

RESEARCH PAPER

## Selection of rice genotypes (*Oryza sativa*) with high nitrogen agronomic efficiency in an Acuíc Durixererts soil, central-southern Chile

Celerino Quezada, Santiago Hernaíz, Iván Vidal, Roberto Alvarado, Rubén Gallegos, and Wilson Yañez

Departamento de Suelos y Recursos Naturales, Facultad de Agronomía, Universidad de Concepción. Casilla 537. Chillán, Chile.

### Abstract

**C. Quezada, S. Hernaíz, I. Vidal, R. Alvarado, R. Gallegos, and W. Yañez. 2013. Selection of rice genotypes (*Oryza sativa*) with high nitrogen agronomic efficiency in an Acuíc Durixererts soil, central-southern Chile. 40(2): 375-385.** Nitrogen agronomic efficiency (NAE) is a key factor that has not been considered in rice breeding programs. The objective of this study was to evaluate nitrogen agronomic efficiency in twenty rice genotypes in an Acuíc Durixererts soil (Quella Series) located in Chile's south central zone (36°04' S, 72° 0' W) over the 2008-09 growing season. The field experiment was carried out in a complete randomized split-plot block design with five N treatments of 0, 50, 100, 150 and 200 kg ha<sup>-1</sup> and twenty genotype sub-treatments. The following agronomic characteristics of the crops were measured: yield, grain fill percentage, and nitrogen agronomic efficiency. The N level had a significant effect on grain yield, NAE and the number of panicles per m<sup>2</sup>. Highly significant differences in all parameters evaluated were observed between genotypes. The nitrogen x genotype interaction had significant effects on plant height, 1000-grain weight and the grain fill percentage. The best performing rice genotypes were as follows: Quila 233006, Quila 223202, CINIA 857, and RQuila 17 with a 50 kg N ha<sup>-1</sup> dose and Ámbar, RQuila 17 and Quila 242105 with 100 kg N ha<sup>-1</sup> dose. These genotypes had high NAE and yield components that may be of use when producing new cultivars. Our results demonstrate the importance of selecting rice genotypes with greater NAE and considering this parameter when making N fertilizer recommendations.

**Key words:** Nitrogen agronomic efficiency, nitrogen dose, rice genotypes.

### Introduction

Nitrogen (N) is an essential nutrient for rice production. N is required during the vegetative

stage to promote growth and tillering, which determines the number of panicles (Samonte *et al.*, 2006). N is also as substrate for starch and protein synthesis during grain development (Jiang *et al.*, 2004). Excessive application of N can have negative effects on sustainable agricultural development (Jian-feng *et al.*, 2011). Rice breed-

ers do not consider nitrogen agronomic efficiency (NAE) as a selection criterion when growing new crops, even though this trait has both economic and ecological implications (Samonte *et al.*, 2006).

Nitrogen use efficiency in cereal production worldwide is approximately 33%; this is due to the loss of N fertilizer from gaseous plant emissions, soil denitrification, surface runoff, volatilization and leaching (Raun and Johnson, 1999; Zhao *et al.*, 2012). The high input rate and the improper timing of N application by farmers results in a low NAE for irrigated rice in China (Peng *et al.*, 2006). Continued efforts are required to select for plants under low N, which is not often considered a priority by plant breeders (Raun and Johnson, 1999).

The yield increase that results from N application is defined as the NAE (kg increase in grain per kg N applied). The plant response to fertilizer is the result of genetic characteristics and crop management (Peng *et al.*, 2006). Timsina *et al.* (2001) emphasized that to develop cultivars for productivity and N-use efficiency, it is necessary to monitor weather and measure crop performance, water irrigation, and soil and plant mineral N. The translocation, distribution and remobilization of absorbed N in different plant organs must also be understood (Ladha *et al.*, 1998; Jiang *et al.*, 2004). Increasing NAE depends on the field-specific management of N and the use of systems that are responsive to soil N supply and plant N status (Cassman *et al.*, 1998).

NAE is determined by the indigenous nutrient supply, the application of fertilizer, crop management practices and climate conditions. According to Tirol-Padre *et al.* (1996), efficient genotypes are those that produce high grain yields at sub-optimal N levels through increased N uptake and/or more efficient N utilization. For cereals in developing countries, NAE ranged between 10 and 30 kg kg<sup>-1</sup> and could reach > 25 kg kg<sup>-1</sup> in a well-managed system with low levels of N use (Chuan *et al.*, 2013). Cassman *et al.* (1998)

found that Asian farmers in irrigated rice systems achieved an NAE of 15.3 kg kg<sup>-1</sup> with standard practices and reached 23.7 kg kg<sup>-1</sup> with improved nitrogen management using a chlorophyll meter.

The global demand for N fertilizer is consistently increasing, driven mainly by cereal production. Globally, approximately 40% of the human population relies on N fertilizer for food production. The use of such a large amount of N fertilizer takes a heavy toll on the health of the environment because the average NAE in an agricultural field is 33% (Ahmad *et al.*, 2008). An increase in grain yield and grain nitrogen use efficiency is an important objective of many rice breeding programs (Wei *et al.*, 2011; Haefele *et al.*, 2008). It is also important to obtain the greatest grain yield potential in rice crops (Jiang *et al.*, 2004) and reduce N-fertilizer requirements to protect the environment (Ladha *et al.*, 1998).

Chilean rice crops are cultivated in a permanent 10-20 cm depth flood system. This system results in significant N losses by leaching, denitrification and volatilization; volatilization alone accounts for a 30-40% loss of applied N (Fillery *et al.*, 1986). To ensure an adequate supply of N throughout the growing season, N is applied as urea into floodwater during sowing, tillering and panicle initiation. Khurana *et al.* (2008) state that site-specific nutrient management leads to an increase in NAE.

Low rice fertility in soils and the high cost of fertilizer make it necessary to select rice crops that not only produce high yield but also use N efficiently, thereby producing grains with higher protein concentration (Samonte *et al.*, 2006). An increase in cereal NAE can be obtained by using varieties with a high harvest index (Raun and Johnson, 1999), applying partial N, and further selecting stable genotypes under different nitrogen environments (Duan *et al.*, 2007). The objective of this study was to evaluate performance, yield components and agronomic characteristics in an Aquic Durixererts soil to identify crops with high NAE.

## Materials and methods

### *Site description*

A field experiment was carried out at the Digua Experimental Station (36°04'S, 72° 0'W, 140 masl) in Parral, Chile during the 2008-09 growing season. This soil is classified as very fine, smectitic, thermic Aquic Durixererts (Quella Series) and is derived from volcanic tuff. The soil is shallow (50 cm-depth) with poor drainage and low run off. The soil texture is classified as clay with an angular blocky structure and dark gray color, and the topography is nearly level and undulating (Stolpe, 2006). The soil had a pH of 5.76 and contained the following components: organic matter (2.34%), nitrogen (7 mg kg<sup>-1</sup>), phosphorous (6.61 mg kg<sup>-1</sup>), potassium (62.7 mg kg<sup>-1</sup>) and incubated nitrogen (10 mg kg<sup>-1</sup>). The climate is Warm Mediterranean with a 983 mm annual rainfall; approximately 65 to 70% of the precipitation occurs between May and August. The annual potential evapotranspiration is 840 mm, with a 4- to 5-month dry period and 4 to 5 frost-free months. The annual temperature is 14.2 °C; the coldest month (July) has a temperature of 4.2 °C, and the hottest month (January) has a temperature of 29.5 °C. The average annual relative humidity is 62.7% (Del Pozo and Del Canto, 1999).

### *Experimental design*

The field experiment was carried out using a completely randomized split-plot block design, consisting of five treatments (N doses), twenty sub-treatments (rice genotypes) and four replications. The following N doses were used: 0, 50, 100, 150 and 200 kg ha<sup>-1</sup>. The following rice genotypes were studied: Diamante, Brillante, Ámbar, Zafiro, Cuarzo, RQuila 28, CINIA 857, Dmu 81m, Quila 201704, Quila 223202, Quila 242415, Quila 233006, Quila 233008, Quila 242101, Quila 242105, RQuila 17, Quila 199604, Quila 157302, Quila 121304 and Quila 156906. Plot sizes were

57.4 m<sup>2</sup> (8.2 × 7.0 m) in the main plots and 1.21 m<sup>2</sup> (1.1 × 1.1 m) in the sub-plots. The total area of the field experiment was 1,091 m<sup>2</sup>.

### *Crop management*

Rice was sowed on October 29<sup>th</sup> on a soil flooded with 5-cm water using 160 kg ha<sup>-1</sup> of pre-germinated seed per dose. N fertilizer in the form of urea was applied as follows: 1/3 was applied during sowing, 1/3 was applied during tillering and 1/3 was applied at panicle initiation. At sowing, phosphorous (100 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> as superphosphate) and potassium (100 kg K<sub>2</sub>O ha<sup>-1</sup> as muriate of potash) were applied to all treatments. Zinc (5 kg Zn ha<sup>-1</sup> as zinc sulfate) and boron (5 kg B ha<sup>-1</sup> as calcite boronate) were also applied because a soil chemical analysis showed zinc and boron deficiency with values below 1 mg kg<sup>-1</sup> (Hirzel, 2007). All fertilizers were applied by hand broadcasting. Weeds were controlled at the initiation of tillering by applying Penoxsulam (200 g L<sup>-1</sup>) at 200 cc ha<sup>-1</sup> and MCPA at 0.7 L ha<sup>-1</sup>. The water level was kept at 10 cm above the soil surface until plant maturity.

### *Crop measurements*

The following measurements were made in this field experiment: rice plants per m<sup>2</sup>, panicle number per m<sup>2</sup>, plant height and days to flowering. Plants per m<sup>2</sup> and panicle number per m<sup>2</sup> were sampled using a metal cylinder (0.1 m<sup>2</sup>) located in each plot, and separation was performed by hand-threshing. Plant height in centimeters and days to flowering were recorded for five individual plants in the middle of each sub-plot; this was considered representative of the rice-growing conditions. Mature samples were arranged (0.49 m<sup>2</sup>) and measured with a portable sensor (Satake Moistex, SS, Satake Corporation, Tokyo, Japan) in the center of each plot containing 23% moisture. Plants were air dried for two days, weighed on an electronic balance (Ohaus,GT-800, Ohaus Corporation, Ohio, USA) and finally processed in a

stationary thresher with 15% rice grain moisture obtained using a sensor (Burrows, DMC- 700, Seedburo Equipment Company, Chicago, USA).

Grain yield ( $\text{t ha}^{-1}$ ) was determined by weighing the paddy rice using an electronic balance (Sartorius, 1216-MP, Sartorius GMBH, Göttingen, Germany). The 1000-grain weight was determined by weighing 1000 grains from each genotype in triplicate using an electronic balance (Sartorius, 1216-MP, Sartorius GMBH, Göttingen, Germany). The filled grain fraction was sieved in a 2.0 mm calibrator, and a 100 g sample was processed in a mill test (Suzuki, MT, Máquinas Suzuki S.A., Santa Cruz do Rio Pardo, Brazil). White grain rice was obtained by separating and filling the broken grains with a fraction separator (Satake, TRG, Satake Corporation, Tokyo, Japan). The harvest index (HI) was calculated by dividing the grain yield (paddy rice) by the biomass (grain + straw).

#### Nitrogen agronomic efficiency (NAE)

The NAE was calculated by dividing the total grain yield per nitrogen dose applied using the following relationship:

$$\text{NAE} = (Y_n - Y_0) / N$$

where: NAE: nitrogen agronomic efficiency ( $\text{kg grain yield per kg}^{-1}$  N applied);  $Y_n$ : grain yield with N ( $\text{kg ha}^{-1}$ );  $Y_0$ : grain yield without N ( $\text{kg ha}^{-1}$ ); N: N dose ( $\text{kg ha}^{-1}$ ).

#### Statistical analysis

All data were exposed to an analysis of variance (ANOVA). Significant differences among treatments, genotypes and interactions were determined by a least significant difference test (LSD) at a 5% level of significance ( $P \leq 0.05$ ) using the Statistical Analysis System (SAS Institute. 1998. UNIX Environment and derivatives. Version 6. SAS Institute Inc., Cary, North Carolina, USA).

## Results and discussion

### Nitrogen dose

Table 1 shows the variance analysis for the yield components, agronomic characteristics and NAE. The N dose had significant effects ( $P \leq 0.05$ ) on the number of panicles per  $\text{m}^2$ , NAE, grain yield, plant height, 1000-grain weight and the grain fill percentage. The N dose did not have significant effects on days to flowering, plants per  $\text{m}^2$  and the harvest index. Genotypes showed highly significant differences ( $P \leq 0.01$ ) in all nitrogen parameters evaluated. The  $N \times$  genotype interaction ( $N \times G$ ) had significant effects only on plant height, 1000-grain weight and grain fill percentage. Similar results were obtained by Belder *et al.* (2004); the harvest index and biomass was not affected by N level.

### Genotype

Rice genotypes had significant differences in plants per  $\text{m}^2$ , panicles per  $\text{m}^2$ , days to flowering, harvest index, NAE and grain yield (Table 2). The genotypes Quila 15690, Diamante, and Ámbar had a greater number of plants per  $\text{m}^2$ , at 417, 380

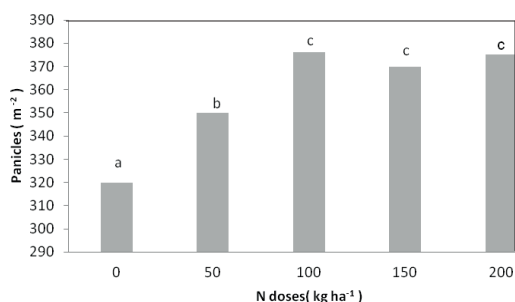
**Table 1.** Yield component variance analysis, agronomic characteristics and nitrogen agronomic efficiency in twenty rice genotypes.

Variable	N	G	NxG	CV (%)
Plants $\text{m}^{-2}$	ns	**	ns	27.3
Panicles $\text{m}^{-2}$	**	**	ns	13.1
Days to flowering	ns	**	ns	2.6
Harvest index	ns	**	ns	6.71
NAE	*	**	ns	40.7
Grain yield	**	**	ns	15.4
Plant height	**	**	*	5.22
1000-grain weight	*	**	*	4.1
Grain fill	**	**	*	8.6

(\*): significant differences; (\*\*): highly significant difference; (ns): no significant difference; N: nitrogen; G: genotype; CV: coefficient of variation.

and 379, respectively. The number of panicles is the greatest yield factor (Sun *et al.*, 2012); in this study, the genotypes Ámbar, Quila 242105 and Quila 242101 had greater panicle numbers per m<sup>2</sup>, at 431, 428 and 422, respectively. For most genotypes, flowering occurred between 87 and 95 days after sowing. Quila 199604 and Quila 157302 had the shortest flowering times at 87 and 88 days, respectively.

Regarding the harvest index (HI), our results indicated that increases in cereal NAE can be obtained in varieties with high HI. The rice genotypes Ámbar, Quila 233006, and Quila 233202 had higher HI at 0.53 kg grain per kg total dry biomass. These HI measurements were greater than those obtained by Mahajan *et al.* (2012), which ranged from 0.35 to 0.42. According to Inthapanya *et al.* (2000), this result suggests that cultivars with high HI are more efficient in nutrient use and perform well in different fertility conditions.



**Figure 1.** Panicle numbers from twenty rice genotypes with five doses of N in an Acuíc Durixererts soil in Parral, Chile. Different letters indicate significant differences ( $P \leq 0.05$ ) according to a LSD test. LSD: least significant difference.

The genotypes with the best grain yield were Brillante, Ámbar, Quila 242101 and Quila 242105 with yields of 11.2; 11.1; 10.7 and 10.6 t ha<sup>-1</sup>, respectively. The rice genotypes Ámbar, Quila 233006, RQuila 17 and Quila 223202 obtained higher NAE measured at 47.7, 44.6, 43.8 and 42.6 kg grain kg<sup>-1</sup> N, respectively.

**Table 2.** Plants m<sup>-2</sup>, panicles m<sup>-2</sup>, days to flowering, harvest index (HI), nitrogen agronomic efficiency (NAE) and grain yield in twenty rice genotypes with five doses of N in an Acuíc Durixererts soil in Parral, Chile.

Genotype	Plants m <sup>-2</sup>	Panicles m <sup>-2</sup>	Days to flowering	HI	NAE (kg grain kg <sup>-1</sup> N)	Grain yield (t ha <sup>-1</sup> )
Ámbar	379.0 ab <sup>1</sup>	431.0 a	92.0 de	0.53 ab*	47.7 a	11.1 ab
Quila 233006	269.0 d	350.0 gh	92.0 cde	0.53 a	44.6 ab	10.0 cdef
RQuila 17	324.0 bcd	351.0 gh	91.0 e	0.49 def	43.8 abc	9.9 cdef
Quila 223202	363.0 abc	398.0 bcd	89.0 f	0.53 ab	42.6 abc	10.4 abcde
Quila 121304	314.0 cd	375.0 defg	93.0 bcd	0.51 bcd	41.7 abcd	10.2 bcde
RQuila 28	376.0 ab	396.0 cd	93.0 bcd	0.48 efg	41.5 abcde	9.1 fg
CINIA 857	354.0 bc	387.0 de	92.0 de	0.50 cde	41.5 abcde	10.4 abcde
Cuarzo	356.0 bc	375.0 defg	93.0 bcd	0.52 abc	40.6 abcde	10.1 bcde
Quila 242105	326.0 bcd	428.0 ab	93.0 bcd	0.52 abc	39.8 abcdef	10.6 abcd
Quila 242101	351.0 bc	422.0 abc	95.0 a	0.52 abc	38.0 abcdefg	10.7 abc
Quila 201704	349.0 bc	364.0 efg	89.0 f	0.46 gh	37.2 abcdefg	8.8 gh
Diamante	380.0 ab	349.0 gh	94.0 abc	0.47 fgh	37.0 abcdefg	9.9 cdef
Brillante	325.0 bcd	331.0 hi	93.0 bcd	0.53 a	36.0 abcdefg	11.2 a
Zafiro	306.0 cd	353.0 fgh	93.0 bcd	0.50 cd	34.0 abcdefg	9.8 cdef
Quila 157302	351.0 bc	356.0 fgh	88.0 fg	0.46 hi	33.6 cdefg	7.9 ih
Quila 156906	417.0 a	363.0 efg	89.0 fg	0.49 def	31.2 defg	9.6 fg
Quila 242415	353.0 bc	370.0 defg	89.0 fg	0.46 gh	30.9 efg	8.0 ih
Quila 199604	322.0 bcd	318.0 i	87.0 g	0.44 i	30.9 efg	7.4 i
Quila 233008	315.0 cd	382.0 def	94.0 ab	0.52 abc	29.5 fg	9.7 def
Dmu 81m	324.0 bcd	370.0 defg	93.0 bcde	0.49 def	29.2 g	9.1 fg
LSD G	58.2	30.4	1.0	0.02	10.7	0.9

<sup>1</sup>Means with different letters in columns indicate significant differences ( $P \leq 0.05$ ) according to a LSD test; LSD: least significant difference; HI: harvest index; N: nitrogen.

N dose had a significant effect on the number of panicles per m<sup>2</sup> up to 100 kg N ha<sup>-1</sup>; at 150 and 200 kg N ha<sup>-1</sup>; however, no significant difference in panicle number was observed (Figure 1). According to Bond *et al.* (2008), this result indicates that rice breeding has decreased the nitrogen load in soils with low natural fertility. Hirzel (2007) suggested that this is because of the second application of N at the tillering initiation stage stimulates panicle production.

#### Nitrogen (N) × genotype (G) interaction

The interaction of N × G had significant effects only on the plant height, 1000-grain weight and grain fill percentage. All genotypes had an increase in plant height (Table 3) as the N dose increased; each genotype had a unique response. The greatest significant differences in plant height were obtained between 0 and 50 kg N ha<sup>-1</sup>. For most genotypes, plant height values ranged from 2

and 11 cm. In the genotypes Quila 201704, Quila 233008 and RQuila 28 genotypes, the plant height values were below the average.

Genotypes showed differential responses in plant height values. Diamante, Quila 201704, Brillante, and Dmu 8 m had increases in plant height at N doses greater than 100 kg N ha<sup>-1</sup>. Quila 233008 and Quila 223202 did not show significant increases in plant height at N doses greater than 100 kg N ha<sup>-1</sup>. This varietal characteristic is important in determining grain yield; short cultivars had greater grain yields (7.5 t ha<sup>-1</sup>) than tall cultivars (6.7 t ha<sup>-1</sup>) and avoid lodging due to heavy rain and wind (Koutroubas and Ntanos, 2003; Timsina *et al.*, 2001)

The 1000-grain weight of the twenty rice genotypes at the five N doses is summarized in Table 3. The results are similar to those for cultivars used in Chile (27-33 g), (Alvarado and Hernaiz, 2007a). The 1000-grain weight for

**Table 3.** Plant height, 1000-grain weight and grain fill percentage in twenty rice genotypes with five doses of N in an Acuífero Durixerets soil in Parral, Chile.

Genotype	Plant height(cm)					1000-grain weight (g)					Grain fill percentage (%)				
	N <sub>0</sub>	N <sub>50</sub>	N <sub>100</sub>	N <sub>150</sub>	N <sub>200</sub>	N <sub>0</sub>	N <sub>50</sub>	N <sub>100</sub>	N <sub>150</sub>	N <sub>200</sub>	N <sub>0</sub>	N <sub>50</sub>	N <sub>100</sub>	N <sub>150</sub>	N <sub>200</sub>
Quila 199604	59.5d <sup>1</sup>	65.5c	68.0abc	69.3a	68.5ab	37.1a	34.0c	38.0a	37.2ab	36.9b	28.9g	37.5j	39.5i	40.2j	47.5h
RQuila 17	64.8c	68.8b	74.0a	76.3a	75.8a	37.4a	36.8b	36.1b	34.7c	33.5d	53.2cde	56.1bcde	64.2a	65.7a	62.7abc
Diamante	64.3d	67.0c	72.0b	78.8a	79.5a	36.8a	36.7a	35.3b	34.3b	34.5b	55.4bc	58.6b	63.5ab	65.4ab	65.5a
Quila 121304	59.3d	68.0c	71.0b	68.5bc	73.8a	37.1a	35.2bc	34.6c	34.3c	35.7b	55.4bc	58.4b	63.3abc	63.6abcd	63.7ab
Zafiro	59.5d	63.3c	69.3b	73.3a	73.8a	35.9a	36.1a	35.2ab	34.4bc	33.4c	58.6b	57.4bc	62.2abc	65.2ab	64.5a
Dmu 81m	57.8d	67.3c	69.5bc	71.5b	75.3a	35.8a	35.3ab	34.6bc	34.2c	34.3bc	54.2cd	58.2b	61.1abc	64.1abcd	64.8a
Cuarzo	59.5d	62.8c	70.5b	70.5b	73.8a	36.4a	35.1b	35.2b	34.2b	32.9c	51.3de	56.7bcd	59.7cd	60.9fde	62.3abcd
Brillante	57.8c	67.3b	69.5b	75.0a	75.5a	35.6a	35.6a	34.8a	33.3b	32.3b	55.7bc	56.6bcde	60.6bc	62.1bcde	63.2abc
CINIA 857	60.3c	66.5b	70.5a	71.3a	72.0a	34.4ab	34.7a	34.8a	33.6bc	32.9c	52.4cde	53.7def	60.5bc	64.5abc	60.0fde
Quila 233006	61.0c	66.5b	68.0ab	69.8a	69.0ab	33.2ab	33.6a	33.8a	33.2ab	32.3b	43.7f	45.9h	50.4g	58.2fg	59.1fde
Quila 223202	63.3c	74.5a	75.0a	71.5b	76.0a	30.6a	30.8a	30.7a	31.5a	30.6a	51.8de	49.2hg	50.5g	53.2i	48.9h
Quila 242105	57.0b	62.3a	62.8a	63.3a	64.3a	30.8ab	31.6a	30.4b	30.5b	30.2b	53.1cde	57.9bc	57.1de	57.1gh	57.5fg
Quila 242101	55.5c	58.3b	64.3a	59.8b	62.5a	31.3a	31.3a	30.8a	30.5a	28.9b	52.5cde	58.4b	54.5fe	60.2fge	49.6h
Quila 233008	63.8d	64.8cd	68.5bc	65.5bc	69.8ab	30.5ab	29.8bc	30.8a	29.6bc	29.4c	51.8de	53.2ef	51.7fg	54.2hi	57.7fg
Quila 201704	68.0d	69.3cd	71.5bc	72.3a	75.5a	30.1ab	30.5a	29.4b	29.2b	30.5a	52.7cde	51.8fg	55.9e	59.2fge	55.2g
Quila 157302	53.0c	65.8ab	69.3a	69.8a	69.3a	30.2a	28.8b	29.1b	28.8b	29.3ab	40.1f	42.1i	46.7h	52.0i	48.7h
Quila 156906	59.8d	67.3c	72.5a	72.0ab	69.8bc	28.3abc	29.3a	29.0ab	27.8c	28.0bc	40.9f	40.0ij	50.0gh	52.5i	55.2g
RQuila 28	56.3b	58.8b	68.0a	66.5a	66.3a	30.4a	29.2b	27.9c	26.9c	27.4c	62.6a	63.2a	63.8ab	65.5a	65.4a
Ámbar	54.0 d	59.0c	60.5bc	63.3a	62.3ab	27.6bc	27.8ab	28.7a	27.7abc	26.8c	50.2de	56.8bcd	62.4abc	61.6cde	60.8bcde
Quila 242415	57.0b	62.3a	62.8a	63.3a	62.3ab	27.3ab	27.3a	26.3b	26.3ab	25.8b	54.3cd	54.8cdef	57.0de	54.1hi	57.9fge
LSD N × G			2.46					1.01						3.4	

<sup>1</sup>Means with different letters in rows indicate significant differences (P≤0.05) according to a LSD test; LSD: least significant difference; N<sub>0</sub>: nitrogen dose.



Quila 223202 did not change with increasing N doses. The 1000-grain weight for RQuila 17 declined significantly with increasing N doses. The 1000-grain weight decreased with increasing N doses of up to 100 kg N ha<sup>-1</sup> in Diamante and up to 150 kg N ha<sup>-1</sup> in Brillante. The value of this parameter ranged from 25.8 to 38.0 g but decreased when N doses higher than 100 kg N ha<sup>-1</sup> were used. These results could be attributed to an increase total number of grains per panicle, a decrease in panicle length and lighter grains (Koutroubas and Ntanos, 2003; Sun *et al.*, 2012). The results support those of Kato *et al.* (2009), who obtained a 1000-grain weight between 24.7 to 35.6 g when applying 180 kg N ha<sup>-1</sup> in a Typic Fluvaquent soil.

N had a significant effect of on the grain fill percentage in the genotype RQuila 28 compared to the other genotypes evaluated. RQuila 28 had 62.6 and 63.2% grain fill at 0 and 50 kg of N ha<sup>-1</sup>, respectively (Table 3). At a dose of 100 kg N ha<sup>-1</sup>, RQuila 17 had a higher grain fill percentage (64.2%). Grain fill was not significantly different in the following genotypes: Rquila 28, Diamante, Quila 121304, Ámbar, Zafiro and Dmu 81m.

At the 150 kg N ha<sup>-1</sup> dose, RQuila 17 had a greater grain fill percentage (65.7%). Grain fill was not significantly different in the genotypes RQuila 28, Diamante, Zafiro, CINIA 857, Dmu 81m and Quila 121304 at this dose. Diamante had the highest grain fill percentage (65.5%) at a dose of 200 kg of N ha<sup>-1</sup>; however, grain fill was not significantly different in RQuila 28, Dmu 81m, Zafiro, Quila 121304, Brillante, RQuila 17 and Cuarzo.

In this study, the percentage of grain fill ranged from 28.9% in Quila 199604 at 0 kg N ha<sup>-1</sup> to 65.7% in RQuila 17 at 150 kg N ha<sup>-1</sup>. This result illustrates the genotypic differences observed. At a low dose of N, only the R Quila 28, CINIA 857, Brillante, RQuila17 genotypes had up to 60% grain fill and plant characteristics that were desirable in selected genotypes with higher NAE. In general, the percentage of grain fill decreased

at N doses higher than 100 kg N ha<sup>-1</sup>. This result was most likely due to the excessively absorbed N being allocated to straw over grain (Jian-feng *et al.*, 2011).

N fertilization had a positive effect on the grain fill percentage. A genotype analysis revealed that only RQuila 28 had grain fill greater than 60% at 0 and 50 kg N ha<sup>-1</sup>. According to Alvarado and Hernaíz (2007b), these differences are not only caused by nitrogen but also by other factors, such as the cultivar, the climate conditions between flowering and harvest, the harvesting system and grain moisture.

#### *Grain yield and NAE*

Interaction effects between G and N were not significant for grain yield and NAE. Similar results were obtained by Singh *et al.* (1998). Grain yield and NAE for twenty rice genotypes and five N doses are summarized in Table 4. Grain yield was positively correlated with N dose, except between 100 and 150 kg N ha<sup>-1</sup> (Figure 2). Similar results were reported by Poshtmasari *et al.* (2007), who found significant grain yield increases in genotypes at a 200 kg N ha<sup>-1</sup> dose. In contrast, Singh *et al.* (1998) found no significant increase in grain yield between 150 to 200 kg N ha<sup>-1</sup>. Lodging occurred in some genotypes, and spikelet sterility was high in the aforementioned study. Mahajan *et al.* (2012) reported that the application of more than 120 kg N ha<sup>-1</sup> did not show any advantage in terms of N use and yield.

NAE decreased when N application was between 50 and 200 kg N ha<sup>-1</sup> (Figure 3). This is in agreement with results from Ohnishi *et al.* (1999) and Peng *et al.* (2007). The lower NAE in rice at 150 and 200 kg N ha<sup>-1</sup> suggests that there are no yield benefits from additional application of N above 100 kg ha<sup>-1</sup> (Timsina *et al.*, 2001). This result indicates that in genotypes with differences in NAE, the changes are due to biochemical and physiological characteristics, root uptake, re-

**Table 4.** Rice grain yield and nitrogen agronomic efficiency (NAE) in twenty rice genotypes with five doses of N in an Acuí Durixererts soil in Parral, Chile.

Genotype	Grain yield (t ha <sup>-1</sup> )					NAE (kg grain kg <sup>-1</sup> N)			
	N <sub>0</sub>	N <sub>50</sub>	N <sub>100</sub>	N <sub>150</sub>	N <sub>200</sub>	N <sub>50</sub>	N <sub>100</sub>	N <sub>150</sub>	N <sub>200</sub>
Quila 199604	5.4	8.1	8.3	10.4	9.7	48.56	26.14	29.76	19.17
RQuila 17	6.6	9.5	12.7	12.1	14.9	51.16	54.58	32.78	36.80
Diamante	7.2	9.5	12.0	12.5	14.3	41.20	43.25	31.73	31.84
Quila 121304	7.0	9.4	13.1	13.8	14.0	42.86	53.41	39.92	30.75
Zafiro	6.4	7.8	10.1	12.4	12.4	29.02	37.13	39.73	30.11
Dmu 81m	7.5	9.7	11.7	11.7	10.8	39.80	37.27	24.83	14.75
Cuarzo	6.5	9.4	11.5	9.9	13.4	56.20	49.43	22.66	34.08
Brillante	8.8	11.1	13.6	13.6	16.1	40.90	42.76	28.25	32.24
CINIA 857	7.7	11.3	12.5	13.4	13.4	64.29	42.66	33.79	25.17
Quila 233006	6.9	10.5	12.2	12.7	14.9	63.42	46.64	33.64	34.85
Quila 223202	7.6	11.1	12.2	12.7	14.9	63.81	41.31	29.69	35.64
Quila 242105	8.1	10.6	14.6	14.1	13.5	43.81	56.87	39.48	23.64
Quila 242101	8.1	10.5	12.7	14.7	15.2	42.21	40.42	38.04	31.44
Quila 233008	8.0	9.8	12.4	12.5	13.1	31.39	38.10	26.36	22.24
Quila 201704	6.1	8.7	10.2	13.0	11.4	46.53	36.99	41.31	24.05
Quila 157302	5.6	8.4	10.3	6.9	11.1	48.62	40.17	21.75	23.93
Quila 156906	9.4	9.0	11.9	12.2	13.6	28.37	40.53	28.43	27.53
RQuila 28	6.5	10.1	12.1	11.5	11.2	64.19	50.28	30.32	21.21
Ámbar	7.2					41.69			45.09
Media	6.3 a <sup>1</sup>	9.6	14.6	14.0	17.5	46.27 a	64.46	39.70	28.30 c
LSD N x G	0.91	8.6 b	10.7 c	11.0 c	11.9 d	11.84	44.02 b	31.72 c	

<sup>1</sup>Means with different letters in the rows indicate significant differences ( $P \leq 0.05$ ) according to a LSD test; LSD: least significant difference; N<sub>0</sub>: nitrogen dose.

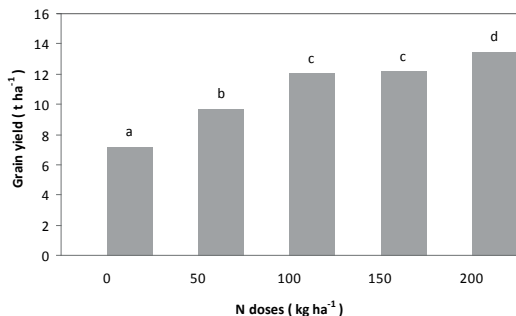
mobilization and translocation of absorbed N to different plant organs (Ladha *et al.*, 1998), plant density, micronutrient deficiency (Hossain *et al.*, 2005) and soil type.

Table 4 shows that the NAE of the twenty rice genotypes varied between 14.75 and 64.46 kg grain kg<sup>-1</sup> N. These results are in agreement with the those reported by Samonte *et al.* (2006), who reported NAE between 25.3 and 63.9 kg grain kg<sup>-1</sup> N. According to Fageria and Barbosa (2001) and Ahmad *et al.* (2008), the genotypes that produce high grain yields in a lower N and respond well to added N are the most desirable; these genotypes can be grown with a limited N supply for environmentally friendly farming systems. The rice genotypes Ámbar, Quila 233006, Quila 223202, CINIA 857 and RQuila 17 had greater NAE values at lower N doses.

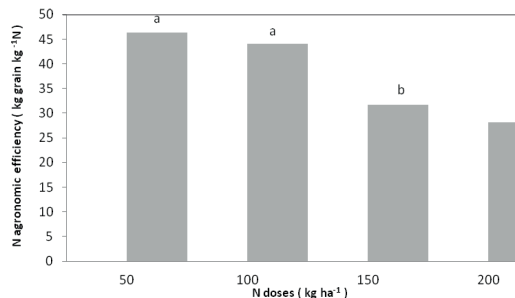
In this study, the genotypes were selected ac-

ording to NAE, 1000-grain weight and grain fill percentage. The best rice genotypes were as follows: Quila 233006, Quila 223202, CINIA 857 and RQuila28 at a dose of 50 kg N ha<sup>-1</sup> and Ámbar Quila 17 and Quila 242105 at a dose of 100 kg N ha<sup>-1</sup>. These genotypes had a NAE average of 64 kg grain kg<sup>-1</sup> N, a 1000-grain weight of 32 g and 53% grain fill at 50 kg N ha<sup>-1</sup>; RQuila 28 had a grain fill of 63.2%. At the 100 kg N ha<sup>-1</sup> dose, the best genotypes had a NAE value of 59 kg grain kg<sup>-1</sup> N, a 1000-grain weight of 32 g and a 61% grain fill. Quila 223202 had high NAE (63.81 kg grain kg N ha<sup>-1</sup>) at 50 kg N ha<sup>-1</sup>, but not selected due to a low grain fill percentage (49.2%). In general, these rice genotypes revealed yield components that may be of interest when developing new cultivars. Samonte *et al.* (2006) reported that a rice genotype with a higher N translocation ratio would be desirable if it was capable of remobilizing N into the grain during





**Figure 2.** Grain yield of twenty rice genotypes with five doses of N in an Acuíc Durixererts soil in Parral, Chile. Different letters indicate significant differences ( $P \leq 0.05$ ) according to a LSD test. LSD: least significant difference.



**Figure 3.** Nitrogen agronomic efficiency (NAE) in twenty rice genotypes with five doses of N in an Acuíc Durixererts soil in Parral, Chile. Different letters indicate significant differences ( $P \leq 0.05$ ) according to a LSD test. LSD: least significant difference.

grain fill.

This study demonstrated that the application of N improved grain yield, panicle number and grain fill percentage but had negative effects on plant height, 1000-grain weight and NAE. The genotypes selected had greater NAE at doses of 50 and 100 kg N ha<sup>-1</sup>. The interaction between nitrogen x genotype had a significant effect only on plant height, 1000-grain weight and grain fill percentage. Among the genotypes evaluated, Quila 233006, Quila 223202, CINIA 857 and RQuila17 at 50 kg N ha<sup>-1</sup> and Ámbar, RQuila 17 and Quila 242105 at 100 kg N ha<sup>-1</sup>

had high NAE and yield components that may be of use when developing new cultivars. Our results demonstrate the importance of selecting rice genotypes with greater NAE and the consideration of this parameter when making N fertilizer recommendations.

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### Resumen

**C. Quezada, S. Hernaíz, I. Vidal, R. Alvarado, R. Gallegos y W. Yañez. 2013. Selección de genotipos de arroz (*Oryza sativa* L.) con alta eficiencia agronómica de nitrógeno en un suelo Acuíc Durixererts, en la zona centro – sur de Chile. Cien. Inv. Agr. 40(2): 375-385.** La eficiencia agronómica de nitrógeno (EAN) es un factor importante que no ha sido considerado en los programas de mejoramiento del cultivo de arroz. El objetivo de esta investigación fue evaluar la eficiencia agronómica del nitrógeno en veinte genotipos de arroz en un suelo Acuíc Durixererts (Serie Quella), ubicado en la zona centro sur de Chile (36°04' S, 72° 0' W) durante la temporada 2008-2009. El diseño experimental fue de bloques completos al azar con arreglo de parcelas divididas, conformado por cinco tratamientos de dosis de nitrógeno de 0, 50, 100, 150 y 200 kg ha<sup>-1</sup> y veinte genotipos de arroz. Se evaluó rendimiento y sus componentes, características agronómicas, porcentaje de grano lleno y EAN. El nivel de nitrógeno tuvo

un efecto significativo en rendimiento de grano, EAN y número de panículas por m<sup>2</sup>. Los genotipos presentaron diferencias altamente significativas en todos los parámetros evaluados. La interacción Nitrógeno × Genotipo tuvo efecto significativo en altura de plantas, peso de 1.000 granos y porcentaje de grano lleno. Los genotipos de arroz con mejor comportamiento fueron Quila 233006, Quila 223202, CINIA 857 y RQuila17, con dosis de 50 kg N ha<sup>-1</sup> y Ámbar, RQuila 17 y Quila 242105, con dosis de 100 kg N ha<sup>-1</sup>, por presentar alta EAN y componentes de rendimiento destacados para producir nuevas variedades. Los resultados demuestran la importancia de seleccionar genotipos de arroz con mayor EAN y considerar este parámetro en las recomendaciones de fertilización nitrogenada.

**Palabras clave:** Dosis nitrógeno, eficiencia agronómica del nitrógeno, genotipos de arroz.

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