhupuram	All
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Higher yield	63.41	60.00	52.08	59.10	70.37	51.51	70.40	59.34
Drought resistant	-	-	4.17	13.64	9.26	15.15	3.70	10.26
Downy mildew resistant	12.19	5.00	12.50	4.54	3.70	9.09	3.70	8.79
Influence of private traders/family members	4.88	10.00	2.08	6.09	5.55	4.54	3.70	4.76
Bold grain size	4.88	5.00	8.33	-	-	6.06	3.70	4.03
Uniform maturity	-	-	6.25	4.54	5.55	3.03	-	3.29
Others*	14.64	20.00	14.59	12.09	5.57	10.62	14.80	9.53
	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)

* Other factors include pest resistance, less of birds' problem, compact earhead, short duration, short height, assured supply of seeds, more fodder yield and easy threshing.

Higher yield has made more than half the number of sample farmers prefer ICs in place of local cultivars. It is as high as 70 per cent of the farmers in Vizhuppuram and Thoothukudi districts. In a study of adoption of improved wheat varieties, Jain and Byerlee (1995) reported significant correlation between yield of a variety and its commercial success. Drought resistance, larger grain size and disease resistance are other important factors that created interest among the farmers to adopt ICs. It appears that the private seed traders influenced about 10 per cent of the farmers in Salem district to adopt ICs. And it was uniform maturity that made 6 per cent of the pearl millet growers to grow ICs in Thiruvannamalai district. Resistance of ICs to drought emerged as second important influencing factors in Perambalur and Virudhunagar districts. It is natural that different factors influence adoption of ICs but higher economic returns in the form of higher yields emerged as the most significant factor

(vii) *Seed Replacement and Economic Life*

Purity of seeds is critical for realising the full benefits of a crop. How smart the pearl millet growers are in replacement of seeds of a given variety? It may be seen from Table 8 that in the case of non-hybrids, more than 70 per cent of the farmers substituted new seeds every year. About 7 per cent of the farmers replaced seeds once in two years. Only in the case of WC-C 75, replacement takes place once in seven years. On an average, 17 per cent of the farmers never replaced their seed. The story on hybrids is different. Technically, hybrids are to be replaced for each season. Only a small group of farmers either used beyond one season or did not replace the seeds.

TABLE 8. SEED REPLACEMENT AND ECONOMIC LIFE - SELECT CULTIVARS

(per cent of farmers)

Cultivars	Seed replacement			Not replaced	Economic life (years)
	1 year	2 years	3 years and more		
(1)	(2)	(3)	(4)	(5)	(6)
ICMS 7703	80	9		11	3-4
ICMV 221	71	-	-	29	-
WC-C 75	64	10	14[a]	12	3-7
HLL	100	-	-	-	-
MAHYCO	73	7	-	20	3
MBH 110	75	-	-	25	3
PBH 13	100	-	-	-	1
PG 5877	92	6	-	2	-
PIONEER	95	5	-	-	2
KM 2	91	9	-	-	2
CO 7	95	5	-	-	1-2
HB 3	100	-	-	-	1

[a]Replacement as 5, 3, 3, 2 and 1 per cent in the third, fourth, fifth, sixth and seventh year respectively.

The stand of a variety in the field depends on several factors, which may include desirable traits of the variety, supply of seeds, entry of new cultivars and strength of extension services. Of several cultivars examined, among the non-hybrids, WC-C 75 has longer life than other cultivars. Hybrids have relatively shorter life period. The entry of new cultivars is primarily responsible for reducing the life of existing hybrids. Further, competition among private companies offers better and improved products in the market leading to shorter span of existing cultivars. The cultivar or varietal changes occur when newer generation of ICs periodically replaces the original ICs. The subsequent impacts of changing cultivars are evolutionary rather than revolutionary which is mainly due to the consequence of first generation ICs.[7] The later generation cultivars offer improvements in varietal traits (Byerlee, 1996).

Tobit Results

(i) *Marginal effects*

The results of estimated Tobit model are presented in Table 9. It may be seen that the farmers' education had a positive and significant influence on adoption of ICs and this was not reflected in average magnitudes shown in Table 5. This may be because beyond certain threshold, education may have a positive impact on adoption. In the present case, the secondary and collegiate level of education might have influenced the adoption behaviour. This may probably be due to better perceptions about improved technologies by the farmers with more education. Though non-farm income is negatively related with the adoption, its effect was insignificant. However, the negative sign of the coefficient implied that the farmers who earned more of non-farm income paid little attention to pearl millet. This can be particularly observed in Salem district where non-farm income was higher. The non-significance of farm size on adoption affirms that ICs, as a technology, is neutral to scale. Irrigation emerges as the more dominant variable. It shows that improved cultivars are preferred in irrigated conditions. The higher level of adoption of hybrids in Kadalur district

supports this view. The distance to market is negatively related to adoption. Most of the improved cultivar seeds are to be bought from the seed shops or agricultural depots which are not located within the village. Thus distance to the markets plays a significant role in adoption. The presence of private seed sector in the locality accelerated the adoption significantly. The estimated coefficients for technology-specific attributes GRAIN and HARV and DOWNY suggest that the farmers' perceptions of technology-specific features must be taken into account in evaluation of determinants of technology adoption. Districts are the proxies for strong regional characteristics (agro-climatic, infrastructure, etc.) which favour or disfavour adoption. The results suggest that Thiruvannamalai, Salem and Thoothukudi districts provided a better production environment for adoption of ICs as compared to the benchmark district, Kadalur. The three remaining districts do not have the same level playing field as that of the above three.

TABLE 9. RESULTS OF THE EMPIRICAL TOBIT MODEL

Variables	Coefficient	Asymptotic t-ratio
(1)	(2)	(3)
CONSTANT	-5.99	-0.44
EDUCATION	3.71	1.91*
NON-FARM INCOME	-11.41	-1.66*
FARM SIZE	0.11	0.43
IRRIGATION	0.35	4.00**
MARKET DISTANCE	-0.94	-1.91*
PRIV SEED	62.75	5.84**
GRAIN	42.22	2.82**
HARV	51.90	3.14**
DOWNY	37.62	1.98*
VIZHUPPURAM DUMMY	-18.22	-1.48
THIRUVANNAMALAI DUMMY	48.30	3.10**
SALEM DUMMY	57.63	3.73**
PERAMBALUR DUMMY	0.99	0.07
VIRUDHUNAGAR DUMMY	19.20	1.55
THOOTHUKUDI DUMMY	24.22	2.02**

Log-likelihood = -1343.9. N = 336. * and ** Significant at 5 per cent and 1 per cent level respectively.

(ii) *Elasticities*

The elasticities computed using the Tobit model results are shown in Table 10. It may be noted that the elasticity of a change in the level of a given explanatory variable comprises two effects. One is the change in the elasticity of adoption intensities of the pearl millet growers who are already adopters. The other effect is the change in the elasticity of the probability of being an adopter. The elasticities suggest that the magnitude of adoption intensity is considerably higher for all the variables. Overall, the computed elasticities show inelastic responses. Elasticity of adoption intensity is higher for irrigation, education, presence of private sector, grain character and irrigation. The total elasticity for education is 0.1898, which is decomposed into 0.1882 for intensity of adoption, and 0.0016 for the probability of adoption. This suggests that a 10 per cent increase in the years of schooling is expected to result in a 2 per cent increase in adoption and intensity of adoption. Non-farm income and scale of farm operation show non-significant influences. The elasticity estimates for percieved technology-specific characteristics appear to be reasonable and they do matter in technology choice.

TABLE 10. TOTAL ELASTICITY DECOMPOSITION FOR CHANGES IN INFLUENCE VARIABLES

Variables	Elasticities of		Total elasticity
	Adoption intensity	Adoption probability	
(1)	(2)	(3)	(4)
IRRIGATION	0.1230	0.0010	0.1350
MARKET DISTANCE	-0.0921	-0.0009	-0.0930
FARM SIZE	0.0104	0.0001	0.0105
NON-FARM INCOME	-0.0292	-0.0003	-0.0295
PRIVATE SECTOR	0.1736	0.0024	0.1760
EDUCATION	0.1882	0.0016	0.1898
GRAIN	0.1414	0.0012	0.1436
HARV	0.1148	0.0025	0.1173
DOWNY	0.0987	0.0006	0.0993

POLICY IMPLICATIONS

Improved cultivars of pearl millet have undoubtedly made important contributions towards an efficient and sustainable agriculture both indirectly through the adoption of land-saving technologies and directly through the more efficient use of external inputs and increased stability of production.

The adoption of ICs of pearl millet in Tamil Nadu is impressive with three-fourths of area planted to them. The spread has steadily expanded in the past decade and reached high levels in many districts in Tamil Nadu. Both the public and private sector research have played a significant role in evolving improved cultivars. ICRISAT and NARS-Public made earlier contributions and breakthroughs in developing ICs of pearl millet. Using the parent material from ICRISAT and NARS, the private sector has come out with a number of hybrids which are increasingly adopted by more and more farmers mainly due to their grain characteristics, yield gains and downy mildew resistance which have enhanced their sustainability. For the spread of ICs, the State Department of Agriculture is the major source of information, followed by fellow farmers and seed shops. The private seed dealers play an enlarged role for the spread of private sector seeds. This has policy implication in the context of growing use of intellectual property rights (IPRs) for biological innovations which in turn raise the issue of the critical role of the private sector in developing and diffusing ICs, because WTO insists on nations to ensure and protect IPRs. Given the expanding role of the private sector in food crops such as pearl millet, the protection of IPRs must not in the future deny the farmers their rights to carry over seeds from their own production and also ensure sale of seeds at reasonable prices to the farmers. Of late, the farmers are very particular to replace the seed within two years, which show their awareness on seed quality.

The results from estimated econometric model suggested that education, irrigation, distance to market centre, presence of private sector seed distribution and regional characteristics have significantly determined the probability of adoption and degree of adoption. Hence, these variables condition the adoption decisions. The results also suggested that technology-specific characteristics such as higher yield, bold grain, uniform maturity and resistance to diseases are important. The researchers on pearl millet must take into account these findings while designing their future research programmes though some of these features are already included in their breeding objectives. Availability of seed, presence of private dealers and good seed material are considered to be equally important factors by the farmers. Agricultural development policy makers and extension workers must note these points while devising policies and their implementation.

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NOTES

1. Its outstanding adaptation to whole range of environments is well reported in the literature (Bidinger and Rao, 1988 and ICRISAT, 1996).

2. The districts which have significant extent of area planted to pearl millet are: Kadalur, Perambalur, Salem, Thiruvannamalai, Thoothukudi, Virudhunagar and Vizhuppuram.

3. Improved cultivars include improved varieties and hybrids.

4. Historically, pearl millet breeding research in Tamil Nadu dates back to late 1930s. The first variety, CO 1, was released in 1939 (see Appendix). Since then, 12 cultivars have been released by Tamil Nadu Agricultural University. Besides, the State Department of Agriculture released two cultivars, KM 1 and KM 2. The history of pearl millet breeding research is well documented by Krishnaswamy, 1962; Bidinger and Rao, 1988; and Anand Kumar and Andrews, 1984.

5. The upshot of occurrence of downy mildew epidemics resulted in the reorganisation of pearl millet breeding in India with a major thrust on building downy mildew resistance in hybrid parents and enhanced efforts in breeding of open pollinated cultivars. The roles of ICRISAT, ICAR and select SAUs are commendable in this regard. The outcome of the efforts was the advent of cytoplasmic (genetic male sterility) line 23 A to produce F1 hybrids. The germplasm from African countries provided a strong base for evolving pest-disease resistant cultivars in India.

6. Though the original model was specified by Tobin (1958), subsequently there emerged several improved versions of the model. Rosett and Nelson's (1975) 2-limit Tobit model is one such version.

7. First generation varieties refer to the varieties which have made breakthrough in the earlier years. WC-C 75 is an example. Later generation varieties are released in the subsequent years with additional improvements over the earlier ones. Often the first generation (earlier ones) are used as parents in the later varieties. Further, first generation varieties possess totally new traits which are distinctly different from traditional varieties. Hence they are referred to as revolutionary (e.g., IR 8 paddy). In the later varieties, only marginal improvements are seen over first generation and hence described as evolutionary.

APPENDIX

PEARL MILLET CULTIVARS GROWN IN TAMIL NADU

Agency (1)	Cultivar (2)	Year of release (3)	Research lag (4)
NARS-Public	CO 1	1939	7
	CO 2	1940	7
	CO 3	1942	7
	CO 4	1953	7
	CO 5	1954	7
	CO 6	1976	N.A
	CO 7	1986	7
	X 1	1950	9
	X 2	1951	9
	X 3	1953	9
	X 4	1980	9
	X 5	1983	7
	X 6	1983	7
	KM 1	N.A.	N.A
	KM 2	1979	N.A
	KM 3	1977	N.A
	HB 1	1965	N.A
	HB 3	1968	N.A
NARS-Private	Eknath 101	1988	N.A
	Eknath 301,302,303	1992	N.A
	Pioneer	1987	N.A
	Pioneer 7602	1995	N.A
	Plantgene	1988	N.A
	MAHYCO 151	1995	N.A
	Pioneer 7686	1996	N.A
	PBH 13,19,37,38	1996	N.A
ICRISAT	WC-C 75	1985	12
	ICMS 7703	1986	11
	ICMV 155	1993	6
	ICTP 8203	1993	5
	ICMV 221	1995	5

Sources: For NARS-Public - *Analytical Report on Variety Release*, Directorate of Agriculture, Government of Madras, Madras.
For NARS-Private - PRA conducted as part of the study.
For ICRISAT Cultivars - *Annual Reports* of ICRISAT.

REFERENCES

Adesina, A.A. and M.M.Zinnah (1993), "Technology Characteristics, Farmers' Perceptions, and Adoption Decisions: A Tobit Model Application in Sierra Leone", *Agricultural Economics*, Vol.9, No.2, pp. 227-211.

Anand Kumar, K. and D.J.Andrews (1984), "Cytoplasmic Male Sterility in Pearlmillet (*Pennisetum americanum (L) Leek*): A Review", *Advances in Applied Biology*, Vol.10, No.1, pp. 11-143.

Bidinger, F.R. and P.P.Rao (1988), *Genetic and Cultural Improvements in the Production of Pearlmillet - A Comparative Assessment for India and Sahelian/Sudan Africa*, Conference Paper No. 486, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India.

Byerlee, Derek (1996), "Modern Varieties, Productivity and Sustainability: Recent Experience and Emerging Challenges", *World Development*, Vol. 24, No. 4, pp. 697-718.

Government of India (1996), *Agricultural Statistics At a Glance*, Directorate of Economics and Statistics, Department of Agriculture and Co-operation; Ministry of Agriculture, New Delhi.

Government of Tamil Nadu (1996), *Agrostat '96*, Directorate of Agriculture, Madras.

Fedar, G.; R. Just and D.Zilberman (1985), "Adoption of Agricultural Innovations in Developing Countries: A Survey", *Economic Development and Cultural Change*, Vol. 33, No. 1, pp. 225-299.

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (1996), *FOOD FROM THOUGHT - Improving the Unimprovable - Succeeding with Pearlmillet*, No. 3, Patancheru, Andhra Pradesh, India.

Jain, K.B.L. and D.Byerlee (1995), *Wheat Breeding in India - Trends and Impacts*, Draft Paper D.F:ICAR/CYMMIT, Mexico.

Krishnamoorthy, S. and K.N.Selvaraj (1997), *Demand and Supply Structure of Agricultural Commodities: Comparative Advantage of Tamil Nadu*, Research Report, Tamil Nadu Agricultural University Press, Coimbatore.

Krishnaswamy, N. (1962), *Bajra - Pennisetum typhoides*, Indian Council of Agricultural Research, New Delhi.

Leagnes, J.P. (1979), *Adoption of Modern Agricultural Technology by Small Farm Operations: An Interdisciplinary Model for Researchers and Strategy Builders*, Cornell International Agricultural Monograph No. 69, Cornell University, Ithaca, New York.

McDonald, J.F. and R.A. Moffitt (1980), "The Uses of Tobit Analysis", *Review of Economics and Statistics*, Vol. 62, No. 2, pp. 318-321.

Myrdal, G. (1968), *Asian Drama*, Vol. II, Pantheon, New York, pp. 959-1530.

Rai, K.N. and C.T.Hash Jr.(1994), "Genetic Enhancement of Pearl Millet at ICRISAT", in M.C.S. Bantilan and P.K.Joshi (Eds.) (1994), *Impact Evaluating ICRISAT Research*, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Hyderabad.

Rauniyar, G.P. and F.M. Goode (1996), "Managing Green Revolution Technology: An Analysis of a Different Practice Combination of Swaziland", *Economic Development and Cultural Change*, Vol. 44, No. 2, pp. 421-437.

Rosett, N.R. and F.D. Nelson (1975), "Estimation of the Two-Limit Probit Regression Model", *Econometrica*, Vol. 43, No. 1, pp. 141-146.

Shakya, P.B. and J.C.Flinn (1985), "Adoption of Modern Cultivars and Fertilizer Use on Rice in the Eastern Tarai of Nepal", *Journal of Agricultural Economics*, Vol. 6, No. 2, pp. 409-419.

Tobin, J. (1958), "Estimation of Relationships for Limited Dependent Variables", *Econometrica*, Vol. 26, No. 1, pp. 24-26.