The Economic Impact of Drought Tolerant Rice Varieties in South India

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Abstract

Drought is the one of the important factors that limit the productivity of rice in the fragile environments of South India. The existing modern varieties of rice do not perform well under drought stress conditions. Tamil Nadu Agricultural University (TNAU) has used a number of techniques to develop drought tolerant (DT) rice varieties – conventional breeding, molecular breeding and genetic engineering. So far the most advanced varieties from DT programs – PMK 3, PMK 4, and RMD 1- were developed through conventional breeding and molecular breeding. The genetic engineering research program for DT is not active at present. DT varieties are based on crosses of land races and high yielding varieties with white slender grain quality. In this study we likely welfare effects generated by the adoption of DT varieties at the regional level. For this purpose a farm level survey was conducted among the 120 farm households in major drought prone districts of Tamil Nadu 2008 – 09. All the selected farmers were provided seeds of DT cultivars (PMK 3, PMK4, RMD 1) as a part of on-farm trials managed by TNAU Scientists. The farmers also grew land races and other HY cultivars of rice in their lands during the season. The results from the cost of cultivation and returns of DT, existing land races and HYVs indicate that the adoption of DT varieties would bring additional benefit to the farmers to the tune of 32.82 per cent despite increase cost of human labor and manures by 15 percent. There was a significant reduction in the cost of other input such as seed, chemical fertilizer and machine power. Reduction in cost and higher productivity together benefited the farmers as a result total returns and the net gain over 20 percent.

I. Rice Research in the State of Tamil Nadu

The major achievement of rice research in Tamil Nadu, as in other parts of India and Asia, has been the development of high yielding MVs and few recent hybrids. Earlier varieties were semi dwarf, high yielding, high tillering with limited attention to grain quality, resistance to abiotic stresses such as drought and salinity, pests, diseases and physical stresses. During 1980s and 1990s, scientists gave attention to developing varieties with characters what were missed earlier and also suitable for different agro ecosystems incorporating suitable traits for enhancing productivity under stress conditions. Zoning of Tamil Nadu based on agro climatic conditions was the main attempt to breed for location specific varieties under the National Agricultural Research System (Table 1). The most formidable gains were realized with advent and introduction of HYVs in the late 1960s. The evolution of the green revolution in Tamil Nadu can be viewed as a two-stage process. First stage refers to widespread adoption of the first generation of MVs. More than 90 percent of area is under modern rice varieties. In the second stage, increasing trend in adoption of MVs was continued but with a wider adoption of later generation MVs, which possessed multiple pest and disease resistance. The MVs in no uncertain terms, contributed to increased rice production. Through the 1960s, paddy yields stagnated at 2-2.50 t ha^{-1}. By each decade from 1970, yields rose by at least one t ha^{-1} in all production environments.

Generally, research focus has been largely directed to irrigated rice in Tami Nadu and only very little attention was paid to research on rainfed rice (Selvaraj et. al, 2002). Empirical evidences show that there is a secular rise in area under HYVs in rainfed and dry land areas and it has reached a reasonable level. But there is a big yield gap between irrigated and rainfed areas. Though the HYVs have spread to dry land areas, adoption of associated technologies has been poor (Asaduzzaman, 1979; Shotelersuk, 1981; Agarwal, 1985; Thapa, 1989; Fugile, 1989; Hossain, 1990; Hossain, 1996). In recent years, more resources are channeled to develop rice varieties meant for rainfed systems. Rice research is funded mostly by Tamil Nadu State Government. Indian Council of Agricultural Research (ICAR) is the second major source of funding for rice research in Tamil Nadu under All India Co-ordinated Rice Improvement Programme (AICRIP). The useful research outcome and the subsequent gains cannot be product of a single institution. Realizing the fact, TNAU has established close linkages with IRRI and Rockefeller Foundation for several decades. Considerable amount of germplasm materials and knowledge have been exchanged between the scientists working in different institutes through networking.

Table 1. Rice varieties for different ecosystems

Duration and Ecosystem	Varieties
Very early or extra early duration (direct seedling)	ASD 17, MDU 5
Early or short duration	ADT 36, TKM 9, ADT 37, ADT, 42, ADT 43, ADT (R) 45, ADTRH 1, IET 1444 (Rasi), CO37, Co47, IR36, IR50, MGR, IR 64, IR72, ASD 16, ASD 18, ASD 20 and TRY (R0 2
Medium duration	ADT 38, ADT 39, ADT 46, IR20, CORH 2, Ponni, Improved White Ponni, ASD 19, Bhavani, MDU 2, MDU 4 and Paiyur 1
Long duration	Ponmani (CR 1009) ADT 44
Water logged situations	ADT 40, TPS 3, Ponmani
Saline/Alkaline conditions	Co 43, TRY 1, CORH 2 and TRY (R) 2
Dry and semi-dry conditions (Direct seedling)	TKM 9, TKM 10, TKM 11, TKM 12, MDU 5, PMK 1, PMK 2, PMK 3 , Anna 4 (PMK 4) , RMD1 and TPS 3
Cold prevalent situations	MDU 3

II. Source of Data

Both secondary and primary data were used for analyzing the effect of drought on rice production and the role of DT rice cultivation in the rainfed rice ecosystems. Secondary data were collected from various published sources of Tamil Nadu State and Research Stations of TNAU. For primary data, farm level survey was conducted among the 120 farm households in major drought prone districts of Tamil Nadu during 2008 – 09. List of farmers (21farmers) supplied with drought tolerant rice varieties namely PMK3 and PMK4 by the Agricultural Research Station, Paramakudi were collected from the scientists. In the same villages, farmers growing traditional varieties and high yielding varieties were randomly selected to make comparison of DT with other rice varieties. About 39 traditional variety growers, 60 high yielding varieties adopters were selected randomly.

Households were classified in to three categories based on the type of cultivars they grown as LR growers, HYV adopters and DT adopters. Out of the 120 sample farmers, 60 rice growers cultivated both HYVs and land races followed by 39 farmers cultivated land races alone and 21 farmers cultivated DT and other HYVs. More than 50 per cent of the respondents cultivating land races were marginal farmers owning 0.62 ha, whereas the share of marginal farmers cultivating high yielding varieties and drought tolerant varieties were 23 percent each to the total. Average size of land holding ranged between 0.62 ha and 4. 28 ha for the LR growers, while it ranged from 0.65 ha to 4.38 ha and 0.68 ha and 5.70 ha for the HYV and DT adopters respectively.

III. Rainfed rice research

Breeding varieties for resistance/ tolerance to biotic and abiotic stresses as well as for improved nutritional qualities are particularly important to meet challenges rising from population growth, environment degradation and nutritional insecurity. During past three decades, improvement of major crops has been achieved mainly through classical genetics and plant breeding methods. Increasing investment on agricultural biotechnology by both the public and private sectors is being made in Tamil Nadu. Currently, much of the plant molecular biology and crop biotechnology work in TNAU has been supported by Rockefeller Foundation and Department of Biotechnology, Government of India, New Delhi. The efficiency of recombination breeding is sustainable through pre-breeding activities of identification of new donors and improvement of the existing germplasm. Besides, the biotechnological tools could play an active supplementary role by generating additional and new variations through tissue culture and r-DNA technolgy, and improving the selection efficiency through marker assisted selection. Though new problems arise, continued search for donor, recombinants and fresh breeding tools will certainly deliver goods, which can satiate the demands of the future in terms of rare but robust rice varieties.

In Tamil Nadu there are more than 10 land races which are occupied one-third of total rice area. These were not producing any significant yield gains for the farmers. Therefore, spreading the newly developed DT varieties is crucial for second 'green revolution' in agriculture, which has to come from rainfed ecosystem. In this context, Tamil Nadu Agricultural University with the support of Rockefeller Foundation developed and released DT rice varieties namely PMK1, PMK2, PMK3, Anna 4 (PMK 4) and RMD1 which are capable of boosting the yield in rainfed areas (Table 2). Several drought tolerant rice lines were developed and they are in the different stages of OFT (On Farm Trails), MLT (Multi Location Trials) and ART (Adopting Research Trials). Drought tolerant rice lines developed through concerted efforts supported by the Rockefeller Foundation include PM00 022, PM02 015, PM03 002, Ashoka 200F, Ashoka228, RM96019, IR64 near isogenic line #17, CPMB ACM 04003 and CPMB ACM 04004. Though, public sector forms one of the major sources of seed supply in Tamil Nadu State, these newly developed drought tolerant rice varieties are not being produced in the State Seed Farms. Tamil Nadu Agricultural University has taken the task of production and distribution of drought tolerant rice varieties and supplied 50047 kg of seeds of DT varieties to the farmers since 2003 covering an area of 667 ha (Table 3). However, fast spread of DT varieties depends on economic and social factors including seed availability, market adoptability and adaptation to this fragile ecosystem.

Table 2. Drought tolerant rice varieties and their characteristics

Characters	PMK 1	PMK 2	PMK 3	PMK 4	RMD 1
Parentage	CO-25 X ADT-31	IR - 13564-149-3 X ASD 4	UPLRI 7/ Co 43	Pantdhan X IET 9911	Selection from TGR 75
Year of Starting	1982	1985	1992	2001	1999
Year of Release	1985	1994	2003	2009	2006
Period to release	3	9	11	6	7
Sp. Features	DT, Non-Lodge	DT, Non-Lodge, water inundating	DT, Non-Lodge, semi dwarf	DT, Non-Lodge, semi dwarf	Salt tolerant, DT, non-lodge
Eco system	Semidry	Irrigated early	Rain-fed, semidry	Rain-fed, Semi dry	Rain-fed
Breeding Method	Conventional	Conventional	Conventional	Conventional	Conventional
Type of cultivar	Pure line	Pure line	Pure line	Pure line	Pure line
Yield	1944	2400	2850	3882	4098
Duration	120-125	110-115	110	100-105	101

Source: Agricultural Research Stations of TNAU

Table 3 Seeds of DT rice produced and distributed by the research stations of TNAU (Kg)

Variety	2003-04	2004-05	2005-06	2006-07	2007-08
PMK 1	2870	400	250	45	-
PMK 2	1400	2050	2460	55	-
PMK 3	800	1328	5589	8700	3000
Anna 4 (PMK 4) – PM 01 011	-	1200	7500	8000	4500
PM 03 002	-	400	750	-	-

Source: Agricultural Research Stations of TNAU

IV. Drought and rainfed rice cultivation

Rice is predominantly grown during the northeast monsoon period (October – January) in the rainfed areas – Ramanathapuram and Sivagangai Districts of the Tamil Nadu State and uncertainty in seasonal rainfall affects rice cultivation to a very large extent in these fragile environments due to lack of supplementary sources of irrigation. Rainfed rice is predominantly cultivated in an area of 71,000 ha in Ramanathapuram and 17,000 ha in Sivagangai (Table 4). There were four moderate and six slight drought years in Ramanathapuram district and one moderate and eight slight drought years in Sivagangai district over the last 30 years (1977-78 to 2006-07)[1]. Estimated probability of drought occurrence was 0.30 for Sivagangai district, while it was 0.33 for Ramanathapuram district. The results indicate that for every two normal years, there is a subsequent drought year in these regions. The shortfall in rainfall was 34.95 percent and 26.66 per cent in Ramanathapuram and Sivagangai districts, respectively during the drought period as compared to the normal period. Due to the frequent occurrence of drought in the Ramanathapuram district during the last thirty years, rice area declined by 30,000 hectares. Average area under rice during drought period was 0.14 million hectares, while it was 0.17 million hectares in the normal period. Reduction in area under rice was 17.54 per cent due to drought. There was a reduction in area under rice in Sivagangai district during the drought period. In Ramanathapuram district area under HYVs and land races declined by 22,000 and 7000 hectares respectively. Similarly, the reduction in area under HYVs and land races was 60,000 and 1000 hectares, respectively in Sivagangai district. It was estimated that, on an average, yield reduction due to drought was 748.50 kg per ha which was 42.30 per cent of yield during the normal period and 93.30 kg per ha (4.20 per cent of normal yield) in Ramanathapuram and Sivagangai districts respectively. As a result of reduction in area and yield due to drought, rice production loss was estimated to the tune of 46 per cent and 15 per cent respectively in Ramanathapuram and Sivagangai district[2]. Average production during the normal year was 0.31 million tonnes, while it was 0.17 million tonnes in the drought period with a reduction of 0.14 million tonnes in Ramanathapuram district.

Table.4. Trends in dry and semidry rice cultivation in the study area (2002-06)

('000 ha)

District/state	Total area	Irrigated area	Dry/semidry
Ramanathapuram	1.25	0.54	0.71
	(100.00)	(43.25)	(56.75)
Sivagangai	0.82	0.65	0.17
	(100.00)	(79.58)	(20.42)
Tamil Nadu	17.09	15.69	1.40
	(100.00)	(91.80)	(8.20)

(Figures in parentheses denote percentage)

5. Varietal adoption behaviour

5.1. Varietal distribution

Varietal decisions are completely farmers' perceptions. If farmers perceive improved variety to be superior to traditional varieties in terms of one or more characteristics, they would like to adopt such improved varieties. Therefore, it is imperative that the varieties meant for water limiting environment should ensure minimal level of yield during the stress period and fetch high returns ultimately the framers are induced to go for higher level of adoption. In rainfed rice production environments most of the farmers are practicing only the traditional methods of cultivation. The farmers rely mainly on traditional varieties, which are low yielding but tolerant to water stress. Land races are cultivated to a large extent in rainfed ecosystem and farmers prefer to grow land races due to their drought tolerant characters. Land races fetch moderately higher revenue during the drought period compared to HYVs, despite higher productivity of modern varieties, due to low cost of production (Selvaraj and Ramasamy, 2006). Of the total area under rice, land races are cultivated to an extent 3.43 per cent in Tamil Nadu (2003-04 to 2005-06), while in Ramanathapuram district land races were cultivated to an extent of 40.55 per cent (Table 5). With the introduction of high yielding modern rice varieties, area under land races declined in the Ramanathapuram and Sivagangai districts with a sharp decline in the State. Displacement of traditional varieties by improved varieties has changed production practices especially in terms of greater use of modern high yielding rice varieties.

Table 5.Trends in coverage of area under modern varieties in Tamil Nadu (ha)

Year	High Yielding Rice Variety		Land Races		Total rice area	
	Average area	CGR (percentage)	Average area	CGR (percentage)	Average area	CGR (percentage)
1984-85 to 2005-06	1919532 (93.31)	-0.53	137671 (6.69)	-6.67	2057204 (100)	-0.01
1984-85 to 1999-00	1984193 (92.51)	0.53	160748 (7.49)	-6.63	2144941 (100)	0.00
1990-91 to 2005-06	1920678 (94.94)	-1.20	102312 (5.06)	-6.14	2022990 (100)	-1.44
2000-01 to 2005 -06 (AGR)	1736328 (96.00)	-0.16	72287 (4.00)	-2.27	1808615 (100)	-0.24
2004-05 to 2005-06 (AGR)	1712419 (96.54)	10.72	60890 (3.43)	8.34	1773309 (100)	10.63

CGR – Compound Growth Rate
AGR – Annual simple Growth Rate

Growing several varieties of rice is a form of diversification that can stabilize total crop output if yields of different varieties are poorly correlated. Varieties with different traits reduce risk by avoiding period-specific risk. It was noticed that all DT adopters adopted this mechanism and they shifted from the cultivation of land races and HYVs during the previous year to DT varieties. DT adopters apart from cultivating PMK3 and PMK4, cultivated ADT 36. Number of rice varieties grown by a single farmer ranging from one to three. About 85 per cent of HYV adopters shifted to HYVs from land races. Number of varieties grown by a single HYV adopter varied from one to five. Only three per cent of the farmers growing land races switched over to modern high yielding varieties, while the remaining farmers have been growing the same variety year after year.

Sample farmers cultivated rice only during the samba season and nearly 10 varieties were grown in the sample farms. Mattai and Chithiraikar were the major land races covering more than 22 per cent of the total area under rice in the sample farms. Continuous use of traditional varieties is due to the non-availability of seeds and farmers lack of awareness about high yielding varieties particularly drought tolerance (DT) rice varieties. Among the HYVs, ADT 36, ADT45, IR36 and ponni were predominantly cultivated, which constitute 72 per cent to the total area under rice.DT varieties like PMK3 and PMK4 were cultivated in 6 per cent of the total area under rice.

Among the high yielding variety growers, ADT36 was found to be the major variety grown by 70 per cent of the farmers during the samba season followed by 14 farmers (19.18 per cent) cultivated ADT 45 variety. Other popular varieties were ponni (6.85 per cent) and IR 36(4.11 per cent).During the last five years majority of the farmers cultivated ADT 36 followed by ADT 45 and ponni. Among the land races growers, nearly 86.67 per cent cultivated mattai followed by ADT36 (6.67 per cent) and ADT45 (4.44 per cent).All the growers of land races cultivated mattai during the last five years. Number of farmers cultivating DT varieties increased from 7 to 21 during 2004-08.With the introduction of drought tolerant varieties like PMK2,PMK3 and PMK4 the farmers growing ADT 36 slowly switched over to drought tolerant varieties.

According to (Selvaraj and Ramasamy, 2006) farmers in the Ramanathapuram district cultivated land races like Mattai, Norungan and Chithiraikar and high yielding varieties namely MDU 5 and IR 20 during 2005.Due to the normal distribution of rainfall the farmers cultivated wide diverse of varieties including land races, high yielding varieties namely ADT 36, ADT45, IR36, Delux Ponni and Culture Ponni, and drought tolerant varieties namely PMK 3, Ashoka228 and Ashoka 200F.Number of varieties cultivated declined due do the better performance of high yielding varieties like ADT 36 and ADT45 during 2008.

5.2. Factors determining adoption of DT rice varieties

5.2.1 Preference characteristics of the varieties perceived by the farmers

Farmers' perceptions regarding cultivation of rice varieties are generally categorized in to agronomic factors, economic factors, grain characteristics and social factors. The agronomic factor includes weed intensity, drought tolerance, pest and disease resistance, response to fertilizer, palatability of straw, adoptability of machinery and yield. Economic factors include price, consumer preference, labour requirement and cost of seed. Grain characteristics include nutritional quality, grain size, colour and milling recovery. Social factor includes extension contact, awareness and economic position of the farmer.

Preference of growing ADT 36, ADT 45, IR20, IR36 and TKM9 was due to nutritional quality as reported by 82 per cent of the sample respondents followed by better yield (77 per cent) and good straw quality (70 per cent). Superiority traits of these HYVs over other varieties such as better milling recovery (68 per cent) and slender grain size (58 per cent) were also reported for preference. Susceptibility to drought (62 per cent), higher seed cost (58 per cent of respondents), higher weed growth (50 per cent) were reported as major constraints in cultivation of these HYVs. On the contrary, lesser input requirement particularly human labour (82 per cent), highly tolerant to drought (62 per cent), low seed cost (61 per cent) and resistant to pests and diseases (46 per cent) were reported by the sample respondents as the main advantages of growing land races. Higher yield followed by drought tolerance were the major reasons for growing DT rice varieties. Majority of the sample respondents (71 per cent) reported that DT rice varieties fetched them higher yield apart drought tolerant character (62 per cent). Further, 62 per cent of the sample respondents also reported that good extension contact and encouragement by the scientists were the important factors for preference towards DT rice varieties. The constraints faced by the DT adopters include non availability of seeds, higher weed growth and more labor requirement.

5.2.2. Economics of Production

Major cultivation expenses for land races growers was cost of machine labour accounting for 48.20 per cent of the total cost of cultivation followed by human labour (22.67 per cent), seeds (13 per cent) and manures (8.39 per cent). Land races growers incurred Rs.8745 per hectare towards cost of cultivation and total return realized was Rs.11859 per hectare. Human labour was the major input sharing 30.07 per cent of the total cost of cultivation followed by machine power (33.18 per cent), manures (9.69 per cent), seed (9.50 per cent) and fertilizers (8.38 per cent) for growers of HYVs. Similarly, for cultivation of drought tolerant rice varieties, human labour was the major input accounting for 37.27 per cent of the total cost of cultivation followed by machine power (29.54 per cent), manures (11.99 per cent), seed (7.29 per cent) and fertilizers (6.09 per cent). Estimated benefit-cost ratio for adopters of land races, HYVs and DT rice cultivars was 1.36, 1.53 and 1.82, respectively (Table 6).

Table 6. Economics of rice production (Rs/ha)

Particulars	**Land Races**	**HYVs**	**DT**
Seeds	1137.29 (13.00)	1535.47 (9.50)	1125 (7.29)
Human labour	1983.05 (22.67)	4862.12 (30.07)	5750 (37.27)
Machine power	4215.25 (48.20)	5363.73 (33.18)	4557.25 (29.54)
Agro chemicals	64.41 (0.74)	528.84 (3.27)	192.86 (1.25)
Fertilizers	116.95 (1.34)	1355.30 (8.38)	940 (6.09)
Manures	733.90 (8.39)	1567.33 (9.69)	1850 (11.99)
Irrigation	-	35.30 (0.22)	144.29 (0.94)
Resowing	-	4.29 (0.03)	25.00 (0.16)
Interest on variable cost @ 6%	495.10 (5.66)	915.14 (5.66)	861.69 (5.59)
Total variable cost	8745.95 (100)	16167.5228 (100)	15427.66 (100)
Total income	11859.44	24670.75	28084.29
Net Income	3113.49	8503.23	12656.63
BCR	1.36	1.53	1.82

5.2.3 Other determinants

Apart from the advantages of growing DT rice varieties over other varieties in terms of yield and returns, other determinants of adoption was also analyzed using Tobit model[3](Table 7). Experience will improve the farmers' skill on growing of DT varieties as these varieties require specific packages to be adopted. More experienced grower may have a lower level of uncertainty about the performance of DT varieties. Farmers with higher experience appear to have often full information and better knowledge and are able to evaluate the advantage of the cultivating DT rice varieties. The findings indicate that experience level of the farmers is positively and significantly influencing the adoption rate of drought tolerant rice varieties. This outcome shows that experience of the farmers should be considered as a prerequisite for selection of farmers for conduct of OFT and other research trails for speedy adoption of new DT varieties.

Higher yield influences the farmers to cultivate DT varieties thus increase the rate of varietal adoption. Drought tolerant varieties withstand drought and production loss is minimal during drought period. Findings indicate that higher yield of DT varieties positively and significantly influence adoption of DT rice varieties. DT rice adopters on an average, realized 2926 kg of rice yield per ha, which was 8 percent higher than the yield of HYVs. Better the price for DT rice varieties the farmers cultivating it. However, the results are against the apriori expectation. It was found that market prices of DT varieties are lower by 6 per cent compared to HYVs. The market price of DT varieties was Rs.805 per quintal, while it was Rs.850 per quintal for HYVs during period of survey.

Table7. Maximum likelihood estimates of Tobit model

Variables	Estimated coefficients	Standard error	t-ratio	Marginal effects
Constant	45.2896	20.2802	2.233	10.0178
Age (years)	-0.0199	0.1573	-0.127	-0.0319
Farming experience (years)	0.3257	0.1605	2.029**	0.1063
Education (years)	0.3095	0.2657	1.165	0.1102
Farm size(ha)	0.1766	0.5050	0.350	0.0650
Yield (kgs/ha)	0.0110	0.0028	3.881**	0.0034
Price (Rs/qtl)	-0.0926	0.0306	-3.029**	-0.0278
Access to extension advice	-0.8862	2.345	-0.378	0.1212
Membership in an organization	-0.1190	2.612	-0.046	0.1341

** represents 5 per cent level of significance.

5.2.4 Technological contribution of DT rice varieties

Total productivity difference between the drought tolerant and high yielding rice varieties was estimated at 9.41 per cent[4]. Among the various sources responsible for total productivity variation, the difference in technology contribution was much higher with 9.20 per cent. Contribution of differences in input use levels to the total productivity difference was 0.21 per cent. Among the various inputs contributing to the productivity difference between drought tolerant and high yielding rice varieties, human labour (0.37 per cent), farm yard manures (0.03 per cent), fertilizer (0.02 per cent) contributed positively (Table 8).

Table 8. Decomposition of productivity difference between the drought tolerant varieties and high yielding rice varieties

Source of productivity difference	Percentage contribution
Total Difference in output	9.41
Source of contribution	
A. Technology	9.20
B.Input use	
1)Seed	-0.20
2) Machine labour	0.00
3)Human Labour	0.37
4)Fertilizer	0.02
5)FYM	0.03
Due to all inputs	0.21

5.2.5. Farm efficiency factor

Efficiency of a farm refers to its performance in the utilization of resources as it is important to evaluate how best the resources are being utilized and what possibilities exist for improving the operational efficiency in the phase of overall resource efficiency. Such efficiency studies could also show whether it is still possible to increase the productivity of DT rice varieties by improving the level of efficiency without actually increasing the resource base. Mean technical efficiency was estimated at 76 per cent for land races growers, 87 per cent for HYVs adopters and 81 per cent for DT adopters[5]. In other words, about 24 per cent of the difference between the actual and the frontier output was observed for land races growers due to technical inefficiency, while it was 13 per cent for HYVs adopters and 19 per cent for DT adopters (Table 9). Majority of the farmers (85 per cent of DT variety adopters) had the technical efficiency ranging from 61-90 per cent and there were only 2 farmers operating at above the 90 per cent level. Among the HYVs adopters, about 58 per cent were found to be operating at the technical efficiency ranging from 76-90 per cent and about 33 per cent were operating at the above 90 per cent level of efficiency. Among the land race growers 44 per cent were operating at above 90 per cent and 18 per cent were operating at below 50 per cent efficiency. The estimates of frequency distribution of efficiency levels revealed that there were wide variations in efficiency levels among growers of land races and such variation is lower among the DT rice variety adopters implying that variability in yield among the DT adopters was low as most of farmers adopted the packages of practices in time with recommended levels.

Table 9. Maximum likelihood estimates of stochastic frontier function

Variables	DT adopters	HYV adopters	Land races growers
Constant	3.5689** (2.03)	6.1065*** (21.27)	6.3021*** (26.958)
Labour(man days/ha)	0.2786* (1.91)	0.0194 (0.48)	0.1298*** (6.08)
Machineries(hrs/ha)	0.3419*** (5.91)	0.0787 (1.07)	0.0175*** (11.06)
Fertilizer (cost/ha)	0.3952** (2.47)	0.0325 (0.76)	0.0790*** (4.55)
Manures(kgs/ha)	0.0268 (0.14)	0.1570 (1.62)	0.0557* (1.78)
σ^2_u	0.1761	0.0784	0.2822
σ^2_v	0.0115	0.0051	0.0734
$\lambda = \sigma_u / \sigma_v$	3.9069	3.9216	1.9609
$\Theta = \sigma^2_u / (\sigma^2_u + \sigma^2_v)$	0.9386	0.9389	0.7934
No. of observations	21	60	39
Mean technical efficiency	0.8110	0.8739	0.7613

(Figures in parentheses indicate estimated asymptotic 't'ratio)
* denotes significance at 1 per cent level,
** denotes significance at 5 per cent level,
*** denotes significance at 10 per cent level.

Implications

With more often occurrence of drought in rainfed rice ecosystems, it is necessary to enhance the adoption of drought tolerant varieties to sustain both household food and income security as these varieties fetch higher income to the farmers and withstand water stress guaranteeing the farmers the required yield to sustaining livelihood. Currently, in the absence of any formalized systems of seed supply, most of the adoption occurs through farmer to farmer seed exchanges and other informal means in these marginal environments. To realize the full benefits of DT rice varieties, improving the existing seed supply and other market mechanisms are crucial. DT rice varieties growing farms are operating at the technical efficiency of 81 per cent indicating that there is a scope to enhance the productivity with existing resources. Therefore, providing extension services like demonstrations and trainings play a crucial role in minimizing the inefficiencies in rice production as DT rice varieties require specific agronomic packages and input levels with timely sowing.

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Notes

1. Drought year was assessed adopting the methodology of Indian Meteorological Department (annual summaries and monthly weather reports) as indicated below

Nature of drought	Rainfall deviation from normal (per cent)
Slight drought	-11 to -25
Moderate drought	-26 to -50
Severe drought	-50 and below

2. Actual rice production during the drought years was compared with the normal production (mean of last 5 years production) to calculate the loss in rice production. Similarly, for estimation of value loss in rice production in monetary terms, real prices were used. The nominal prices prevailing during the particular crop years were deflated to get the real prices. Whole sale price indices were collected from the published sources to estimate real prices. By keeping 1980-81 as the base year the indices were converted to real ones in order to eliminate the inflation effect on prices by keeping the index of initial year as 1.

3. Limited dependent variable model was used to identify factors determining farmers' adoption and intensity of adoption of DT rice varieties. Adoption of DT varieties like many other farm technologies is subjected to two response choices, namely; adoption and non-adoption. A particular technology is adopted when the expected utility from using it exceeds that of non-adoption. Though it is not observed directly, the utility(U_{ij}) for a particular farmer (i) to use a particular technique (j) can be defined as a farm-specific function (H_i) of some vector of technology associated characteristics(X_j), plus a error term with zero mean and constant variance (e_{ij}) thus

$$U_{ji}=e_jF_i\ (H_i,\ Xi)+e_{ji}\quad j=1,\ 2;\ i=1\ldots\ n, \qquad \text{--- (1)}$$

Where, 1 represents adoption of the new technology and 0 represents continued use of the old technology. The i th farmer adopts j=1 if $U_i1>U_i0$. The utility of adoption U_{ij} can be inferred from farmers' continuous choice over a predefined interval (intensity of adoption). Before running the limited dependent variable model all the hypothesized explanatory variables were checked for the existence of endogenity and multi-collinearity problem. Presence of endogenity was detected by Hausman Endogenity Test.

The empirical model used for the Limited Dependent Model is

$Y = a+\beta1AGE+\beta2EXP+\beta3EDU+\beta4\ FSIZE+\beta5YIE+\beta6PRI+\beta7\ EXT+\beta8MEM+e_i$

Where,

Y is the dependent variable which is a proportion of area under DT rice varieties to the total rice area and expressed in percentage.

Explanatory variables,

AGE = age of the farmer (years)
EXP = experience of the farmer (years)
EDU = education of the farmers (years)

FSIZE = farm size (ha)
YIE = yield of rice (kgs/ha)
PRI = price of the rice (Rs/qtl)
EXT = access to extension service (dummy 1=if access to extension advice and 0=otherwise)
MEM = member in any farmers organization (dummy 1=member in any organization, and 0=otherwise)

4. Output decomposition model was used for investigating the contribution of various constituent sources to the productivity difference between the cultivation drought tolerant and the high yielding rice varieties. For any two production functions, the total change in the productivity could be brought out by shifts in the production parameters that defined the production function itself and by the changes in the input use levels. Two separate production functions, one for drought tolerant rice varieties and another for high yielding rice varieties cultivation were fitted to analyze the productivity difference between the drought tolerant and high yielding rice cultivation attributable to technology.

Logarithm form of Cobb-Douglas production function for high yielding variety rice cultivation is;

$$\ln Y_h = \ln a_{h0} + a_{h1} \ln SEED_h + a_{h2} \ln ML_h + a_{h3} \ln HL_h + a_{h4} \ln FERT_h + a_{h5} \ln FYM_h + U_C \quad \text{-- (1)}$$

In logarithm form, Cobb-Douglas production function for drought tolerant rice variety rice cultivation is;

$$\ln Y_d = \ln a_{d0} + a_{d1} \ln SEED_d + a_{d2} \ln ML_d + a_{d3} \ln HL_d + a_{d4} \ln FERT_d + a_{d5} \ln FYM_d + Ud \quad \text{---- (2)}$$

Taking differences between (1) and (2) and adding some terms and subtracting the same terms.

$$\ln Y_d - \ln Y_h = (\ln a_{d0} - \ln a_{h0}) + (a_{d1} \ln SEED_d - a_{h1} \ln SEED_h + a_{d1} \ln SEED_d - a_{d1} \ln SEED_d) + (a_{d2} \ln ML_d - a_{h2} \ln ML_h + a_{d2} \ln ML_d - a_{d2} \ln ML_d) + (a_{d3} \ln HL_d - a_{h3} \ln HL_h + a_{d3} \ln HL_d - a_{d3} \ln HL_d) + (a_{d4} \ln FERT_d - a_{h4} \ln FERT_h + a_{d4} \ln FERT_d - a_{d4} \ln FERT_d) + (a_{d5} \ln FYM_d - a_{h5} \ln FYM_h + a_{d5} \ln FYM_d - a_{d5} \ln FYM_d) + (U_d - U_h) \quad \text{----} \quad (3)$$

By using logarithm rule equation (3) becomes;

$$\ln (Y_d/Y_h) = \{\ln [a_{d0}/ a_{h0})\} + \{ (a_{d1} - a_{h1}) \ln SEED_d + (a_{d2} - a_{h2}) \ln ML_{d2} + (a_{d3} - a_{h3}) \ln HL_d + (a_{d4} - a_{h4}) \ln FERT_d + (a_{d5} - a_{h5}) \ln FYM_d \} + \{ a_{d1} \ln (SEED_d/SEED_h) + a_{d2} \ln (ML_d/ML_h) + a_{d3} \ln (HL_d/HL_h) + a_{d4} \ln (FERT_d/FERT_h) + a_{d5} \ln (FYM_d/FYM_h) \} + [(U_2 - U_1)] \quad \text{----} \quad (4)$$

This equation involves decomposing the logarithm of ratio of per hectare productivity of drought tolerant rice varieties and high yielding rice varieties. This is approximately a measure of percentage change in per hectare output between the drought tolerant and high yielding varieties of rice cultivation. The summation of first and the second terms on the right hand side of the decomposition model together represented the productivity difference between the drought tolerant and high yielding rice cultivation attributable to technology. The third term provided the productivity difference between the drought tolerant and high yielding rice varieties attributable to the differences in the input use. The variables specified are :

Y_d (Productivity): Productivity of drought tolerant rice varieties (kgs)
Y_h (Productivity): Productivity of high yielding varieties (kgs)
SEED (Seed): Quantity of seed used for the cultivation by the sample farmers (kgs)

ML (Machine labour): The hours of usage of machine labour both owned and hired was calculated for the different type of operations prevailed in the study area.
HL (Human labour): Human labour was estimated in terms of eight hours of work per day (man days)
FERT (Fertilizers): Cost of fertilizers was based on the actual prices paid by the sample farmers including the cost of transportation and other incidental charges if any.
Farm yard manure: Cost of FYM used in the cultivation of both cultivars of rice was measured. The cost was imputed at the market price in the village including cost of transportation and other incidental charges, if any.

5**.** Technical efficiency refers to the ability to minimize input use in the production of a given output vector or the ability to obtain maximum output from a given input vector. In the present study to understand the technical efficiency among the DT adopters and non-DT rice adopters (HYVs and land races growers) stochastic frontier model was employed (Kalirajan and Shand, 1989). The empirical model used in the present study is as follows

$$\ln YD = \ln a0 + \beta 1 \ln FR + \beta 2 \ln MR + \beta 3 \ln LR + \beta 4 \ln MC + e$$

Where,

YD - Yield of rice (kg/ha)
FR - Fertilizer cost (Rs/ha)
MR - Manures (kg/ha)
LR - Labour (man days/ ha)
MC - Machine (hrs/ha)
e - Systematic and random error components.

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