Increasing rice productivity by improving population and nitrogen management

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ABSTRACT

One of the main goals in agriculture nowadays is to maximize production efficiency, through resources optimization by improving processes. New cultivars with a different growing strategy, including length of cycle, canopy structure, "stay-green" capability, and disease-tolerance, push us to review the known recommendations in basic management factors, as plant density and nitrogen (N) fertilization. INIA Merín, an *indica*-type cultivar recently released in Uruguay was tested under various plant densities and N fertilization topdressing doses, in three contrasting sites and for two years. Growing parameters, including yield and yield components, were analyzed using mixed models. Seed density directly influenced plant population, reaching the optimum plant number with 110 to 150 kg ha^{-1} seed. No interaction between plant density and nitrogen fertilization was recorded for any variable. Biomass and grain yield were affected by both analyzed parameters, being N more relevant in magnitude. A denser plant population and a higher N amounts increased grain yield by 9 % and 24%, respectively. A linear regression between yield and nitrogen amount was set, inducing the hypothesis that there is still yield to explore through an augment in nitrogen topdressing.

Key words: plant density, fertilization, INIA Merín, *indica* type.

1. Introduction

Reaching high efficiency in productivity is one of the main goals in nowadays production systems, and the release of new modern cultivars needs to be complemented with management information. The cultivar INIA Merín (Perez de Vida et al, 2016) has an erect plant structure, long cycle, very high yield potential, an important response to nitrogen and is blast-resistant, having low risk of lodging and is also more tolerant to shoot diseases. Although a local objective recommendation system about N fertilization exist (Fertiliz-Arr), it was created with other cultivar types. Management of some basic production factors as plant population and nitrogen response have to be assessed in various environments (soil types, temperatures), in order to check those recommendations under different conditions in the different rice production areas.

2. Material and Methods

Six experiments distributed in three sites: Paso de la Laguna (PL), Pueblo del Barro (PB) and Paso Farías (PF), from East to North, and during two years (2016-2017 and 2017-2018 for PL and PF, or 2017-2018 and 2018-2019 for PB). The cultivar used was INIA Merín, *indica* type, a long grain and long cycle, high productive and blast resistant. Four plant densities and four N treatments were combined (Table 1), and installed over fields where rice rotated with pastures (grasses and legumes), using direct seeding or minimum tillage over a previous summer land preparation.

Table 1. Seed density (viable seeds m^{-2}), seed rate (kg ha^{-1}) and nitrogen fertilization (kg N ha^{-1}) treatments.

Seed density (SD) Viable seeds m^{-2}	**Seed rate (SR)** Kg seeds ha^{-1}	**Nitrogen treatments** Kg N ha^{-1}
1: 195	60-70	1: control; 0 (ETI) + 0 (PI)
2: 325	100-110	2: medium; 45 (ETI) + 30 (PI)
3: 488	150-160	3: Fertiliz-Arr[1]; X (ETI) + Y (PI)
4:650	190-210	4: high; 68 (ETI) + 45 (PI)

ETI: at early tillering; PI: at panicle initiation; [1] local rice fertilization recommendation system created by INIA Uruguay (http://www.inia.uy/investigaci%C3%B3n-e-innovaci%C3%B3n/programas-nacionales-de-investigaci%C3%B3n/Programa-Nacional-de-Investigacion-en-Produccion-de-Arroz/fertiliz-arr-una-herramienta-inia-para-la-fertilizaci%C3%B3n-en-arroz).

The experimental design was a factorial in randomized blocks with three replicates, with all the combinations between plant densities and N treatments, in 16 m^2 plots each. Measurements included plant recovery (PR, in number and percent), aboveground biomass in panicle initiation - R3 (BiR3) and previous harvest (BiHa), NDVI at R3 (NDVIR3), grain yield (Yi), yield components (panicles per area –Pa-, filled-grains per panicle –Fgp-, 1000 grains weight –W1000-, floret sterility -%St-) and harvest index (HI). The statistical analyses were carried out with Infostat (www.infostat.com.ar), using mixed models where plant density, N fertilization and their interaction were considered fixed factors, and year, site and block as random factors. Regression analysis was also explored for grain yield and N.

3. Results and Discussion

Plant density directly influence PR; though more viable seeds m^{-2} resulted in more plants m^{-2} (Figure 1), the percentage of PR diminished from 195, 325, 488 and 650 viable seeds m^{-2} (64%, 64%, 52% and 46%, respectively). A minimum plant stand recommendation for rice field conditions in Uruguay is usually between 200 and 250 plants per m^2.

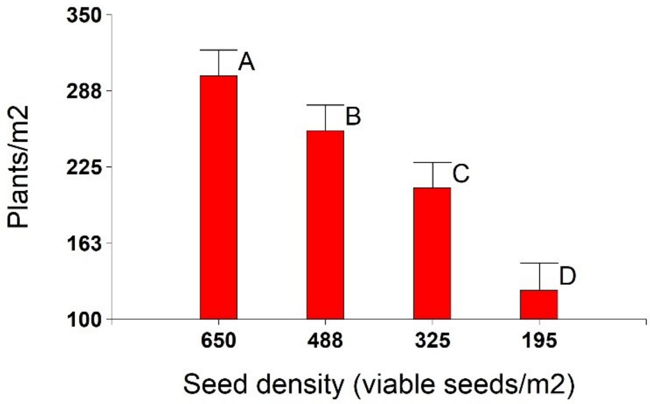

Figure 1. Average plants recoveries for different viable seed densities, in the six experiments (three sites, two years) evaluated.

All the other variables were analyzed by both factors, plant density and N, and in the majority of them, both had significant individual effects (Table 2). No interactions were detected for any variable analyzed.

Biomass changes at R3 were mainly driven by N, with a significant gap of 700-800 kg ha^{-1} within the control and the other N treatments. As seen in previous studies (Marchesi and Castillo, 2016), NDVIR3 was directly associated by N, with a positive response from 0.53 to 0.70 between extreme treatments. At harvest, both N and density had effects, with greater differences determined by N, of 3000 to 4000 kg ha^{-1}. The HI was quite stable with values of 0.51-0.52, with no changes between treatments, denoting the relevance in trying to obtain an abundant biomass crop.

Table 2. Significance of the plant density and nitrogen treatments over the variables analyzed for INIA Merín in six experiments (three sites and two years)

Variables	**Factors**			R^2
	Plant density	Nitrogen	Pl Den*Nitro	
BiR3	0.0153	<0.0001	ns	0.73
NDVIR3	ns	<0.0001	ns	0.69
BIHa	0.0019	0.0002	ns	0.70
HI	ns	ns	ns	--
Yi	0.0061	<0.0001	ns	0.72
Pa	0.0032	0.0116	ns	0.59
Fgp	<0.0001	ns	ns	0.75
W1000	ns	<0.0001	ns	0.56
%St	ns	ns	ns	--

BiR3= aboveground biomass in panicle initiation (R3); NDVIR3= NDVI at R3; BiHa= biomass previous harvest; HI= harvest index; Yi= grain yield; Pa= panicles per area; Fgp= filled-grains per panicle; W1000= 1000 grains weight; % St= floret sterility; ns = no significant.

Relative to yield components, Pa was dependent on both density and N, with a positive response: higher density implied higher Pa, and the equivalent with N, with a maximum increase of 10% in both cases. However, Fgp was only affected by seed density and in an inverse relationship, associated to the number of Pa. On the other hand, W1000 was influenced just by N. Yet, floret sterility did not changed in a clear pattern with the analyzed variables.

Respect to Yi, both variables density and N were relevant. Higher plant density and higher N amounts increased Yi 9 % and 24%, respectively. In a more detailed analysis of the association between Yi and N, within each plant density level or in average, a linear regression was adjusted (Figure 2).

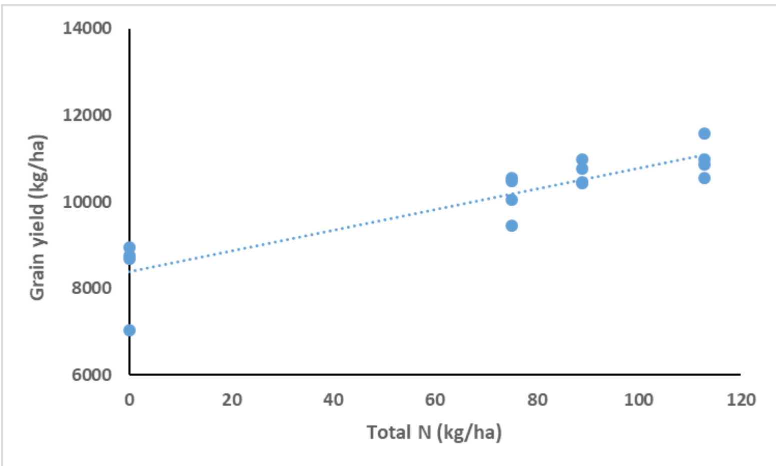

Figure 2. Linear regression between total N applied and grain yield for all plant densities, INIA Merín.

From an agronomic approach, it is known an excess of N could induce a decline in grain yield, due to different reasons (Dobermann and Fairhust, 2000). Therefore, a polynomial model would be more suitable, but higher N rates must be explored in order to know the point or region on the equation where the amount of N would be detrimental for Yi in INIA Merín. This concept is in accordance with Fabini et al (2020), where they could not find a detrimental N amount for this cultivar, also with 200 kg ha^{-1}, as it was reported for older ones, as INIA Olimar (Deambrosi and Mendez, 2007).

Conclusions

For most of the analyzed variables, this cultivar responded to nitrogen and seed density, but with different magnitudes. Plants per unit area and percent recovery were positive and inversely influenced by plant density, respectively. The plant density to achieve the optimal population of 200 to 250 plants m^{-2} for INIA Merín was among 105 and 155 kg ha^{-1} seeds, depending on the year.

Plant density affected biomass, grain yield and some yield components, as panicles per area and filled grains per panicle. On the other hand, N also affected biomass, NDVI, grain yield, panicle per area and 1000 grains weight. The magnitude of the N effect was higher than plant density, for most of the variables.

Grain yield was positively affected by both plant density and N, but yield increases were 9 % and 24% for both factors, respectively. Therefore, the relevance of N is undoubted. Moreover, the adjusted linear regression would imply INIA Merín could be able to explore higher yields if more N is applied. An even harvest index between 0.51 and 0.52 would assure that the additional biomass produced by an extra N availability for the crop, finally end in grain yield.

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