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Comparison of Rice N Uptake in Paddies with Different Organic Carbon

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Efficient use of all inputs is vital to achieve and sustain high crop yields, maintain resource quality and minimize environmental pollution. Fertilizer N is one of the major inputs in rice production. Blanket fertilizer recommendations do not take into account the high field-to-field variability and within-season dynamic changes in indigenous N supply. Since the plant growth reflects the total N supply from all sources, plant N status will be a good indicator of N availability to crops at any given time. Leaf colour chart (LCC) is simple portable diagnostic tool, to determine the timing of N top dressing. We used it to test need-based N-management approaches for rice (*Oryza sativa* L.) and compared LCC with split three rates (45, 90 and 135) and three timing at two sites, in northern Iran. Grain yield, yield attributes, total N uptake and fertilizer-N use efficiency were measured. All treatments showed significant grain yield increase relative to zero-N control. Yield loss was observed when split 135 timing was used in both sites due to lodging and pest damage. Grain yield of LCC treatments were higher than split treatments. The grain yield of zero-N control in site 2 was 18.5 % higher than that of site 1 due to higher soil organic matter percent. LCC 5 treatment had higher AE than LCC 4 and fixed - 135 at the less N rate. As a result LCC treatments indicated that N management based on LCC shade 5 helped avoid over application of N to rice.

Key Words: Split, Leaf colour chart, Nitrogen management, Rice.

INTRODUCTION

Crop yields in the world have continuously increased to meet population growth, partly because of the increase in fertilizer nutrient input especially N fertilizer[1]. To maximize grain yield, farmers often apply a higher amount of N fertilizer than the minimum required for maximum crop growth[2]. Nitrogen use efficiency is relatively low in irrigated rice because of rapid N losses from ammonia volatilization, the nitrification, surface runoff and leaching in the soil-flood water system[3,4].

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The magnitude and nature of N losses vary depending on the timing, rate and method of N application, source of N fertilizer, soil chemical and physical properties, climate conditions and crop status. In general, ammonia volatilization is the major pathway of N loss in irrigated rice[5]. Nitrogen use efficiency is separated into different component indices by agronomists using N-omission plots[6]. The yield increase that results from N application in comparison with no N application is defined as the agronomic N use efficiency (AEN, kg grain yield increase per kg N applied). Cassman[7] and his colleagues that AEN was 15-18 kg kg^{-1} in the dry season in farmer's field in the Philippines. The average RE(N) (recovery efficiency of fertilizer-N that used to express the percentage of fertilizer N recovered in above ground plant biomass at the end of cropping system) is 30 % for irrigated rice in Asia[8].

Site-specific N management such as real-time N management (RTNM) and fixed-time adjustable-dose N management (FTNM) was developed to increase the N use efficiency of irrigated rice[8,9]. In real time N management N is applied only when the leaf N content is below a critical level. In this approach the timing and number of N applications vary across season and locations while the rate of each N application is fixed. The leaf N content is estimated non-destructively with a chlorophyll meter (SPAD) or leaf colour chart (LCC). SPAD can quickly and reliably assess the N status of a crop based on leaf area. The high cost of SPAD keeps it out of reach of many Asian farmers. Leaf colour chart is an inexpensive alternative to the chlorophyll meter[10]. Like the chlorophyll meter, the critical colour shade on the LCC needs to be determining to guide N applications.

In a fixed time N management, one-third of the 120 kg N ha^{-1} for rice has been recommended to be applied basally immediately before soil puddles and rice transplanting. Many farmers also apply a dose of N *ca.* 1 week after transplanting in lieu of basal application. As rice seedling take *ca.* 7 d to recover from transplanting shock[11], it is likely that most N applied *ca.* 7 d after transplanting (DAT) is not used by plants and is lost. As LCC-guided N management in rice starts at 2 week after transplanting, the usefulness of applying a dose of N basally or at *ca.* 7 DAT needs to be examined. Norman and his group, conducted a field trial in rice given 80,120 and 160 lbN/acre in (i) one dose before sowing (ii) in one dose on to the mud after draining for peg down (iii) 50 % before sowing, 25 % 1 week after the five-leaf stage and 25 % three weeks after the five-leaf stage (iv) 50 % to the mud after draining for midseason N application in rice[12]. Result suggested that N application from panicle initiation (PI) to panicle differentiation (PD) growth stage is the best time for N application[13]. In another research the most efficient N application occurred when majority of N was applied 4 week after sowing.

The objectives of this study are to (1) evaluate different N management strategies for increasing AEN (2) to develop optimal N management for Fajr variety using RTNM and FTNM (3) To compare grain yield in this variety over a different range (4) Decreasing N inputs to protect the environment without reducing crop yield. (5) Compare the efficiency of to critical LCC values for guiding N-fertilizer applications in rice.

EXPERIMENTAL

Field experimental was conducted with rice in 2008 on a Typic dysterudept at the experimental farms of Mazandaran Rice Research Center (28′36º N, 23′52º E, 29.8 maltitwe) located in North of Iran. The area receives on average 743.2 mm year^{-1} rainfall. Mean maximum and minimum temperatures are 31.2 and 15.3 ºC during rice cropping (April to August).

TABLE-1
SOIL (0-15 cm) PROPERTIES OF RICE EXPERIMENT SITES (2008)

Experimental site	Sand (%)	Clay (%)	pH	EC (ds/m)	Organic carbon (%)	TNV (%)	P olsen (mg kg^{-1})	K ammonium 1 M acetate (mg kg^{-1})
Site 1	30	32.6	6.96	1.63	3.20	20	5.90	240
Site 2	28	38.6	7.05	1.45	0.78	20	6.15	240

Experimental design and treatments: At each site, twelve N treatments were arranged in a randomized complete block design with three replicates. The 12 N treatments in Table-2 were different fertilizer N management strategies, including three fixed-N split and LCC treatments. The three fixed-N split treatment had total N rates of 45, 90 and 135 kg N ha^{-1} with three time of N application that had been shown in Table-2. The two treatments with LCC consisted of applying N (14 kg ha^{-1}) when rice leaf colour was less than shade 4 (LCC< 4) and 5. Thershold LCC values were picked up from studies carried out by peng and his colleagues[9]. Control plot received a full dose of phosphorous, potassium and zinc but no nitrogen.

Crop management: After removing crop residues, the land was plowed, puddled and leveled for rice transplanting in April 2008. Four to five week old rice seedlings were transplanted at 20 cm × 20 cm spacing in 12 m^2 plots in experimental sites. A dose of 50 kg P ha^{-1} (as super phosphate) and 100 kg K ha^{-1} (as K_2SO_4) and 25 kg Zn ha^{-1} (as $ZnSO_4$) was incorporated in to the soil before last puddling. The plots were kept flooded throughout the growing season. Hand-weeding was done and pest control followed standard practices. Crops were harvested by hand at ground level at maturity on 28 August, 2008. Grain and straw yields were determined from an area (5 m^2) located at the center of each plot. Grains were separated from straw using a plot thresher, dried in a batch grain dryer and weighted. Grain moisture was determined immediately after weighing and sub samples were dried in an oven at 65 ºC for 48 h. Grain weights for rice expressed at 140 g kg^{-1} water content-straw weights were expressed on oven dry basis.

Plant sampling and analysis: Grain and straw sub samples were dried at 70 ºC and finely ground to pass through a 0.5 mm sieve. Nitrogen content in grain and straw was determined by digesting the samples in sulfuric acid (H_2SO_4), followed by analysis for total N by a micro-Kjeldahl method[14]. The N in grain plus that in straw was taken as a measure of total N uptake.

TABLE-2
TREATMENTS USED IN RICE EXPERIMENTS DURING 2008, MAZANDARAN, IRAN

Number	Treatment details	Time of N application
Zero-N control	Zero-N control	—
Fixed-45	Fixed-N split with total N rate of 45 kg N ha^{-1}	Application of N in three equal splits at basal, early tillering and panicle initiation (i)
Fixed-45	Fixed-N split with total N rate of 45 kg N ha^{-1}	Application of N in three splits at 20% Seven days after transplanting, 40% early tillering and 40% panicle initiation (ii)
Fixed-45	Fixed-N split with total N rate of 45 kg N ha^{-1}	Application of N in two equal splits at 50% early tillering and 50% panicle initiation (iii)
Fixed-90	Fixed-N split with total N rate of 90 kg N ha^{-1}	Application of N in three equal splits at basal, early tillering and panicle initiation (i)
Fixed-90	Fixed-N split with total N rate of 90 kg N ha^{-1}	Application of N in three splits at 20% Seven days after transplanting, 40% early tillering and 40% panicle initiation (ii)
Fixed-90	Fixed-N split with total N rate of 90 kg N ha^{-1}	Application of N in two equal splits at 50% early tillering and 50% panicle initiation (iii)
Fixed-135	Fixed-N split with total N rate of 135 kg N ha^{-1}	Application of N in three equal splits at basal, early tillering and panicle initiation (i)
Fixed-135	Fixed-N split with total N rate of 135 kg N ha^{-1}	Application of N in three splits at 20% Seven days after transplanting, 40% early tillering and 40% panicle initiation (ii)
Fixed-135	Fixed-N split with total N rate of 135 kg N ha^{-1}	Application of N in two equal splits at 50% early tillering and 50% panicle initiation (iii)
LCC 4	14 kg N ha^{-1} with 30 kg ha^{-1} at basal	LCC 4 whenever LCC<4
LCC 5	14 kg N ha^{-1} with 30 kg ha^{-1} at basal	LCC 5 whenever LCC<5

Leaf colour chart measurement: The LCC developed by IRRI 1996 consisted of six green strips showing increasing greenness with increasing number. The chart was used to take weekly reading starting 15 DAT. Ten disease-free rice plants, were randomly selected in the plot and the colour of the youngest fully expanded leaf of selected plants was compared by placing its middle part on top of the colour strip in the chart. Reading was taken up to 50 % flowering stage. If more leaves read below a critical value (LCC 4 and 5) a dose of 14 Kg N ha^{-1} was applied.

Data analysis: Analysis of variance was performed on yield parameters to determine effect of N management treatments using SAS. Duncan's multiple range test was used at 0.05 level of probability to test difference, between treatment means. The N use efficiency measures, RE[15] and AE[6], were calculated as follows:

RE (%) = [(TNU in N-fertilized plot-TNU in zero-N plot)/ quantity of N fertilizer applied in N-fertilized plot] × 100

AE (Kg grain/ Kg N applied) = (grain yield in N-fertilized plot-grain yield in zero- N plot)/ quantity of N fertilizer applied in N- fertilized plot

where, TNU is the total N uptake in grain and straw.

RESULTS AND DISCUSSION

Yield response: Nitrogen treatments had a significant effect on grain yield (Table-3). The zero-N control produced the lowest yield among the treatments that received N application in both sites according to nutrient shortage in the unfertilized plots. Yield loss was observed when split 135 timing (i) was used in both sites. Grain yield of real time management (LCC 4 and 5) was higher than that of fixed-time N management (split treatments), but the increase was insignificant. The grain yield of Zero-N control in site 2 was 18.5 % higher than that of site 1.

The harvest index was the highest when nitrogen was applied of 90 kg ha^{-1} which was similar to 45 and 135 kg N ha^{-1}. Harvest index were significantly influenced by the time of nitrogen application and the highest values were obtained with timing (i) which was followed by with timing (ii) and (iii) which were statistically similar to LCC 4 and 5 (Table-3).

TABLE-3
GRAIN YIELD AND YIELD ATTRIBUTES OF FAJR GROWN UNDER TWELVE TREATMENT

Treatments		N rate (kg/ha^{-1})	Grain yield (t/ha^{-1})	Panicle (m^{-2})	Grain filling (%)	Grain weight (mg)
Site 1						
Zero-N control		0	4.5^{e}	327^{f}	90^{a}	22.6^{b}
Fixed-45	Timing (i)	45	5.7^{cd}	385^{def}	89^{a}	23.6^{ab}
Fixed-45	Timing (ii)	45	5.67^{cd}	381^{def}	91.2^{a}	22.7^{ab}
Fixed-45	Timing (iii)	45	5.4^{d}	358^{ef}	89.5^{a}	23.5^{ab}
Fixed-90	Timing (i)	90	7.36^{ab}	481^{ab}	90.3^{a}	24.1^{ab}
Fixed-90	Timing (ii)	90	7.40^{ab}	425^{bcd}	92.2^{a}	24.3^{ab}
Fixed-90	Timing (iii)	90	6.40^{bc}	397^{cde}	90.6^{a}	23.3^{ab}
Fixed-135	Timing (i)	135	5.80^{cd}	512^{a}	80.2^{a}	24.2^{ab}
Fixed-135	Timing (ii)	135	7.20^{ab}	454^{abc}	90^{a}	23.3^{ab}
Fixed-135	Timing (iii)	135	6.91^{abc}	404^{cde}	90.5^{a}	24^{ab}
LCC 4		90	7.38^{ab}	450^{abc}	89.5^{a}	23.4^{ab}
LCC 5		90	7.91^{a}	480^{ab}	90.1^{a}	23.1^{ab}
Site 2						
Zero-N control		0	5.4^{e}	316^{g}	87.2^{ab}	22^{a}
Fixed-45	Timing (i)	45	6.15^{cd}	465^{cd}	88.5^{a}	21.5^{a}
Fixed-45	Timing (ii)	45	6.10^{cd}	425^{def}	84.7^{ab}	22.8^{a}
Fixed-45	Timing (iii)	45	6.06^{d}	387^{f}	87.8^{ab}	21.7^{a}
Fixed-90	Timing (i)	90	7.14^{a}	493^{bc}	87.6^{ab}	22^{a}
Fixed-90	Timing (ii)	90	6.66^{abc}	416^{ef}	88.7^{a}	22^{a}
Fixed-90	Timing (iii)	90	6.86^{ab}	408^{ef}	89.3^{a}	21.7^{a}
Fixed-135	Timing (i)	135	5.54^{de}	518^{ab}	82.5^{b}	21.1^{a}
Fixed-135	Timing (ii)	135	6.95^{ab}	437de	86.4^{ab}	22.7^{a}
Fixed-135	Timing (iii)	135	7.33^{a}	558^{a}	85.6^{ab}	22.1^{a}
LCC 4		90	6.84^{ab}	430.5^{de}	86.5^{ab}	23.1^{a}
LCC 5		90	7.35^{a}	540.8^{a}	86.5^{ab}	21.9^{a}

Note: Within a column for each variety, means followed by the same letters are not significantly different according LSD (0.05).

Panicle number responded significantly to N application (Table-3). Panicle m^{-2} in fixed-135 were higher than other treatments and the highest panicles number were obtained from fixed-135 timing (i) that showed significant difference with other treatments in site 1. The same happened in site 2 (Table-3).

Grain filling percentage showed no significant difference among N application treatment except fixed-135 timing (i). That produced the lowest grain filling in site 1. The same happened in site 2, but the decrease in fixed-120 timing (i) was insignificant. No significant difference was showed in grain weight among N application treatments relative to Zero-N control in both sites (Table-3). Total N uptake was proportional to total fertilizer-N rate. Total N uptake increased as N rates increased (Table-4).

TABLE-4
N UPTAKE, TOTAL FERTILIZER N APPLIED AND RECOVERY AND AGRONOMIC EFFICIENCIES (RE AND AE RESPECTIVELY) OF N TREATMENTS ACROSS TWO SITES IN MAZANDARAN, IRAN

Treatments	N rate (kg/ha^{-1})	Total N uptake (kg ha^{-1})	RE (%)	AE (kg kg)
Site 1				
Zero-N control	0	95^{d}	–	–
Fixed-45	45	115^{c}	44.4^{b}	24.8^{b}
Fixed-45	45	118^{c}	51.1^{b}	24.2^{bc}
Fixed-45	45	120^{c}	55.5^{ab}	18.35^{c}
Fixed-90	90	153^{b}	64.4^{ab}	30.9^{b}
Fixed-90	90	150^{b}	61.1^{ab}	31.3^{b}
Fixed-90	90	148^{b}	58.8^{ab}	20.9^{c}
Fixed-135	135	175^{a}	59.2^{ab}	9.03^{c}
Fixed-135	135	178^{a}	61.4^{ab}	19.3^{cd}
Fixed-135	135	180^{a}	62.9^{ab}	17.2^{d}
LCC 4	90	143^{b}	53.3^{ab}	31.1^{b}
LCC 5	90	145^{b}	55.5^{ab}	37.0^{a}
Site 2				
Zero-N control	0	90^{d}	–	–
Fixed-45	45	117^{c}	60^{a}	17.04^{b}
Fixed-45	45	115^{c}	55.5^{a}	16.0^{b}
Fixed-45	45	120^{c}	66.6^{a}	13.7^{bc}
Fixed-90	90	150^{b}	66.6^{a}	19.5^{ab}
Fixed-90	90	154^{b}	71.1^{a}	14.2^{bc}
Fixed-90	90	149^{b}	65.5^{a}	16.4^{b}
Fixed-135	135	178^{a}	65.1^{a}	1.1^{d}
Fixed-135	135	174^{a}	62.2^{a}	11.6^{c}
Fixed-135	135	180^{a}	66.6^{a}	14.4^{bc}
LCC 4	90	145^{b}	61.1^{a}	16.1^{b}
LCC 5	90	141^{b}	56.6^{a}	21.8^{a}

Note: Within a column for each variety, means followed by the same letters are not significantly different according LSD (0.05).

At both sites, fixed-135 treatments had the highest total N-uptake among the N-treatments. The difference in total N-uptake among fixed-135 and other treatments was consistent across two sites.

A significant difference among N treatments in RE was observed at site 1. (Table-4). There was no significant difference among LCC and split treatments at site 2. Recovery efficiency ranged from 42 to 71 %. Large variation in AE was observed across in treatments. There was a significant difference in AE at two sites. At site 2 AE was lower than site 1. In similar rate of N-fertilizer, LCC 5 had a significant difference in AE with fixed-90. The same happened at site 1. AE was lowest in the fixed-135 timing (i) at both sites (Table-4).

AE ranged from 9.03 to 37.0 kg kg^{-1} and 1.1 to 21.8 kg kg^{-1} at site 1 and 2, respectively. Lowest values of AE occurred in fixed-135 timing (i) at both sites. The low values of AE indicate that, this plot had no significant increase yield than the zero-N control. This was possible when excessive N application caused mutual shading, lodging and pest damage in this plot.

Another factor that caused low AE of irrigated rice at two sites was the improper timing of N application (i) that is similar to farmer's fertilizer practice in Iran. Peng and his colleagues[16] speculate that the excessive N application (180 kg N ha^{-1}) would cause rice to be susceptible to lodging and less resistant to diseases such as sheath blight and blast. In the modified farmer's fertilizer practice at timing (ii), (iii), the value of AE increased with the same N rate relative to timing (i). LCC 5 treatment had higher AE than LCC 4 and fixed-135. Accordingly grain yield showed an increase in LCC 4 and 5 relative to other treatment in both sites. As a result, in the moderate N fertilizer rate (90 Kg N ha^{-1}), LCC is a simple tool to determine the timing of N top dressing to rice and the critical value of LCC 5 was more beneficial in enhancing the growth of fair variety at both sites.

Singh and his group[17] indicated that N management based on LCC shade 4 helped avoid over application of N to rice in India. It is found in Philippine that application of N at 25 kg ha^{-1} based on biweekly LCC 5 observations was the best method of nitrogen management[18]. The zero-N control grain yield at site 1 was lower than site 2. The low yield level of the zero-N control at site 1 can be explained by the lower soil organic matter percent. At similar N rate, site 1 generally had higher AE than site 2. The difference in grain yield between the two sites, might contribute to the difference in AE between them. Total uptake increased and RE % decreased as N rate increased. It is not possible to achieve high AE with improved N management strategies[17].

RE ranged from 42.2 to 71.1 %. The low AE was not associated with RE. This suggested that the fertilizer N absorbed by the crop was not converted into grain efficiently at both sites, where a higher RE was observed at site 2, regardless of N treatments compared with that of site 1. There was no significant difference in panicle m^{-2} between fixed-45 and zero-N control. LCC treatments, fixed-90 and fixed-135 were equally effective in improving panicle m^{-2}. There was no significant difference in grain filling and grain weight parameters among N treatment at both sites, because of inefficient role of nitrogen in these parameters. An exception happened in fixed-135 timing (i) that showed a significant decrease relative to other treatments due to excessive and improper timing of N application that caused lodging in this plot.

Conclusion

The leaf colour chart (LCC) is a simple, easy-to-use and inexpensive tool to monitor crop N status in the field and to achieve high grain yield and agronomic efficiency. The high input rate of fertilizer N and improper timing of N application is resulted in lower grain yield of irrigated rice associated with poor AE and not with RE. All treatments showed significant grain yield increase relative to zero-N control. Yield loss was observed when split 135 timing (i) was used in both site due to lodging and pest damage.

Grain yield of LCC treatments were higher than split treatments. The grain yield of zero-N control in site 2 was18.5 % higher than that of site 1 due to higher soil organic matter percent. LCC 5 treatment had higher AE than LCC 4 and fixed - 135 at the less N rate. As a result improvement in AE will be possible by adapting knowledge intensive technology of fertilizer management such as leaf colour chart N management[18-20].

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