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The Assessment of Nitrogen Balance Under Flooding and Saturation Circumstances Using N-15

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خلاصة

إن استخدام النظير - 15 للنيتروجين يعتبر من أهم الطرق المستخدمة لمتابعة التغيرات في النيتروجين خاصة بأراضي الأرز. في تجربة استخدم فيها الحقن بسماد كبريتات الآمونيوم المرقم بالنيتروجين - 15 بأعمدة تربة خاصة، تم دراسة أثر كل من وجود النبات والظروف الغدقة وكذلك اضافة المادة العضوية (قش الأرز بنسبة 1٪) على جهد فقد النيتروجين.
أوضحت النتائج زيادة المجموع الخضري والمحصول باضافة قش الأرز - كما أظهرت النتائج انخفاض معدل فقد النيتروجين نتيجة للظروف الغدقة. وقد وجد أن نسبة النيتروجين المستعاد في حالة وجود النبات هي 75٪، 56٪ تحت الظروف الغدقة والمشبعة على التوالي بينما كانت 86٪، 73٪ في حالة عدم وجود نبات منزرع مما يؤكد دور النبات النامي. ويتضح من النتائج أن الحقن العميق للسماد وكذلك الظروف الغدقة ذات تأثير جيد على خفض معدل فقد النيتروجين.

Abstract

The use of ^{15}N- balance techniques has already identified N-loss as a major problem in lowland rice management. Ammonium sulphate labelled with 5% N-15 atom ex. as a basal fertilizer was injected through special column in order to study the effect of flooding and saturation condition on the potential loss of nitrogen fertilizer. Rice straw at a rate of 1% was incorporated with the soil in order to study the role of rice straw (as a source of organic matter) on N-loss. Results show that the application of

rice straw under flooding condition resulted in increased biomass. It was observed that flooding circumstances may reduce the loss of nitrogen. Since N-recovery under flood and non flood rhizosphere (with plant) conditions were about 75% and 56%, respectively. The effect of rice root (rhizosphere) on nitification has been observed. Results of flood and non flood rhizoshere show that the nitrogen recovery were about 75% and 86%, respectively. Results show an indirect evidence that the processes of rhizosphere nitrification denitrification resulted in a significant amount of N-loss. It is evident that deep placement and flooded condition proved to be an effective means of reducing the potential of N-loss.

Introduction:

Rice is very responsive to nitrogen fertilization, and the high-yield potential of modern varieties cannot be realized without adequate N supply to the plant during the entire growing season. The behaviour of N in flooded soils is markedly different from its behaviour in drained soils that receive atmospheric oxygen. Flooding the soil affects the fate of added N as well as native soil N, and must be taken into consideration in the N fertilization of low land rice [7]. The unique reactions undergone by N in flooded soils result in considerable loss of applied N fertilizer. Alternative N fertilizer management practices are needed to increase productivity and N use efficiency in lowland rice [17].

Nitrogen use efficiency in flooded rice is low. ^{15}N recovery rarely exceeds 30-40% in low land rice. The causes of low N recovery are ammonia (NH_3) volatilization, denitrification, leaching, immobilization and ammonium (NH_4) fixation [14, 16].Attention has been focused on the effect of urea management on flood water properties (3) primarily because it was assumed that NH_3 loss was greater from urea than from NH_4^+-N sources such as $(NH_4)_2SO_4$ or NH_4Cl.

Most laboratory and greenhouse studies show NH_3 volatilization to be negligible from $(NH_4)_2SO_4$ amended floodwater [8]. In contrast (Fillery and De Datta, 1986), show that appreciable NH_3 loss can occur when $(NH_4)_2SO_4$ is applied to flood water 18 to 20 d after transplanting of rice seedling.

Subsurface placement of the N fertilizer into the anaerobic soil zone has been proposed as a possible method to imporove the utilization of N fertilizer by the rice [4]. This method is intended to minimize losses due to NH_3-volatilization as well as losses via nitrification denitirification reactions [10].

The objective of this study was to:

i) investigate the plant uptake and total recovery in the soil-plant system of ^{15}N-labelled $(NH_4)_2SO_4$ injected to flooded and saturated.

ii) assess the maximum potential loss of N where conditions are favourable for both nitrification and denitrification in the root zone of rice.

Material and Methods

The study was performed at the Soils and Water Res. Dept. AEA, Cairo, Egypt. The characteristic of the studied soil was clay loam with 0.0211% total nitrogen, pH 8.10; Ec 1.05 m 5 Cm^{-1} organic matter 0.58%. Air-dried soil was placed in (PVC) (25cm long and 15cm id) and sealed at a bottom. Four rubber septa 2 cm had been installed at the bottom portion of the (pvc) column Fig.(1). column were filled with 4 kg soil, adequate deionized water containing P and k, was added to each column to obtain saturated soil conditions and a final concent- ration of 40 mg and 50 mg/kg, respectively. Columns were divided into two treatments, one under flood condition with and without plants (Rhizosphere and non rhizosphere) and the other was under saturated circumstances as described before. 1% rice straw was incoroperated with the soil. In addition, 2% rice straw was mixed throughly with the top surface as a buffer zone. Twenty one -day-old rice seedlings were transplanted to each column in equal. Ammonium sulphate labelled with 5 atom% ^{15}N excess was injected in Rhizosphere and non rhizosphere (15 cm depth) at a rate of 50 mg N/kg soil. After two months from transplanting, plants were harvested, shoots and roots were separated, dried at 60°C, ground and analyzed for total kjeldahl N [2]. The residual soil-N was analyzed too. A sub soil sample was extracted with 2M KCl, and the filtrate was analyzed for inorganic N. All plant samples were analyzed for (TKN). Both plant and soil samples were subsequently analyzed for ^{15}N content using emission spectrophotometry.

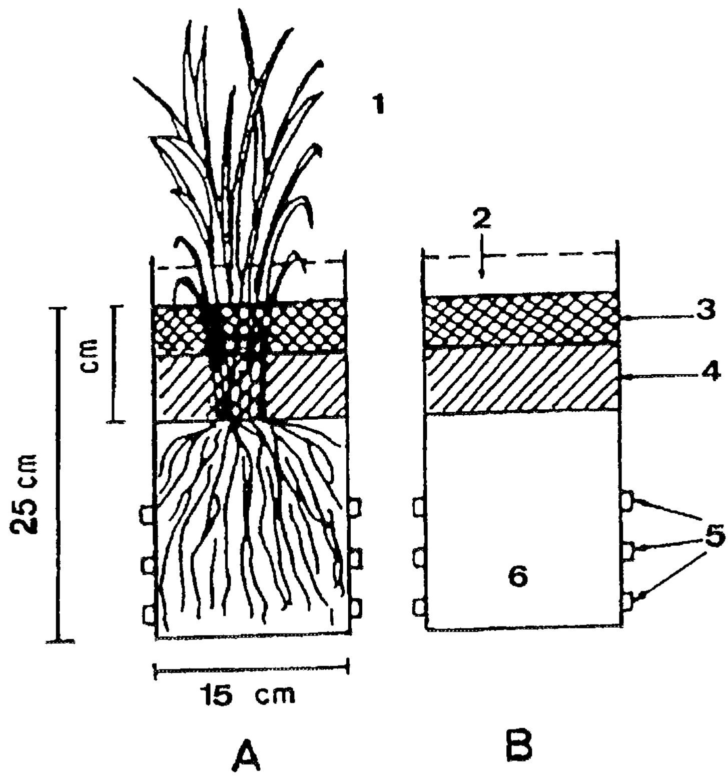

Fig.1. Schematic presentation of the rice rhizosphere (A) and non-rhizosphere (B) systems used. (1) Rice plant; (2) floodwater; (3) reduced soil with 2% rice straw; (4) reduced soil with 1% rice straw; (5) rubber septa used for ^{15}N injection; and (6) reduced soil with $^{15}NHO_4$ N.

Results and Discussion

- Plant growth and N-uptake

Data in Table.1 show that dry matter and N-uptake by rice plant grown in flood and non flood condition treated with and without rice straw. It was observed that the application of rice straw at a rate of 1%, stimulated the biomass of rice plant. Results showed that about 25 and 22 g/column in comparison with about 19 and 15 g/column for flood and non flood condition in the presence or not of rice straw, respectively. The phenomenon may be explained by the role of organic matter particularly in rice field. Flood soils greatly differ from drained soil in mineralization and immobilization reaction of N. One of the major differences is the rate of organic matter decomposition. Organic matter breakdown proceeds at slower rate in submerged soil as compared with a drained soil. The slower rate of decomposition taking place flooded soils, might be expected to retard the release of N. The low requirement of the anaerobic organisms for N causes organically bound, N to be released to a rice crop earlier in the growing season than would be the case for an upland crop. This readily release of NH_4 from anaerobically decomposing organic matter is partially responsible for the good response of rice to added organic matter. One can assume that the uptake of nitrogen will be much more under flooded condition than the non flood. Patrick and Delaune, [10], stated that in flooded soils, organic-N is mineralized to NH_3 from which is only inorganic form involved to any extent in mineralization-immobilization reactions. They also stated that NH_4^+-N enters the organic N pool much more readily than does NO_3^--N form. Most investigators have found that the heterotrophic microorganisms responsible for N-immobilization prefer NH_4^+ than NO_3^--N form. Reddy et al., [16]; Abou Seeda et al. [1], stated that anaerobic conditions, where no excess flood water was present, nitrate production proceeded faster and followed zero-order kinetics as compared with a slower reduction rate and apparent first order kinetics when the soil was overlyin by 3 cm layer of flood water. It has been stated that thinly oxidized layer may reduce the loss of nitrogen. Engler and Patrick, [6], stated that the presence of organic matter may play an important part for the thickness of aerobic layer, which is a function of balance between optimum supply and consumption of oxygen, [10, 14]. Reddy and Patrick, [14] stated that the buffer soil containing a high C/N ratio such as rice straw in soil resulted in a remarkable decrease in the loss of nitrogen.

The data in Table 2 show that rice plants grown under flooding soil condition incoroporated with rice straw had more 15N atom excess value than plants grown under saturated (non flooded) condition with or without rice straw. The same table gives the % of Ndff and % of Ndfs. From this Table, it could be seen that about 42 and 38% of the nitrogen is supplied by the fertilizer (% Ndff) in plants grown under flooding conditions treated with or without rice straw, while about 58 and 62% by the soil, respectively. Data showed that under saturation condition, about 35 and 37% of total N-uptaken are derived from fertilizer and about 65 and 63% are derived from soil treated with or without rice straw.

Plant recovery

A total balance of the applied fertilizer nitrogen is given in Table 3. The data refer to the analysis of plant ^{15}N and the soil at that time in the rhizosphere and non rhizosphere. It can be seen that in rhizosphere treatments 58.3% of applied N-15, with 8.8 and 49.5% of the added N-recovered in roots and shoots of rice plants grown under flooding soil treated with 1% rice straw, respectively. While, plants grown under saturated condition, recovered about 44.4% of added ^{15}N, with 37.3 and 7.05% for the previous treatments, respectively. Data showed that without rice straw addition, about 42 and 36% of the added N was removed by plants grown under flooding and saturation conditions, respectively. Although fertilizer N was the major pool from which the rice plant derived its N, the soil provided the remaining N needs of the plant when the readily available fertilizer was depleted or not available. These conclusions support results found by other researchers [13, 19]. They showed that, with deep placement, all of the fertilizer-N uptake occurred within 3 to 4 weeks.

Soil recovery

Amounts of fertilizer N recovered from the soil are shown in Table 3. In the rhizosphere soil column, under both flood and non flood conditions, data showed a rapid disappearance of applied NH_4

-^{15}N of which about 3 and 2% inorganic and the other form was detected as inorganic fraction amounted to about 13 and 10%. About 16% of the total nitrogen recovery were detected at the end of the growth period, under flooded and non flooded conditions in the presence of rice straw, respectively. Without rice straw application, the fractions amounted to about 8 and 2% in flooded soil; 11 and 2% in non flooded soil for inorganic and organic fraction, respectively. This may be due to that most of the ^{15}N was probably immobilized in the upper soil zone, which was treated with rice straw. Similar results were also obtained [14].

Total plant and soil recovery

The recovery of the fertilizer $^{15}NH_4$-N in the total system was affected by soil condition and amendments (Table 3). In this concern, data showed that the recovery of fertilizer N in the presence of rice straw was greater than without rice straw under both flood and non flood conditions. Results recorded for total N recovery under flood and non flood rhizosphere, indicated about 75 and 56% in the presence of rice straw; 51 and 50% of applied N without rice straw respectively. On the other hand, about 25 and 44%; 49 and 51% of the added N were not accounted for, for the above mentioned treatments, respectively. Reddy and Patrick [15], stated that nitrogen losses due to nitrification-denitrification reaction can be prevented if;

a) nitrification is prevented, thus maintaining inorganic N in NH_4^+ form,

b) placing the fertilizer in the root zone and

c) increasing the O_2 demand in the root zone by increasing the organic matter content of the soil. These are some of the potential management strategies that can be used to prevent N-losses for rice field. Fillery et al.[7] reported that under laboratory and green house studies, they showed that NH_3 volatilization was greater from urea than from NH_4^+-N sources such as $(NH_4)_2SO_4$ or NH_4Cl added to flooded soil. They added that NH3 loss to be negligible from $(NH_4)_2SO_4$ amended flood water.

Nitrogen recovery in the non rhizosphere system (without plant)

Concerning, the non rhizosphere treatments, data in Table 3 indicate that 64.8 and 55.6% of the added N were still present in the inorganic ^{15}N fraction, and only 21.4 and 16.8% of the added N were recovered in the organic fraction for flood and non flood circumstances in the presence of rice straw addition, respectively. Without rice straw application, the magnitude was different. In this respect, the amounts of ^{15}N recovered were 48.8 and 41.2%; 14.8 and 11.3% for the above mentioned treatments, respectively. Reddy and Patrick [14] concluded that nitrogen loss due to denitrification in the presence of rice plants was found to be significant. However, the magnitude of N-loss was lower as compared with that for systems without plant. They added that although $15\,NH_4^+$ was injected in the lower portion of the soil core, it appears that some of the added $^{15}NH_4$-N had diffused into the upper zones where it was immobilized, thus decreasing loss of N due to nitrification-denitrification reaction in the upper zones. Data in Table 3 show that total N recovery in the non rhizosphere system were 86.2 and 72.5% of added N in the presence of rice straw, while, it recorded 63.6 and 52.4% without rice straw, under flood and non flood conditions, respectively.

The extensive loss of applied ^{15}N labelled $(NH_4)_2SO_4$ is the obvious major cause of the poor recovery of the added N by the soil without rice straw application. In this concern, losses from $(NH_4)_2SO_4$ was reduced from 36.4% under flooded system without rice straw to 13.8% in the presence of rice straw. While, under non flood condition, it was reduced from 46.6 to 27.6% of the added N under the previous treatments, respectively. This is due to the buffer soil containing a high C/N ratio straw in the upper soil zone which decreased the loss of N, as indicated by 21.4 and 16.8% of the added N recovery in soil organic fraction under flood and non flood system, respectively.

From this experiment, it could be noticed that N loss in the rhizosphere treatment was found to be markedly higher than the non rhizosphere treatment. Net effect of the rhizosphere in N loss was calculated [14] as follows:

$$N_{RL} = N_{RH} - N_{NRH}$$

where N_{RL} = N loss due to rhizosphere only,

N_{RH} = N loss in the treatment containing plant.

N_{NRH}= N loss in the nonrhizosphere treatment (no plants), where N loss due to upward movement was minimized.

Estimated N loss due to the rhizosphere effect (N_{RL}) under these experimental condition was about 11 and 12% of the added N under flood condition with and without rice straw application,respectively. These may explain the N losses encountered by other researchers [12, 17] when fertilizer N was placed in the root zone.

Results from this study present an indirect evidence that the processes of rhizosphere nitrification denitrification were active, resulting in a remarkable amount of N loss. It can be concluded that rice straw incorporation and N injected at 15 cm deep placement could reduce N loss due to preventing upward diffusion of NH_4- ^{15}N from the bottom portion of the core to the overlying flood water. Because of the high C/N ratio of the rice straw, any ^{15}N diffused will be readily immobilized.

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TABLE 1: DRY MATTER AND NITROGEN UPTAKE BY RICE PLANT GROWN IN FLOODED AND NON FLOODED CONDITIONS AMENDED WITH OR WITHOUT RICE STRAW.

Plant Part	Flooded		Non flooded	
	D.M. (g/column)	N-uptake (mg/column)	D.M. (mg/column)	N-uptake (mg/column)
		With rice straw		
Shoot	16.54	210.06	14.63	179.95
Root	8.78	67.61	7.52	60.91
Biomass	25.32	277.67	22.15	240.86
		Without rice straw		
Shoot	12.33	163.99	10.11	157.72
Root	6.67	54.69	5.22	39.67
Biomass	19.00	218.68	15.33	197.39

TABLE 2: ^{15}N EXCESS, N-DERIVED FROM BOTH FERTILIZER (NDFF) AND SOIL (NDFS) IN DIFFERENT PART OF RICE PLANT GROWN IN FLOODED AND NONFLOODED CONDITIONS AMENDED WITH OR WITHOUT RICE STRAW.

Plant Part	Flooded			Non flooded		
	N-15 a.e	Ndff	Ndfs	N-15 a.e	Ndff	Ndfs
With rice straw						
Shoot	2.15	47.08	52.92	1.92	41.47	58.59
Root	1.21	26.13	73.87	1.07	23.11	76.89
Biomass	1.94	41.99	58.01	1.62	35.05	64.95
Without rice straw						
Shoot	1.97	42.55	57.45	1.84	39.73	60.26
Root	1.14	24.62	75.38	1.12	24.19	75.81
Biomass	1.76	38.07	61.93	1.70	36.62	63.38

TABLE 3: RECOVERY AND BALANCE OF N-15 LABELLED $(NH_4)_2SO_4$ IN SOIL AND RICE PLANT AS AFFECTED BY RICE STRAW APPLICATION.

Para-meters	Flooded		Nonflooded		Flooded		Nonflooded	
	Ndff mg/Col	Recovery %	Ndff mg/Col	Recovery %	Ndff mg/Col	Recovery %	Ndff mg/Col	Recovery %
	--------	Rhizosphere		-------	-------	Nonrhizosphere		------
With rice straw								
Plant								
Shoot	98.91	49.45	76.62	37.31	---	---	---	---
Root	17.67	8.84	14.08	7.04	---	---	---	---
Soil								
Inorg. N	5.53	2.77	3.41	1.71	129.59	164.80	1111.23	55.6
Organ. N	26.84	13.42	20.63	10.32	42.76	21.38	33.67	16.8
Total N	32.37	16.19	24.04	12.02	172.35	86.18	144.90	72.4
Total Recov	148.95	74.48	112.74	56.37	172.35	86.18	144.90	72.4
Loss	51.05	25.53	87.26	43.63	27.65	13.82	55.10	27.5
Without rice straw								
Plant								
Shoot	69.78	31.35	62.68	31.34	---	---	---	---
Root	13.47	6.74	9.60	4.80	---	---	---	---
Biomass	83.25	41.63	72.28	36.14	---	---	---	---
Soil								
Inorg. N	16.37	8.19	22.10	11.05	96.63	48.82	82.31	41.1
Organ. N	3.22	1.61	4.66	2.33	29.61	14.81	22.54	11.2
Total N	19.59	9.70	26.76	13.38	127.24	63.62	104.85	52.4
Total Recov	102.65	51.32	99.04	49.52	127.64	63.62	104.85	52.4
Loss	97.35	48.68	10.96	50.48	72.26	36.38	95.15	47.5