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Yield Response of Rice to Added Phosphorous and Potassium Fertilizer in the Dry Zone of Sri Lanka

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ABSTRACT

Purpose: *Continuous application of Phosphorous (P) and Potassium (K) fertilizer over a long period in rice (Oryza sativa L) cultivation may lead to their accumulation in the soils. So, further addition of such fertilizers may be a waste in rice cultivation and also lead to environmental pollution. Thus, field experiments were carried out to study the yield response of rice to added P and K fertilizer under irrigated conditions in Low Humic Gley soils in the Dry Zone of Sri Lanka.*

Research Method: *For the P response study, an experiment was conducted over three consecutive seasons in a rice field where P fertilizer had not been applied for 10 years before the initiation of the experiment, and for the K response study, an experiment was conducted over two consecutive seasons in a rice field where recommended K fertilizer had been continuously applied before the initiation of the experiment. Data on grain yield and yield components, milling quality, important soil properties, and soil and plant P and K contents were recorded and analyzed statistically.*

Findings: *Grain yield, yield components and milling quality of rice did not respond to added P fertilizer over three consecutive seasons in a rice field where P fertilizer had not been applied 10 years before the initiation of the experiment. Soil P analysis indicated that enough soil P was available to maintain an adequate plant P level so that application of P fertilizer in rice cultivation can be avoided at least for about 11½ years (10 years + three seasons) without affecting grain yield and milling quality in Low Humic Gley soils in the Dry Zone of Sri Lanka while saving the cost for P fertilizer. The short-term response of grain yield in rice to added K fertilizer appeared dependent on the grain yield level obtained. No yield response of rice to added K was observed up to the yield level of about 4 t/ha. Thus, the application of K fertilizer can be avoided over two consecutive seasons without affecting grain yield in rice in Low Humic Gley soils in the Dry Zone of Sri Lanka if the yield level is 4t/ha or lower.*

Research Limitation**:** *Further studies at different locations in farmers' fields are needed to confirm the applicability of the findings of the present study in farmers' fields in the Dry Zone of Sri Lanka.*

Originality/ Value: *Long term (over 11½ years) P response study in rice. Such a long-term P response study in rice has not been reported to date. The short-term K response in rice is dependent on the grain yield level achieved.*

Keywords: *Grain yield response, Phosphorous (P) and Potassium (K) fertilizer, Rice*

INTRODUCTION

Sri Lanka's rice farming exclusively depended on organic manure before the 1950s. High-yielding rice varieties were introduced for cultivation during the 1960s in Sri Lanka (Herdt *et al.* 1983) and these varieties responded heavily to added fertilizer. This was the beginning of the

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use of chemical fertilizer by farmers in Sri Lanka (Dalrymple, 1986) and now it has reached its peak while becoming a much-discussed topic. For rice growth and development, the application of 16 elements has been recommended and these recommendations vary according to soil type, climatic conditions, variety, grain yield level, cultivation method, etc (IRRI, 2018).

Nitrogen (N), Phosphorous (P), and Potassium (K) are macro-nutrients needed in high amounts for plants in various stages of crop growth. Accordingly, for rice cultivation, these fertilizers were widely used as a mixture of N:P:K in a ratio of 5:15:15 as the basal application, only N as the top dressing, and a mixture of N:K in a ratio of 30:20 as the top dressing mixture in Sri Lanka (Wijewardena, 2005). As stated by the Ministry of Agriculture, N, P and K fertilizers have been applied on average at the rate of 360 Kg/ha which provided 111kg of N, 23 kg of P_2O_5 and 34 kg of K_2O, and 478Kg/ha which provided 146kg of N, 34 kg of P_2O_5 and 46 kg of K_2O in *Maha* 2016/17 and *Yala* 2017, respectively for rice cultivation in Sri Lanka (Ministry of Agriculture, Sri Lanka, 2017).

It has been nearly 57 years to the date since 1961 that N, P, and K fertilizers were being added to the soil. Due to the continuous and heavy application of fertilizer which can partly be attributed to fertilizer subsidies granted by the Government, P & K nutrients particularly P may have highly accumulated in Sri Lankan rice soils. Acquisition of applied P by crop plants is very low so around 80% of P becomes immobile and unavailable for plant uptake because of adsorption, precipitation, or conversion to the organic forms (Holford, 1997). Chandrajith *et al*., (2010) reported that rice soils are polluted with potentially toxic metals due to the widespread application of P fertilizer containing trace chemical elements known for their nephrotoxic effects. Heavy use of P fertilizers is not only a considerable expense for farmers but also an ecological risk because the remaining soil P is a major contributing factor to the eutrophication of lakes and rivers by run-off, leaching, and soil erosion (Hart *et al*. 2004). Efficient nutrient management in rice is assumed of great importance because along with high production levels of rice, it ensures minimal leakage of applied nutrients to the environment. Thus, studies on the yield response of rice to added P & K fertilizer have become of prime importance at present.

No yield response has been observed in rice to P fertilization at five study sites and K fertilization with rates ≥90 K_2O/ha has resulted in significant rice yield increases at two sites. However, these increases were not as great as expected (Slaton *et al.* 2004). Similarly, for the Brazilian condition, it has been reported that yearly broadcast or banded application of K can be expected to result in a significant increase in grain yield of low land rice on a Low Humic Gley soil (Fageria *et al*. 1990). Increasing total N, P, and K uptake and N, P and K harvest index (NHI, PHI, and KHI) are more important rather than applying more fertilizers. This has been shown in research done in Sarawak a state of Malaysia and further, it has described more increases in red rice yield, improve soil, water, and air quality, and also reduction of nutrient input cost. (Mansi and Wasali,2019). Rice crops grown in most of the lowlands do not show a positive response to added P fertilizer (Wijesundera, 1990) due to continuous application and accumulation of P in lowland rice fields (Sirisena *et al*. 2013).

Potassium plays an important role in enzyme activation, photosynthesis, photosynthate translocation, protein synthesis, and plant water relations and is also vital in the plant's ability to resist disease (Marschner, 2011). The efficient use of K is also important in reducing the overall cost of crop production (Dhillon *et al*. 2019). Over time, insufficient K fertilization leads to crop K deficiency and yield loss (Dobermann *et al*. 1998); (Maschmann *et al*. 2010). As such, fertilizer-K recommendations should take into consideration: existing soil-test K values to inform about the availability of K (Slaton, 2020); the rice yield response to added K (Dobermann, Cassman, Mamaril, & Sheehy, 1998); (Maschmann, Slaton, Cartwright, & Norman, 2010); (Uddin, Sarker, & Rahman, 2010); the output price for the crop; and the cost of fertilizer K. Department of Agriculture (DOA), Sri Lanka has revised the P nutrient recommendation for sustainable P fertilizer management as no yield response of rice to added P fertilizer has been reported (Sirisena *et al*. 2018). Moreover, the importance of a site-specific nutrient management-based approach for P & K fertilizer application has been studied (Buresh *et al.* 2010). Further, there is a possibility of totally avoiding P and K fertilizer application for rice over a certain period as already applied P and K over a long period may have accumulated in rice soils in adequate quantities. However, long-term P response studies are lacking and even short-term K response studies are limited to rice in the Dry Zone of Sri Lanka. Thus, the objectives of the present study were to ascertain the status of yield response of rice to added P in a rice field where P fertilizer was not applied over ten years and to added K in a common rice field and to explain observed yield responses by yield components of rice.

MATERIALS AND METHODS

The present study was conducted at the Rice Research and Development Unit of CIC Agri Businesses at Pelwehera, Dambulla (7.88681 N, 80.675222 E) in the Dry Zone of the country. The soil type of the experimental site was Low Humic Gley (LHG) soils according to the local soil classification. However, according to the USDA soil taxonomy and FAO soil classification, this particular soil type is coming under Typic Endoequalfs and Eutic Glaysols, respectively. The LHG soil has resulted in a rice grain yield in the range of 7-8t/ha under well-managed conditions in Sri Lanka (Wickramasinghe, 2010).

Yield response to added P

Yield response of rice to added P was conducted over three consecutive seasons in a rice field where P fertilizer had not been applied over ten years before the initiation of the experiment. P response trial had two treatments viz. no added P (no P) and recommended dose of added P (with P) and the experiment was laid out in a Randomized Complete Block Design with four replications in Yala or Dry season in 2017. The experimental plot size was 3 × 6 m^2. The same plots were used for 'no P' and 'with P' treatments in repeated trials from the inception of the study in Yala 2017. The experiment was managed as per the recommendations given by the Dept. of Agriculture and the variety used was CIC Tikiri Kekulu which is a three-month new improved rice variety with a high response to added fertilizer. The method of stand establishment practised was seed broadcasting which is adopted by more than 90% of the farmers in the country.

Yield response to added K

The yield response of rice to added K was conducted over two consecutive seasons in a common rice field. Yield response to added K study also had two treatments viz. no added K (no K) and recommended dose of added K (with K) and the experiment was laid out in a Randomized Complete Block design with two replications in Maha or the wet season in 2017/18. Two replications appeared adequate as the experiment is expected to be long-term. The plot size was 3 × 6 m^2. The same plots were used for 'no K' and 'with K' treatments in repeated trials from the inception of the study. The trial was managed similar to that of the P response trial. A fertilizer responsive new improved three-month rice variety viz. CIC Tikiri Kekulu was used in the trial every season and the method of stand establishment practised was seed broadcasting.

Data recording

Data on total plot yield at 14% moisture content, yield components (number of panicles/m^2, number of spikelets/panicle, filled grain percentage, and weight of 1000 grains), and milling quality were recorded. Yield data for the P response experiment were collected over three consecutive seasons viz. 2017 *Yala,* 2017/18 *Maha,* and 2018 *Yala* and for the K response experiment were collected over two consecutive seasons viz. 2017/18 *Maha* and 2018 *Yala*. The yield components and milling quality data were recorded only in 2018 *Yala*.

The soils of the experimental plots were analyzed before sowing seeds in 2018 *Yala* for both the available and total P and K contents at CIC Soil and Plant Analytical Laboratory which is accredited for ISO 17025 laboratory quality management system. Extractable soil P element; Modified Olsen method, extractable K element, pH, and EC were performed by the Soil Test Method – ASI (Agro Service International) (Portch and Hunter, 2002). Total P and K in soil were analyzed by digesting the soil samples using a tri-acid mixture; Nitric acid: Sulfuric acid: Perchloric acid extraction (9:4:1) (Motsara, M.R. and Roy, R.N., 2008). UV Visible Spectrophotometer; Cary60UV and Atomic Absorption Spectrophotometer (AAS); Varian/SpectAA-110 EL022096425 were used to analyse P and K elements respectively. pH and EC tested to the ratio at 1: 2.5 mixture-water using the pH meter; EUTECH pH 700 and EC meter; Hach/Sension5. P and K nutrients in the whole rice plant at harvesting were also analyzed using the tri-acid extraction method (Motsara, M.R. and Roy, R.N., 2008) at the same laboratory in 2018 *Yala.*

Data Analyses

Combined analyses of variance (ANOVA) over seasons were performed for plot yield data of both P and K response trials. Yield component and milling quality data were analyzed using t-tests in both P and K response trials as the results were taken from one season trial involving only two treatments in each of the P and K trials.

RESULTS AND DISCUSSION

Soil analysis

Some important soil properties of the experimental plots are presented in Table 01. No difference in soil pH between P treatments but a slight difference between K treatments was observed. Although almost similar EC levels between P treatments were observed, 'with K' treatment showed a considerably higher EC level than that of 'no K' treatment. Extractable P content was slightly higher in the 'with P' treatment than that of the 'no P' treatment while total P content showed no difference between treatments. Extractable K content was slightly higher in the 'with K' treatment than that of the 'no K' treatment. However, interestingly the total K content was lower in the 'with K' treatment than that of the 'no K' treatment.

Yield response to added P

Grain yield of rice under 'no P' and 'with P' treatments over three consecutive seasons are presented in Table 02. The two-way interaction effect of P × Season was found to be not significant at a 5% level indicating that the different P treatments responded the same to different seasons. This allowed averaging the grain yields of two P treatments separately over seasons though seasonal differences in grain yield were significant. Whatever the grain yield level in the range of 3.6 – 6.7 t/ha, the grain yield of rice did not respond to added P fertilizer in any of the seasons tested in a field where P was not applied for 10 years before the initiation of the experiment. Thus, no response of rice to added P fertilizer was observed even after adding P over 1½ years (three seasons) in a rice field where P fertilizer had not been applied for 10 years. This indicated that rice can be cultivated without adding P over a long period of at least 11½ years (10 years + 3 seasons) in the LHG soils in the Dry Zone of Sri Lanka. No such long-term P response study in rice has been reported to date. However, short term studies conducted by Slaton *et al.*, (2004) reported that rice yields were not increased by P fertilization at five study sites in 2004 and Sirisena *et al.*, (2018) reported that rice crops grown in most of the low lands did not show a positive response to added P fertilizer while not showing P deficiency symptoms. Wijesundera (1990) also reported that crops grown in most of the lowlands do not show a positive response to added P fertilizer. In addition, the present study should be continued in the same place and same plots to ascertain how many more years rice can be cultivated without adding P fertilizer with no yield reduction in the LHG soils in the Dry Zone of Sri Lanka.

Table 01: Selected soil characteristics of the plots applied with different Phosphorus and Potassium treatments in 2018 *Yala*

Soil Characteristic[£]	P* treatments		K** treatments	
	No P	With P	No K	With K
pH(1:2.5 Soil: Water)	7.55±0.21[§]	7.61±0.42	7.20±0.28	7.92±0.31
EC (µS/cm, 1:2.5 Soil: Water)	192±34.39	215±58.86	150±4.49	258±30.6
Extractable P (ppm)	10.3±1.45	15.3±3.35	-	-
Total P (ppm)	147±17.61	140±11.54	-	-
Extractable K (ppm)	-	-	60±9.8	106±14.6
Total K (ppm)	-	-	1258±39.2	1149±8.1

*£ EC – Electrical conductivity * P –Phosphorus, ** K –Potassium, - Data not recorded, § ±standard error and sample sizes for P and K were 3 and 2, respectively.*

Table 02: Grain yield of rice under 'no P' and 'with P' treatments over three consecutive seasons

Season	P treatment§	
	No P	With P
	< ---------- Grain yield (t/ha) --------- >	
2017 *Yala*	6.43	6.61
2017/18 *Maha*	5.60	6.14
2018 *Yala*	3.69	3.98
Average *	5.24	5.57

*§ P- Phosphorous and Two way interaction of P × Season was not significant at 5% probability level * Average 'With P' and 'No P' treatments over seasons were found to be not significantly different at 5% probability level.*

The absence of yield response of rice to added P fertilizer could be explained through yield components studied in 2018 *Yala* (Table 03). None of the yield components out of four, responded to added P fertilizer confirming the absence of yield response. How the milling quality of rice has been influenced by the application of P fertilizer was also studied in 2018 *Yala*. Head grain percentage of 45.3% under 'no. P' treatment was found to be not significantly lower than that of 49.5% under 'with P' treatment at a 5% probability level by a t-test so that head grain% of rice was also not affected by avoiding the application of P fertilizer.

Table 03: Grain yield components of rice under 'no P' and 'with P' treatments in the 2018 *Yala* season

Yield component	P treatment means*		t-test	
	No P	With P	SE[§]	test
No. of panicles/sq ft	40.47	34.95	6.09	Ns
No. of spikelets/panicle	66.00	82.61	6.71	Ns
Filled grain %	69.33	68.34	6.26	Ns
Thousand-grain weight (g)	23.92	22.59	0.38	Ns

**P– Phosphorous, §- Standard error of the mean difference, Ns – Not Significant at 5% probability level.*

The absence of yield response to added P fertilizer in rice was also supported by soil P analysis (Table 01) where extractable P content of 10.33 ppm found in the 'no P' treatment before the initiation of the experiment in 2018 *Yala* was adequate to supply P requirement of the rice plant. In addition, the total P contents under 'no P' and 'with P' treatments were almost the same. The reason may be that around 80% of added P becomes immobile and unavailable for plant uptake because of adsorption, precipitation, or conversion to the organic forms (Holford, 1997) so that enough P is available even in the no P treatment due to heavy application of P fertilizer in the past. Sirisena *et al*., (2013) reported that P has been accumulated in lowland rice soils due to the continuous application of P fertilizer. In the plant P analysis, plant P contents between 'no P' (0.71 ppm) and 'with P' (0.65 ppm) treatments were found to be not significantly different at a 5% probability level by a t-test further confirming that the application of P fertilizer can be avoided without affecting the rice plant. This indicated that enough soil P has been accumulated in the soil by application of P fertilizer over a long time since the 1960s so that soil P has not been depleted and influenced to reduce plant P level even after continuous rice cultivation over about 11½ years without application of P fertilizer.

In addition, rice plants may also have a mechanism to utilize even fixed Phosphorous (non-available Phosphorous) in the soil up to some extent (Rausch and Bucher, 2002). Neither grain yield nor yield components nor head grain % of rice were responding to the application of P fertilizer for at least 11½ years as available P were adequately present in the LHG soil at Pelwehera, Dambulla in the Dry Zone of Sri Lanka. Therefore, the application of P fertilizer can be avoided without affecting grain yield and milling quality as measured by head grain % at least for about 11½ years in rice cultivation in the Dry Zone of Sri Lanka. Thus, by avoiding the application of P fertilizer, about Rs. 3750/= per ha can be saved from the cost of cultivation at present.

Yield response to added K

Grain yield of rice under 'no K' and 'with K' treatments over two consecutive seasons are presented (Table 04). The two-way interaction effect of K × Season was found to be significant at a 5% probability level indicating that the different K treatments responded differently to different seasons.

The grain yields of rice increased with added K fertilizer in 2017/18 *Maha* and this is in agreement with Slaton *et al.,* (2004) who observed a positive yield response of rice to K fertilization with rates ≥90 K_2O/ha at two sites. However, rice yield did not significantly increase with added K fertilizer in 2018 *Yala*. The reason may be that the grain yield level of rice was comparatively much lower (around 4 t/ha) in 2018 *Yala* than that of (around 6 t/ha) in 2017/18 *Maha* and existing soil K content may be adequate to achieve a grain yield level as low as 4 t/ha obtained in 2018 *Yala.*

The absence of yield response of rice to added K fertilizer in 2018 *Yala* could be explained by the response of yield components to added K fertilizer studied in the same season

Table 04: Grain yield of rice under 'no K' and 'with K' treatments over two consecutive seasons

Season	K treatment*	
	No K	With K
	< ---------- Grain yield (t/ha) --------- >	
2017/18 *Maha***	5.09	7.06
2018 *Yala****	4.03	3.93

K- Pottasium and Two-way interaction effect of K × Season were significant at 5% probability level, ** 'With K' and 'No K' treatments in 2017/18 Maha were found to be significantly different at 5% probability level, * 'With K' and 'No K' treatments in 2018 Yala was found to be not significantly different at 5% probability level.*

Table 05: Yield components of rice under 'no K' and 'with K' treatments in 2018 *Yala* season

Yield component	K treatment*		t-test	
	No K	With K	SE§	test
No. of panicles/sq ft	31.16	39.53	6.3	Ns
No. of spikelets/panicle	70.66	88.33	1.0	S
Filled grain %	79.87	63.73	26.6	S
Thousand-grain weight (g)	23.12	22.45	0.42	Ns

**K – Potassium, §- Standard error of the mean difference, Ns – Not Significant and S – Significant at a 5% probability level*

(Table 05). The number of panicles/sq.ft and the thousand-grain weight were not increased by adding K fertilizer. However, no. of spikelets/panicle increased and filled grain % decreased by adding K fertilizer so the combined effect of those two components ultimately showed no influence of added K fertilizer on grain yield. Thus, finally added K fertilizer did not increase the grain yield of rice when the yield level was as low as around 4 t/ha.

How the milling quality of rice was influenced by the application of K fertilizer was also studied in 2018 *Yala*. Based on the t-test, the head grain percentage of 53.2% under 'no. K' treatment was found to be not significantly different from that of 48.5% under 'with K' treatment so the head grain% of rice was also not influenced by added K fertilizer after two seasons when grain yield level was as low as 4 t/ha. Neither grain yield nor yield components of rice were responding to the application of K fertilizer up to the grain yield level of about 4 t/ha. However, the grain yield of rice responded to added K fertilizer when the yield level was higher than 4 t/ha. In addition, head grain% in rice was also not reduced by avoiding the application of K fertilizer when the yield level was low. However, the influence of K fertilizer on head grain % of rice should be further studied at comparatively higher yield levels.

The absence of yield response to added K fertilizer in rice was also supported by soil K analysis (Table 01) where extractable K content of 60 ppm found in the 'no K' treatment before the initiation of the experiment in 2018 *Yala* appeared adequate to supply K requirement of the rice plant at low yield levels. In addition, the total soil K contents under 'no K' and 'with K' treatments were almost the same.

In the plant K analysis, there was no difference in plant K content between 'no K' (1.89 ppm) and 'with K' (1.86 ppm) treatments further confirming that the application of K fertilizer can be avoided without affecting the rice yield at yield levels 4 t/ha or lower. This indicates that the soil K that has been accumulated in the soil by application of K fertilizer over a long period since the 1960s is adequate for the rice plant at yield levels lower than 4 t/ha.

To confirm whether the application of K fertilizer can be avoided at low yield levels or whether the amount of K applied can be reduced in general in rice cultivation, further studies have to be conducted over several more seasons. In addition, the influence of soil and plant K contents on the grain yield of rice should also be further studied at comparatively higher yield levels. However, at present, the application of K fertilizer appears cost-effective in rice cultivation only in areas where the yield level is higher than 4 t/ha in the Dry Zone of Sri Lanka.

CONCLUSIONS

Whatever the grain yield level obtained, there was no significant yield response of rice to added P fertilizer over three consecutive seasons even after 10 years of avoiding the application of P fertilizer. Thus, the application of P fertilizer for rice can be terminated for at least 11½ years without affecting grain yield no matter the level of grain yield as P is available in the soils in adequate quantities in the Dry Zone of Sri Lanka.

The yield response of rice to added K fertilizer depended on the grain yield level obtained. No yield response was observed up to a yield level of about 4t/ha. Thus, at present, the application of K fertilizer appears not cost-effective in rice cultivation if the yield level of rice is 4 t/ha or lower in the Dry Zone of Sri Lanka. If the grain yield of rice is 4t/ha or lower, application of K fertilizer can be avoided without affecting yield at least over two consecutive seasons in the Dry Zone of Sri Lanka.

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