AGRONOMIC EFFICIENCY AND GRAIN QUALITY OF UPLAND RICE CULTIVARS AS A FUNCTION OF NITROGEN TOPDRESSING

EFICIÊNCIA AGRONÔMICA E QUALIDADE DO GRÃO EM CULTIVARES DE ARROZ DE TERRAS ALTAS EM FUNÇÃO DO NITROGÊNIO EM COBERTURA

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ABSTRACT: This study aimed to evaluate the agronomic efficiency and grain quality of rice cultivars as a function of nitrogen application in upland conditions with supplemental sprinkler irrigation. The experiment was carried out in 2012/13 at Jaboticabal-SP on a randomized block and split plots design with four replications. The plots were composed of twelve rice cultivars (BRS Aroma, BRS Monarca, BRS Primavera, BRS Sertaneja, BRSMG Curinga, Caiapó, CIRAD 141, Guarani, IAC 165, IAC 201, IAC 202, and IAC 25), and two levels of nitrogen application (0 and 100 kg of N ha^{-1}) in topdress at the R_1 stage (panicle differentiation) as subplots. The N application intensifies the degree of lodging, mainly at Caiapó, Guarani, IAC 165, IAC 201 and IAC 25 cultivars. The N application affects the number of sterile spikelets per panicle, mainly in CIRAD 141, BRS Sertaneja, IAC 202, and BRS Aroma cultivars. Caiapó cultivar shows higher grain yield and agronomic efficiency in function of N application, followed by BRS Monarca, BRSMG Curinga, IAC 165, and IAC 202. Although Caiapó, CIRAD 141, Guarani, IAC 165, IAC 202, and IAC 25 cultivars present better results, all the others cultivars also present acceptable values of milling yield, without N application effects. The grain protein content in rice is increased by the N topdressing application.

KEYWORDS: *Oryza sativa*. Sprinkler irrigation. Yield components. Nutritional quality and technology.

INTRODUCTION

In Latin America, Brazil stands out as the only region with potential to increase rice production and meet the future demand, corresponding to 1.53% of area and 1.69% of world production, and is the largest producer among the South American countries, accounting for 55% of the production (USDA, 2013). In the agricultural year 2011/12, rice occupied a total area of 2,427.1 hectares, of which approximately 50% with lowland rice using controlled irrigation. Once the production per unit area of lowland rice (5,779 kg ha^{-1}) is higher than that produced in upland conditions (1,472 kg ha^{-1}), the irrigated system contributed to 77.4% of the total production in the country (11,600.3 tons) (CONAB, 2013).

Due to the fact that there is no availability to create new agricultural lands for lowland rice production, the upland rice is the alternative to meet the needs of Brazilian consumers and generate exportable surpluses, for its potential growth exceeding 50 million hectares for expansion, especially in climatically favored regions with supplemental sprinkler irrigation. This system requires cultivars with some basic features such as: low/intermediate height, narrow, short and straight leaves, short cycle, lodging resistance, high yield potential, fine-long grain, good milling yield, and good cooking behavior (FORNASIERI FILHO; FORNASIERI, 2006), as well as adaptation of cultural practices that make the system more efficient. In this respect, nitrogen (N), considered as the main factor limiting the productivity of rice under conditions of adequate water availability, deserves special attention (FAGERIA; BARBOSA FILHO, 2001; DAWSON et al., 2008).

The N is one of the main nutrients involved in productivity (FAGERIA; BARBOSA FILHO, 2001; FAGERIA; BALIGAR, 2005; MINGOTTE et al., 2013) and in improving the nutritional grain quality of rice (MINGOTTE et al., 2012; CHEN et al., 2012). It is the second macronutrient required by rice plants (103 kg of N to produce 3 t of grains ha^{-1}) and the first in harvest exportation (34 kg of N t^{-1} of grains) (MALAVOLTA et al., 1997; FORNASIERI FILHO; FORNASIERI, 2006; MINGOTTE et al., 2014). On the other hand, the N excess reduces the grain production because the vegetative growth is increased, specially in tillers and leaves, resulting in lodging and damage (FARINELLI et al., 2004) and favoring well-known diseases like *Pyricularia grisea* (Cooke) Sacc (PRABHU; SILVA, 2005).

Fidelis et al. (2012), by evaluating the efficiency and response of six upland rice cultivars

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(BRS-Bonança BRS-Caiapó, BRS-Sertaneja, BRSMG-Curinga, BRSMG-Conai and BRS-Primavera) in function of N-urea fertilization (20 and 120 kg of N ha^{-1}), identified BRSMG-Curinga as a responsive obtaining 1,552 kg ha^{-1} (20 kg of N ha^{-1}) and 2.337 kg ha^{-1} (120 kg of N ha^{-1}). However, this cultivar didn't show N efficiency, for this reason, it was indicated for high technology systems. BRS-Bonança, BRS-Caiapó, and BRS-Primavera were efficient and non-responsive, once their yields were superior to average results (1,909 kg ha^{-1}) under low N. One important fact is the non-occurrence of nitrogen efficient rice cultivars in this research.

Barreto et al. (2012) evaluated the agronomic performance of rice cultivars (BRS MG Curinga, BRS Monarca, BRS Pepita, BRS Primavera, and BRS Sertaneja) under three times of N application (100% in sowing; 50% in sowing, and 50% in tillering; and 100% in tillering) and four N-amonium sulfate rates (0, 50, 100, and 150 kg of N ha^{-1}). This experiment pointed out BRS Primavera and BRS Sertaneja as the most productive cultivars when N rates were applied 50% in sowing and 50% in tillering, and BRS Monarca presented the higher response with total N in tillering. However, the researchers observed that the BRS Sertaneja responded linearly to the increase of N, obtaining 14.2 kg grain per kg of N applied.

In this context, this study aimed to evaluate the agronomic efficiency and grain quality of commercial rice cultivars as a function of nitrogen topdressing application in upland conditions with supplemental sprinkler irrigation.

MATERIAL AND METHODS

The experiment was conducted in 2012/13 crop year at Jaboticabal-SP-Brazil (21°14'05" S and 48°17'09" W), with 615 m of altitude. The climate, according to Köeppen classification, is considered as Aw (megathermal climate/tropical wet), with rainy summer and relatively dry winter. The crop was sowed in Rhodic Hapludox (EMBRAPA, 2006). The soil chemical attributes were determined in soil samples from 0-20 cm depth as described by Raij (1987) (**Table 1**).

Table 1. Soil chemical attributes in the 0-20 cm depth in the experimental area prior to the experiment, Jaboticabal-SP-Brazil, 2012/13 $^{(1)}$.

P resine	M.O.	pH	K^+	Ca^{2+}	Mg^{2+}	H+Al	SB	T	V
mg dm^{-3}	g dm^{-3}	$CaCl_2$	--------------------	mmolc dm^{-3}	--------------------				%
53	16	5,6	1,8	30	21	16	52	68,8	77

[1] P resine – phosphorus; M.O. – organic matter; H+Al - potential acidity; SB - sum of bases; T - cation exchange capacity; V - base saturation.

The area was previously cultivated with upland rice and prepared by deep plowing and two diskings. The basic fertilization consisted of 24 kg of N ha^{-1}, 84 kg of P_2O_5 ha^{-1}, and 48 kg of K_2O ha^{-1} with 0.3% Zn and was based on the soil analysis and fertilizer recommendation for upland rice, with sprinkler irrigation for the State of São Paulo with expected yield of 4 ton ha^{-1} (CANTARELLA et al., 1997).

The experiment was arranged in a randomized block design in a split-plot scheme with four replications. The treatments consisted of a combination of 12 rice cultivars in the plots (BRS Aroma, BRS Monarca, BRS Primavera, BRS Sertaneja, BRSMG Curinga, Caiapó, CIRAD 141, Guarani, IAC 165, IAC 201, IAC 202, and IAC 25) and two levels of nitrogen application in the splitplots (0 and 100 kg ha^{-1}), using ammonium sulfate as a source. Nitrogen was applied at topdressing at the R_1 stage (panicle differentiation) of the Counce et al. (2000) scale, referred as the spikelet differentiation (1.5 to 2.0 cm long in the panicle primordial stage), according to recommendations of Matsushima (1979). Each experimental unit was represented by six rows, with 5 m length, spaced by 0.45 m, and seeding rate of 200 viable seeds per m^2; using the center six rows for evaluations, except 0.5 m of the extremities.

The weed control was made in pre-emergence using a pendimethalin-based herbicide (1.5 kg a.i. ha^{-1}) and in post-emergence with a cyhalofop butyl ether-based herbicide (270 g a.i. ha^{-1}), in addition to mechanical control measures. The irrigation was applied by conventional sprinkler system. The irrigation management was carried out by readings on tensiometers (gauge type) installed at depths of 10 and 20 cm and the soil water retention curves, with irrigation applied when the tensiometer indicated values corresponding to 0.07 MPa (FORNASIERI FILHO; FORNASIERI, 2006). The environmental averaged data collected during the experiment conduction is presented in **Figure 1**.

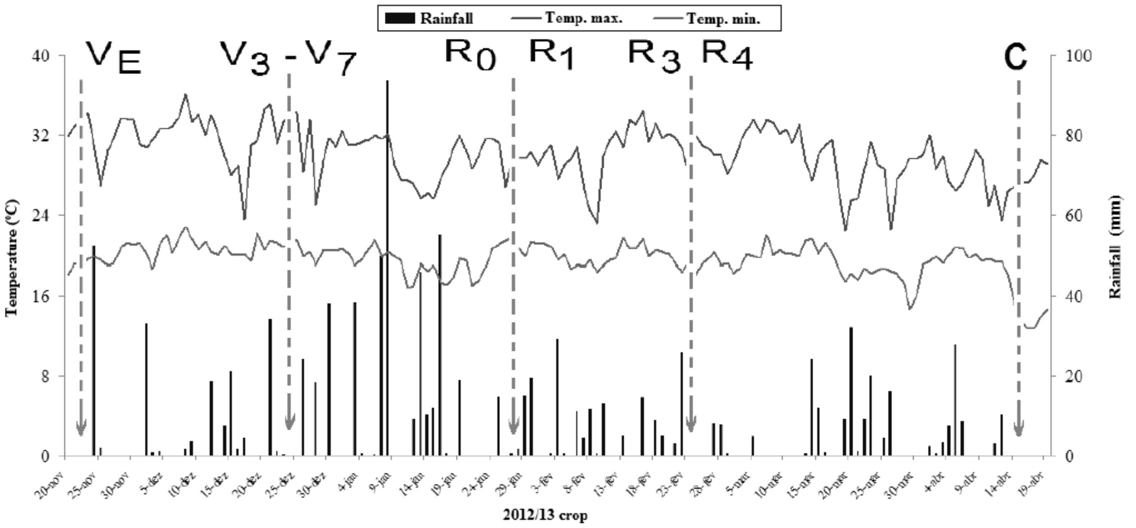

Figure 1. Environmental averaged data every five days of rainfall, maximum and minimum temperature during development of rice cultivars in function of N topdressing rates (0 and 100 kg of N ha^{-1}) in Jaboticabal-SP-Brazil, 2012/13 crop. Sowing on 20/11/2012; V_E (emergence); V_3-V_7 (tillering); R_0 (neck node) e R_1 (panicle differentiation); R_3-R_4 (microsporogenesis); C (harvest).

The total degree days for flowering (ΣGDD) was measured during the period between emergency and 50% flowering plants stage, according to the expression: $GD=\sum^{df}_{i=di} (T_i-T_b)$, where GD = degree-day, di = initial stage of the study (days), df = final stage in the study (days), T_i = average daily temperature (ºC), T_b = basal temperature (15ºC).

At flowering stage, flag leaves (CANTARELLA et al., 1997) were submitted to nondestructive chlorophyll content measurement (SPAD index) with CCM-200®. The same leaves were collected for determination of total N leaf (MALAVOLTA et al., 1997).

At the end of the cycle, when 2/3 of caryopses, in 50% of panicles, were hard and the remaining were medium-hard, 15 panicles were randomly picked per splitplot and stored in a cold chamber. Then, the panicles of the center rows were harvested. All plants on 0.50 m of one of the center rows were sampled (low cutting) to determine the dry matter of grain and straw (culms and straw). The threshing was done mechanically and drying was applied under natural conditions.

The plant height (cm) was determined by averaging ten plants per experimental unit, measured from ground level to the tip of the tallest panicle, during the dough stage. The lodging degree was determined by visual evaluation performed immediately before the final harvest, using a grading scale where: 1 = no lodging; 3 = up to 25% lodged plants; 5 = 25-50% lodged plants; 7 = 50-75% of lodged plants; 9 = 75 to 100% of lodged plants.

The number of panicles per area was counted on each plant in 1 m of the center rows at harvest of each experimental unit. The total number of spikelets per panicle was counted on the 15 casually plants collected per experimental unit at the final harvest. The number of grains per panicle was obtained by counting the number of filled spikelets contained in the 15 panicles per experimental unit, after separation from unfilled spikelets in an airflow sorter. The spikelet fertility was determined from the ratio between the number of grains per panicle and the number of spikelets per panicle multiplied by 100.

The 1000-seed mass (g) was determined from eight subsamples of 100 seeds per experimental unit and weighed on a two decimal place balance. The result, in grams, was transformed into 13% moisture content (wet basis). Moisture content in grains was obtained by the oven method, at 105 ± 3 ºC for 24 hours. Panicle length (cm) was measured from the base of the panicle (first node) to the apex spikelet on fifteen panicles per experimental unit. Paddy grain yield was determined after harvest, threshing, blowing, and drying of the material collected from the center rows of ach experimental unit. After weighing, data were transformed into kg ha^{-1} (13% wet basis).

The agronomic efficiency (AE) was calculated using the following formula: $AE = (G_f - G_u/N_a)$ = kg of grain per kg of N applied (FAGERIA; BALIGAR, 2005; MINGOTTE et al., 2014), where G_f is the grain yield of the fertilized plot (kg), G_u is the grain yield in the unfertilized plot (kg), and N_a is the quantity of nutrient applied (kg).

In addition, parameters such as milling yield, as well as crude protein contents of grains were evaluated. For this purpose, samples of 100 g of paddy rice were benefited at SUZUKI machine. The samples milling time was defined by two periods, 10 seconds to stripping and 90 seconds to burnishing. The integral and broken grains were classified with "trieur" number 1. In each sample were collected lemma and palea (husk) and bran, separately. The crude protein (g kg^{-1}) was determinate by the N-total content in grain integral by the sulfuric digestion (Kjeldahl), with values multiplied by 5.95 (glutelin factor).

The data were submitted to ANOVA by F test ($p<0.05$), and the Scott-Knott test ($p<0.05$) was applied to group means among cultivars using the complex variances calculated within each nitrogen rate.

RESULTS AND DISCUSSION

Concerning ΣGDD, it was observed that cultivars presented the same values without effects of the N application. It was found out that among the cultivars, IAC 25, Guarani, and BRS Primavera showed the lowest values of this characteristic, showing their earliness (**Table 2**).

The index SPAD and leaf total N content did not differ among rice cultivars and were not influenced by N topdressing application (**Table 2**). Regarding the leaf total N, the values obtained are in the range considered suitable (27 to 35 g kg^{-1}) as described by Cantarella et al. (1997).

Regarding plant height, BRS Curinga, CIRAD 141 and IAC 202 showed the lowest values and IAC 25, IAC 165, Guarani and Caiapó stands out as the greatest height. A plant with lower height is an important feature to reduce the possibility of lodging of the crop when conducted under appropriate conditions such as availability of water and N fertilizers. Regarding these characteristics, besides occurring genetic variability among cultivars, nitrogen fertilization influenced both traits. There was a significant interaction C x N for the degree of layering (**Table 2**). The height may compromise the plant lodging, especially in cases of delayed harvest after maturation, and under these conditions the quality of the final product may be impaired due to rainfall occurrences.

In general, the tallest cultivars showed more susceptibility to lodging degree, as observed in Caiapó, Guarani, IAC 165, IAC 201, and IAC 25. BRS Aroma, BRS Monarca, BRS Primavera, BRS Sertaneja, BRS Curinga, CIRAD 141, and IAC 202 showed reduced height compared to the others and were insensitive to the nitrogen application about the lodging. Mauad et al. (2003) reported that there was no influence of N on lodging of cultivar IAC 202, under sprinkler irrigation. These results show that the height and lodging degree are features that are strongly linked, especially in traditional cultivars that have high stature. The high N application rates before the growth stage modifies the reproductive structure, increasing the biosynthesis of phytohormones, particularly auxin, which stimulates the expansion processes and the cell division, extending from the stem internodes and hence the plant height can lead to lodging (MARSCHNER, 1995).

As for the number of tillers per plant and the number of panicles per area, there were no differences among rice cultivars experienced without N application. However, the N topdressing promoted increase in this variable (**Table 2**). N favors root growth and stimulates tillering (MALAVOLTA, 1981), leading to the increase of the number of spikelets per panicle when applied in the initial development of the rice, on the other hand, when applied in the last development stages, N improves the grain protein content.

Cornélio et al. (2003) reported that N fertilizer near panicle initiation increases the number of panicles per ha^{-1}. It is known that in practice, the N supplied adequately promotes increase in the number of tillers per area. This fact relates to the ability of the plant to develop tillers (FORNASIERI FILHO; FORNASIERI, 2006). Barreto et al. (2012) certified that applying all N at tillering increases the number of panicle in BRSMG Curinga, BRS Monarca, BRS Pepita, BRS Primavera, and BRS Sertaneja cultivars.

Table 2. Total degree days for flowering (ΣGDD), SPAD index, total N leaf, plant height and lodging degree and number of tillers per plant and panicles per area on rice cultivars in function of N topdressing, Jaboticabal-SP-Brazil, 2012/13 (1).

Treatments	ΣGDD [2]		SPAD index	Total N leaf	Plant height	Lodging degree [2,3]		Tillers per plant	Panicles m^{-2}
	--- ºC ---		-	-- g kg^{-1} --	-- cm --	- score -		-- n --	-- n --
Cultivars (C)	+N	-N	-	-	-	+N	-N	-	-
BRS Aroma	901,7 Ab	901,7 Ab	37,2	36,0	79,2 b	1,5 Aa	1,2 Aa	3,3	159,0
BRS Monarca	962,7 Ad	962,7 Ad	24,3	36,1	82,6 b	1,2 Aa	1,2 Aa	3,8	177,2
BRS Primavera	836,0 Aa	836,0 Aa	35,1	37,9	82,9 b	1,4 Aa	1,2 Aa	3,8	197,8
BRS Sertaneja	922,7 Ac	922,7 Ac	35,4	34,7	77,9 b	1,4 Aa	1,2 Aa	3,7	161,6
BRSMG Curinga	939,7 Ac	939,7 Ac	30,5	37,2	70,8 a	1,2 Aa	1,2 Aa	3,5	187,8
Caiapó	931,5 Ac	931,5 Ac	32,0	35,9	96,1 c	1,8 Bb	1,2 Aa	3,0	164,2
CIRAD 141	994,7 Ae	994,7 Ae	35,7	36,2	76,0 a	1,2 Aa	1,2 Aa	3,5	152,0
Guarani	836,0 Aa	836,0 Aa	26,7	33,6	97,4 c	2,4 Bb	1,5 Aa	3,1	151,4
IAC 165	884,0 Ad	884,0 Ad	23,9	35,6	96,8 c	2,2 Bb	1,5 Aa	3,6	172,2
IAC 201	889,7 Ab	889,7 Ab	24,6	35,6	84,4 b	2,0 Bb	1,2 Aa	3,6	183,6
IAC 202	957,0 Ad	957,0 Ad	34,6	34,5	70,8 a	1,2 Aa	1,2 Aa	3,7	172,2
IAC 25	831,2 Aa	831,2 Aa	30,8	31,2	99,7 c	2,2 Bb	1,6 Aa	3,6	196,2
CV (%)	3,1		47,5	10,0	6,4	28,6		26,2	32,4
N rates (kg ha^{-1})									
0	907,3		30,8	35,3	81,0 a	1,3 a		3,3 b	169,8
100	907,3		31,0	35,5	88,1 b	1,6 b		3,8 a	176
CV (%)	1,0		8,7	9,2	3,0	17,0		18,29	15,9
F Test									
C	28,4**		0,9 ^{ns}	1,9 ^{ns}	30,13**	3,71**		0,5 ^{ns}	0,6 ^{ns}
N	0,09^{ns}		0,1 ^{ns}	0,1 ^{ns}	179,44**	44,33**		15,1**	1,2 ^{ns}
C x N	10^9**		1,4 ^{ns}	1,8 ^{ns}	1,36^{ns}	3,49**		1,1 ^{ns}	1,4 ^{ns}
Mean	907,3		30,9	35,4	84,5	1,5		3,5	86,5

[1] Means followed by different letters differ by Scott-Knott test (p<0.05). ** (p<0.01), ^{ns} no significant, respectively by F test (p<0.05). [2] Breakdown of the interaction C x N. Different capital letters indicate differences among lines between presence and absence of N. Different small letters in the column indicate differences among rice cultivars. [3] Data transformed to $(x + 0,5)^{1/2}$.

Regarding the panicle length, all cultivars showed similar values and it was found out that the N topdressing application did not affect their increase (**Table 3**). Buzetti et al. (2006) found a linear increase of panicle length simultaneously raising the level of nitrogen in coverage during two years in IAC 201 and IAC 202 cultivars.

There were no differences among cultivars in terms of the number of nods per panicle, showing non-significant results as the N topdressing application (**Table 3**). In rice, the N application may increase the number of nods per panicle and the number of spikelets per panicle, promoting higher grain yield (FORNASIERI FILHO; FORNASIERI, 2006). One hypothesis to explain the non-occurrence of this fact in the present experiment could be the high content of organic matter in the soil (**Table 1**), but this is possibly due to yield N application at R_1 stage, rather than R_0, according to Matsushima (1979) recommendations.

As for the total number of sterile spikelets per panicle, significant differences for cultivars, N topdressing application and C x N interaction were observed (**Table 3**). Among the 12 genotypes, BRSMG Curinga and Guarani showed the lowest number of sterile spikelets per panicle in function of N applying, and this application also didn't interfere with the number of fertile spikelets per panicle, a number affected only by genetic factors.

Bordin et al. (2003) found increases in the number of spikelets per panicle grenades in function of N levels. Farinelli et al. (2004) and Arf et al. (2003) observed no influence of N in this parameter, using urea as source. Regarding spikelet fertility, there were no differences between cultivars differing in N topdressing application. All cultivars, except BRS Aroma, CIRAD 141, and IAC 202 showed values of 70% spikelet fertility (**Table 3**).

The total number of spikelets per panicle suffers influence of genotype, environmental conditions, and the amount of N accumulated in the leaves (FORNASIERI FILHO; FORNASIERI, 2006). The deficiency of this nutrient reduces the number of spikelets per panicle, which in turn presents itself as an important component production (MATSUSHIMA, 1979).

The factor most closely connected with the degeneration on rachis-branches and spikelets is the weather condition during the reduction division stage. Thus, when the rice plant faces cloudy and rainy weather, cool temperatures, drought or heavy flood in the period of reduction division, the number of degenerated rachis-branches and spikelets is remarkably increased. In this way, the occurrence of sterile spikelets in the experiment can be explained by the occurrence of high temperatures, causing decrease ovules fertilization and consequently sterile spikelets (**Figure 1**).

Regarding the thousand grain weight, the highest values were observed in IAC 25, IAC 165, and Guarani cultivars (**Table 3**). However, this component was not affected in function of N topdressing application, because it is a stable varietal characteristic (genetic), being basically controlled by the gap between the lemma and palea (FORNASIERI FILHO; FORNASIERI, 2006).

The grain yield was increased in function of N application, mainly in BRS Monarca, BRSMG Curinga, Caiapó, IAC 165, and IAC 202 cultivars, with values of 5,359; 4,854; 6,452; 5,039, and 4,940 kg ha^{-1}, respectively. Regarding the agronomic efficiency, cultivars that were more responsive to N were the same that had higher grain yield, with special emphasis to BRSMG Curinga and Caiapó, which showed 15.9 and 19.8 kg of grain produced per kg of N applied, respectively. The Caiapó cultivar presented simultaneously higher grain yield and agronomic efficiency depending on the N topdressing application, followed by BRS Monarca, BRSMG Curinga, IAC 165, and IAC 202 (**Table 3**).

Table 3. Panicle length, nods per panicle, spikelets sterile per panicle, spikelet fertility, 1000-seed mass (TSM), grain yield and agronomic efficiency (AE) on rice cultivars as a function of N topdressing, Jaboticabal-SP-Brazil, 2012/13 (1).

Treatments	Panicle length	Nods per panicle	Spikelets sterile ^{2}		Spikelet fertility	TSM	Grain yield ^{2}		AE
	-- cm --	-- n --	-- n --		-- % --	-- g --	-- kg ha^{-1} --		-- kg kg^{-1} --
Cultivars (C)	-	-	+N	-N	-	-	+N	-N	-
BRS Aroma	26,5	18,6	90,32 Bc	61,97 Aa	67,5 b	25,5 c	3.259 Ad	2.921 Ac	3,4
BRS Monarca	26,4	16,4	70,92 Ac	52,30 Aa	72,7 a	29,3 b	5.359 Ab	4.3.93 Ba	9,7
BRS Primavera	26,9	15,6	57,25 Ab	58,25 Aa	75,0 a	25,5 c	4.299 Ac	3.224 Bc	10,8
BRS Sertaneja	25,7	15,6	99,62 Bc	71,72 Ab	72,1 a	27,7 b	3.962 Ac	2.702 Bc	12,6
BRSMG Curinga	26,4	15,2	28,77 Aa	32,65 Aa	81,9 a	25,7 c	4.854 Ab	3.260 Bc	15,9
Caiapó	26,9	15,4	55,12 Ab	54,62 Aa	75,6 a	28,6 b	6.452 Aa	4.471 Ba	19,8
CIRAD 141	26,7	18,1	104,85 Bc	77,27 Ab	61,0 b	24,6 c	2.831 Ad	2.377 Ac	4,5
Guarani	25,4	16,8	32,77 Aa	43,10 Aa	77,6 a	33,9 a	4.135 Ac	3.536 Ab	6,0
IAC 165	24,8	15,5	55,52 Ab	64,15 Aa	72,7 a	35,1 a	5.039 Ab	3.715 Bb	13,2
IAC 201	25,8	17.8	84,95 Ac	67,22 Ab	74,2 a	24,5 c	3.892 Ac	3.335 Ac	5,6
IAC 202	27,2	16,7	94,52 Ac	100,20 Ac	68,9 b	24,6 c	4.940 Ab	3.735 Bb	12,0
IAC 25	28,0	16,0	45,55 Ab	52,10 Aa	77,6 a	32,7 a	4.212 Ac	3.082 Bc	11,3
CV (%)	9,6	18,4	28,8		11,0	10,1	13,6		-
N rates (kg ha^{-1})									
0	26,2	16,6	61,3		72,9	28,0	3.396 b		-
100	26,6	16,4	68,3		73,1	28,3	4.436 a		-
CV (%)	5,3	10,3	21,7		7,6	9,8	12,0		-
F Test									
C	0,9^{ns}	1,1^{ns}	9,9**		3,7*	14,6**	17,02**		-
N	2,4^{ns}	0,2^{ns}	6,0*		0,0^{ns}	0,3^{ns}	116,62**		-
C x N	0,9^{ns}	1,6^{ns}	2,5*		1,2^{ns}	0,7^{ns}	2,15*		-
Mean	26,4	16,5	64,8		73,0	28,1	13,6		3,4

[1] Means followed by different letters differ by Scott-Knott test ($p<0.05$). ** ($p<0.01$), ^{ns} no significant, respectively by F test ($p<0.05$). [2] Breakdown of the interaction C x N. Different capital letters indicate differences among lines between presence and absence of N. Different small letters in the column indicate differences among rice cultivars.

Overall differences were observed in milling yield among rice cultivars without influence of N application (**Table 4**).

When it came to whole and to broken grain yield, which at the national level are assigned as favorable values ≥ 40 % and < 28 % , respectively (FORNASIERI FILHO; FORNASIERI, 2006), the observed values fall within this parameter. Freitas et al. (2001), Bordin et al. (2003), and Boldieri et al. (2010) observed that N fertilization increased the percentage of whole grains in some cultivars, but not in others. Farinelli et al. (2004) found no influence of N fertilization on the yield of whole grains. Thus, it appears that the whole grain yield is more dependent on the genotype of N application and can be affected by the environmental conditions and time of harvest. Fornasieri Filho; Fornasieri (2006) reported that the IAC 202 presents great whole grain yield in processing.

Table 4. Milling efficiency (percentage of whole grains, broken grains, bran, husk, and milling yield), and grain crude protein content on rice cultivars in function of N topdressing, Jaboticabal-SP-Brazil, 2012/13 $^{(1)}$.

Treatments	Milling efficiency					Grain protein
	Whole grains	Broken grains	Bran	Husk	Milling yield	
		------------ % ------------				--- g kg^{-1} ---
Cultivars (C)						
BRS Aroma	55,5 b	15,7 c	7,8	21,0	71,2 b	120,6
BRS Monarca	49,3 c	21,4 b	6,8	22,5	70,7 b	112,1
BRS Primavera	35,3 d	34,1 a	8,4	22,3	69,4 b	109,0
BRS Sertaneja	63,2 a	9,0 d	6,8	21,0	72,2 b	110,5
BRSMG Curinga	57,3 b	14,3 c	6,9	21,5	71.5 b	110,5
Caiapó	66,2 a	7,0 d	7,1	19,7	73,2 a	109,4
CIRAD 141	64,4 a	9,4 d	7,5	18,7	73,8 a	114,2
Guarani	53,5 c	20,0 b	7,7	18,8	73,5 a	113,4
IAC 165	58,7 b	15,8 c	6,8	18,6	74,5 a	113,0
IAC 201	57,2 b	15,0 c	7,4	33,0	72,2 b	121,0
IAC 202	54,9 b	17,8 c	7,7	19,6	72,7 a	105,2
IAC 25	52,4 c	22,4 b	8,0	17,1	74,9 a	101,4
CV (%)	8,0	26,5	15,5	50,2	3,1	17,1
N rates (kg ha^{-1})						
0	55,1	17,1	7,5	21,3	72,2	105,9 b
100	56,3	16,5	7,3	21,0	72,9	117,5 a
CV (%)	8,6	24,8	17,3	12,1	3,5	14,7
F Test						
C	26,6**	21,4**	1,6^{ns}	1,2^{ns}	4,0**	0,7^{ns}
N	1,5^{ns}	0,5^{ns}	1,0^{ns}	0,4^{ns}	1,4^{ns}	12,0*
C x N	0,9^{ns}	1,4^{ns}	1,0^{ns}	1,1^{ns}	0,7^{ns}	0,8^{ns}
Mean	55,7	16,8	7,4	21,1	72,5	111,7

[1] Means followed by different letters differ by Scott-Knott test (p<0.05). ** (p<0.01), ^{ns} no significant, respectively by F test (p<0.05).

The factors of study did not cause effects to bark and bran and the N fertilization did not influence the milling yield. Differences were observed in function of rice cultivars, especially Caiapó, CIRAD 141, Guarani, IAC 165, IAC 202, and IAC 25. However, all cultivars presented values considered acceptable, since in Brazil, it is assigned as a reference for milling yield 68% (FORNASIERI FILHO; FORNASIERI, 2006) and 60% of milling yield is considered reasonable (USBERTI FILHO et al., 1986).

As for the grain crude protein content was not significant differences among cultivars. However, the N application promoted an increase of 11% in these values (**Table 4**). During the grain filling plants compete for assimilates, which in turn varies according to the amount of N absorbed during the whole crop cycle, affecting the crude protein content (KELLING; FIXEN, 1992). The N supply promotes translocation of this nutrient in the form of grain protein, producing grains with a higher nutritional value.

CONCLUSIONS

The nitrogen topdressing application intensifies the degree of lodging, mainly at Caiapó, Guarani, IAC 165, IAC 201, and IAC 25 cultivars.

The nitrogen application affects the number of sterile spikelets per panicle, mainly in CIRAD 141, BRS Sertaneja, IAC 202, and BRS Aroma cultivars.

Caiapó cultivar shows higher grain yield and agronomic efficiency in function of nitrogen topdressing application, followed by BRS Monarca, BRSMG Curinga, IAC 165, and IAC 202.

The grain protein content in rice is increased by the nitrogen topdressing application.

Although Caiapó, CIRAD 141, Guarani, IAC 165, IAC 202 and IAC 25 cultivars present better results, all the others cultivars also present acceptable values of milling yield, without nitrogen topdressing application effects.

RESUMO: O objetivo do trabalho foi avaliar a eficiência agronômica e a qualidade do grão em doze cultivares de arroz em função da aplicação de nitrogênio em cobertura no sistema de cultivo em terras altas com uso de irrigação suplementar. O experimento foi conduzido na safra 2012/13 em Jaboticabal-SP, no delineamento experimental de blocos casualizados em parcelas subdivididas, com quatro repetições. Os tratamentos foram constituídos pela combinação de 12 cultivares (BRS Aroma, BRS Monarca, BRS Primavera, BRS Sertaneja, BRSMG Curinga, Caiapó, CIRAD 141, Guarani, IAC 165, IAC 201, IAC 202 e IAC 25) nas parcelas, e duas doses de N em cobertura (0 e 100 kg de N ha^{-1}) nas subparcelas. A aplicação do N em cobertura no ponto algodão (R_1) intensificou o grau de acamamento, principalmente nas cultivares Caiapó, Guarani, IAC 165, IAC 201 e IAC 25, de porte mais elevado. A adubação nitrogenada em cobertura interferiu no número de espiguetas estéreis por panícula, em especial nas cultivares CIRAD 141, BRS Sertaneja, IAC 202 e BRS Aroma, respectivamente. A cultivar Caiapó apresentou maior produtividade de grãos e eficiência agronômica em função da aplicação de nitrogênio em cobertura, seguida por BRS Monarca, BRSMG Curinga, IAC 165 e IAC 202. Quanto ao rendimento de engenho mesmo ocorrendo destaque para Caiapó, CIRAD 141, Guarani, IAC 165, IAC 202 e IAC 25, todas as demais cultivares apresentaram valores aceitáveis, sem alterações devido à aplicação de nitrogênio em cobertura. O teor de proteína bruta nos grãos de arroz foi incrementado pela aplicação de nitrogênio em cobertura.

PALAVRAS-CHAVE: *Oryza sativa.* Irrigação por aspersão. Componentes de produção. Qualidade nutricional e tecnológica.

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