Response of rice to midseason nitrogen applications in Uruguay

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Farmers plant rice in dry soil surface conditions in Uruguay. According to rainfall, flushing (one or two) is required to prevent water stress before establishing the permanent flood 40–60 d after planting.

Nitrogen split applications are recommended, according to type of soil, rotation system, time of seeding, and planting method. When N is needed, tillering and panicle initiation are the appropiate times to apply it.

Three experiments were conducted to improve the efficiency of N split applications. In the first one, using cultivar Bluebelle, treatments consisted of different timing of N applications at tillering related to irrigation (–9 to +3 days, before or after flushing). According to the Tukey range test (0.05), there were no significant differences in dry matter yield and N uptake at panicle initiation (PI) among timing treatments. It rained at least once in the application period in both years. The response of two rice cultivars of different growth duration (one japonica and one indica type) to different timing of N split applications at tillering and PI was examined across two growing seasons. The responses of the varieties in 1998 and 1999 were different. Within one year, the cultivars' responses to N timing treatments differed. Weather conditions and diseases affected the responses.

Management and breeding are continually changing and their co-evolution creates new opportunities for improving rice production. Advancing yield potential should be coupled closely with improving systems, practices, and tools for management (IRRI 1994). Three factors should be taken into account: efficiency in the use of nutrients, efficiency in the use of water, and the instability of weather conditions. As yield potential increases, different rates or timing from present applications may be required. Interference among neighboring plants may differ if cultivars of distinct tillering and root growth capability are planted.

Farmers plant drilled or broadcast rice in dry soil surface conditions in Uruguay. According to rainfall, irrigation flushing (one or two) is required to prevent water stress before establishing the permanent flood 40–60 d after planting.

Field research work demonstrated the advantages of applying nitrogen one, two, or three times according to type of soil, rotation system, land preparation, planting method, time of seeding, disease history, and climatic conditions, but no more than 70 kg N ha^{-1} is used. When split applications are needed, tillering and panicle initiation are the appropriate times to apply N. The number of panicles m^{-2} depends on seeding rate, percent emergence, and tiller number. There is a close correlation between the number of tillers and the amount of N absorbed during this period. Spikelets per panicle is determined during the early reproductive growth stage; the number of spikelets observed at maturity is the difference between the number of differentiated primordia and the number of those that degenerate (Mae 1997).

Three experiments were conducted to improve the efficiency of N split applications. The objective of the first was to determine N uptake at panicle initiation (PI) when the nutrient was applied at tillering, as urea, varying the number of days before or after flushing. To study the effects of different timing of N split applications at tillering (T) or at PI was the objective of the second and third experiments, respectively.

Materials and methods

Experiment 1

A complete randomized block design (CRBD) with 10 treatments and 4 replications was used. In treatments 1–7, 10 kg N ha^{-1} was applied at planting and 23 kg N ha^{-1} topdressed at tillering; in treatment 8, 33 kg N ha^{-1} was applied at planting; in treatment 9, 10 kg N ha^{-1} was applied only at planting and a check (treatment 10) with no N was included. Treatments consisted of different timing of applications related to irrigation: –9 (T1), –6 (T2), –3 (T3), –1 (T4), 0 (T5 on water), +1 (T6), and +3 (T7) days before or after flushing. Long-grain cultivar Bluebelle was broadcast-planted in the two growing seasons (1993-94 and 1994-95). Whole aboveground plant samples were taken at random from 0.3×0.3 m^2 on each plot at PI. Main stem and tiller dry matter production were determined. The samples were washed and dried in an oven at 60 °C for 48 h, ground in a stainless-steel Wiley mill, and analyzed for N content by Kjeldahl digestion.

Experiments 2 and 3

The response of two rice cultivars of differing growth duration to different timing of N split applications was examined across two growing seasons. El Paso 144, indica type, and INIA Tacuarí, cold-tolerant long-grain japonica type (Blanco et al 1994), the most extensively planted cultivars in Uruguay, were used. Cultivar El Paso 144, with longer growth duration, needs 1,577 temperature-units, base 10, from emergence to maturity, and INIA Tacuarí needs 1,492 (adapted from Méndez and Roel 1997, 1998). El Paso 144 begins tillering earlier (195 temperature-units, base 10, from emergence to tillering initiation, vs 216 for INIA Tacuarí), but INIA Tacuarí reaches panicle initiation, flowering, and maturity in a shorter time.

A CRBD design with 4 replications was used with a split-plot arrangement of treatments. Cultivars were drill-planted in the large plots and N split applications were located in the subplots.

In experiment 2, treatments consisted of applications of the same nitrogen rate (23 kg N ha^{-1}) at 5-d intervals after the development of the fifth leaf.

Whole aboveground plant samples were taken at random from 0.16 m^2 on each plot at PI. Dry matter (DM) production was determined. The samples were washed, dried in an oven at 60 °C for 48 h, ground in a stainless-steel Wiley mill, and analyzed for N and P content and uptake.

In experiment 3, treatments consisted of applications of the same nitrogen rate (23 kg N ha^{-1}) at 5-d intervals after internode elongation. In the last season, a check without N application was included in both experiments.

Plant samples were taken from two drill-rows 16 cm wide and 30 cm long on each plot at harvest to study grain yield components. The number of panicles per unit area was counted and 15 randomly selected panicles were chosen to determine empty and filled grains. The rice plants of the nine center rows of each plot were harvested; the grain was weighed and moisture was determined and corrected to 13%. Simple correlation analyses between certain variables were performed.

Results and discussion

Experiment 1

The combined analysis of 2 y showed that application treatments significantly affected total, main stem, and tiller DM production and N uptake (Table 1). N uptake

Table 1. Effects of treatments on dry matter (DM) yield and N uptake (experiment 1).

Treatment[a]	DM yield (t ha^{-1})[b]			N uptake
	Main stem	Tillers	Total	(kg ha^{-1})
9 dbf	2.5 ab	1.0 a	3.6 a	42.4 a
6 dbf	2.7 a	0.9 ab	3.6 a	41.8 a
3 dbf	2.5 ab	0.8 abc	3.3 ab	36.5 abc
1 dbf	2.4 abc	0.7 abc	3.2 ab	38.7 ab
On water	2.6 ab	0.7 abc	3.3 ab	35.2 abc
1 daf	2.4 abc	0.7 abc	3.0 abc	36.5 abc
3 daf	2.2 abc	0.7 abc	2.9 abc	38.0 ab
100% basal	2.5 abc	0.8 abc	3.3 ab	36.5 abc
No topdressing	1.9 bc	0.6 bc	2.5 bc	29.7 bc
No N	1.8 c	0.5 c	2.2 c	26.1 c
Prob.	0.0	0.001	0.0	0.000
CV (%)	16.2	38.3	14.0	21.2
Mean	2.3	0.7	3.1	36.1

[a]dbf = days before flushing, daf = days after flushing. [b]Mean separation test, Tukey (0.05). Numbers followed by different letters are significantly different.

varied in a trend similar to that of total DM yield. Total N absorbed in treatments 1 and 2 (–9 and –6 d before flushing) was significantly different only from that of checks 9 (no topdressed N) and 10 (no N). According to the Tukey range test (0.05), there were no significant differences among timing treatments (1 to 8). It must be taken into consideration that it rained at least once in the period of application in both years (68.3 mm in 1993-94 and twice, 4 and 15 mm, in 1994-95) and rainfall could incorporate the N urea into the soil, thus preventing N losses.

Experiment 2

A decrease in tiller DM was found in 1998 for INIA Tacuarí when the N split application was delayed after 10 d (342 temperature-units, base 10) following the development of the fifth leaf (probability 0.013). No significant differences were detected for El Paso 144 in the same growing season (De los Santos and Jacques 1999).

Figure 1 presents mean temperatures, average of 10 d. Colder temperatures were registered in the last two growing seasons in comparison with the average of 28 y (1972-99).

Dry matter yield (t ha^{-1}) and N and P uptake (kg ha^{-1}) were significantly affected by treatments in the two cultivars in 1999 (Table 2). Nitrogen was applied the same calendar days for both varieties and El Paso 144 began tillering 3 d earlier than INIA Tacuarí. An increase was observed until 5 d after tillering (292 temperature-units, base 10), followed by a decrease in the three dependent variables. During the period tillering + 10 d to tillering + 20 d, strong wind and rainfall occurred and 50% of the days presented minimum temperatures below 15 °C; this apparently affected the response of the crop to N application.

Treatments also significantly affected the number of panicles m^{-2} (Table 2). El Paso 144 had maximum production at 5 d after tillering and INIA Tacuarí at 15 d after tillering.

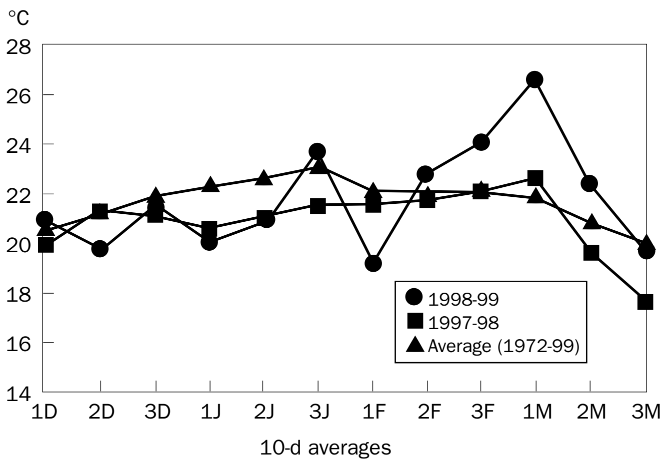

Fig. 1. Mean temperatures (average of 10 d). D = December, J = January, F = February, M = March.

Table 2. Dry matter (DM) yield and N and P uptake at panicle initiation (experiment 2, 1999).

N application treatment (d after tillering)[a]	DM yield (t ha^{-1})		N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		Panicles m^{-2}	
	Tacuarí	EP 144	Tacuarí	EP 144	Tacuarí	EP 144	Tacuarí	EP 144
Check	3.2	3.3	49.5	50.7	6.4	6.9	539	625
0	3.8	3.8	59.8	60.6	7.8	8.7	558	647
5	4.1	4.3	68.6	67.6	8.9	9.4	566	766
0	2.6	3.5	55.8	54.8	7.4	7.8	617	596
15	3.6	3.5	58.6	59.0	7.4	7.7	621	591
20	4.0	3.7	64.8	59.0	8.3	7.6	550	531
Prob.	0.08	0.001	0.02	0.005	0.03	0.000	0.02	0.000
CV%	11.4	7.2	11.9	9.2	11.6	7.5	6.1	8.8
Mean	3.7	3.7	59.5	57.7	7.7	8.0	575	626

[a]Tillering occurred at 5 d for INIA Tacuarí and 8 d for El Paso 144.

Table 3. Simple correlation coefficients between certain variables (1999, experiment 2).

Variables[a]		INIA Tacuarí		El Paso 144	
X	Y	r	Prob.	r	Prob.
DM yield	Panicles m^{-2}	–0.18	ns	0.60	0.001
DM yield	Filled grains panicle^{-1}	0.55	0.005	–0.55	0.005
DM yield	Filled grains m^{-2}	0.45	0.03	–0.12	ns
DM yield	Grain yield	0.60	0.001	0.06	ns
N uptake	Panicles m^{-2}	–0.08	ns	0.49	0.01
N uptake	Filled grains m^{-2}	0.53	0.007	–0.12	ns
N uptake	Grain yield	0.56	0.004	0.04	ns

[a]DM = dry matter at panicle initiation.

Simple correlation analysis showed different trends and significances for the cultivars (Table 3). For short growing season cultivar INIA Tacuarí, filled grains panicle^{-1}, filled grains m^{-2}, and grain yield were positively and significantly correlated with DM yield at PI. Nitrogen uptake at PI was also positively and significantly correlated with filled grains m^{-2} and grain yield. Neither DM yield nor N uptake at PI were related to the number of panicles m^{-2}. On the other hand, filled grains panicle^{-1} was negatively and significantly correlated with DM yield at PI in El Paso 144; the number of panicles m^{-2} was positively and significantly correlated with DM yield and N uptake at PI for the long growing season cultivar.

Experiment 3

Only INIA Tacuarí was affected significantly by PI treatments in 1998. Grain yield and the number of panicles m^{-2} decreased when N was applied late (Fig. 2A,B). These

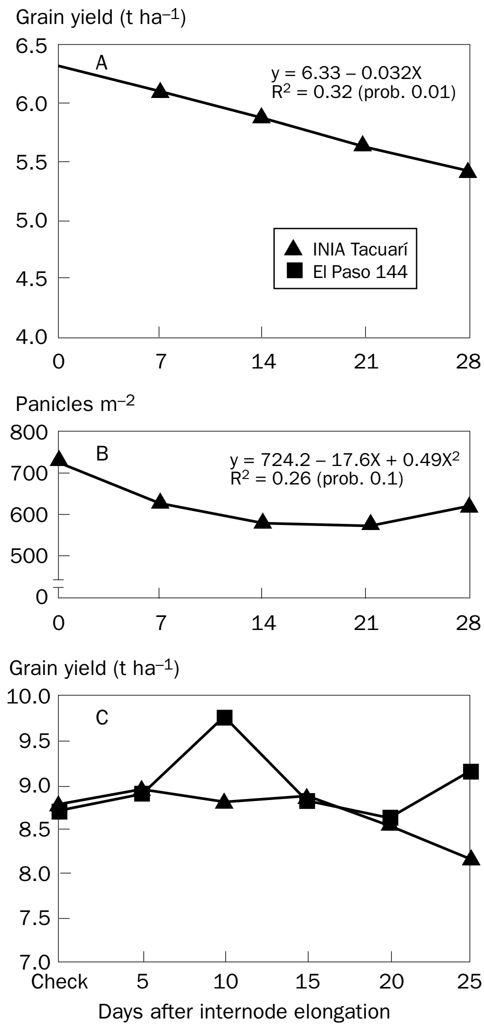

Fig. 2. Effects of timing of N at panicle initiation on 1998 INIA Tacuarí grain yield (A), on 1998 INIA Tacuarí number of panicles m^{-2} (B), and on 1999 grain yields for INIA Tacuarí and El Paso 144 (C).

results suggest that delayed applications of N cannot help the most recently formed tillers to develop panicles (De los Santos and Jacques 1999). Méndez and Deambrosi (1995) found an increase in the number of panicles m^{-2} of cultivar Bluebelle at harvest as a result of applications of N at PI, suggesting an effect on the survival of tillers.

Figure 2C presents the grain yield response of the cultivars to PI treatments in 1999. In this case, the long growing season El Paso 144 increased grain yield with N applications, but INIA Tacuarí did not. Figure 1 shows that low temperatures occurred in January and February; these weather conditions probably affected more the performance of the short growing season variety, which was in the sensitive reproductive stage at that time.

Treatments significantly affected the number of potential grains $panicle^{-1}$ (prob. 0.04), filled grains $panicle^{-1}$ (prob. 0.07), and stem rot severity index (adapted from Ou 1972) at harvest (prob. 0.05) in cultivar INIA Tacuarí. When N was applied, grain yield was negatively correlated with the degree of disease severity ($r = -0.41$, prob. 0.07).

Only grain yield varied significantly in response to treatments for El Paso 144 (prob. 0.01); no significant differences were found in grain yield components. The number of panicles m^{-2} was negatively correlated with filled grains $panicle^{-1}$ ($r = -0.43$, prob. 0.06). The degree of disease severity (stem rot) was negatively correlated with filled grains m^{-2} ($r = -0.44$, prob. 0.05).

Conclusions

Experiment 1

There were no significant differences (Tukey 0.05) in total DM production (main stem + tillers) at PI among N timing treatments at tillering. There were no significant differences (Tukey 0.05) in nitrogen uptake (kg N ha^{-1}). Only two treatments (applications 9 and 6 d before flushing) were significantly different (Tukey 0.05) for treatments 9 (no N topdressed) and 10 (no N).

Experiments 2 and 3

The responses of INIA Tacuarí (cold-tolerant, japonica type) and El Paso 144 (indica type) differed in the two growing seasons.

Within 1 y, the cultivars' responses to N timing treatments were different. Increasing biomass or sink size through N applications did not necessarily contribute to increased yield in Uruguay.

Weather conditions and disease occurrences may affect the expected responses to nutrient application.

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Notes

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