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LEACHING LOSSES OF NITROGEN, PHOSPHORUS AND POTASSIUM FROM THE SANDY LOAM SOIL OF OLD BRAHMAPUTRA FLOODPLAIN (AEZ-9) UNDER CONTINUOUS STANDING WATER CONDITION

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Abstract

An experiment was conducted at the net house of the Department of Soil Science, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh during February to June (boro season) of 2009. The objective was to find out the leaching loss of N, P, and K in the Old Brahmaputra Floodplain Soil under continuous standing water (CSW) condition. The soil was sandy loam in texture having pH 6.6, total N 0.08%, available P 7.00 mg/kg, exchangeable K 0.07 me/100g soil, and available S 7.5 mg/kg. The experiment was laid out in completely randomized design with three replications. There were six treatments, such as T_0 (control), T_1 (N_{120} P_{25} K_{60} S_{20} recommended dose), T_2 (N_{180} P_{37} K_{90} S_{30} kg/ha i.e., 150% of the recommended dose), T_3 (75% N of T_1 from chemical fertilizer and 25% N from cowdung 2.5 t/ha and PKS of recommended dose from chemical fertilizer on the basis of PKS content in cowdung), T_4 (as T_1 but N_{109} kg/ha from USG) and T_5 (as T_1 but N applied as foliar spray). The nutrients P, K, and S were applied as basal dose in the pots while urea was applied in three equal splits except T_4 and T_5. One USG per pot was placed after 7 days of transplanting in T_4. In T_5, urea was applied as foliar spray at 10 days interval. Leachates from individual pots were collected at 15 days intervals to determine the amount of loss of NPK. Results showed that leaching loss of NPK in the sandy loam soil under CSW condition varied widely due to different treatments over time. The total leaching loss of N, P, and K during the growing season varied from 22.23 to 91.21, 0.063 to 1.95, and 35.22 to 42.01 kg/ha, respectively. Application of chemical fertilizer at higher rates resulted in greater loss of nutrients. Integrated approach of fertilizer management could minimize such losses to a great extent. Application of N in the form of USG reduced the N loss significantly.

Keywords: Leaching loss, plant nutrients, sandy loam soil, continuous standing water, boro rice.

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Introduction

There are many interrelated factors, both natural and managerial, responsible for the deterioration of soil fertility. This decline may occur through leaching, soil erosion and crop intensive cropping (Donova *et al.,* 1998). When we apply fertilizer in soil for obtaining maximum yield, a significant amount of nutrients is lost through leaching, which might hamper the crop production and pollutes the environment. Leaching loss varied from soil to soil and the rate of loss differed from nutrient to nutrient. Generally, N fertilizers are completely water soluble and a significant portion is lost through leaching. In well-drained sandy soils, much of the nitrate can be lost by leaching as water moves nitrate down through the soil profile (Camberato *et al*., 2008). Nitrogen was lost through leaching, both as and even after application of the ammoniacal form in a reduced soil zone. The magnitude of fertilizer-N leaching varies depending on soil condition and the method of fertilizer application (Velu *et al*., 2001; Vlek *et al.,* 1980; Xing *et al*., 2000). Leaching loss of N occurs in the form of NO_3^- and NH_4^+ from rice fields and the extent of loss by NO_3^- N is more than 90%. Keeping the rice field under standing water for a long time favours more leaching loss than keeping the field under saturation or alternate wetting and drying. Surface application of nitrogenous fertilizers in light textured soil because more nitrate loss. Application of N fertilizers at higher doses cause higher leaching loss. Soils having low organic matter status cause more leaching loss of nitrogen than soils rich with organic matter. It is estimated that upland lateritic sandy loam soils at Bhubaneswar cause 23-24% loss of applied nitrogen. Leaching losses in rice field studied in sandy loam mixed red and black soils of Hirakud command area are accounted at 45-46% under saturated condition, whereas, under submerged condition, the losses were 80-84% (S. K. Sahu *et al.,* 2006). Phosphorus is less mobile in soil and leaching loss is lower as compared to other nutrients. Besides, phosphate is extremely reactive and binds strongly with aluminum, iron, manganese, calcium, and other elements present in soils. Phosphorus losses vary from one event to another depending upon amount, intensity, and duration of rainfall (Sharpley, 1997). Phosphorus inputs in the form of mineral P fertilizer and/or animal manures may be a significant non-point source of pollution as a result of P leaching (Toor *et al.,* 2004; Gurpal *et al*., 2004). Fahmi *et al.,* 2012 showed that rice straw (RS) application was effective in preventing P loss from the soil at 6 weeks after planting (WAP) and decreased the pH of leachate at all observations time but it increased Fe^{2+} concentration in leachate (0.07-0.42% Fe^{2+} in the soil were leached or 2-5 folds higher than without RS application). M. W. de Oliveira *et al.,* 2002 found that in the first three weeks, the largest losses of N by leaching occurred, originating from soil/sugarcane remains-N. The mean of leached N during the experimental period of 11 months was of 4.5 kg/ha. The mean losses of K^+, Ca^+ and Mg^{2+} were of 13, 320, and 80 kg/ha, respectively. Generally, the amount of K loss from the soils is quite high. The risk of K

leaching loss under humid tropical conditions is very high, especially when higher rates of K fertilizers are applied on freely drained soils of low CEC (Pieri *et al.,* 1986). The proper potassium fertilization management using adequate amounts of fertilizers and crop rotation can minimize K losses, which is important economically and environmentally. However, such studies are very scanty under different soil, water, and agro-climatic conditions of Bangladesh. The present study was, therefore, undertaken to determine the leaching loss of N, P, and K in sandy loam soil of the Old Brahmaputra Floodplain (AEZ-9) under continuous standing water (CSW) condition.

Materials and Method

Leaching loss of NPK under continuous standing water (CSW) condition was studied through an experiment at the net house of the Department of Soil Science, BAU, Mymensingh in the boro season (February to June) of 2009. Soil was collected from the river side of Brahmaputra and it was processed by hand. The soil of the experiment was sandy loam in texture with pH 6.6, total N 0.08%, available P 7.00 µg/g, exchangeable K 0.07 me/100g soil, and available S 7.5 µg/g, respectively (Table 1). Each pot received 6.67 kg soil (weight in dry basis) with an opening at the bottom for collecting leachates. The upper surface area of the pot was 380 cm^2. boro rice cv BRRI dhan29 was used as the test crop. One hill (3 seedlings) was planted in each pot. The treatments were T_0 (control), T_1 (N_{120}, P_{25}, K_{60}, S_{20} kg/ha, recommended dose of fertilizer (BARC, 2005)), T_2 (N_{180}, $P_{37.50}$, K_{90}, S_{30} kg/ha, 150% of T_1), T_3 (75% N of T_1 from chemical fertilizer and 25% N from cowdung 2.5 t/ha and PKS of recommended dose from chemical fertilizer on the basis of PKS content in cowdung), T_4 (as T_1 but N_{109} kg/ha from USG) and T_5 (as T_1 but N applied as foliar spray). N, P, K, and S content in cowdung was 1.2, 1, 1.6, and 0.13%, respectively. Fertilizers were applied as per treatments. All the fertilizers except urea were applied as basal to the individual pots and mixed well. The first split of urea was applied as top dressing after 10 days of transplanting boro rice followed by the second and third splits at 35 and 58 days after transplanting. In case of the treatment T_4, one piece (0.90 g) of USG was placed in each pot after 10 days of transplanting. In that case, doses of N was 109 kg/ha. In case of foliar application of urea (T_5), one-third urea was applied after 10 days of transplanting and rest portion was sprayed at the rate of 3% in 6 equal splits at 10 days interval after the first application. Leachates from individual pots were collected in every day which were preserved in refrigerator and all leachates were mixed together at 15 days intervals and analyzed for N by rapid test method using soil testing kit, P by Olsen method (Olsen *et al.,* 1954), K by flame photometer (Black, 1965) and S by turbidimetric method (Page *et al*., 1989). But in case of initial soil analysis, total N was

determined by micro-Kjeldhal method (Page *et al*., 1989), texture by hydrometer method (Black, 1965) and pH by glass electrode pH meter method (Black, 1965).

Table 1. Physical and chemical characteristics of the initial soils.

Characteristics	Results
A. Physical characteristics	
% Sand	46.8
% Silt	48.0
% Clay	5.2
Soil texture	Sandy loam
B. Chemical characteristics	
Soil pH	6.6
Total N (%)	0.08
Available P (µg/g)	7.00
Exchangeable K (me/100 g soil)	0.07
Available S (µg/g)	7.50

Results and Discussion

Results presented in Table 2 indicated the leaching loss of N, P, and K in sandy loam soil due to different rates of fertilizer treatments under CSW condition over time. It was revealed that the leaching loss of nutrients from the fertilized pots was significantly higher over control irrespective of type of nutrients and study period. The maximum leaching loss of nutrients was recorded due to application of fertilizers at higher rates. The loss of N was maximum when urea was applied at higher rates (T_2) followed by urea application at recommended dose either as splits or foliar sprays. Application of N in the form of USG (T_4) reduced the leaching loss, while the minimum loss was recorded with integrated fertilization (T_3). Almost similar trend of leaching loss was observed in case of P and K also. The leaching loss of NH_4-N, NO_3-N, P, and K in sandy loam soil due to different treatments under CSW condition at 1st 15 (1-15) days after transplanting (DAT) ranged from 1.50 to 5.50, 0.50 to 1.50, 0.070 to 0.225, and 2.33 to 2.80 mg/kg soil, respectively, which was equivalent to 3.88 to 14.21, 1.29 to 3.88, 0.183 to 0.584, and 6.02 to 7.24 kg/ha.

A significant variation in the leaching loss of N, P, and K due to different treatments in sandy loam soil under CSW condition was noted at 2nd 15 (16-30) DAT but the rate of losses was less as compared to 1st 15 days (Table 2). The leaching loss of NH_4-N, NO_3-N, P and K at 2nd 15 (16-30) DAT due to different treatments ranged from 1.40 to 5.20, 0.40 to 1.40, 0.031 to 0.154, and 2.53 to 2.82 mg/kg soil, respectively, which was equivalent to 3.18 to 11.82, 0.91 to 3.18, 0.071 to 0.351, and 5.75 to 6.36 kg/ha, respectively. During this period, the maximum leaching loss of nutrients was also observed in pots where higher rates of fertilizers were applied (T_2). Integrated fertilization (T_3) practice exhibited the

Table 2. Leaching loss of N, P, and K due to different treatments from sandy loam soil under CSW condition over time at 1st 15 (1-15) and 2nd 15 (16-30) days after transplanting (DAT).

Leaching Period	Treatments	Available NH_4-N		Available NO_3-N		Available P		Available K	
		mg/kg	Total loss (kg/ha)	mg/kg	Total loss (kg/ha)	mg/kg	Total loss (kg/ha)	mg/kg	Total loss (kg/ha)
1-15 days	T_0	1.50 d	3.88 e	0.50 e	1.29 e	0.070 d	0.183 e	2.33	6.02
	T_1	4.50 b	11.63b	1.10 b	2.84 b	0.155 b	0.401 b	2.66	6.87
	T_2	5.50 a	14.21 a	1.50 a	3.88 a	0.225 a	0.584 a	2.80	7.24
	T_3	3.50 c	9.05 d	0.80 d	2.07 d	0.101 c	0.263 d	2.46	6.36
	T_4	4.00 bc	10.34c	1.00 c	2.58 c	0.120 bc	0.310 bc	2.53	6.53
	T_5	4.50 b	11.63 b	1.10 b	2.84 b	0.146 b	0.380 c	2.60	6.72
	SE(±)	**0.554**	**1.430**	**0.137**	**0.354**	**0.021**	**0.056**	**NS**	**NS**
16-30 days	T_0	1.40 d	3.18 d	0.40 d	0.91 d	0.031 c	0.071 c	2.53	5.75
	T_1	4.20 b	9.54 b	1.00 b	2.27 b	0.101 ab	0.231 ab	2.66	6.04
	T_2	5.20 a	11.82 a	1.40 a	3.18 a	0.154 a	0.351 a	2.82	6.36
	T_3	3.20 c	7.27 c	0.75 c	1.70 c	0.055 bc	0.126 bc	2.60	5.91
	T_4	3.40 c	7.73 c	0.90 c	2.05 c	0.063 bc	0.143 bc	2.62	5.95
	T_5	3.70 c	8.41 c	0.70 c	1.59 c	0.074 bc	0.170 bc	2.60	5.91
	SE(±)	**0.510**	**1.169**	**0.137**	**0.310**	**0.018**	**0.040**	**NS**	**NS**

Figure(s) in a column having common letter(s) do not differ significantly at 5% level of significance.

T_0 = control, T_1 = N_{120} P_{25} K_{60} and S_{20} kg/ha, T_2 = N_{180} $P_{37.50}$ K_{90}, and S_{30} kg/ha, T_3 = 75% N of T_1 from chemical fertilizer and 25% N from cow dung 2.5 t/ha and PKS of recommended dose from chemical fertilizer on the basis of PKS content in cowdung, T_4 = As T_1 but N_{109} kg/ha from USG and T_5 = As T_1 but N applied as foliar spray.

Table 3. Leaching loss of N, P, and K as influenced by different fertilizer treatments from sandy loam soil under CSW condition at 3rd 15 (31-45) and 4th 15 (46-60) days after transplanting (DAT).

Leaching Period	Treatments	Available NH_4-N		Available NO_3-N		Available P		Available K	
		mg/kg	Total loss (kg/ha)	mg/kg	Total loss (kg/ha)	mg/kg	Total loss (kg/ha)	mg/kg	Total loss (kg/ha)
31-45 days	T_0	1.30 c	2.56 d	0.35 d	0.69 f	0.011 c	0.020 c	2.50 c	4.93 b
	T_1	4.25 a	8.38 b	1.10 b	2.17 b	0.062 b	0.124 b	2.90 a	5.75 a
	T_2	5.30 a	10.45 a	1.45 a	2.86 a	0.103 a	0.204 a	2.93 a	5.77 a
	T_3	3.60 ab	7.09 bc	0.85 bc	1.68 c	0.012 c	0.024 c	2.86 b	5.64 a
	T_4	3.45 ab	6.80 bc	0.80 c	1.58 d	0.012 c	0.024 c	2.83 bc	5.58 a
	T_5	3.20 b	6.31 c	0.70 c	1.38 e	0.016 c	0.032 c	2.86 b	5.64 a
	SE(±)	**0.540**	**1.064**	**0.152**	**0.300**	**0.016**	**0.031**	**0.064**	**0.128**
46-60 days	T_0	1.25 c	2.67 d	0.30 c	0.64 f	0.032 c	0.070 d	2.60 c	5.55 b
	T_1	4.00 ab	8.54 b	1.00 ab	2.13 b	0.104 a	0.222 a	2.96 b	6.32 a
	T_2	5.10 a	10.89a	1.30 a	2.77 a	0.106 a	0.228 a	3.06 a	6.53 a
	T_3	3.35 b	7.15 bc	0.70 b	1.49 d	0.043 bc	0.094 c	2.90 b	6.19 a
	T_4	3.50 b	7.47 bc	0.75 b	1.60 c	0.049 bc	0.105 bc	2.92 b	6.23 a
	T_5	3.00 b	6.40 c	0.65 b	1.39 e	0.052 b	0.111 b	2.95 b	6.30 a
	SE(±)	**0.518**	**1.106**	**0.138**	**0.294**	**0.013**	**0.028**	**0.063**	**0.136**

Figure(s) in a column having common letter(s) do not differ significantly at 5% level of significance.

T_0 = control, T_1 = N_{120} P_{25} K_{60}, and S_{20} kg/ha, T_2 = N_{180} $P_{37.50}$ K_{90}, and S_{30} kg/ha, T_3 = 75% N of T_1 from chemical fertilizer and 25% N from cowdung 2.5 t/ha and PKS of recommended dose from chemical fertilizer on the basis of PKS content in cowdung, T_4 = As T_1 but N_{109} kg/ha from USG and T_5 = As T_1 but N applied as foliar spray.

Table 4. Leaching loss of N, P, and K as influenced by different fertilizer treatments from sandy loam soil under CSW condition at 5th 15 (61-75) and 6th 15 (76-90) days after transplanting (DAT).

Leaching Period	Treatments	Available NH_4-N		Available NO_3-N		Available P		Available K	
		mg/kg	Total loss (kg/ha)	mg/kg	Total loss (kg/ha)	mg/kg	Total loss (kg/ha)	mg/kg	Total loss (kg/ha)
61-75 days	T_0	1.20 e	2.65 d	0.25 d	0.60 d	0.035 d	0.087 c	2.60 c	6.27 c
	T_1	4.10 b	9.88 b	1.10 b	2.65 b	0.088 b	0.214 a	3.05 ab	7.35 a
	T_2	5.15 a	12.41 a	1.35 a	3.25 a	0.101 a	0.245 a	3.20 a	7.71 a
	T_3	3.40 c	8.19 c	0.75 c	1.81 bc	0.059 c	0.143 b	2.94 b	7.09 b
	T_4	3.30 c	7.95 c	0.60 c	1.45 c	0.061 c	0.148 b	2.82 b	6.80 bc
	T_5	2.95 d	7.11 cd	0.65 c	1.57 c	0.061 c	0.148 b	2.97 b	7.16 b
	SE(±)	**0.535**	**1.321**	**0.159**	**0.383**	**0.009**	**0.023**	**0.084**	**0.201**
76-90 days	T_0	1.00 c	2.63 c	0.20 d	0.53 d	0.077 c	0.203 c	2.55 c	6.70 c
	T_1	3.70 ab	9.72 ab	0.90 ab	2.36 ab	0.121 a	0.318 a	3.10 ab	8.14 ab
	T_2	4.70 a	12.34 a	1.20 a	3.15 a	0.124 a	0.335 a	3.22 a	8.40 a
	T_3	3.00 b	7.88 b	0.65 bc	1.71 bc	0.093 b	0.247 b	2.96 b	7.77 b
	T_4	3.00 b	7.88 b	0.50 cd	1.31 cd	0.090 b	0.236 b	2.90 b	7.62 b
	T_5	2.60 b	6.83 b	0.45 cd	1.18 cd	0.098 b	0.258 b	3.00 ab	7.88 ab
	SE(±)	**0.4143**	**1.0880**	**0.0962**	**0.2526**	**0.0028**	**0.0075**	**0.0628**	**0.1649**

Figure(s) in a column having common letter(s) do not differ significantly at 5% level of significance.

T_0 = control, T_1 = N_{120} P_{25} K_{60} and S_{20} kg/ha, T_2 = N_{180} $P_{37.50}$ K_{90}, and S_{30} kg/ha, T_3 = 75% N of T_1 from chemical fertilizer and 25% N from cowdung 2.5 t/ha and PKS of recommended dose from chemical fertilizer on the basis of PKS content in cowdung, T_4 = As T_1 but N_{109} kg/ha from USG and T_5 = As T_1 but N applied as foliar spray.

minimum loss. Similarly, at 3rd 15 DAT (31-45), the leaching loss of NH_4-N, NO_3-N, P, and K varied from 1.30 to 5.30, 0.35 to 1.45, 0.011 to 0.103, and 2.50 to 2.93 mg/kg soil, respectively, which was equivalent to 2.56 to 10.45, 0.69 to 2.86, 0.020 to 0.204, and 4.93 to 5.77 kg/ha (Table 3). The corresponding values of leaching loss of NH_4-N, NO_3-N, P and K at 4th 15 DAT (46-60) ranged from 1.25 to 5.10, 0.30 to 1.30, 0.032 to 0.106, and 2.60 to 3.06 mg/kg soil, respectively, which was equivalent to 2.67 to 10.89, 0.64 to 2.77, 0.070 to 0.228, and 5.55 to 6.53 kg/ha (Table 3). The leaching loss of NH_4-N, NO_3-N, P, and K in sandy loam soil due to different treatments under CSW condition at 5th DAT (61-75) ranged from 1.20 to 5.15, 0.25 to 1.35, 0.035 to 0.101, and 2.60 to 3.20 mg/kg soil, respectively (Table 4). Leaching loss of N, P, and K at 6th DAT (76 to 90), varied significantly due to different treatments in sandy loam soil under CSW condition (Table 4). The leaching loss of NH_4-N, NO_3-N, P, and K during this period ranged from 1.00 to 4.70, 0.20 to 1.20, 0.077 to 0.124, and 2.55 to 3.22 mg/kg soil, respectively, which was equivalent to 2.63 to 12.34, 0.53 to 3.15, 0.203 to 0.335, and 6.70 to 8.40 kg/ha (Table 4).

The loss of NH_4-N for the treatment T_1 was 4.5 mg/kg at 15 DAT, which was reduced by 6.7% at 30 DAT and then remained almost static up to 75 DAT but sharply reduced by 17.8% at 90 DAT showing a loss of 3.70 mg/kg. Similarly, at 15 DAT loss of NO_3-N was 1.10 mg/kg which reduced by 9.1% at 30 DAT then at 45 DAT amount of loss increased again as like as at 15 DAT. Intensity of N loss was increased after the urea top dress. The loss was highly reduced by 18.2% at 90 DAT. Almost similar trend was found in other treatments except USG treatment. In that case, loss was very high at 15 DAT in comparison to other growing periods. P loss was low at 45 DAT in comparison to 60, 75, and 90 DAT. It might be due to more requirements of P at 45 DAT for reproduction of plant. K loss gradually increased with the growing period.

Table 5. Total leaching loss of NPKS from sandy loam soil under CSW condition.

Treatment	N (kg/ha)			P	K
	NH_4-N	NO_3-N	Total	(kg/ha)	
T_0	17.57	4.66	22.23	0.63	35.22
T_1	57.69	14.42	72.11	1.51	40.47
T_2	72.12	19.09	91.21	1.95	42.01
T_3	46.63	10.46	57.09	0.90	38.96
T_4	48.17	10.57	58.74	0.97	38.71
T_5	46.69	9.95	56.64	1.10	39.61

The total leaching loss of NH_4-N, NO_3-N, P, and K during the growing period (90 days) of boro rice due to different treatments under CSW condition ranged from 17.57 to 72.12, 4.66 to 19.09, 0.63 to 1.95, and 35.22 to 42.01

kg/ha, respectively (Table 5). The total N loss during the period ranged from 22.23 to 91.21 kg/ha. About 41.6, 38.3, 29.1, 33.5, and 28.7% of applied N was lost through leaching for the treatment T_1, T_2, T_3, T_4, and T_5, respectively. Leaching loss of N in the form of NH_4-N 33.4% while 8.1% applied N was lost as NO_3-N for the treatment T_1. In the other treatments, almost similar trend was found (Table 5). Leaching loss of P for the treatment T_1, T_2, T_3, T_4, and T_5 was 3.52, 3.52, 1.08, 1.36, and 1.88%, respectively. Another nutrient K was lost through leaching T_0 = Control, T_1 = N_{120} P_{25} K_{60} S_{20} kg/ha, T_2 = N_{180} $P_{37.5}$ K_{90} S_{30} kg/ha, T_3 = 75% N of T_1 from chemical fertilizer and 25% N from cowdung 2.5 t/ha and PKS of recommended dose from chemical fertilizer on the basis of PKS content in cowdung, T_4 = As T_1 but N_{109} kg/ha from USG, T_5 = As T_1 but N foliar spray was 8.8, 7.5, 6.2, 5.8, and 7.3% for the treatment T_1, T_2, T_3, T_4, and T_5, respectively. Application of fertilizers at higher rate resulted more leaching loss of nutrients, while the minimum loss of nutrients was noted with the integrated fertilization. Although losses of nutrients in percentage of T_2 treatments were lower than that of T_1, total losses of nutrients were more in the treatment T_2. The slow release of nutrients from the organic manure might have resulted in low loss of nutrients for T_3. Again, USG releases N slowly which contributed to low loss of N. Losses of P was minimum in the USG treated pot, it might be due to more vegetative growth of plant and more nutrient uptake. The reason for low loss of N from the foliar spray treatment is quite obvious.

Conclusion

Leaching loss of essential plant nutrients like N, P, and K from the sandy soil of Old Brahmaputra Floodplain (AEZ-9) under Continuous Standing Water (CSW) condition for boro rice cultivation was quite significant. Application of chemical fertilizer at higher rates resulted in greater loss of nutrients. Integrated approach of fertilizer management could minimize such losses to a great extent. Application of N in the form of USG may be helpful in reducing the N loss appreciably.

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