Phosphorus Loss into Ground Water in Paddy Soils as Influenced by Irrigation System and Rate of Added-P

Mashali, S*; S. Shaheen; H. EL-Ramady; A. Khattab and A. Balba

Abstract

A field experiment was carried out in delta Nile region of Egypt, to elucidate the impact of irrigation system and graded phosphorus fertilizer rates on P loss into ground water in paddy soils (heavy clay soil). Three irrigation system were used: submergence with continuous head of water (about 8 cm), irrigation with saturation percent and discontinous irrigation where soil was irrigated every 7 days. The rate of applied P were 45 and 90 Kg P_2O_5/acre as super phosphate.

Values of dissolved reactive phosphorus (DRP) in ground water increased under saturation and discontinuous irrigation compared to it under submergence condition (e.g.,0.25,0.18 and 0.14 mg P/L, respectively) under 90 Kg P_2O_5 /ac. and after 15 days of added-P. Accumulation values of DRP in ground water after 105 days at 90 Kg P_2O_5 /ac. of added-P were 1.18,0.76 and 0.67 mg P/L under saturation, discontinuous and submergence irrigation methods, respectively. The rate of loss for DRP in ground water was the highest under saturation method at 90 Kg P_2O_5 /ac. (0.01 mg P/L/day).

Results also showed that, accumulated total phosphorus (TP) at the end of ground water collection (105 days after transplanting) when 90 Kg P_2O_5 /ac. was added were 2.78,2.18 and 1.69 mg P/L under discontinuous, saturation and submergence irrigation system, respectively. Also, the rate of loss for TP was the highest under discontinuous irrigation condition (0.025 mg P/L).

These results indicated that, increasing added phosphorus fertilizer let to increasing P loss into ground water by leaching through the soil profile .In addition, phosphorus loss into ground water was increased with decreasing added water for irrigation in paddy soils (increasing drought regime) and that was not expected.

Key words: Phosphorus loss, Ground water, Paddy soils, Irrigation system, Egypt

I. Introduction:

Soils that are over fertilized with P and exhibit a high capacity to sorb P (such as Egyptian soils) often results in a build-up of P, increasing the risk of adverse environmental effects from P loss to ground water.

Transport of P from agricultural soils to surface water has been linked to eutrophication of lakes and estuaries. The movement of agricultural P is related to factors such as soils chemical and mineralogical properties, soil test P levels, agricultural management and irrigation method.

Total P losses from poorly drained clay soils may range from 0.01 to 1.17 mg P/L or higher (Simard *et al.,* 2000a,b). The quantities of P leached through soil increase after fertilizer application.

Rice plant is adopted to grow in flooded soils, but it also grows well in non-flooded soils. To produce 1 kg rice grain, farmers have to use 2-3 times water more than another grain. There are different irrigation ways for the reduction of entrance of water to rice field, such as saturation of farm's soil instead of submergence (Dong *et al.,* 2004), also irrigation after some days of water disappearance from soil surface and interval irrigation.

Therefore, the objectives of this study are to test the effect of different levels of inorganic P fertilizers and different irrigation regime on P losses into ground water, rice grain yield and P uptake by plants.

II. Materials and Methods

A field experiment was conducted in the clay soil at Nile Delta of Egypt during the summer season. Soil pH (1::2.5 soil water suspension) was 7.85, soil texture was clayey with 52% clay and available P was 6.57 mg P/kg soil (Olsen *et al.*, 1954)

This study was carried out in split plot design with three replicates as follows: 1) three treatments of irrigation regime as main plots and (2) three rates of phosphorus fertilizer as sub-plots. All plots received 60 kg N/acre as urea and 10 kg $ZnSO_4$/acre.

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To estimate phosphorus loss to ground water, pizometer of polyethylene (6.5 cm in diameter) were installed to 1.5 m depth by auger in all plots. Water samples were collected from pizometers every 15 days for three months. One half of each water sample was filtered (<0.45 μm) and analyzed for Dissolved Reactive Phosphorus (DRP). Total P was determined by digestion with persulfate (sulfuric perchloric acid digestion) for the unfiltered water samples (Williams *et al.,* 1995). Total P and DRP were measured colormetrically by method of Murphy and Riley (1962).

Phosphorus concentration of plant samples was determined according to Gerick and Kurmies (1952) in the digested plant solution and P-uptake were calculated from P concentration, in grain yield.

III. Results and Discussion:

The main goal of this study was to identify the leaching of P into ground water. Therefore the water samples of ground water were taken every 15 days until the end of growth season. Dissolved reactive P (DRP) and total P were determined and accumulated P also was calculated.

III.1. Dissolved reactive phosphorus (DRP):

Results in Fig. 1, 2 and 3 show the absolute values of DRP concentration in ground water every 15 days under all treatments. These concentrations were increased under 90 kg P_2O_5 of added-P compared to it under 45 P_2O_5. This was in agreement with these results by Zhang *et al.* (2006), they found that the DRP concentration in subsurface water was increased when rate of added P increased. The highest values of DRP was found at 15 and 30 days after planting under all treatments then decreased with time. That indicates the increase of fixing capacity of our soils for P fertilizer with time.

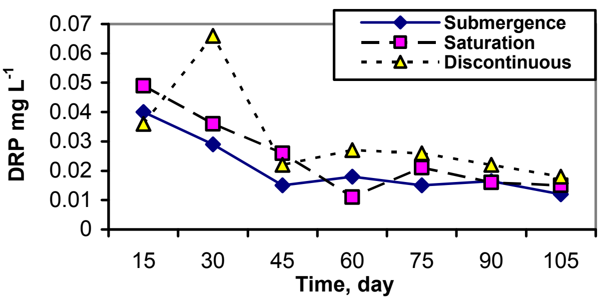

Fig. (1) DRP concentration in ground water with time without added-P.

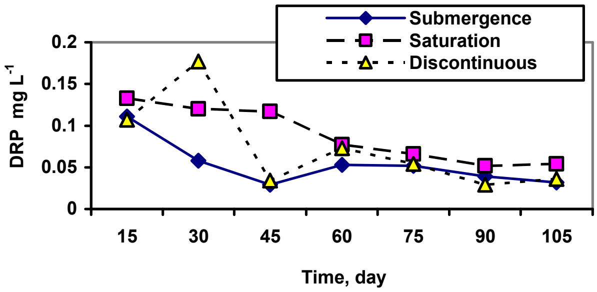

Fig. (2) DRP concentration in ground water with time under 45 kg P_2O_5/acre of phosphorus application.

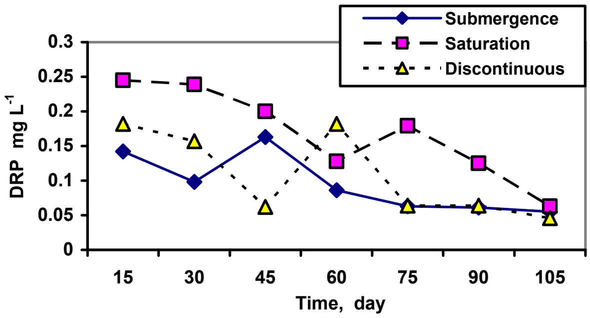

Fig. (3) DRP concentration in ground water with time under 90 kg P_2O_5/acre of phosphorus application.

Accumulation values of DRP at the end of growth season were the highest under saturation treatment of irrigation regime compared to the other two methods of irrigation (Fig. 4).

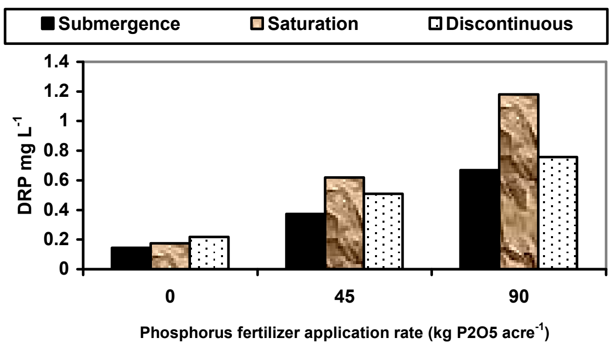

Fig (4). Total accumulation of dissolved reactive phosphorus concentration in ground water with time.

III.2. Total phosphorus:

The absolute values of total P (TP) in ground water every 15 days are shown in Table 1. These values were increased under 90 kg P_2O_5 compared to 45 kg P_2O_5 of added-P at all periods of water collection. Values of TP in ground water also were increased with increasing drought regime and the highest values was found only at 30 days of transplanting such as DRP concentration.

Accumulation values of TP at the end of ground water collection are shown in Fig. 5 under all treatments. Accumulation values were the highest under discontinuous irrigation regime compared to the other two irrigation methods for all levels of added P. The highest concentration of TP were obtained at 90 kg P_2O_5 of added-P. These findings are in agreement with those reported by Zhang *et al*. (2004), they found that, one day after phosphorus application in rice field total P had increased with increasing added-P.

Table (1): Concentration of total phosphorus in ground water samples during rice season, mg L^{-1}.

Time (day)	Added-P kg P_2O_5 $acre^{-1}$	TP concentration, mg/L		
		Submergence	Saturation	Discontinuous
15	Zero	0.087	0.095	0.146
	45	0.200	0.230	0.251
	90	0.331	0.496	0.499
30	Zero	0.091	0.153	0.160
	45	0.241	0.313	0.313
	90	0.430	0.514	0.529
45	Zero	0.051	0.095	0.138
	45	0.153	0.157	0.193
	90	0.260	0.364	0.368
60	Zero	0.022	0.109	0.098
	45	0.066	0.168	0.208
	90	0.220	0.233	0.393
75	Zero	0.036	0.044	0.131
	45	0.102	0.128	0.186
	90	0.204	0.219	0.321
90	Zero	0.033	0.036	0.076
	45	0.063	0.102	0.164
	90	0.124	0.226	0.397
105	Zero	0.029	0.044	0.084
	45	0.066	0.087	0.142
	90	0.117	0.128	0.270

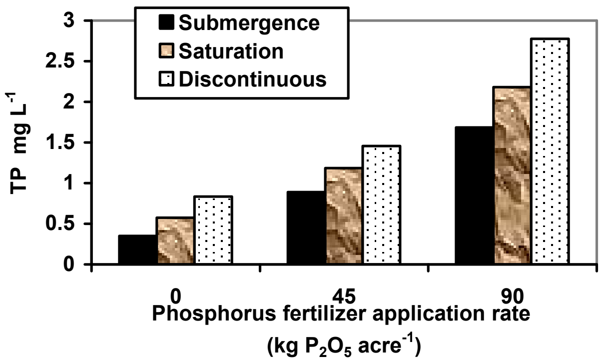

Fig. (5). Total accumulation of total phosphorus concentration with time.

The rate of loss for TP was calculated by regression equation from its values at different times under rates of added-P and irrigation treatments (Fig. 6). Data showed that, the highest rate of loss (0.025 mg/L/day) was found under discontinuous irrigation condition with 90 kg P_2O_5/acre ($Y = 0.025\ x + 0.229$, $r^2 = 0.994$).

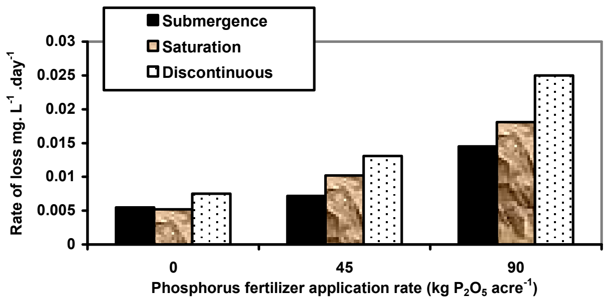

Fig.(6). Rate of loss for total phosphorus in ground water with time.

III.3. Rice grain yield:

Fig. (7) show the rice grain yield under all treatments either for irrigation regime or level of added-P. Results showed that, the main effect on rice grain yield was coming from irrigation regime. The highest grain yield was found under submergence irrigation compared to the other two irrigation methods. That indicates the importance of irrigation water and its quantity for rice crop under heavy clay soils.

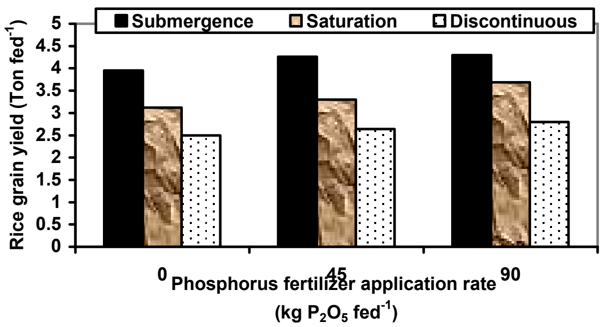

Fig. (7) Rice grain yield under different irrigation system and phosphorus application rate.

The difference between rice grain yields did not significantly differ for P level within method of irrigation, but the highest grain yield was found at 90 kg P_2O_5/acre under all irrigation methods. These findings are in agreement with Wilson *et al.* (2000), they found that, in Arkansas, rice yield responses to phosphorus fertilization have been found almost exclusive on alkaline soils or soils disturbed by land leveling.

III.4. P-uptake by rice grains:

Phosphorus concentrations in plant parts at flowering stage and its uptake by rice grains are shown in Table (2). Results showed that, increasing P added increased P concentration either in green plant parts or in rice grains. Highest P concentration was found under submergence irrigation at 90 kg P_2O_5/acre. The rate of increasing P in green plant were 3.44, 4.69 and 3.25 fold under submergence, saturation and discontinuous irrigation, respectively at 90 kg P_2O_5/acre. The corresponding values of increasing rate in grain yield were 5.15, 3.86 and 3.70 fold under the same irrigation system and rate of added-P.

Phosphorus uptake by rice grains was increased with increasing P addition under all irrigation regimes but the highest uptake was obtained under submergence irrigation.

Table (2):Phosphorus concentration in plant samples at flowering stage and grain yield .

Rate of added P kg P_2O_5/ acre	P conc. in green plant samples		P conc. in grains		Calculated P uptake kg P_2O_5/ acre
	µg/g	%	µg/g	%	
Submergence					
0	830	0.08	1331	0.13	12.04
45	2779	0.27	4954	0.49	48.32
90	2858	0.28	6852	0.68	67.47
Saturation					
0	548	0.05	1032	0.10	7.37
45	1385	0.13	1621	0.16	12.25
90	2571	0.25	3986	0.39	33.68
Discontinuous					
0	331	0.03	707	0.07	4.05
45	447	0.04	1374	0.13	8.31
90	1077	0.10	2618	0.26	16.78

IV. Conclusion :

Under our Delta heavy clay soils conditions and rice crop we can say that:

1. Phosphorus losses by leaching into ground water was very little (about 3 mg/L and 1.5% of added P fertilizer) which did not encourage Eutrophication phenomenon in estuaries.
2. Decreasing P leaching into ground water under submergence irrigation regime was not expected, but this may be due to soil physical conditions (e.g. compaction conditions).
3. Maximum rice yield and its P uptake were obtained under submergence irrigation method.

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