Introduction of New Technologies in Agriculture: A Study of the Challenges in the Adoption of Hybrid Rice in India

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Abstract

Rice is India's number one foodgrain and is crucial to its food security. Raising its production with increasing demand and escalating commodity prices is a major challenge. The promising hybrid rice technology, despite its success in neighboring China and Bangladesh, has faced serious difficulties in India. The study examines the complexities in the introduction and adoption behavior of hybrid rice. It develops a conceptual framework to understand the adoption which includes technological, economic, behavioral, market and policy factors. The research uses secondary data, interviews, and primary farmer sample surveys to explore and test the conceptual model. Preliminary specific findings on the processes, determinants and challenges in the adoption of hybrid rice are reported. This would help in identifying critical factors and recommendations of relevance to this and other such technologies.

1. Introduction

Raising food production in the context of rapidly increasing food demand and escalating commodity prices is a major challenge in India, and breakthroughs are urgently required. One such promising breakthrough is the hybrid rice technology, which despite significant success in neighboring countries such as China and Bangladesh, has faced serious challenges on its introduction in India. Rice is India's number one foodgrain and is crucial for the country's food security. In this context, the study attempts to examine the complexities in the introduction of new technologies, with a focus on the experience and adoption behavior for hybrid rice, on which little comprehensive work is available.

A literature survey is done to identify all the factors that influence the adoption of new technologies in developing country agriculture. Based on this, a conceptual framework is developed which can help comprehensively understand and explain the adoption of such technologies. This includes technological, economic, behavioral, market and policy related factors. Information for the research is collected through secondary data sources, interviews, and a small pilot primary farmer sample surveys in one state. The data is analyzed through tabulation and simple econometric methods.

2. The importance of rice in India

The annual growth rates of production of total foodgrains as well rice were the highest in the period following the introduction of HYVs during Green Revolution. However, the growth rates have shown a decelerating trend in the recent decades. The production growth rates have

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dropped to as low as 1.21 and 1.19 percent per annum for total foodgrains and rice respectively during the period 1992-93 to 2009-10 (Table 1).

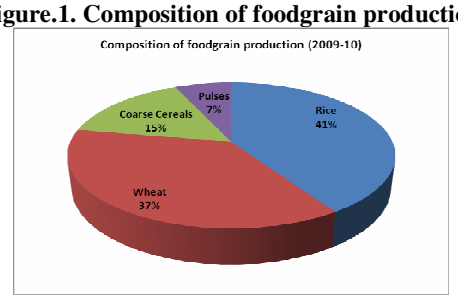
Table.1. Annual growth rates for foodgrain production

	Rice	Wheat	Coarse Cereals	Pulses	Total Foodgrains
1952-53 to 1971-72	2.73	5.59	1.53	0.19	2.51
1972-73 to 1991-92	3.22	4.72	0.53	1.24	2.88
1992-93 to 2001-02	2.08	2.64	-0.35	-0.36	1.69
1992-93 to 2009-10	1.19	1.52	0.98	0.46	1.21

Source: Ministry of Agriculture, Government of India

Within the country, rice occupies one-fourth of the total cropped area, contributes about 41 percent to the total foodgrain production (Fig.1). It continues to play a major role in the food security of the nation. The post-independence era, after a food crisis, witnessed unparalleled developments in the form of the green revolution. Increase in rice yields, area and greater cropping intensity transformed India from a net rice importing country in the mid-1960s to a limited exporter of rice by the early 1990s.

Figure.1. Composition of foodgrain production



The growth rates of production and yield were as high as 3.22 percent and 2.64 percent post Green Revolution. However, in the last two decades the growth has slowed considerably. The area growth has become negligible in the last two decades and the production and yield growth rated have dropped to about 1 percent. Such low growth rates raise questions about the country's ability to feed its people in the future. Therefore, there is an urgent need of enhancing productivity levels, particularly in rice.

Table.2. Annual growth rates for rice

	Area	Production	Yield
1952-53 to 1971-72	1.18	2.73	1.54
1972-73 to 1991-92	0.58	3.22	2.64
1992-93 to 2001-02	0.85	2.08	1.23
1992-93 to 2009-10	0.09	1.19	1.10

Source: Ministry of Agriculture, Government of India

3. Hybrid Rice Technology

The research work on hybrid rice is reported to have started first in China in 1964, but the earliest hybrids were released for cultivation only in 1976 (Janaiah et al, 2002). More than 50% of the rice area in China is now reported to be under hybrid rice cultivation and it contributes about 60% of the total rice production. Hybrid rice is believed to have helped

China produce 20 million tonnes of additional paddy every year and save more than 2 million ha of agricultural land for other uses (Julfiquar et al, 2003).

Hybrid rice is seen as a viable and proven technology even in other countries such as Bangladesh, Indonesia, Philippines and Vietnam. In these countries, this technology is being considered as a tool to ensure food security (Hasanuddin & Suyitno, 2001), eliminate rice imports (Sana et al, 2001), and feed people in rural and far off areas. It also helps in dealing with the shortage of agricultural land and to make way for other high economic value farm products and with available markets (Dan, 2001).

The concentrated research efforts to develop and use hybrid rice technology in India were initiated since 1989. The Indian Council of Agricultural Research (ICAR) led the hybrid rice research in the country with the help of international organizations. The first four rice hybrids were released in the country during 1994. Since then 43 hybrid varieties have been released for cultivation from public and private sector by 2010.

Table.3. Area under hybrid rice in India

Year	Gross Rice Area (mn ha)	Area planted to hybrid rice	
		ha	% of gross rice area
1996	42.84	50	0.12
2000	45.16	175	0.39
2004	42.59	570	1.34
2005	41.91	750	1.79
2006	43.66	1000	2.29
2007	43.81	1100	2.51
2008	43.77	1400	3.2

Source: Estimated based on seed production during preceeding year considering seed rate at 15 kg per ha.
Source for seed data: Ramesha et al (2009).

However, even by 2000, only 0.39 percent of the total rice area was planted with hybrid rice and as of 2008, hybrid rice occupied merely 3.2 percent of the total rice area. The spread of hybrid rice technology is clearly extremely slow as compared to other new seed technologies such as Bt cotton which rapidly spread from zero to more than 90 percent of area under cotton between 2002 and 2010. According to the industry experts too, the adoption rates are not picking up as expected and it is reported that the farmers are dropping out of hybrid rice cultivation. This is despite hybrid rice being made a major component of the National Food Security Mission, and huge efforts and investments made by the public and private sectors in research and development of hybrid rice. It thus becomes extremely important to examine the reasons behind the slow adoption of hybrid rice in the country, and suggest possible solutions.

4. Literature on technology adoption

Adoption of a technology in agriculture is often seen as a multi-stage process and the time required for each stage varies. It is often seen as a five stage process: awareness, interest, evaluation, trial and adoption. According to the *Innovation diffusion model* (Rogers, 1962), access to information about the innovation or a new technology is one of the most important factor determining the adoption decisions taken by the farmers. Information reduces the uncertainty and risk and induces adoption by the farmers who are risk-averse (Feder &O'Mara in Feder & Slade, 1984). The extension services, (Adesina & Zinnah, 1993), fellow farmers (Gandhi & Namboodiri, 2006), and promotion by private firms (Brown, 1981) have been shown to be influential in the decision making process of the farmers.

Adoption decisions are also said to be influenced by age (Saka et al, 2005), gender (Lin, 1991), experience, education (Rogers, 1962, Hayami & Rutton, 1971, Lin, 1991) of the decision maker. Apart from this the social network, exposure to the outside world (Rogers, 1962), personal circumstances and family situation (Pannell, 2006) also have an impact on the choice of using a technology.

It has been also shown in many studies such as by Griliches (1957), Mansfield (1961, 1963), (Lin, 1991) and Pannell et al (2006) that adoption of a technology in a market economy is substantially an economic decision process. Farmer's adoption of a new crop variety is substantially determined by the relative profits offered by it (Janaiah et al, 2002), Chengappa et al (2003), Hossain et al (2003). Traxler & Byerlee (1993) explains adoption in terms of joint–product profitability. Straw yield and fodder quality (Kshirsagar et al, 2002) are important factors in crops such as rice especially for farmers who have livestock. Government interventions such as procurement and minimum support price encourge farmers to adopt a particular technology because of reduced risks and uncertainty (Sunding & Zilberman, 2000). The ease of trial also affects the adoption decisions in case of agricultural technologies (Kshirsagar et al, 2002).

It was observed during the Green Revolution that the new technology was adopted immediately by the large farmers (Hazell & Ramasamy, 1991). Lipton & Longhurst (1989) pointed out that 'when the farmer's wealth or economic resource base in considered, those with higher incomes tend to be the main adopters' (Herdt & Capule in Lipton & Longhurst, 1989). The accessibility of a place and hence, the role of distance and geography of a particular place in technology adoption has also been emphasized by Rogers (1962) and Sunding and Zilberman (2000). Adesina & Zinnah, (1993) included taste, yield, ease of cooking, tillering capacity, ease of threshing, milling recovery rate etc of rice grain as the variables to explain the adoption behavior.

Lin (1991) considered credit as an important factor influencing the adoption of technology. Small farmers might find it difficult to buy these inputs in sufficient quantity and within time (Duwayri et al, 1999). The absence of collateral and high interest rates are some of the other factors which might restrict the availability of capital to the farmers even if the credit source is present (Cromwell, 1996 in Chaudhary, 2000).

Supply is a mechanism through which innovation is made available to potential adopters (Brown, 1981). Supply of the technology is depends on factors like - IPR (Gandhi & Patel, 2001), investment in R&D, lack of parental lines (Paroda in Tran, 2003), limited heterosis (Virmani, 2001), cost of production etc. Once released, adequacy of seed supply (Nguyen et al,1998) and timely supply of the seeds are very important (Singh, 2000). Brown (1981) and Coughlan et al (2009) studied the distribution related factors in adoption of new technologies and concluded that channel decision and pricing of the product play an important role.

5. Studies on hybrid rice in India

Janaiah (2002) studied the adoption of hybrid rice in five major states of India - West Bengal, Tamil Nadu, AP, Karnataka, Orissa. Spatial variation in the output of hybrid rice was found across the five states. While the all India average of yield gain across five states was 16%, the highest yield advantage was reported in West Bengal (52.9%) and the lowest was reported in Tamil Nadu (-18.6%) where it could not perform even at par with the inbred varieties. Janaiah

also reported that more than 80 percent of the farmers considered hybrid rice grain as having poor quality. Low yield advantage of hybrid rice over inbreds was reported in Andhra Pradesh and Tamil Nadu. Another major work was done by Chengappa, Janaiah & Gowda in 2003 in the state of Karnataka, in which high seed cost and low output price were found as the factors leading to lower profitability of hybrid rice in the state. It was also observed that the presence of extension services led to adoption of hybrid rice by the farmers. It was also found that the impact of source of seeds influnced the adoption decisions.

Significant gaps still exist in term of having an integrated and comprehensive understanding and insight on the adoption of hybrid rice in India and in a developing country context. While most of the literature on hybrid rice has focussed on economic viability and grain characteristics, the importance various other factors such as the potential of the technology, demand creattion, supply and distribution and more have not been adequately considerd in the context of adoption of new technologies such as hybrid rice in agriculture.

6. The conceptual model

Many researchers believe that adoption studies in developing country settings such as India should be placed in the broadest possible framework because of the large number of factors and forces affecting the adoption process and rate (see for example Hodgdon & Singh (n.d), Desai & Stone (1987) and Gandhi & Desai (1992)).There is a need for a comprehensive framework that includes supply as well as demand side elements, non-price factors, and market as well as non-market factors.

One such conceptual framework has been developed at the International Food Policy Research Institute (IFPRI) through the works of Desai & Stone (1987) and Gandhi & Desai (1992). The framework was developed for agricultural input of fertilizers and has been extended by Gandhi & Patel (2001) to other agricultural inputs. It is relatively comprehensive and appears to cover almost all factors influencing technology adoption in the context of a developing country. It is a multi-level model which is mediated by a number of factors and may be usefully applied to comprehensively study the adoption of hybrid rice in India, as well as other technologies. The framework adapted and developed for hybrid rice in India is shown in Figure. 2 and its major elements/ stages are described below.

Agronomic Potential: It has been defined as the 'maximum amount to which the input can be used to give the beneficial physical effect' (Gandhi & Patel, 2001). It can be either an absolute increase in the production or saving the loss of production, therefore, effectively increasing the production, from the same input use. Technology adoption and diffusion will not take-off without such a potential. R & D can create new agronomic potential in the form of - relative yield advantage, resistance to lodging, drought, pests and diseases, fertilizer responsiveness etc
On a macro-level, total cultivable area, rainfall, irrigation, soil quality etc are the factors which determine the agronomic potential of the technology.

Agro-economic Potential: Agronomic potential is essential but not enough. The agronomic potential of a new technology needs to be economically viable and attractive. It should have a market value which is good enough to recover the costs, and result into profits. The agro-economic potential is determined by the the price obtained for the output and the cost of inputs.

The output price is a function of the grain quality and its demand. The profitability of the technology is also affected by the govenrment interventions such as input subsidy and minimum support price, as well as competing input prices.

Effective Demand: Agronomic potential per se is not enough, especially in a developing country context, until awareness and demand are created. Creation of demand involves processes which cause the farmers to use the new technology or input fully from a situation where there was absolutely no use of the technology (Desai & Stone, 1987). The farmer must be aware of the technology and should have the willingness to take the risk. This is determined by the availability of information, extension services, private promotion, age, education, gender, experience etc of the farmer. Cheaper and easier credit facilities may promote the adoption of costly technologies. The crop management practices, the proper package of practices and training offered to the farmers also have an impact on the choice of technology by the farmers.

Actual Consumption

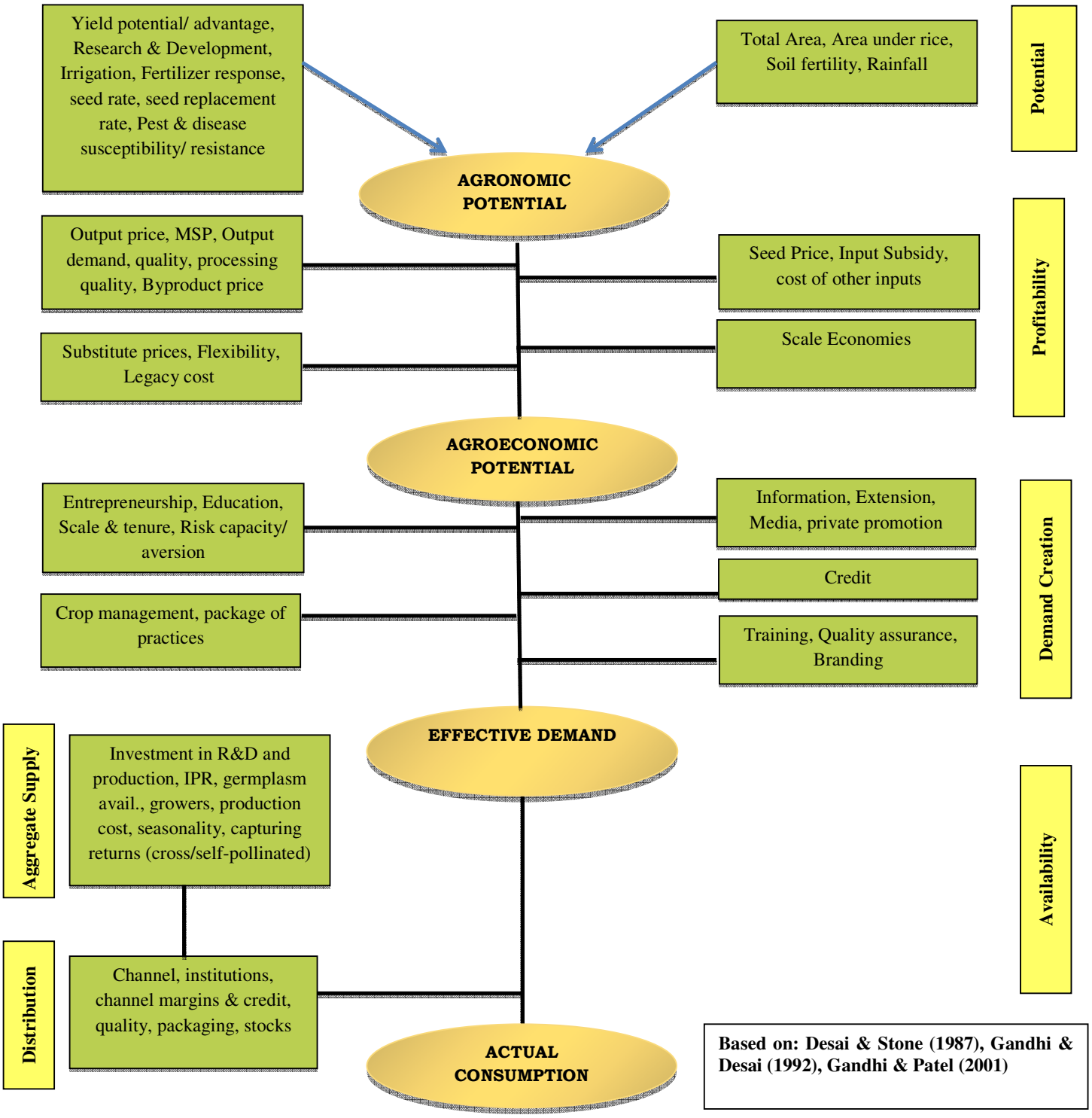
Even after the effective demand has been created, the actual consumption or use of the technology would be limited by:

a) Aggregate Supply: Supply of seeds often requires large investments in R&D, subsidies, germplasm availability, WTO policies and intellectual property rights (IPR). Seasonality, availability of farmers to produce seed, suitable climate, maintaining purity are some of the factors that affect seed production and hence determine the aggregate supply.

b) Distribution: The distribution is critical especially in the developing country context of huge numbers of dispersed small farmers. This depends on the development of distribution channels. The margins, marketing credit, cost of carryover stocks, and storage issues can be major factors affecting the decision of the dealers and retailers. For a farmer, the quality of the seed, its timely availability, the ease of finding a retailer or dealer are some of the primary requirements. It is also important for the packaging of the technology to be according to the farmers' needs.

All these factors determine the adoption of a particular technology by the farmers and improvement in any of these may lead to increased adoption or use of the technology. A conceptual framework developed on these lines for the context of hybrid rice is shown in Figure 2.

Figure.2. Conceptual Framework



7. Data

In order to initiate the study of hybrid rice adoption behavior of the farmers, a preliminary pilot sample survey was conducted in the Indian state of Gujarat during 2011-12. Based on the conceptual framework, and preliminary interviews with the farmers and seed companies/ dealers, a detailed questionnaire was developed. A test sample of 32 farmers was surveyed over a number of districts of the state. The choice of districts was based on the market presence of hybrid rice in the region. Three of these districts – Surat, Navsari and Valsad are located in the south while Anand and Kheda are located in the central region. About 50 percent of the farmers surveyed were in the central districts and rest in the southern districts. The sample profile is given in Table 4. About 60 percent of the farmers surveyed had 6 to 12 years of schooling, 6.25 percent were illiterate and 18.75 percent had college education. In landholding size, 43.75 percent of the respondents were marginal farmers and had less than 1 hectare of land, while only 15 percent were large and owned more than 10 hectares of land.

Table. 4. Sample profile

District	Surat	Navsari	Valsad	Kheda	Anand
	5 (15.63%)	5 (15.63%)	6 (18.75%)	12 (37.50%)	4 (12.50%)
Age (in years)	20-30	31-40	41-50	51-60	Above 60
	7 (21.88%)	7 (21.88%)	10 (31.25%)	5 (15.63%)	3 (9.38%)
Education	Nil	1 to 5		6 to 12	Above
	2 (6.25%)	5 (15.63%)		19 (59.38%)	6 (18.75%)
	Marginal farmers	Small farmers		Medium farmers	Large farmers
Area owned	< 1 ha	1-2 ha		2-10 ha	>10 ha
	14 (43.75%)	5 (15.625%)		8 (25%)	5 (15.625%)

8. Analysis of adoption behavior of the farmers

By design, all the farmers in the sample were aware of hybrid rice, see Table 5. 93.75 percent of the sample farmers had previously grown hybrid rice. 81.25 percent of the total sample was currently growing hybrid rice, indicating that there was some discontinuation of hybrid rice cultivation.

Table.5. Awareness and cultivation status of hybrid rice

N=32	Yes	No
Awareness about hybrid paddy?	32 (100%)	0 (0%)
Ever grown hybrid paddy?	30 (93.75%)	2 (6.25%)
Currently growing hybrid paddy?	26 (81.25%)	6 (18.75%)

Farmers' assessment on various aspects of the conceptual model was obtained through the questionnaire. The responses were generally taken on a 5-point scale. The responses for the agronomic potential of hybrid rice are shown in Table.6. Nearly 94 percent of the farmers agreed that hybrid rice gave substantial yield advantage over the non-hybrid varieties. Hybrid rice was considered to have more tillers than the varieties by most of the farmers. On responsiveness to the fertilizer application, about 47 percent of the sample farmers agreed that hybrid rice responds well to the fertilizer application, while 37.5 percent had a neutral view.

Majority of the farmers (65%) responded that the hybrid rice did not have much pest and disease problems (though some disagreed), while about 54 percent were neutral regarding stress tolerance of hybrid rice. These responses indicate that there is not much difference between hybrids and varieties in pests, diseases and stress tolerance. In the weighted average scores, yield advantage had the highest score followed by tillering capacity, and pests/diseases had the lowest score, among the various elements of agronomic potential. These show the major features of agronomic potential.

Table. 6. Assessment of agronomic potential (Figures in percentage)

	N=32 Mean Score: 3.8616	Strongly Agree (Yes)	Agree (Yes)	Partially Agree / Disagree	Disagree (No)	Strongly Disagree (No)	No esp.	Wtd Avg Score
		5	4	3	2	1		
1	In your experience, hybrid paddy gave a substantial increase in the yield relative to other varieties	34.38	59.38	6.25	0.00	0.00	0.00	4.281
2	Hybrid paddy has better tillering capacity than other varieties	18.75	68.75	9.38	3.13	0.00	0.00	4.031
3	Hybrid paddy responds well to the fertilizers used	18.75	28.13	37.50	3.13	0.00	12.5	3.714
4	Hybrid paddy did not have much insect problem	15.63	50.00	12.50	21.88	0.00	0.00	3.594
5	Hybrid paddy did not have much disease problem	15.63	50.00	12.50	21.88	0.00	0.00	3.594
6	Hybrid paddy is tolerant to stress – drought/salinity/flood	18.75	25.00	53.13	0.00	0.00	3.13	3.645

The assessment of agroeconomic potential of hybrid rice i.e. the economic profitability was done in terms of input cost, output price, grain quality and demand (Table.7). While 65 percent of the respondents felt that the hybrid rice seeds are expensive, nearly 70 percent reported the absence of any subsidy or free distribution of seed. Regarding the demand of hybrid rice in market, majority of the respondents reported that the price that they get in the market is not good and there is no facility of government procurement of hybrid paddy in their region. By-product (straw and grass) of hybrid rice has been considered as a major advantage by all the farmers. As far as the cooking quality of hybrid rice is concerned, farmers had a mixed opinion. By-product advantage has the highest score (4.563) followed by need for lesser input (3.8444). The scores indicate that no difference in by-product and other input requirements are major positive factors, were as lack of government procurement, seed subsidy, high seed price, and poor output price are the major negative factors.

Table. 7. Assessment of agroeconomic potential (Figures in percentage)

	N=32 Mean Score: 3.1415	Strongly Agree (Yes)	Agree (Yes)	Partially Agree / Disagree	Disagree (No)	Strongly Disagree (No)	No Resp	Wtd Avg Score
		5	4	3	2	1		
1	The seeds of hybrid paddy are not very expensive	9.38	21.88	3.13	40.63	25.00	0.00	2.500
2	Free /subsidized hybrid paddy seeds are distributed during some years	3.13	3.13	18.75	31.25	40.63	3.13	1.935
3	Hybrid paddy does not require any excessive input – labor/farm/machinery/pesticide/ irrigation/ fertilizer	21.88	46.88	25.00	6.25	0.00	0.00	3.844
4	The cost of production of hybrid paddy is lower than varieties	18.75	18.75	28.13	31.25	3.13	0.00	3.188
5	Hybrid paddy fetches a premium price in the market	3.13	3.13	25.00	50.00	15.63	3.13	2.258
6	The government procurement of hybrid paddy is very	3.13	0.00	12.50	18.75	65.63	0.00	1.563

	useful							
7	Hybrid paddy has no disadvantage in terms of by-product	56.25	43.75	0.00	0.00	0.00	0.00	4.563
8	Hybrid rice has good cooking quality for own consumption	9.38	28.13	21.88	28.13	9.38	3.13	3.000

Effective demand of hybrid rice for each of the farmer in the sample was measured by assessing the personality traits, access to information, credit etc (Table.8). Almost 49 percent of the sample reported that they were generally willing to take the risk of trying a new technology. Most of the farmers accepted that they were aware of hybrid rice and its benefits. Absence of extension activity for hybrid rice evident as 65 percent of farmers said that the extension agent did not talk to them or tell them about hybrid rice. Information sharing by dealers and promotion by the seed companies was reported to be present in the region by 96 percent and 67 percent of the farmers respectively. Connectivity of the village with the town had the highest weighted average score. It was very closely followed by interaction with fellow farmers and information sharing by the dealers and salesmen. Lack of extension and training are the major negative factor.

Table. 8. Assessment of effective demand (Figures in percentage)

	N=32 Mean Score: 3.7122	Strongly Agree (Yes)	Agree (Yes)	Partially Agree / Disagree	Disagree (No)	Strongly Disagree (No)	No Resp.	Wtd Avg Score
		5	4	3	2	1		
1	You are generally willing to take risks of trying new technologies	12.50	34.38	28.13	25.00	0.00	0.00	3.344
2	You are well aware about the hybrid paddy and the benefits of growing hybrid paddy	15.63	62.50	15.63	3.13	0.00	3.13	3.935
3	You have received training/information regarding the package of practices to follow	18.75	21.88	28.13	31.25	0.00	0.00	3.281
4	Extension workers have talked to you about hybrid paddy	0.00	12.50	21.88	43.75	21.88	0.00	2.250
5	Dealers and salesmen have talked to you about hybrid paddy	15.63	81.25	3.13	0.00	0.00	0.00	4.125
6	There is substantial promotion of hybrid paddy by the private companies	9.38	56.25	31.25	3.13	0.00	0.00	3.719
7	There is adequate credit availability for your farming activities	15.63	84.38	0.00	0.00	0.00	0.00	4.156
8	Fellow farmers have told you about the benefits of growing hybrid paddy	37.50	56.25	3.13	0.00	0.00	3.13	4.355
9	The village has good connectivity with the town	40.63	59.38	0.00	0.00	0.00	0.00	4.406
10	The dependence on the non-farm income is very less	21.88	43.75	9.38	21.88	3.13	0.00	3.594

Most of the farmers reported affirmatively regarding the supply of hybrid rice seeds in their region (Table.9). Only 6.25 percent of the farmers reported that hybrid rice seeds were not available when they needed them. Apart from this, majority of the sample said that hybrid rice seeds were easily and timely available through many companies in their region.

Table.9. Assessment of aggregate supply (Figures in percentage)

	N=32 Mean Score: 3.9688	Strongly Agree (Yes)	Agree (Yes)	Partially Agree / Disagree	Disagree (No)	Strongly Disagree (No)	No Resp.	Wtd Avg Score
		5	4	3	2	1		
1	As far as you know, hybrid paddy seeds are easily available in your state and district	21.88	65.63	6.25	3.13	0.00	3.13	4.097

2	Hybrid paddy seeds are easily available when you need them	25.00	56.25	12.50	6.25	0.00	0.00	4.000
3	There are many companies supplying hybrid paddy seeds in this region	18.75	65.63	12.50	3.13	0.00	0.00	4.065

When asked about the channel of hybrid rice seed distribution (Table.10), majority of the farmers denied that the seeds were available through government and cooperative sources. Only 6.25 percent of the sample reported instances of seeds not available or stock outs. Majority of the sample was satisfied with the quality of the hybrid rice seed which was available to them.

Table.10. Assessment of distribution (Figures in percentage)

	N=32 Mean Score: 3.4643	Strongly Agree (Yes)	Agree (Yes)	Partially Agree / Disagree	Disagree (No)	Strongly Disagree (No)	No Resp.	Wtd. Avg Score
		5	4	3	2	1		
1	Hybrid paddy seed is available easily through government/cooperative sources in your village	0.00	3.13	6.25	75.00	12.50	3.13	2.000
2	The suppliers generally have the stock of hybrid paddy seeds when required	15.63	65.63	12.50	6.25	0.00	0.00	3.906
3	Hybrid paddy seeds through the channels is of good quality	9.38	84.38	6.25	0.00	0.00	0.00	4.031
4	The packaging size of hybrid paddy is appropriate	15.63	84.38	0.00	0.00	0.00	0.00	4.156
5	The source of seeds helps with other requirements such as credit	9.38	37.50	40.63	9.38	0.00	3.13	3.484

The mean scores for the farmers' responses on different components of the conceptual model were calculated. This would give a broad assessment about the problem areas. The scores indicate that the main problem area appears to be the agro-economic potential. Ignoring distribution (which is affected by one low score), the other problem area is creation of effective demand. Aggregate supply has the highest mean score followed by agronomic potential. Agro-economic potential has the lowest mean score.

Table.10a. Assessment of distribution (Figures in percentage)

	N=32	Mean Score
1	Assessment of agronomic potential	3.8616
2	Assessment of agroeconomic potential	3.1415
3	Assessment of effective demand	3.7122
4	Assessment of aggregate supply	3.9688
5	Assessment of distribution	3.4643

An overall assessment was made by asking some direct overall questions to farmers regarding the hybrid rice on a 5-point scale. About 90 percent of the sample farmers rated the yield advantage of hybrid rice as good to very good. However, only 34 percent of the sample farmers were satisfied and happy with the grain price of hybrid rice in the market. Similarly, seed cost appears to be a major issue for most of the farmers in the sample with almost 87 percent of them reporting disadvantage of hybrid rice in terms of seed cost. However, when asked whether they will use hybrid rice in future, about 90 percent indicated they would while

nearly 10 percent were undecided about it. This seems to indicate the high importance of yield advantage.

Table. 11. Overall assessment of perception regarding hybrid paddy (Figures in percentage)

		Very Good	Good	Satisfactory	Poor	Very Poor
		5	4	3	2	1
1	How would you rate the yield advantage of hybrid paddy as compared to varieties?	37.50	53.13	9.38	0.00	0.00
2	How would you rate the price advantage of hybrid paddy output as compared to varieties?	3.13	18.75	12.50	37.50	28.13
3	How would you rate the seed cost advantage of hybrid paddy as compared to varieties?	3.13	9.38	43.75	43.75	0.00
4	How would you rate your overall experience/satisfaction with hybrid paddy?	9.38	56.25	31.25	3.13	0.00
		Definitely Yes	Yes	May be	No	Definitely No
5	Will you grow hybrid paddy in future?	43.75	46.88	9.38	0.00	0.00

9. Regression Analysis

Regression analysis was done by taking the scores for overall satisfaction as the dependent variable. The independent variables included in the model were – scores for agronomic potential (AP), agroeconomic potential (AEP), effective demand (ED), aggregate supply (AS) and distribution (D), age, education and landholding size.

Model 1. Overall Satisfaction = *f* (AP, AEP, ED, AS, D)

In the first model, overall satisfaction was modeled as a function of scores for agronomic potential (AP), agroeconomic potential (AEP), effective demand (ED), aggregate supply (AS) and distribution (D). The R-square for the model was 0.637. The point estimates for the constant term, AP and ED were significant. The AP has an expected positive relationship with the overall satisfaction. Similarly, the sign for the point estimate of ED is positive as expected. The signs for the point estimates of AEP, AS and D are negative but not statistically significant indicating that they were not strongly related to the satisfaction score.

Table. 12. Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.798[a]	.637	.567	.449584

a. Predictors: (Constant), D, AP, ED, AS, AEP

b. Dependent Variable: Overall Satisfaction

Model	Coefficient			t	Sig.
	B	Std. Error	Beta		
Constant	-3.119	1.089		-2.865	0.008
AP	0.858	0.234	0.503	3.67	0.001
AEP	-0.044	0.319	-0.028	-0.138	0.892
ED	1.232	0.306	0.724	4.025	0.000
AS	-0.09	0.159	-0.107	-0.564	0.578
D	-0.161	0.25	-0.106	-0.643	0.526

Model. 2. Overall Satisfaction = *f* (AP, AEP, ED, AS, D, Landholding)

In the second model, overall satisfaction with the technology was modeled as a function of AP, AEP, ED, AS, D and Landholding. This model has a slightly higher R-square (0.641) than the previous model. Here also, only the point estimates for constant, AP and ED are significant. AS and D have unusual negative sign but these are not statistically significant. AE is positive but not statistically significant. Landholding shows a positive but non-significant relationship with the overall satisfaction with hybrid rice. This indicates that the satisfaction level does not vary with farm size, showing that the technology may be scale neutral.

Table.13. Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
2	.800[a]	.641	.554	.455999

a. Predictors: (Constant), Land, D, AP, ED, AS, AEP

b. Dependent Variable: Overall Satisfaction

Model	Coefficient			t	Sig.
	B	Std. Error	Beta		
Constant	-2.962	1.144		-2.589	.016
AP	.839	.240	.492	3.497	.002
AEP	.038	.359	.024	.105	.917
ED	1.118	.379	.657	2.949	.007
AS	-.063	.169	-.076	-.375	.711
D	-.180	.256	-.118	-.702	.489
Landholding	.012	.023	.081	.523	.606

Model.3. Overall Satisfaction = *f* (AP, AEP, ED, AS, D, Land, Age)

In the third model, another variable of age of the farmer was added to the list of independent variables existing in the model 2. The R-square in this model further improved a little to 0.665. In this model, again only the point estimates of constant, AP and ED came out to be significant. The estimates of AP, AEP and ED have expected signs. The point estimates for landholding and age also have positive sign indicating that the overall satisfaction increases with landholding size and age, but these are not statistically significant.

Table.14. Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
3	.815[a]	.665	.567	.449600

a. Predictors: (Constant), Age, Land, D, AP, ED, AS, AEP

b. Dependent Variable: Overall Satisfaction

Model	Coefficient			t	Sig.
	B	Std. Error	Beta		
Constant	-3.226	1.146		-2.815	.010
AP	.777	.241	.455	3.217	.004
AEP	.052	.355	.033	.146	.885
ED	1.090	.374	.641	2.912	.008
AS	-.106	.170	-.127	-.624	.539
D	-.074	.265	-.049	-.280	.782

Landholding	.003	.024	.021	.133	.896
Age	.009	.007	.173	1.310	.203

Model.4. Overall Satisfaction = *f* (AP, AEP, ED, AS, D, Land, Age, Education)

In model 4, another variable of education was added to the list of independent variables present in the model 3. The R-square for this model improved further a bit. However, the adjusted r-square remained the same. The point estimates for constant, AP and ED are the significant variables as in other models. Other independent variables – AEP, D, age and education have the expected signs but are not statistically significant. Age and education are relatively more significant which may indicate that overall satisfaction increases age and education of the farmer. Landholding has an insignificant and negative relationship with the overall satisfaction of the hybrid rice.

Table. 15. Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
4	.824[a]	.679	.567	.449359

a. Predictors: (Constant), Education, AP, Age, AS, Land, D, AEP, ED

b. Dependent Variable: Overall Satisfaction

Coefficients[a]

Model	Coefficient			t	Sig.
	B	Std. Error	Beta		
Constant	-3.245	1.145		-2.833	.009
AP	.726	.246	.426	2.947	.007
AEP	.126	.362	.081	.349	.730
ED	.913	.413	.537	2.211	.037
AS	-.105	.169	-.126	-.621	.541
D	.018	.280	.012	.064	.950
Landholding	-.003	.025	-.020	-.122	.904
Age	.012	.007	.216	1.560	.132
Education	.025	.025	.151	1.013	.322

a. Dependent Variable: Overall Satisfaction

Thus, we have formulated 4 different models using various combinations of the independent variables. The point estimate of constant is negative and significant in all the 4 models. Similarly, the point estimates agronomic potential (AP) are significant in all the models and have an expected positive relationship with the overall satisfaction with the technology. It shows that agronomic potential is very significant factor in this technology. The point estimates for the agroeconomic potential (AEP) has a negative sign in the first model and positive sign in all other models. However, these estimates are not significant in any of the cases. Effective demand, represented by ED in the model has positive and significant point estimates in all the above models. It shows the importance of information, training, credit facility and the economic situation of the farmers are important in determining the overall satisfaction with the technology. The point estimate of Aggregate Supply (AS) indicates negative effect of this variable on the dependent variable in all the four models. However, this is not statistically significant. The point estimates of distribution (D) show a variable relationship across the models. While it is positive in some, it is negative in others and it is not significant in any of the models. Landholding, age and education generally show positive

relationships with satisfaction on this technology but they are not statistically significant indicating that the relationship is not strong.

Table.16. Summary results of regression models used:

Model	1	2	3	4
Dependent Variable	Overall Satisfaction	Overall Satisfaction	Overall Satisfaction	Overall Satisfaction
Independent Variables	AP, AEP, ED, AS, D	AP, AEP, ED, AS, D, Land	AP, AEP, ED, AS, D, Land, Age	AP, AEP, ED, AS, D, Land, Age, Education
R-Square	0.637	0.641	0.665	0.679
Adjusted R-square	0.567	0.554	0.567	0.567
Constant	-3.119 (0.008)	-2.962 (0.016)	-3.226 (0.01)	-3.245 (0.009)
AP	0.858 (0.001)	0.839 (0.002)	0.777 (0.004)	0.726 (0.007)
AEP	-0.044 (0.892)	0.038 (0.917)	0.052 (0.885)	0.126 (0.73)
ED	1.232 (0.00)	1.118 (0.007)	1.09 (0.008)	0.913 (0.037)
AS	-0.09 (0.578)	-0.063 (0.711)	-0.106 (0.539)	-0.105 (0.541)
D	-0.161 (0.526)	-0.18 (0.489)	-0.074 (0.782)	0.018 (0.95)
Landholding		0.012 (0.606)	0.003 (0.896)	-0.003 (0.904)
Age			0.009 (0.203)	0.012 (0.132)
Education				0.025 (0.322)
Note: Statistical significance is given in the parenthesis below the coefficients.				

10. Conclusions

The study attempts to examine the complexities in the introduction of new technologies, with a focus on the experience and adoption behavior for hybrid rice, on which little comprehensive work is available. Rice is the most important crop for food security in India. Based on the literature, a conceptual framework is developed which includes technological, economic, behavioral, market and policy factors, to comprehensively understand the adoption behavior of hybrid rice technology. A farmer questionnaire is developed based on the framework and data is collected from a pilot sample of farmers.

The results indicate the usefulness of the framework since it is able to explain about 66 percent of the variation in satisfaction with the technology. Yield advantage and tillering capacity are found to be important positive factors and pests/diseases important negative factors in the agronomic potential. No difference in by-products and other input requirements, are major positive factors, whereas lack of government procurement, seed subsidy, high seed price, and poor output price are the major negative factors in the agro-economic potential. Connectivity with towns, interaction with fellow farmers, and information sharing by dealers are the major positive factors, and lack of extension and training are the major negative factor

in creation of effective demand. Features of aggregate supply, and distribution of seeds are positive and not seen as major concerns.

Overall, the agro-economic potential appears to be the major problem area. The regression results indicate the agronomic potential and effective demand are the major determinants of satisfaction with hybrid rice technology. Land holding, age and education are positively related but not statistically significant. Good yield is indicated as the major overall advantage whereas high seed prices and poorer output prices appear to be the major disadvantages. However, a large majority indicate that they would grow hybrid rice in the future, which shows the high importance of the yield advantage.

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