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Investigation of Impact of Phosphate Fertilizer Applied to Paddy Fields on Water Quality of Nearby Reservoirs

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ABSTRACT: Phosphorous (P) is an essential element to plant growth and development necessitating P fertilizer applications for agricultural crops for better yields. Paddy, the main food crop of Sri Lankans is a fertilizer intensive crop where phosphorus nutrition is achieved via triple super phosphate applications. Since water circulating system of paddy fields are connected to other water bodies this soluble P can contaminate the nearby waterbodies. To detect the extent of P fertilizer leaching from paddy fields, a lysimeter experiment was carried out in the Low Country Intermediate zone, Sri Lanka for four consecutive growing seasons from 2015 to 2016. Paddy fields under two management practices; control run-off and continual run-off conditions were selected for the study. The farmers practice the Department of Agriculture recommended fertilizer application schedules. Lysimeters were placed in a Randomized Complete Block Design with triplicates at upper and lower ends of the gradient of the each site. Water samples were collected below the root zone, at a depth of 30 cm, irrigated, run-off, nearby water reservoirs and analyzed for water soluble of phosphate. The highest concentration of total phosphate in leached water (0.88 mg/L) did not exceed the drinking water standard threshold level of 2 mg/L of Phosphate. The quantified leached total Phosphate amount for controlled run-off condition and continual run-off condition were 0.49 ± 0.10 kg/ha and 0.46 ± 0.04 kg/ha, respectively without statistically significant differences. It represented 2% of the applied P fertilizer content of both sites. This indicates that paddy cultivation under both the conditions does not pose a threat to water quality of the nearby water bodies if the farmers adhere closely to the Department of Agriculture recommended fertilizer schedules.

KEYWORDS: Leaching, Paddy, Phosphate.

I. INTRODUCTION

Phosphorous (P) is an essential nutrient for plant growth, and is a nonrenewable resource (Cordell, et al., 2009) too. P can be found attached to sediment particles or as dissolved organic and inorganic forms. The amount of required P level for optimal plant growth is not in one-third of the cultivable lands in the world (MacDonald et al., 2011). Therefore, mineral P fertilizer and/or animal manure are applied extensively to increase crop yield (Yao et al., 2021). Phosphorous in the soil does not leach easily like nitrate with the downward movement of water. When P fertilizer is incorporated into the soil, Phosphate iron binds with Aluminium (Al), Iron (Fe), Calcium (Ca), and other elements (Shen et al., 2011), which are present in all soils at relatively high levels. Such compounds bind tightly with the soil clay and organic matter reducing P bioavailability leaching and runoff to surface water bodies, primarily along with colloids and/or particles, may be a substantial non-point source of water pollution (Toor et al., 2004). Since P is less mobile in soil, and leaching loss was found to be lower as compared to the other nutrients (Islam et al., 2014). But, it could be frequent enough to cause environmental eutrophication in the water bodies (Hart et al., 2004). The study was an attempt to quantify the leaching loss of phosphate from paddy lands to and feasibility of contaminating waterbodies.

II. MATERIAL AND METHOD

A. Study Area

The study was conducted in two experimental paddy fields in the Low country Intermediate Zone (7.53 N, 80.44 E, 115 m), in Kurunegala district in Sri Lanka. The experiment was carried out from 2015 to 2016 during two cultivation seasons using supplementary irrigation: Yala season runs from May to the end of August during the South-West monsoon, and the Maha season runs from September to March the following year during the North-East monsoon (Paddy Statistic, 2017).

B. Experimental field arrangement

Experiment fields were established in selected two paddy plots (RR_1 and FR_2) having an area of 10 x 10 m^2 (0.01 ha). At RR_1 site BG 358 (3 and 1/2 months), Samba was grown under supplementary irrigation. The plot was well managed, controlled run-off, and maintained at full flooded (about 4 cm of standing water) condition. Triple superphosphate (TSP, 46%) was applied as the sole source of P fertilizer at the rate of 55 kg/ha (23.5 kg P ha^{-1}) as a basal application. Rice plants were transplanted after P fertilizer (TSP) application.

At the FR_2 site, rice variety BG 352 (3 and 1/2 month), Nadu was grown by direct sawing and all other management practices were carried out as per the recommendation of the Department of Agriculture. Triple superphosphate (TSP, 46%) was applied as the sole source of P fertilizer at the rate of 50 kg/ha (23.0 kg P ha^{-1}) as a basal application.

After the field was prepared, non-weighable lysimeters were placed in a Randomized Complete Block Design (RCBD) with triplicates at the upper and lower ends of the gradient of the site and filled with soil that had the same bulk density. At the RR_1 site, rice seedlings were transplanted both in the field and in each lysimeter. Following direct sowing, one rice plant was allowed to develop in each lysimeter at the FR_2 site while following standard agronomic practices. At RR_1, runoff losses were controlled and the water level in the field was regulated appropriately, but not at the other site.

C. Sampling and Analysis

Sampling of water from the lysimeters was carried out 7 to 10 day intervals throughout the entire crop growing period. Samples were collected below the root zone, at a depth of 30 cm and sample volumes were measured and were subjected to analysis of total Phosphate concentrations (mg/L) by vandomolybdophosphoric acid colorimetric method as per APHA 4500-P C (APHA, 2000). The total amount of phosphate lost due to leaching was calculated for one hectare (kg/ha) per growth cycle by employing the same method.

Same times water samples were collected from irrigated, run-off and nearby water reservoirs and was subjected to the same analysis.

D. Statistical Analysis

Data were analyzed using a multiple regression analysis to determine the relationship between PO_4^{3-} -P leaching losses with study sites, cropping seasons (Yala and Maha), gradients of the site (upper and lower, years (2015 and 2016), and amounts of fertilizer applied. Treatment differences were considered statistically significant at $P < 0.05$. Statistical analysis was done by Minitab 17 (Minitab Inc, 2017) software package.

III. RESULTS AND DISCUSSION

A. Phosphate (PO_4^{3-}) concentration in irrigated, and leached water on both study sites

Phosphate was not detected in irrigated water, run-off water or samples collected by nearby reservoirs in each cropping season during the study period. However, low levels of phosphate were detected in leached water collected into the lysimeters.

The mean values of concentration of phosphate (mg/L) in leached water for each cropping season at site RR_1 in the years 2015 and 2016 are given in figure 1.

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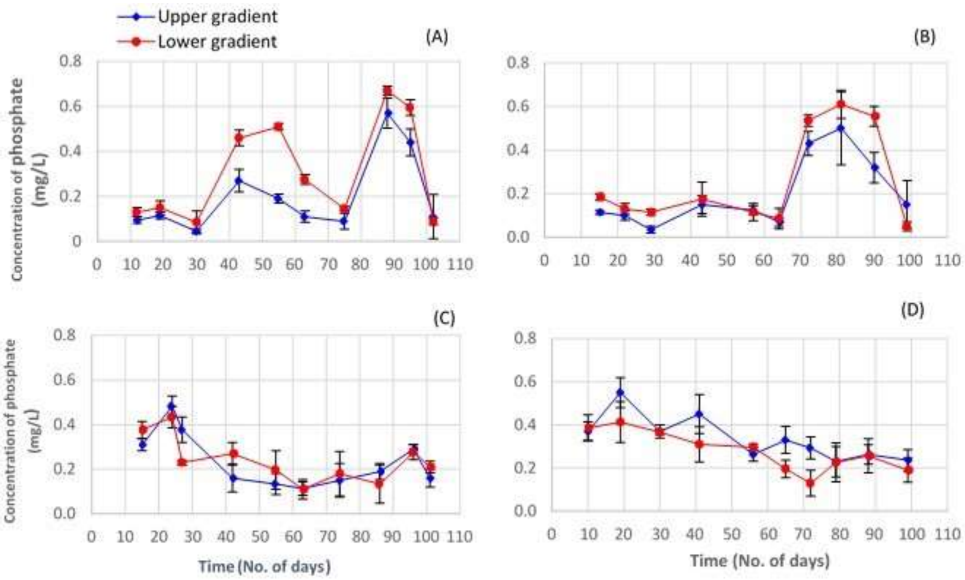

Figure 1: Changes of phosphate in the leachate at the 30 cm soil depth within each cropping season at site RR_1 in 2015 and 2016; A: 2015 Yala, B: 2015/16 Maha, C: 2016 Yala, D: 2016/17 Maha. Bars represent standard deviations.

Based on figure 1, in the 2015 Yala and Maha seasons, a moderate increase in Phosphate concentration (0.6 mg/L) was detected at both ends of gradients which gradually decrease towards the end of the season (0.1 mg/L). In the 2016 Yala and 2016/17 Maha seasons, there were no distinct changes in the pattern of variation of phosphate concentration in leached water through the entire growing period. The maximum phosphate concentration was recorded at 0.88 mg/L, which did not exceed the threshold level of total phosphate (PO_4^3) in the drinking water, 2.0 mg/L (SLS 614, 2013).

The mean phosphate concentrations (mg/L) in leached water at site FR_2 for each cropping season in the years 2015 and 2016 are given in figure 2.

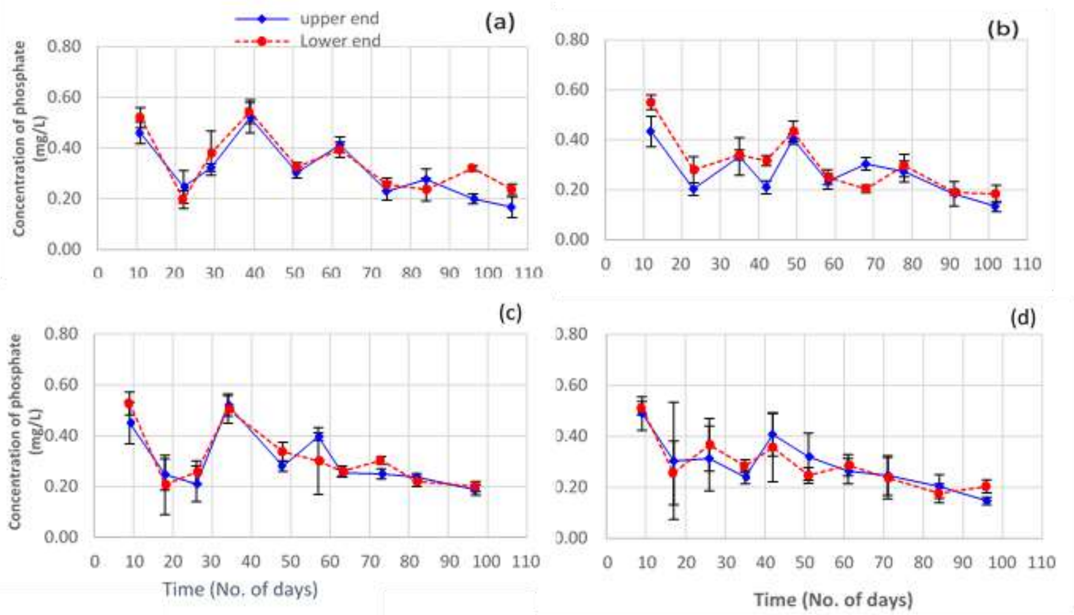

Figure 2: Changes of phosphate in the leachate at the 30 cm soil depth within each cropping season at site FR_2 in 2015 and 2016; a: 2015 Yala, b: 2015/16 Maha, c: 2016 Yala, d: 2016/17 Maha. Bars represent standard deviations.

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According to figure 3.2, for all four seasons, the highest phosphate concentration was exhibited at the 1st sample point after one week post fertilization. There were no noticeable changes in the pattern of variation on phosphate concentration, recording increases and decreases for the rest of the samples for the lower and upper ends of the gradients. As per Xiao, et al., (2015) phosphorous loads were relatively high during the early stages of paddy flooding but steadily declined as the flooding lasted.

Phosphorous fertilizer (TSP) was applied to the soil, and P is quickly converted to unavailable forms (Hellal et al., 2019) and accumulated in the paddy field (Nagumbo et al., 2013)

Since P was less mobile in soil, leaching loss was lower as compared to the other nutrients (Islam et al., 2014). However, some compounds will break down to release soluble P over time by various mechanisms (Vadas et al., 2011), and increased P outflow to the surface water may result from increasing the accessible P content in paddy soil (Sharpley et al., 2001). The flowing water contains some quantity of dissolved phosphate which had resulted of drainage from paddy fields as observed in the the current study.

B. Loss of Phosphate by leaching below the root zone of rice

The total amounts of PO_4^{3-}-P lost per unit area (kg/ha) of site RR_1 and FR_2 for four consecutive cropping seasons in the years 2015 and 2016 are given in Table 2.1. and figure 2.3.

Table I: Loss amount of PO_4^{3-}-P (kg/ha) below the root zone, 30 cm soil depth, at controlled run-off (RR_1 site) and continual run-off (FR_2 site) for each cropping season in years 2015 and 2016.

Cropping season	RR_1 site Mean PO_4^{3-} P (kg/ha)	FR_2 site Mean PO_4^{3-} P (kg/ha)
2015 Yala	0.45	0.52
2015/16 Maha	0.46	0.44
2016 Yala	0.40	0.42
2016/17 Maha	0.63	0.44
Average	**0.49 ± 0.10**	**0.46 ± 0.04**
Avg (Yala)	0.43 ± 0.04	0.47 ± 0.07
Avg (Maha)	0.55 ± 0.12	0.44 ± 0.00

The average leaching loss amount for the site RR_1 was 0.49 kg/ha and it contributes to a 2% loss relative to the applied P fertilizer. For site FR_2, the average amount lost was 0.46 kg/ha (2%) for the four cropping seasons.

The leaching loss of PO_4^{3-} -P of the lower gradient was significantly higher with compared to the upper gradient while site, year and cropping seasons were not statistically significant. It was observed that a significant downward movement of Phosphate-P at the rice field. Hu and Huang, 2014 reported that run-off and drainage of Phosphorous from paddy lands were major sources of nonpoint source pollution. P usage efficiency could be improved, and P intake could be controlled to prevent further P accumulation, and to manage the hazardous effect of Phosphorus (Sharply et al., 2001; Hart et al., 2004).

IV. CONCLUSION

According to the experiment conducted for rice for four consecutive cropping seasons from 2015 to 2016, the recorded highest Phosphate concentration was 0.88 mg/L which did not exceed the threshold levels recommended for drinking water, 2 mg/L (SLS 614, 2013). Phosphate were not detected in irrigated, run-off and nearby recoveries. However, 0.5 kg/ha of Phosphate was leached out from both sites, contributing to a loss of 2% of applied prosperous of the Triple Super Phosphate.

A significant amount of phosphorus could be lost through leaching by paddy cultivating, and threats water contamination by raising the phosphate levels in nearby surface water bodies. The current study emphasizes the necessity of curbing phosphate pollution from the paddy cultivations due to the usage of chemical fertilizers and cares for aqua ecosystems for the future.

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