eISBN 978-967-16145-1-8

*Konvensyen Kebangsaan Kejuruteraan Pertanian Dan Makanan 2019* ***MSAE2019-ARWM09***
*21 Mac 2019, Wisma Tani, Kementerian Pertanian dan Industri Asas Tani Malaysia, Putrajaya*

# Temporal Variation of Ammonium in *Sulfic Tropaquept* Cultivated with Rice in Experimental Pots

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**Abstract**
*Hypothetically, monitoring of soil solution $NH_4^+$-N dynamics may allow estimation of nitrogen (N) transformation rates such as the rates of nitrification, denitrification, mineralisation and immobilisation. Such observations can be used to evaluate and improve performance of N dynamics models for flooded rice systems. Therefore, the objective of this study was to evaluate temporal variation of ammonium dynamics in fertilised and flooded rice pots. Concentrations of $NH_4^+$-N were determined in soil solutions that were extracted by MacroRhizon samplers. MacroRhizon is a soil solution sampler with a pore size of 0.15 µm manufactured by Rhizosphere Research, the Netherlands. In comparison to typical soil sampling methods, some advantages of using MacroRhizon are repeated sampling at the same spot possible, easy to install and less disturbance to the soil due to the small diameter, and maximum pore size of 0.2 µm which requires no further filtering prior to chemical analysis. Results showed that under current agronomic and management practices, broadcast N application had no obvious and consistent influence on soil solution $NH_4^+$-N. Analysis of the results suggest that suitability of soil solutions extracted using the MacroRhizon samplers as alternatives for the labourious and destructive conventional soil samplings is subject to further investigation.*

Keywords: Nitrogen, ammonium, Rhizon, soil solution, flooded soil, rice

## Introduction

In 2012, about 184,047,280 kg of urea and compound fertilisers, which cost about RM 361,200,692, was subsidised by the Farmers Organisation Authority Malaysia to fertilise 693,654 hectares of rice fields in the Peninsular Malaysia (Farmers Organisation Authority Malaysia 2013). Nitrogen use effeciency in flooded rice systems is only about 50% (Ladha et al. 2005).

Hypothetically, monitoring soil $NH_4^+$ dynamics may allow estimation of N transformation rates such as the rates of nitrification, denitrification, mineralisation and immobilisation, and availability of N for rice uptake, and is useful to improve the accuracy of N dynamics model for flooded rice fields. However, there are only a few reports (Makarim et al. 1991; Dobermann et al. 1994) on temporal and spatial ammonium-nitrogen ($NH_4^+$-N) trends in the soil of flooded rice fields. Consequently, models that are developed to simulate the N dynamics of flooded rice fields, are not typically validated simultaneously against temporal floodwater and soil N trend (Gaydon et al. 2012; Katayanagi et al. 2013). Katayanagi et al. (2013) claimed that the soil available $NH_4^+$-N is a key factor in simulating N processes, and, therefore, N dynamics models must be validated against soil $NH_4^+$-N to improve simulation accuracy.

In the presence of the urease enzyme, urea applied in flooded rice fields hydrolyses into $NH_4^+$ and bicarbonate ion. $NH_4^+$ is either attached to the negatively charged clay particles or resides in the soil solution. Conventionally, $NH_4^+$ is determined in soil core samples, but this technique is destructive and laborious. An alternative is to use Rhizon or MacroRhizon for the determination of $NH_4^+$.

The Rhizon sampler, developed by Rhizosphere Research, Wageningen, the Netherlands, offers the following advantages: repeated sampling at the same sampling spot, portable, easy to install and less disturbance to the soil due to the small diameter, maximum pore size of 0.2 µm which requires no further filtering prior to chemical analysis, more inert compared to ceramic samplers and preserves the redox potential of the extracted solutions when used with vacuum test tubes (Shotbolt 2010). The Rhizon samplers have been used to extract solutions for monitoring of inorganic N or other ions or elements in soil microcosm studies (Bodelier et al. 2000; Wang et al. 2009; Yan et al. 2000; Murtaza et al. 2011).

To date, only two studies (Makarim et al. 1991; Dobermann et al. 1994) have evaluated the use of Rhizon samplers to collect soil solution for monitoring temporal and spatial variation in $NH_4^+$-N in flooded rice fields. The influence of split N application on temporal variation in $NH_4^+$-N in the soil solution was clearly observed in Makarim et al. (1991), but not in Dobermann et al. (1994). These contradicting results suggest that the use of Rhizon samplers to extract soil solutions is subject to further investigation.

Therefore, the objective of this study is to evaluate temporal variation of ammonium dynamics in fertilised and flooded rice pots using MacroRhizon samplers. In this study, we used the MacroRhizon to sample the soil solution instead of the conventional soil sampling.

## Materials and methods

Four experimental pots were constructed (Fig. 1) and each pot was filled with soil taken from Plot 3153 at Block C, Sawah Sempadan, Tanjung Karang, Malaysia (3° 28' 09.63" N, 101° 13' 26.48" E). The soil is *Sulfic Tropaquept* or also known as Jawa Series. The soil texture is 43.9% clay, 47.8% silt and 8.2% sand (Aimrun and Amin 2009). The pots were placed outdoor, under a shed, near the Soil and Water Conservation Lab at Biological and Agricultural Engineering, Universiti Putra Malaysia. The soil was submerged with distilled water for approximately one week to eliminate the 'border effect' and to reduce the percolation rate to less than 4 mm/day. The topsoil was ploughed manually to emulate the practice in the fields.

Four germinated MR219 seeds (equivalent to 7 day after sowing) were transplanted in each pot. The floodwater level was maintained at about 5 cm by adding distilled water. The nitrogen treatments are described in Table 1. Fertilisation timing and rates were based on farmers' practice.

The soil solution samples were extracted using MacroRhizon samplers on 19, 21, 23, 27, 30, 32, 38, 40, 42, 44, 46, 52, 57 and 60 day after sowing (DAS). Extraction of one sample took about 8 hours. Samples were analysed immediately or stored at less than 4˚C when immediate analysis was not possible. The soil solutions were analysed for $NH_4^+$-N based on the Keeney and Nelson (1982) steam distillation method.

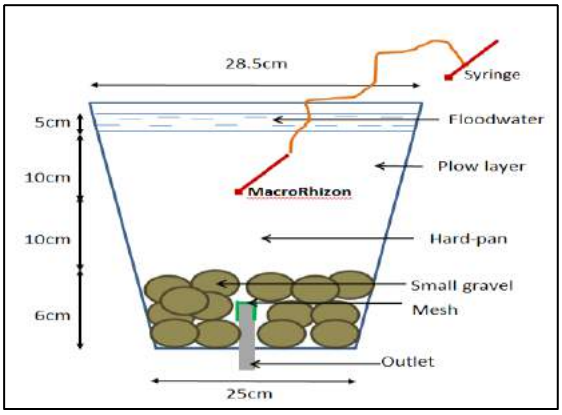


*Fig. 1 Cross section of an experimental pot.*

*Table 1 Nitrogen treatments in the experiment*

| Treatment label | Rice plants | Rate of N in kg/ha | | |
|---|---|---|---|---|
| | | **20 DAS** | **37 DAS** | **54 DAS** |
| P1 | √ | 24.5 | 36.8 | 34.5 |
| P2 | - | 24.5 | 36.8 | 34.5 |
| P3 | √ | 24.5 | 36.8 | 34.5 |
| P4 (control) | - | 0 | 0 | 0 |

*DAS is day after sowing. The nitrogen fertiliser was in the form of urea for application on 37 DAS. For 20 and 54 DAS, compound fertiliser, which contained urea, phosphorus, potassium and other micronutrients, was applied.*

In addition, hourly soil temperatures were measured using sensors placed in the soil and connected to a data logger. The soil and floodwater pH were recorded only once per day.

## Results and discussion

The soil temperature followed a diurnal trend ranging from 26˚C at 19:00 hrs to 32˚C at about 14:00 hrs. High soil temperature at mid-day was expected in soils flooded with shallow water depth. The temporal variations of soil solution $NH_4^+$-N in the four experimental pots are shown in Fig. 2.

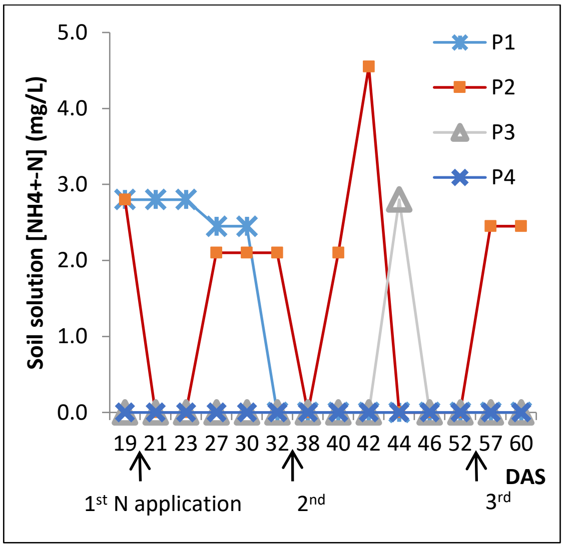


*Fig. 2 Temporal variation of concentrations of $NH_4^+$-N in soil solutions extracted using MacroRhizon samplers.*

The initial soil solution $NH_4^+$-N concentrations for P1, P2, P3 and P4 prior to nitrogen applications were 2.8, 2.8, 0 and 0 mg N $L^{-1}$, respectively. Fig. 2 shows that there was no obvious increase in soil solution $NH_4^+$-N in P1 and P3 after each fertilisation. P2 was fertilised and did not contain any rice plant, but no increase in soil solution $NH_4^+$-N was observed in P2 either. Visual inspection on P2 on 24 DAS revealed that application of nitrogen resulted in significant algae bloom and weed growth in the control pot.

Algae bloom and weed growth were also observed in P1 and P3. Concentrations of nitrate in the soil solutions were consistently below the detection limit for all four pots.

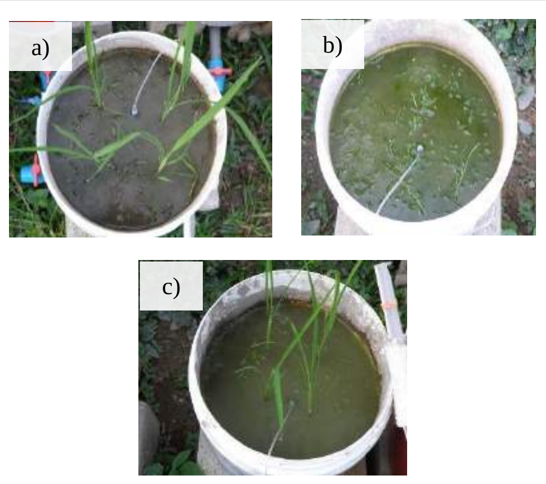


*Fig. 3 a) P1, b) P2 and c) P3 observed on 24 DAS.*

Overall, results showed that under current agronomic and management practices, broadcast N application had no obvious influence on soil solution $NH_4^+$-N concentrations. Three hypotheses were formulated: 1) The applied nitrogen may not be stored in the soil. The applied nitrogen may be lost due to either strong competition of nitrogen uptake between rice plants, weed and algae, or nitrogen may be emitted to the atmosphere in the form of gasses. 2) Some of the $NH_4^+$ may get strongly attached to the soil particles, and can only be extracted via rigorous shaking and chemical reaction. Conventionally, extraction of $NH_4^+$ in a soil sample involves mixing 3 g of the field-moist soil sample with 30 mL 2 M KCl at 140 rpm for 90 minutes (Maynard et al. 2008). 3) Dilution effect due to the distilled water added to maintain the floodwater at a constant depth was unlikely. Based on our calculations, about 4 mg N $L^{-1}$ was expected in P2 6 days after the first fertilisation assuming the followings; a nitrogen gift of 24.5 kg N $ha^{-1}$, 50% soil void, well distributed solute in the whole floodwater-soil system, distilled water was added 7 times to maintain 5 cm of standing water depth, and no N sink such as plant uptake or ammonia volatilisation. The concentration of nitrogen in P2 was expected to be even higher than 4 mg N $L^{-1}$ as the hard pan was well compacted to ensure very low saturated hydraulic conductivity. Fillery et al. (1984) reported that 2 days after a nitrogen gift of 30kg N $ha^{-1}$ when rice crop panicle initiation stage, the floodwater contains about 40 mg N $L^{-1}$.

## Conclusions

By analysing the soil solutions extracted using the MacroRhizon, results showed that under current agronomic and management practices, broadcast N application had no obvious and consistent influence on soil solution $NH_4^+$-N. Analysis of the results further suggests that the suitability of soil solutions extracted using the MacroRhizon samplers as alternatives for the labourious and destructive conventional soil samplings requires further investigation.

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