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DEEP PLACEMENT: A METHOD OF NITROGEN FERTILIZER APPLICATION COMPATIBLE WITH ALGAL NITROGEN FIXATION IN WETLAND RICE SOILS

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Key words

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Summary

The effect of different methods of nitrogen fertilizer application on the algal flora and biological nitrogen fixation (Acetylene-reducing activity) in a wetland rice soil was studied in pot and field experiments. Broadcast application of urea inhibited nitrogen fixation and favored the growth of green algae. In contrast, deep placement of urea supergranules (1–2 g urea granules) did not suppress the growth of N_2-fixing blue-green algae and permitted acetylene-reducing activity on the soil surface to continue virtually uninhibited.

Introduction

For centuries, Asian rice farmers have practiced a unique system of rice production that maintains a degree of soil nitrogen fertility and ensures modest but stable yields without the use of chemical fertilizers[16]. Blue-green algae (BGA) play an important role in this system by providing a steady input of fixed nitrogen[12]. Unfortunately, broadcasting nitrogen fertilizers in the paddy field inhibits this source of free nitrogen[15]. Pressure to increase food production has caused a rapid increase in the use of nitrogen fertilizer (mostly urea) on rice in Asia, particularly with the introduction of improved varieties[13]. That and the fact that most farmers broadcast fertilizers into the floodwater[4] suggests a widespread reduction in algal nitrogen fixation. Surface application is probably the most inefficient method[9] because the nitrogen fertilizer is subject to extensive losses through ammonia volatilization, nitrification-denitrification, runoff and leaching.[2]

For many years scientists have known that deep placement of fertilizers can dramatically improve the efficiency of nitrogen use[3,5,7]. Practical means of deep placement in puddled rice soils were not however available until the recent development of urea

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supergranules and briquettes which are 1–3 g discrete particles normally placed 10 cm deep in the soil, at a rate of one for every 4 hills of rice. Experiments in 11 countries have shown that deep placement of urea supergranules and the use of a slow-release fertilizer – sulfur coated urea (SCU) – increases rice yields compared with conventional split application of urea[9]. In some fertilizer experiments at the International Rice Research Institute (IRRI) we observed that the algal flora in plots varied greatly. In this note, we describe subsequent experiments to test the hypothesis that deep placement of urea is compatible with algal nitrogen fixation.

Materials and methods

The field experiment was conducted on a flooded Maahas Clay (Aquic Tropudalf) using 16 m^2 plots with 4 replicates in a randomized block design. The treatments were: Control (no nitrogen); urea as supergranules (3 g each, 1 for 4 hills, placed 10 cm deep [87 kg N ha^{-1}]); broadcast urea (58 kg N ha^{-1} basal + 29 kg N ha^{-1} applied 5–7 days before panicle initation); broadcast ammonium sulphate (58 kg N ha^{-1} basal + 29 kg N ha^{-1} applied 5–7 days before panicle initiation); and broadcast sulphur-coated urea (21% release in 7 days, 87 kg N ha^{-1}, basal). All treatments received a basal application of 30 kg P_2O_5 ha^{-1}, 20 kg K_2O ha^{-1} and 10 kg Zn ha^{-1}. The rice variety IR36 was transplanted at 20 × 20 cm spacing, 5 March 1979.

To measure acetylene-reducing activity (ARA) seven cores of soil (2 cm diameter), including the floodwater, were removed from each plot along a transect at 15 days after transplanting. The cores were enclosed in a 900-ml plastic cylinder and incubated with 10% acetylene in air under natural light at 32–35°C. After 30 and 60 minutes incubation, ethylene was analysed by gas chromatography.

The top 1 cm of soil and the floodwater of the same core samples were mixed and used for chlorophyll a measurement (30% acetone v/v) and algal enumerations[6].

The pot experiment was conducted under controlled temperature (night 29°C, day 35°C) and humidity (70%). Representative acidic, neutral, and alkaline soils were selected. Each pot (25 cm diameter 30 cm high) received 20 kg soil. To provide an indigenous algal inoculum, 800 g of corresponding surface soil, collected separately, was spread on top of that soil. Because high light intensity inhibits the growth of BGA[10], one set of pots was fully exposed; the other was shaded by a screen that reduced the light intensity by 84%. The three fertilizer treatments were: control, urea supergranule (0.46 g N) placed 10 cm deep in the center of the pot, and broadcast urea (0.46 g N per pot). All pots received 15 kg P_2O_5 ha^{-1} as a basal dressing. Three pots were used for each treatment. ARA measurements were made 15 days after fertilizer application. Each pot was covered tightly with a polyethylene sheet with an injection port. After 1 hour of incubation under 10% acetylene in air, gas samples were removed for ethylene analysis. Dominant and associated algae were determined by microscopic observations.

Results and discussion

In the field experiment the surface application of urea completely inhibited ARA; the other broadcast fertilizer (ammonium sulphate and sulphur-coated urea) also reduced ARA markedly (Table 1). On the other hand, deep placement of urea permitted 70% of the N_2-fixing activity of the control. The number of N_2-fixing BGA also reflects that trend. However the total algal biomass, estimated by the chlorophyll measurements, was greater in the presence of broadcast urea and ammonium sulphate, mainly because of unicellular green algae growing at the expense of the fertilizer nitrogen.

In the pot experiment the soil pH strongly influenced the ARA (Table 2); ARA was highest in the alkaline soil (Tiaong) and lowest in the acid soil (Luisiana), thus confirming

Table 1. Effects of fertilizer placement on the algal flora and N_2-fixation in a field experiment

Treatment	Control	Urea supergranule (deep placement)	Urea (broadcast)	Ammonium sulphate (broadcast)	SCU (broadcast)
ARA:					
μ Mol C_2H_4 m^{-2} h^{-1}	70	48	0	17	27
(% of the control)	(100)	(69)	(0)	(24)	(39)
μg Chlorophyll a. cm^{-2}	12.4	12.3	21	15.2	11.8
Number of N_2-fixing B.G.A. cm^{-2} of soil	2.0×10^5	1.7×10^5	0.7×10^5	1.4×10^5	1.6×10^5
Number of green algae cm^{-2} of soil	$< 10^4$	5.0×10^5	1.0×10^7	1.2×10^7	1.2×10^6

Table 2. The effect of fertilizer management on nitrogen fixing activity (μ mol C_2H_2 m^{-2} h^{-1})

	Luisiana (pH 5)		Maahas clay (ph 7)		Tiaong (pH 8)	
Treatment	Shaded	Unshaded	Shaded	Unschaded	Shaded	Unshaded
Control	6.0	1.0	4.8	5.3	24.4	62.1
Urea deep placement	4.1	1.3	7.5	170.0	24.7	41.4
Urea broadcast	0.6	2.3	0.4	0.7	7.7	3.5

Table 3. The effect of mode of application of fertilizer on the dominant algal species in three soils

Treatment	Luisiana (pH 5) Shaded	Luisiana (pH 5) Unshaded	Maahas clay (pH 7) Shaded	Maahas clay (pH 7) Unshaded	Tiaong (pH 8) Shaded	Tiaong (pH 8) Unshaded
Control	Filamentous green algae, Diatoms	Filamentous green algae, Diatoms	*Pithophora*	*Pithophora*	Spirulina, Coccoid green algae	Spirulina, Coccoid green algae, *Pseudo-anabaena*
Urea deep placement	Diatoms, *Euglena*	Filamentous green algae, Diatoms	*Pithophora*	*Cylindro-spermum*	*Spirulina*, Coccoid green algae	*Spirulina*, Coccoid green algae
Urea broadcast	*Euglena*, *Filementous* green algae, Diatoms	Filamentous *green* algae, Diatoms, *Euglena*	*Euglena*	*Euglena*, *Pithophora*	*Spirulina*, Coccoid green algae, *Euglena*	*Spirulina*, Coccoid green algae, *Euglena*

that alkaline conditions favour the growth of N_2-fixing BGA[12]. No clear-cut effect of light on ARA was observed, probably because the maximum incidental light intensity was moderate (50 Klx). For all soils and light intensities, surface application of urea strongly inhibited ARA. In contrast, the deep placement of urea supergranules maintained the ARA at about the same rate as the control. The exceptionally high ARA observed in the unshaded Maahas clay with deep-placed urea treatment was due to the predominant growth of *Cylindrospermum* sp. (Table 3) which is seldom observed in the field. Whether or not its occurrence is an artifact of pot experiments, the result clearly demonstrates that deep placement of urea does not inhibit N_2-fixation by algae. Apart from the exceptional growth of Cylindrospermum, the dominant species of N_2-fixing algae were the same in the urea deep placement treatments and in the control. In contrast, broadcast urea encouraged the growth of Euglena, thus confirming the field experiment results (Table 1).

We conclude that surface broadcast application of nitrogen fertilizer, which is widely practiced by Asian farmers, not only inhibits nitrogen fixation but also encourages the growth of green algae. These deleterious algae immobilize the fertilizer nitrogen, making it temporarily unavailable to the plant[7,14]. Green algae also increase the pH of the floodwater, encouraging fertilizer nitrogen loss by ammonia volatilization[1,6]. Deep placement of urea supergranules, in contrast, does not disturb the natural algal N_2-fixing system; thus deep placement provides a bonus of nitrogen to the ecosystem.

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