Adoption of Eco-Friendly Technologies to Reduce Chemical Fertilizer Usage in Paddy Farming in Sri Lanka: An Expert Perception Analysis

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Abstract

This paper explores the "experts point of view" on the possibility of a (1) package of Eco Friendly Technologies (EFTs) comprised of 'Slow release fertilizer', 'Organic carbon' and 'Microbes' and incorporated those into the root ball of the rice plant at the nursery stage and then healthy seedlings are established in the paddy fields by way of 'Parachute Technology' to reduce the chemical fertilizer use in two common seed establishment methods in paddy cultivation, i.e. (2) 'Broadcasting', and (3) 'Transplanting'. The aspects those govern this behavior were identified in consultation with of a panel of scientists, and then classified into six major aspects, namely: (i) Level of 'Acceptance' (AC); (ii) 'Cost' of application in the field (CT); (iii) effect on the 'Environment' (EN); (iv) expected 'Performance' (PF); (v) existing 'Regulation' (RG), and (vi) availability of related 'Services' (SE). Having incorporated these into a questionnaire in the form of attitudinal statements (n=18) supported by a 10-point likert-scale, it was administered in-person with 32 experts to get their views. The data coded were subjected to the tests on Scale Reliability and Unidimensionality to evaluate their internal validity and reliability, and Aggregate Mean Scores were derived. The outcome of analysis show that experts perceive that EFT were in a "better" position in compared to the Broadcasting with regard to the aspects of: EN, PF and RG and "poor" with regard to: AC, SE and CT. In the context of EFTs vs. Transplanting, expert perceptions were "better" with regard to CT, AC and EN, but they perceive that EFTs are not in position to offset the benefits they enjoy in terms of SE, RG and PF. The outcome of analysis highlights the importance of generating private incentives for farmers to reduce monetary and transaction costs associated with use of EFTs and an appropriate institutional set up to regulate the fertilizer markets fully, as those non-competitive or distorted markets would demotivate farmers desire to go for this type of environmentally friendly technologies.

Keywords: *Chemical fertilizer use, Eco-friendly technologies, Expert perceptions, Paddy sector*

1. Introduction

The primary form of agriculture in Sri Lanka is rice production. Although paddy cultivation in the country has largely been based on organic fertilizer for many years (Weerahewa *et al*., (2014), introduction of "chemical fertilizers" has created several issues and/or changes to the industry of which some are perceived to be "beneficial" to the user (e.g. easy use), while others are considered the "costs" (i.e. high price, foreign exchange, environmental pollution). As a result, continuous use of chemical fertilizers in large quantities has become a topic of discussion at various circles, including the academic and political as well the media. The highest proportion of agrochemicals imported to Sri Lanka has been utilized for rice (e.g. over 70% of national fertilizer usage) (Jayasumana *et al*., 2013). In fact, many argue that farmers use excessive chemical fertilizer in their fields, well above the recommended levels, as they receive the products at considerably subsidized rates (Rodrigo and Abeysekara, 2015), and at the same time, a considerably low use efficiencies are reported, i.e. about 50 - 70% is lost.

Herath *et al*., (2015) reported that the access for inorganic fertilizers through heavily subsidized fertilizer schemes such as "Kethata Aruna" discouraged farmers to adapt Best Management Practices (BMPs) in their cultivations to a larger extent. The topic of developing "eco-friendly farming technologies" (EFTs) that could reduce chemical fertilizer usage while safeguarding food security and environmental health in Sri Lanka is of greater interest amongst the scientists and policymakers for a long time. Although many formal and informal discussions were there, on the importance of introducing such technologies into the agricultural sectors, in general, and the paddy sector, in particular, there was no program that integrates several such technologies and put forward which to the potential farmers as a "package" recently. Perhaps, the economics of producing and delivering of such a package of EFTs were not examined from the "empirical" point of view and to a depth by means of a systematic analysis.

Why it is important to look into the socio-economic aspects of production of a new technology? The simple answer is: the 'profitability' is matter for farmers to adopt any technology/ instrument/agricultural input in their fields. Farmers' decision to adopt an innovative technology depends highly on whether it generates sufficient "returns" to them over the potential "expenses", or in other words, the 'profits' and/or 'increased benefits' from adoption of new technology over and above what is already in place

against the 'decreased costs' due to the introduction of new technology. In light of this, introduction of any "non-profitable" technology to the farming systems, although it may be in a much better place in terms of generating significantly higher "social benefits", would lead into 'failures in the market' even in the very short-run, and such actions might, at the same time, push a farming system that is already running on "marginal basis" into further issues, for example call for 'government intervention'. We have consistently seen in the past that such interventions are called not in the form of regulation or facilitation to adopt, but to mere compensate the potential loses in the form of "subsidies".

These suggest that it is of paramount importance to carry out multiple socio-economic analyses to see extent to which the new technologies/good practices in place, in this case the EFTs developed, are 'financially viable' and 'socially acceptable' etc. to the farming communities and to the society, as a whole.

If we move back to the paddy production in Sri Lanka, more than 95 percent of paddy farmers in Sri Lanka use 'Broadcasting' as the seed establishment method in their paddy cultivation. Though it requires less labor, the seed requirement is high and nutrients are lost due to "blanket application". It is said that the present status of estimated fertilizer use efficiency has been varying from 20 to 40 percent (Sirisena *et al*., 2016). While the excessive use enhances the cost of production significantly, in the long-run it augments environmental pollution and lesser and lesser levels of yield. In light of the above disadvantages associated with broadcasting, 'Transplanting' has been in place as the best available alternative to establish seeds.

Department of Agriculture in Sri Lanka has taken some initiatives to introduce a new mechanism in replace of the techniques listed above, which was named as 'Parachute Technology' in 2005. This is considered a "seed saving" technology in paddy cultivation since under which the seed requirement per acre has been reduced to as low as 12 kg. Further, it is promoted as a "water saving" technology as it requires relatively less quantity of irrigation water compared to the traditional rice transplanting method. Moreover, it is recognized as a "labor saving" technology as the demand for skilled labor to adopt this technology in the field is less compared to the traditional transplanting method.

A multidisciplinary, multi-phased and multi-stakeholder research project has been in effect (with the funding from National Research Council of Sri Lanka) of which the overall objective is to resolve those issues pertaining to high chemical fertilizer use by developing a 'package' of best management practices for those who

involve with paddy cultivation, in particular. This package of EFTs will be comprised of a number of innovations and/or innovations to the existing technologies that are capable of reducing the use of synthetic agrochemicals and inorganic fertilizer in Sri Lanka significantly, i.e. 'Slow release fertilizer', 'Organic carbon' and 'Microbes'; all of which are incorporated into the root ball of the rice plant at the nursery stage and then healthy seedlings are to be used in the fields by way of 'Parachute Technology'.

Out of a number of 'deliverables' proposed through this project, one of the specific objectives is to assess the "socio-economic aspects" associated with the process of production and use of such EFTs in the context of paddy cultivation sector in Sri Lanka. This paper, in particularly, assess such benefits and costs from the "experts point of view", where the newly proposed package of EFTs (embodied with the features highlighted above) were evaluated against what has been existing, i.e. use of chemical fertilizers abundantly through 'Broadcasting' and 'Transplanting' methods.

2. Experimental Section

2.1 Theoretical Framework

The theoretical framework used in this study was set to find straightforward answers to the economic research problems of: what are the attitudes and perceptions of "Experts" towards 'development' and use' of ETFs in paddy cultivation as a partial replacement to the chemical fertilizer (CF) in use? What are the (private and social) benefits and (private and social) costs associated with development and use of ETFs in compared to the use of CF and whether those benefits overweigh the costs?

As stated elsewhere, three prominent methods in use in paddy cultivation to establish seeds in the field, i.e.: (A) 'Broadcasting'; (B) 'Transplanting' (i.e. assumed to be the "best alternative available at present"), and (C) the 'Parachute Technology' (i.e. seedlings incorporated with those proposed EFTs) were considered in our attempt to evaluate the suitability of each method from 'economics point of view' over the others. Those key aspects that determine the existing or expected "benefits" and "costs" of adoption or non-adoption of those EFTs for paddy cultivation in replace of chemical fertilizers (CF) were then identified through a process of consultation had with of a panel of scientists from the universities, public sector/research institutions who possess expert knowledge on those EFTs in concern and the CFs.

The in-depth discussions had with these experts helped to identify several key areas where the users of these EFTs (i.e. paddy farmers in this case) would have concerns in their attempts to use in their cultivations in

future. Those aspects were then classified into six major criteria, on the general agreement of the panel of experts, including: (1) Level of 'Acceptance' (AC); (2) 'Cost' of application in the field (CT); (3) effect on the 'Environment' (ET); (4) expected 'Performance' PC); (5) existing 'Regulation' (RT), and (6) availability of related 'Services' (SE). Based on the views expressed by these experts during the personal communications, each aspect was supported by several statements explaining different facets related to the aspect in concern (see, Table 1).

To assess the perceptions of an expert on a given aspect at a time in relation to these three methods (i.e. where he/she placed the "existing" technologies, separately: first in terms of Broadcasting and then considering the Transplanting, in relation to the EFT to be introduced). Each statement was set against a ten–point "Likert Scale" ranging from 'extremely good' (+5) to 'extremely poor' (-5). In doing so, the EFT was always placed at "zero" in the ten-point likert scale as shown in Figure 1. This way the respondent, based on his/her perceptions, was in a position to choose where he/she should place the Broadcasting (and then Transplanting) in relation to the EFT and in terms of the phenomenon explained in the statement of concern.

2.2 Data Collection and Analysis

Those statements explained different aspects n=18) were incorporated into a questionnaire together with the 10-point likert-scale and several other questions to explore the demographic characteristics of the expert. This questionnaire was administered with 32 experts panel of experts selected include the leading personalities from the fields of applied and social sciences, including agriculture, biology, food, chemistry and soil etc. as well as agricultural economics, marketing, agribusiness and extension etc., and with sound knowledge and exposure to those EFTs.

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Extreamly Poor	*Very Poor*	*Somewhat Poor*	*Little Poor*	*Slightly Poor*	*Same As* EFT	*Slightly Better*	*Little Better*	*Somewhat Better*	*Very Good*	*Extremely Good*
81– 100%	*61– 80%*	*41 – 60%*	*21- 40%*	*0 – 20%*		*0 – 20%*	*21 – 40%*	*41 – 60%*	*61 – 80%*	*81 – 100%*

Figure 1: 10-Point likert-scale used

Table 1: Set of statements explaining different facets of the six aspects considered

No	Statement	Notation
1	Possibility of the farmer to self-produce if required using the own resources	AC1
2	Workload associated with farmers to apply it in the paddy field	AC2
3	Cost of production of a unit of technology in terms of the inputs required (e.g. labor, capital)	CT1
4	Expenses associated with application of it in the paddy field	CT2
5	Wastage / over-utilization of the resources	CT3
6	In-situ and/or potential damages to the environmental quality	ET1
7	Implications on farmer/human health & safety	ET2
8	Sustainability of ecosystems through soil fertility improvement	PC1
9	Dependency on soil, water and/or weather conditions in the field	PC2
10	Ability to mix-up/combine with other technologies adapt in paddy farming	PC3
11	Improvements to productivity of the paddy fields	PC4
12	Requirement of adding a separate and/or an additional organic manure application	PC5
13	Improvements to predictability of paddy production	PC6
14	Acceptance by government/regulatory agencies as a technology to be used in paddy farming	RT1
15	Government intervention to regulate the technology and to design policies (e.g. tax, incentives)	RT2
16	Improvements to energy efficiency in paddy production	SE1
17	Prior knowledge of farmers about the technology in concern	SE2
18	Requirement of external support / advice (e.g. Ext. Officers) to decide on application	SE3

Note: AC – Acceptance; CT - Cost-CT; ET – Environment; PC – Performance; RT – Regulation; SE - Services

The response given by an expert to a particular aspect was coded in such a way that a negative (positive) value was given for those statements for which the respondent considered the proposed EFT is better (worse) than the Broadcasting method. For example, if the expert in question perceived that the "sustainability of an ecosystem enhances when those EFTs that possess an ability to bring improvements to soil fertility are applied using Parachute Technology, and in consequently, now that it requires applying a less amount of chemical fertilizer in compared to what is required under the Broadcasting" [i.e. Broadcasting is "Poorer" than EFTs in term of this criterion (PC1)], the expert would

select a point from left side of the likert-scale (i.e. 0 to 4). If we assume that he/she perceived it is as: "Somewhat Poor", then the 2nd point in the likert-scale to be marked (i.e. EFTs is +3 points ahead of the Broadcasting related to PC1).

Similarly, if the expert perceived that the "workload associated with a farmer to apply the proposed EFTs in the paddy field is much higher than that is needed for Broadcasting, and as a result, Broadcasting is "Little Better" than EFTs in term of this criterion, she/she would select the 7th-point in the likert-scale (i.e. EFTs is -2 points behind the Broadcasting related to AC2). In a case where the respondent judged that both EFT and Broadcasting (or Transplanting) is same in terms of the aspect in concern the resulting value was zero. Once this exercise was completed for the case of EFT and Broadcasting; the same was evaluated in the case of EFT and Transplanting.

Once all the data were coded (i.e. responses of all experts for all statements using 10-point likert-scale), the Scale Reliability of the statements were tested using the "Cronbach alpha" value, which measures how well a set of indicators measure a single Unidimensional Latent Construct. The alpha values above 0.7 generally accepted as demonstrating the scale is internally consistent or reliable (Henson and Traill, 2000). However, given multi-dimensionality and orthogonal nature of data in this type of expert perception analysis the alpha values exceeding 0.5 can also be considered sufficient (Lord and Novick, 2008).

Once confirmed the fact that the derived constructs (i.e. those six aspects in this case) are reliable and unidimensional, the next step was to determine the degree to which two variables' movements were associated. To determine which the Correlation Coefficient was measured, where a correlation of -1.0 indicates a 'perfect negative' correlation, while a correlation of 1.0 indicates a 'perfect positive' correlation. While the correlation coefficient measures a degree to which two variables are related, it only measures the linear relationship between the variables. A correlation greater than 0.8 is generally described as "strong", whereas a correlation less than 0.5 is generally described as "weak". Once these were established, the values on the likert-scales were used to derive Mean Score of each statement and then the Aggregate Mean Scores of the six aspects in concern (Jayasinghe-Mudalige and Henson, 2006).

3. Results and Discussion

3.1. Outcomes of Confirmatory Factor Analysis

The outcomes of analyses on Scale Reliability and Unidimensionality, which were carried out to prove whether those six aspects selected and then elaborated through 18 statements explore the perceptions of those experts sufficiently, suggest

that those statements are 'valid' and 'reliable' (Table 2). As such, the responses provided by the panel of experts on the likert-scale for these statements can be used to derive indices to reflect the relative strength of each aspect independently.

Table 3 reports the values pertaining to Correlation Coefficient of six aspects considered. There was no correlation greater than 0.8, generally described as strong, and all values were less than 0.5, generally described as weak; so, these aspects stand individually to characterize the underline phenomenon. The Mean Scores pertaining to eighteen attitudinal statements and six aspects, respectively, are shown in Figure 1 and Figure 2 for the cases of: (1) EFT vs. Broadcasting, and (2) EFT vs. Transplanting, where the negative (positive) values indicate that EFT is better (worse) than broadcasting (or in the case of transplanting).

Table 2: Descriptive statistic, reliability and unidimensionality for constructs

Construct	Variable	Broadcasting			Transplanting		
		Factor loading >0.3	**Mean**	**Cronbach Alpha**	**Factor Loading >0.3**	**Mean**	**Cronbach Alpha**
Acceptance (AC)	AC1	0.70	1.60	0.59	0.52	-0.71	0.40
	AC2	0.70			0.52		
Cost (CT)	CT1	-	0.99	0.29		-0.79	0.57
	CT2	-			0.71		
	CT3	0.61			0.71		
Environment (ET)	ET1	0.77	-1.19	0.74	0.67	-0.14	0.62
	ET2	0.77			0.67		
Performance (PC)	PC1	-	-1.17	0.55	0.59	0.23	0.69
	PC2	-			0.58		
	PC3	0.81			-		
	PC4	0.53			0.42		
	PC5	0.30			0.74		
	PC6	0.75			0.72		
Regulation (RT)	RT1	0.74	-0.62	0.70	0.71	0.29	0.65
	RT2	0.74			0.71		
Services (SE)	SE1	0.57	1.28	0.49	-	0.30	0.54
	SE2	0.62			0.83		
	SE3	0.90			0.84		

Table 3: Correlation coefficient matrix

		AC	CT	ET	PC	RT	SE
Broadcasting	**AC**	1.00					
	CT	0.14	1.00				
	ET	0.32	0.23	1.00			
	PC	-0.40	-0.21	0.16	1.00		
	RT	-0.31	-0.02	-0.15	0.53	1.00	
	SE	0.43	-0.01	0.28	-0.08	-0.11	1.00
Transplanting	**AC**	1.00					
	CT	0.33	1.00				
	ET	-0.27	0.28	1.00			
	PC	-0.24	0.17	0.69	1.00		
	RT	0.06	0.44	0.50	0.48	1.00	
	SE	0.47	0.13	-0.38	-0.27	-0.28	1.00

3.2 Broadcasting and Transplanting vs. EFT

Under this scenario, perceptions of experts on EFT, reflected by the Aggregate Mean Score, was considered "better" related to the aspects of: Environment (-1.19), Performance (-1.17) and Regulation (-0.62) and "worse" with regard to: Acceptance (1.60), Services (1.28) and Cost (0.99). A high positive value (2.38) on the phenomenon explained in statement AC2 (see, Table 1) highlights the fact that experts, in general, perceive that farmers would prefer less amount of work associated with Broadcasting in compared to the EFTs. Further, the value obtained for the statements CT1 and CT2 were positive, and suggests that experts perceive that the initial cost of adopting EFTs is higher than that for Broadcasting; so, farmers would have concerns on financial aspects related to the application of EFTs. Moreover, the experts were on the view that amount of waste of seed paddy was less in EFT in compared to the Broadcasting method, where the values obtained for the statement SE1 was negative, while that for SE2 and SE3 was relatively high and positive. These suggests the importance of capacity development of farmers on these EFTs and establishing proper extension services to promote EFTs countrywide. In the context of Transplanting vs. EFTs, perceptions of experts on EFT was "better" with regard to Cost (-0.79), Acceptance (-0.71) and Environment (-0.14), but they perceive that EFTs are not in position to offset the benefits they enjoy in terms of Services (0.30), Regulation (0.29) and Performance (0.23). It was revealed that compared to the Transplanting, EFT was, in

fact, better in terms of both initial cost of application and total costs associated with the production (i.e. CT1, CT2 and CT3 possess negative values). Overall, these suggest that experts consider Transplanting as "more environmentally friendly technology" compared to Broadcasting, or in other words, the Broadcasting leads to inefficient chemical fertilizer use over the other technologies. We may also notice that none of the statements, and in turn, for any of the six aspects considered, the Mean Score did not go above 2.5 in the ±5 scale, except 2.62 in SE2 for Transplanting. In fact, for the cases where the EFT is considered better than Broadcasting and Transplanting, these values, in general, are less than 2.0. Further, the range of the Mean values obtained for individual statements and six aspects for the case of Transplanting were, for the most part, smaller than that on Broadcasting and, for majority of cases, completely in the reverse side.

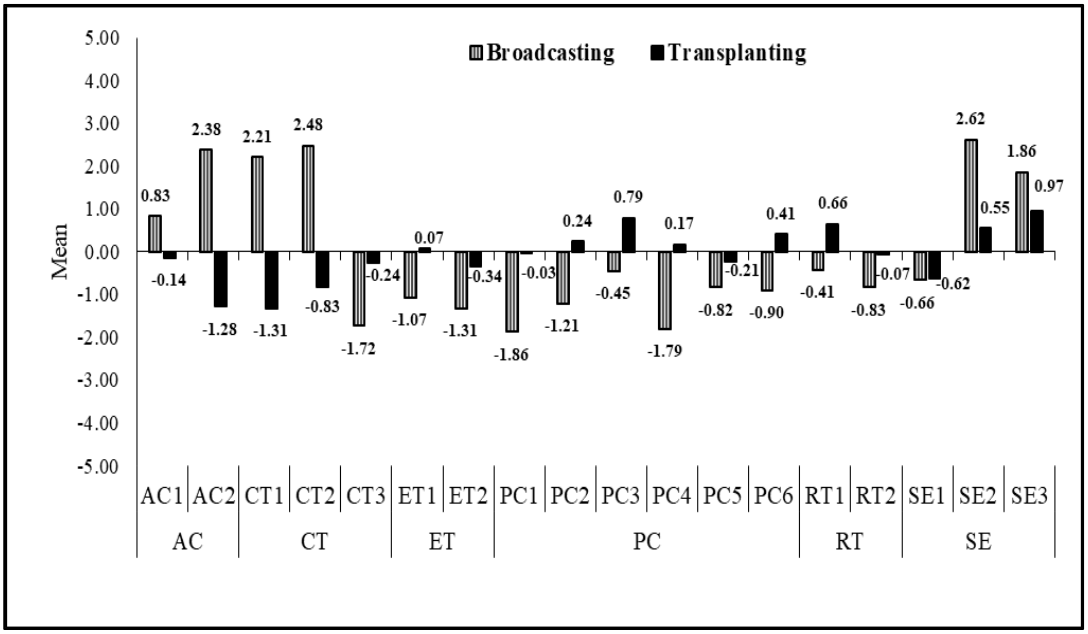

Figure 2: Mean scores of the statements

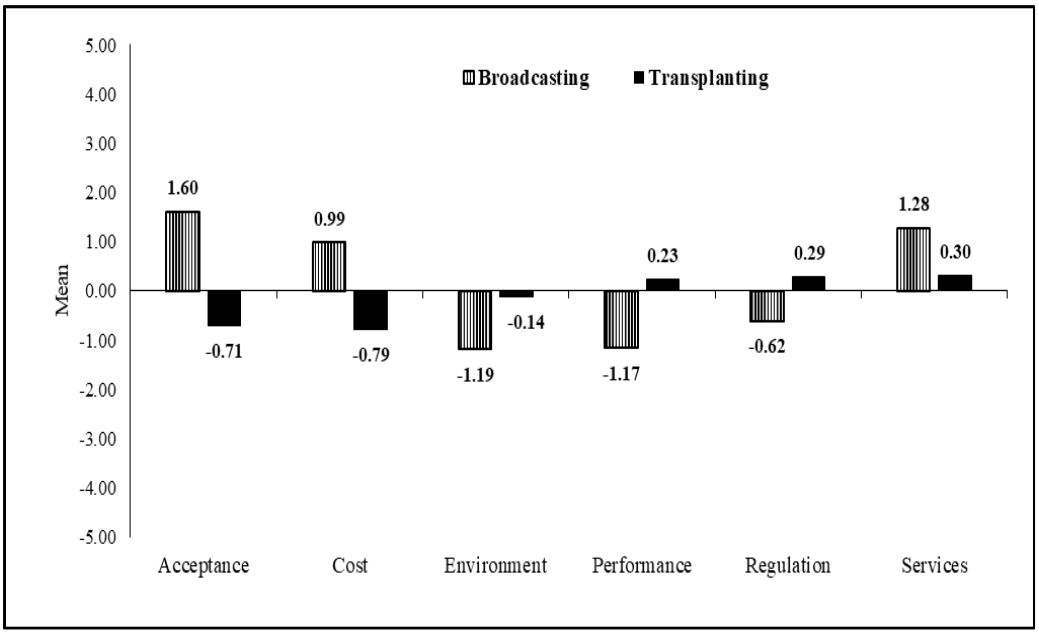

Figure 3: Mean scores of the six aspects

4. Conclusions

The outcome of analysis, overall, suggest that experts perceive that EFTs can play a significant role towards reduction of chemical fertilizer use in Sri Lankan paddy cultivations if the key issues associated with use of which in this industry are addressed satisfactorily. It points out that this process of replacing those prominent seed establishment methods that consume large quantities of chemical fertilizer, especially broadcasting, through the EFTs in future may not take place automatically, but would require a greater effort from different stakeholders, including the farmers, those in the supply chain and the government. Such a support would be in the form of providing appropriate services, including extension and availability of those inputs (EFTs) extensively at a competitive price. While providing these sorts of private incentives to reduce monetary and transaction costs of searching, negotiating and verification for quality of EFTs to be used, the respective institutions should also have mechanisms to regulate the fertilizer markets fully, as those non-competitive or distorted markets would demotivate farmers desire to go for this type of environmentally friendly technologies. Therefore, it is a prerequisite to set up proper institutional framework, with the participation of both private and public and characterize by partnerships and/or co-regulations like in developed countries, that is required to produce, promote and regulate these technologies before those EFTs were

released to the society at large in order to avoid common policy failures that everybody has seen and experienced in relation to paddy and fertilizer markets in the country.

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