Availability and utilization of fertilizer nitrogen by rice under alternate flooding

II. Effects on growth and nitrogen use efficiency

R. N. SAH and D. S. MIKKELSEN
Department of Agronomy and Range Science, University of California, Davis, CA 95616, USA

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Summary A greenhouse pot experiment was conducted with three nitrogen sources—$^{15}$N-depleted ammonium sulfate (A/S), urea and sulfur-coated urea (SCU), three N levels—0, 50 and 200 ppm and 5 irrigation treatments consisting of continuous flooding and one and two cycles of alternating flooded-saturated/drained conditions with rice. Growth, tillering, dry matter yield and N uptake were measured and nitrogen use efficiency (NUE) was calculated.

The dry matter yield, plant height, tillering, N uptake by rice plants and NUE were the highest under continuous flooding, were slightly reduced under alternating flooded-saturated treatments but were drastically reduced under alternating flooded-drained treatments. Growth and nitrogen uptake by rice was increased with increasing rates of N application. In general, A/S was found to be superior to urea and SCU as N sources under each irrigation treatment. The dry matter yield and NUE were reduced to as low as 55% and 52%, respectively, when the soil was subjected to alternating flooded-drained conditions. Fertilized rice plants utilized 4 times more native soil-N than non-fertilized rice.

Introduction

Continuous submergence provides an ideal environment for rice production under most soil and climatic conditions. Not only is the yield and nitrogen use efficiency usually better under continuous submergence but continuous flooding also provides an excellent means of weed control. In many rice growing areas of the world, however, continuous flooding is not maintained either due to shortage of water or for crop management purposes, the field has to be drained.

Rice grown under rainfed-lowland conditions in the tropics and sub-tropics may experience one or more cycles of alternate flooding (anaerobic conditions) and draining (aerobic conditions) due to irregular rainfall distribution and non-uniform field flooding. Drill-seeded rice is intentionally cultured with a program of flush and drain irrigation before permanent flood is applied. Direct water-seeded rice is often drained to enhance seedling and root development. Drainage of rice is also practiced for weed and insect control and to alleviate the
accumulation of toxic gases and organic acids in flooded soils. Aerobic soil conditions may reoccur several times before rice is kept under continuous flood. The alleviation of organic acid and toxic gas formation also occurs with drainage. Intentional drainage of this type also allows aerobic-anerobic conditions to occur in the soil.

Alternate flooding and drainings occasionally provide a management practice to alleviate certain rice crop production problems. This practice, however, also provides an environment which contributes to nitrogen losses by nitrification, and subsequently leaching and denitrification.

The present experiment was designed to study the effect of alternate flooding on the growth of rice and nitrogen use efficiency.

Materials and methods

The basic experimental design and treatments are reported in Part I of this paper, but two more irrigation treatments were added to evaluate the effects of one and two cycles of alternate flooding. The number of irrigation treatments, thus, became 5.

1) Continuous flooding (Flooded): same as in Part I.

2) One cycle of alternating flooded-saturated conditions (Sat-1): continuous flooding (0–8 days)—continuous saturation (16–24 days)—continuous flooding for the remaining experimental period.

3) Two cycles of alternating flooded-saturated conditions (Sat-2): Reported as treatment b in Part I.

4) One cycle of alternating flooded-drained conditions (FC-I): Continuous flooding (0–8 days)—drained and irrigation withheld until soil moisture approached field capacity (soil moisture tension of 0.25 bars)—continuous flooding for the remaining period of the experiment.

5) Two cycles of alternating flooded-drained conditions (FC-2): Reported as treatment C in Part I. The term "alternate flooding will be used for treatments 2–5 together.

The methods and amounts of N, P and K application was the same as in Part I.

Rice plants were grown in each treatment and were harvested 45 days after transplanting. The samples were dried at 60°C for 48 hours and dry weight was recorded. Nitrogen analysis on representative samples of dried and ground plant material was done by the micro Kjeldahl method. Based on nitrogen present in plant material of treated (T) and control (C) pots and the amount of N applied (A) as N-fertilizers, the apparent nitrogen use efficiency (NUE) was calculated (Apparent NUE = 100 (T–C)/A). In the case of the 15N-depleted ammonium sulfate (A/S) treatment, aliquots were acidified with HCl after micro-kjeldahl N determination, evaporated to dryness and then analyzed for 15N by a mass spectrometer. Based on atom excess of 15N in the plant samples, NUE was calculated. Analysis of variance and all possible correlation and regression analysis was done on dry matter yield, tillering and NUE.

Results and discussion

A significant reduction in plant growth, tillering and N uptake was found in the treatments of alternate flooding and draining of soil. The findings are discussed in the following sections: