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Invited Paper

Strategies Recommended to Minimize Fertilizer Usage in Rice Cultivation of Sri Lanka

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Introduction

Rice is the staple food in the Sri Lankan diet and an average person in Sri Lanka consumes about 110 kg of rice per annum. As such, to meet the rice requirement of the 22 million people in Sri Lanka, 2.42 million tons of rice is required. This quantity of rice is equal to 3.7 million tons of paddy (AgStat, 2019). To provide the required quantity, paddy cultivation is practiced in all parts of Sri Lanka covering various soil groups. To maximize rice production, high-yielding short-age rice varieties have been introduced to most of the paddy fields and these varieties are grown in two seasons per year (*Yala* and *Maha*). The productivity of the above high-yielding rice grown in different soil groups varies from 2 t ha^{-1} to 7 t ha^{-1}. In addition to inherent soil productivity, cultural practices, as well as climatic factors also contribute to this yield variability. Plant nutrient management is essential to achieve the yield potential of rice varieties. Nutrient removal with the harvest is 20 kg of N, 3 kg of P, 17 kg of K, and 50 g of Zn per one ton of yield, and the removal is increasing with the increase of yield (Dobermann and Fairhurst, 2000). Essential plant nutrients are required by rice plants in balanced proportion for optimum growth and yield. Out of essential plant nutrients, Nitrogen (N), Phosphorous (P), and Potassium (K) are the primary macronutrients; Calcium (Ca), Magnesium (Mg), and Sulphur (S) are the secondary macronutrients; and Ferrous (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Boron (B), Molybdenum (Mo) and Chlorine (Cl) are the micronutrients. A nutrient deficiency may appear when essential nutrients are not in sufficient quantities to meet the requirements of a growing rice plant. When these nutrients are in excess nutrients toxicities may appear in the rice plant. Therefore, it is important to maintain the nutrients at the critical limits of a rice plant to obtain a normal plant growth and yield. Paddy yield levels are determined by the limiting nutrients (Table 1). Optimum and critical nutrient levels in soil and rice plant are shown in Table 2.

Table 1. Yield level determinants of limiting nutrients (SAARC, 2009)

Paddy Productivity (t ha^{-1})	Limiting Nutrient
Below 2.0	Nil
2.0 – 3.0	N and K
3.0 – 4.0	N, P and K
4.0 – 5.0	N, P, K and Zn
More than 5.0	N, P, K and Zn + other nutrients

Fertilizer recommendation for rice

In Sri Lanka, N, P, and K are the major nutrients that are supplied through chemical and organic fertilizer for rice in both *Yala* and *Maha* seasons while supplying Zn as a micronutrient only during the *Maha* season. The major component of the current fertilizer recommendations for rice comprises of chemical fertilizers (Urea, Triple Supper Phosphate (TSP), Muriate of Potash (MOP), Zinc Sulphate) but the application of organic manure has been encouraged in every recommendation to improve yield levels (Sirisena, 2013). First fertilizer recommendation for rice was introduced by the Department of Agriculture in 1956 and it has been renewed in 1959, 1964, 1971, 1980, 1990, 1993, 1996, 1998, 2001, and 2013 based on fertilizer availability, farmers' response, nutrient accumulation, fertilizer use efficiency, environmental pollution, yield levels, and water availability.

Fertilizer recommendation in 2001 was introduced by taking into consideration the target yields. Target yield levels considered at that time were 4, 5, 6, and 7 t ha^{-1}. Based on the target yields, the whole country was categorized into 8 ecological conditions considering dry and intermediate zones, wet zone, major irrigated, minor irrigated, and rainfed paddy fields.

Fertilizer use efficiency was the main factor considered in the 2013 fertilizer recommendation. Accordingly, the country was categorized into 4 major groups Dry and Intermediate zone – irrigated paddy, Dry and Intermediate zone – rainfed paddy, Wet zone – irrigated paddy, and Wet zone – rainfed paddy.

The total recommended fertilizer quantity for major irrigated and minor irrigated paddy fields were 512 kg ha^{-1} and 425 kg ha^{-1}, respectively in 2001. It was reduced to 340 kg ha^{-1} for irrigated paddy fields in 2013. Urea, TSP and MOP usage in paddy fields have been reduced from 312 to 225 kg ha^{-1}, from 112.5 to 55 kg ha^{-1}, and 87.5 to 60 kg ha^{-1}, respectively with the introduction of a number of nutrient saving techniques (DOA, 2001; Sirisena, 2013). Therefore, total fertilizer usage was cut down by 25% from 2001 to 2013 for the majority of the paddy fields located in the dry and intermediate zone under irrigated conditions.

Table 2. Optimum and critical nutrient levels in soil and rice plant tissues (Dobermann and Fairhurst, 2000, Bandara *et al*., 2003, Sirisena *et al*., 2019)

Nutrient	Soil		Plant tissue	
	Optimum	Critical	Optimum	Critical
Nitrogen (N)	-	-	2.9% – 4.0%	< 2.5%
Phosphorous (P)	5 – 10 ppm	< 5 ppm	0.2% - 0.4%	< 0.1%
Potassium (K)	80 – 160 ppm	< 40 ppm	1.8% - 2.6%	< 1.5%
Zinc (Zn)	1 – 4 ppm	< 1 ppm	25 – 50 ppm	< 15 ppm

Introduction of granular urea in place of prilled urea in the 2013 fertilizer recommendation reduced N losses in paddy fields while minimizing N fertilizer use in paddy fields. Further, N supply from rice straw and rice stubble, and other organic substances were identified as a mechanism to provide N requirement for the first two weeks from rice establishment, and accordingly basal application of N fertilizer was removed from the fertilizer recommendation (DOA, 2001, Sirisena 2013). Accordingly, 15 kg of urea per hectare is saved from this method. The application time of N fertilizer has been changed and a number of applications at lesser quantities have been introduced. Accordingly, the N application has been changed from 3 applications to 4 applications.

With the evidence on P response field experiments carried out island-wide, P accumulation of paddy fields in intensive rice growing areas was observed (Sirisena *et al*., 2013). Taking P accumulation into consideration, P fertilizer use in paddy fields was minimized by reducing the critical level of soil P levels from 10 ppm to 5 ppm. In addition, the application of TSP levels was reduced from 112 to 55 kg ha^{-1}.

Based on K fertilizer response studies conducted island-wide, rice straw and rice stubble were identified as good sources of K to maintain the exchangeable K in rice fields at the early growth stage of rice (Sirisena *et al*., 2015). Accordingly, no basal application of MOP was recommended in the Fertilizer Recommendation unveiled in 2013. Reduction of basal application of MOP fertilizer helped to reduce the quantity of MOP application from 87.5 kg ha^{-1} to 60 kg ha^{-1} (DOA, 2001, Sirisena, 2013). To avoid the yellow colour appearance of rice during the maximum growth stage and to improve the grain filling of rice, K application was recommended at 4 and 6 weeks after plating in 2013 recommendation.

Application of Zn was recommended for almost all paddy fields to maximum utilization of other plant nutrients and it is advised to apply $ZnSO_4$ once a year only in the *Maha* season (Bandara, 2001).

The fertilizer recommendation of the DOA for rice cultivation published in 2013 is shown in Table 3.

Table 3. Fertilizer recommendation for rice cultivation in 2013

Ecological Condition	Chemical Fertilizer (kg ha^{-1})				Organic matter / Compost
	Urea	**TSP**	**MOP**	**$ZnSO_4$ (Only in *Maha* season)**	
Dry and intermediate zone irrigated paddy fields	225	55	60	5	**Option 1:** Straw and stubble: 5 t ha^{-1} Organic matter 1. Green manure: 1 t ha^{-1} and 2. Cattle manure: 4 t ha^{-1} OR Poultry manure 2 t ha^{-1} 3. Partially Burn Paddy Husk (PBPH): 625 kg ha^{-1}
Dry and intermediate zone rainfed paddy fields	175	35	50	5	
Wet zone irrigated paddy fields	140	35	50	5	
Wet zone rainfed paddy fields	100	55	110	5	**Option 2:** Straw and stubble: 5 t ha^{-1} Compost: 2.5 t ha^{-1}

Source: (Sirisena, 2013)

Soil test-based fertilizer application

The above fertilizer recommendations of the DOA for rice have been given on a very broad basis as agro ecological zone basis, yield levels, and water availability. This blanket recommendation is a single recommendation provided for thousands of rice-growing farmers. To provide a more specific recommendation for individual land units based on soil nutrient levels of particular fields, soil test-based fertilizer recommendation was initiated in 1993 and updated in 2014 by reducing the level of application of fertilizer based on soil fertility levels. In the 2014 soil test-based fertilizer application, the minimum level of soil P to apply P fertilizer has been reduced from 10 ppm to 5 ppm. Soil test-based fertilizer application for K fertilizer in Dry and Intermediate Zone and Wet Zone and P fertilizer in Dry and Intermediate Zone and Wet Zone are shown in Tables 4, 5, 6, and 7.

Table 4. Soil test-based fertilizer application of K fertilizer for rice in Dry and Intermediate Zone

Soil test values	Amount of MOP to be added (kg ha^{-1})			
	Irrigated paddy fields		Rainfed paddy fields	
	4 WAE	6 WAE	4 WAE	6 WAE
>40 ppm K	25	35	25	25
40 – 80 ppm K	20	25	20	20
80 – 160 ppm K	10	10	10	10
>160 ppm K	nil	nil	nil	Nil

Source: DOA, 1993; RRDI, 2014
*WAE - Weeks After Establishment

Table 5. Soil test-based fertilizer application of K fertilizer for rice in Wet Zone

Soil test values	Amount of MOP to be added (kg ha^{-1})				
	Irrigated paddy fields		Rainfed paddy fields		
	4 WAE	6 WAE	2 WAE	4 WAE	6 WAE
>40 ppm K	25	25	35	45	30
40 - 80 ppm K	20	20	20	30	20
80 - 160 ppm K	10	10	10	15	10
>160 ppm K	nil	nil	Nil	nil	Nil

Source: DOA, 1993; RRDI, 2014

Table 6. Soil test-based fertilizer application of P fertilizer for rice in Dry and Intermediate Zone

Soil test values	Amount of TSP (kg ha^{-1})	
	Irrigated paddy fields	rainfed paddy fields
0 -5 ppm P	55	35
5 -10 ppm P	30	20
>10 ppm P	Nil	Nil

Source: DOA, 1993; RRDI, 2014

Table 7. Soil test-based fertilizer application of P fertilizer for rice in Wet Zone

Soil test values	Amount of TSP (kg ha^{-1})	
	Irrigated paddy fields	rainfed paddy fields
0 -5 ppm P	35	55
5 -10 ppm P	20	30
>10 ppm P	Nil	Nil

Source: DOA, 1993; RRDI, 2014

Using the above information GN division-based fertilizer recommendation was introduced in 2016 and it helped to reduce the unwanted application of P and K fertilizer in many locations island wide. In some of the GN divisions, application of P fertilizer was completely cut down (DOA, 2018).

Application of organic manure to paddy fields

Results of the long-term experiment conducted at the Rice Research and Development Institute (RRDI), Batalagoda reveals that the highest yield (5.2 t ha^{-1}) has been given by NPK recommendation + Organic manure application and this was followed by NPK only (4.7 t ha^{-1}) and then organic only (3.4 t ha^{-1}) applications with the same rice variety Bg 358. The lowest yield has been observed by the control (no fertilizer treatment) and it was 2.6 t ha^{-1}. This pattern has been observed throughout last 17 years (34 seasons). This continuously emapsizes the importance of applying NPK chemical fertilizer with organic manure to attain a higher productivity from rice in the country (Figure 1). Application of organic manure to paddy fields is always encouraged to improve soil conditions and fertility.

This Integrated Plant Nutrient System (IPNS) is defined as a holistic approach to plant nutrition since the nutrients are provided by both inorganic and organic sources to maintain and sustain soil fertility and enhance crop productivity in an ecologically compatible, socially acceptable, technically appropriate and economically viable manner (Gopal and Saha, 2008).

Farmers are further encouraged to adopt ploughing techniques when and where ever possible to improve fertilizer use efficiency and reduce fertilizer use in paddy field.

Reduction in use of urea through the introduction of Leaf Colour Chart (LCC)

LCC has been developed and introduced for Dry and Intermediate Zone and Wet Zone as a low- cost method to determine the N content in rice leaves. Based on the LCC values, urea can be applied according to the requirement. By using LCC N application can be reduced by 25% (Sirisena *et al.*, 2006)

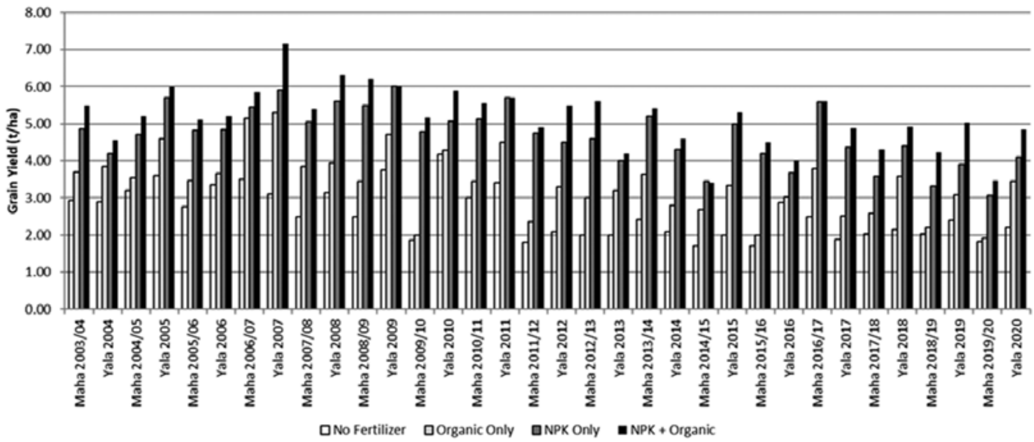

Figure 1. Grain yield of rice with NPK chemical fertilizer with organic manure during 34 seasons

Use of Nano Urea

Application of Nano urea in place of prilled urea helps to reduce at least 25% of the current N fertilizer used. (Madusanka *et al*., 2015; Sirisena, 2012)

Rice varietal response to low levels of N

Response of rice varieties to the application of N fertilizer is varying. Accordingly, varieties that give high yields at low levels of N fertilizer should be identified. Studies conducted at RRDI so far has identified an aerobic rice variety (Areon 9-3), which has the ability to give more yield from less nitrogen fertilizer (Sirisena *et al*., 2021).

Nitrogen enrichment to partially burnt rice husk

Maximize N retention in soil enhances the use efficiency of N fertilizer. Successful results have been obtained with the enrichment of partially burnt rice husk (PBRH) with urea. Experimental results have shown that nitrogen level in PBRH can be increased from 0.8 % to 6% with urea enrichment. Application of nitrogen enriched PBRH gave more yield than that of application of urea alone and as such urea application can be cut down by 112 kg ha^{-1} by this method (AgTech 55, 2021).

Alternative seasons P application

Alternate season P application was introduced to paddy fields, which is having soil available P levels Between 5 – 10 ppm. TSP is recommended to apply only in *Yala* seasons and this saves 50% of P fertilizer usage (AgTech 07, 2016 and DOA, 2019).

Seedling treated with P fertilizer in parachute nursery

Instead of the application of a large quantity of P fertilizer to paddy fields directly, 3 – 4 particles of TSP can be placed into the hole of the parachute tray and soil and paddy seeds can be placed afterward. This method needs less P fertilizer and saves 25 kg of TSP per hectare and reduces soil and water pollution (AgTech 07, 2016; AgTech 69, 2022 and DOA, 2019).

Soil test kit-based P and K fertilizer application

Soil test kit-based fertilizer application was introduced as an alternative to troublesome lab test based fertilizer application. It is an easy, low cost, user friendly, and time saving method of soil testing. This increases the fertilizer use efficiency and save TSP and MOP by applying them based on the need of plants (Sirisena *et al*., 2019 and DOA, 2019).

Map-based fertilizer recommendation

Soil map-based fertilizer application was initiated to promote site-specific fertilizer application. Soil fertility maps and fertilizer recommendations based on soil fertility were developed for paddy field in Kurunegala, Anuradhapura, and Polonnaruwa districts. These maps, which are available in .kml format can be opened in Google Earth Pro®. When selecting the required paddy field by clicking on the virtual map, fertilizer recommendation can be seen. This will benefit to reduce unwanted application of fertilizer and also it saves money spending on fertilizer and minimizes soil and water pollution (Rathnayake *et al*., 2018, 2019; DOA, 2019).

Map-based soil reclamation

To obtain maximum paddy fields as well as to reduce fertilizer loses through soil fertility problems soil fertility maps can be utilized. Soil pH, soil EC and OM maps for Kurunegala, Anuradhapura and Polonnaruwa districts have been developed and are available in .kml file format. They can be opened in Google Earth Pro®. When selecting the required paddy field by clicking, recommended remedial measures will appear in the screen for soil reclamation. This helps to correct the conditions in paddy fields to increase the fertilizer use efficiency and productivity (Rathnayake *et al*., 2019 and DOA, 2019).

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