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Development of Clearfield rice cultivars in Uruguay

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ABSTRACT *- Even though red rice populations have been maintained under control in Uruguay through cultural practices, as high use of certified seed and rotations with pastures, there is an opportunity to incorporate chemical control through introduction of Clearfield Rice system. The technology is based in the use of imidazolinone herbicides and tolerant varieties (non GMO), allowing the chemical control of red rice and a wide number of weeds. Varieties of the 1st generation of resistance, as IRGA 422 (Indica), widely grown in Brazil, do not provide consistent resistance to herbicide under low temperatures, that are common in Uruguay, making red rice control unsatisfactory. CL 161 (tropical Japonica), a variety of the 2nd generation of resistance grown in the US, shows limited yield potential and long growth duration in Uruguay. Recently, INTA (Argentina) developed a new source of resistance in Indica background (Puitá INTA CL). In Uruguay, introduction of resistant germplasm has been carried out by INIA under research agreements with BASF Corporation, with the purpose of developing Clearfield cultivars adapted to local conditions. First generation of resistant germplasm was introduced in 1998 and the 2nd generation in 2001. Introduced germplasm was used in selection and in crosses with local germplasm, either of Indica and tropical Japonica background. Herbicides used for 1st and 2nd generations were imazethapyr + imazapic (75 + 25 g/ha), and imazapyr + imazapic (74 + 25 or 110 + 37 g/ha), respectively. 1st generation germplasm was discarded in 2003 because of the above mentioned problems. Since then, cultivar development focused on 2nd generation. In 2005/06, 172 breeding lines were included in preliminary yield tests. Average yield of Clearfield check varieties CL 161 and Puitá were 6390 and 7914 kg/ha, respectively, with excellent milling. Some breeding lines showed yields as high as 10 t/ha and some of them combined high yields (> 9 t/ha) and excellent milling. About 50% of the lines were selected and are being tested in 2006/07.*

KEY WORDS *– Clearfield rice; cultivar development; imidazolinone tolerance.*

I. INTRODUCTION

URUGUAY grows 165,000 ha of irrigated rice and average grain yield of the last 3 years was 7.3 t/ha. High use of certified seed (85%), rotation with pastures for grazing of cattle and other cultural practices, as manual elimination of red rice (*Oryza sativa* L.) plants, have contributed to maintain populations of this weed under control. However, there is an increased concern about spread of red rice, that has been reported as being present in 31% of the cultivated area, mostly in patches or isolated plants [1]. This drives the attention to chemical methods for controlling red rice, especially to *Clearfield* production system, that has not yet been adopted in the country, which involves the use of imidazolinone (IMI) herbicides and tolerant varieties. Such varieties were developed using conventional breeding methods, therefore are not genetically modified organisms (non GMO) [2].

Imidazolinone herbicides inhibit acetohydroxy acid synthase (AHAS), a central enzyme in the synthesis of some aminoacids [3], [4]. These herbicides control a broad spectrum of weeds in IMI-tolerant crops, including weeds that are closely related to the crop itself, as red rice. Several variant AHAS genes conferring IMI-tolerance were discovered in plants through mutagenesis and selection, and were used to create IMI-tolerant crops [4]. In rice, mutagenic treatment (EMS) of the cultivar AS3510, with M2 sprayed with imazethapyr, originated a mutant line (93AS3510), which was parent of several IMI-tolerant varieties (CL121, CL141 and IRGA 422). The rice variety Cypress was also mutagenized, and M2 was treated with imazapyr and imazapic, originating 12 mutant lines. Highly resistant varieties or hybrids (CL 161, XL8) were developed from one of these mutants (PWC-16) [3] - [5]. Both mutants have different single codon changes in their AHAS genes and have been used extensively to transfer resistance into leading cultivars [4], [5]. The IMI resistance trait is reported to be inherited as a single dominant gene [2], and single co-dominant nuclear gene [5]. In herbicide tolerance tests with imazethapyr, PWC-16 had a tolerance level of 8 times that of 93AS3510 [3]. Recently, INTA (Argentina) developed a new source of resistance, releasing the indica variety Puitá INTA CL.

In Uruguay, varieties of 1st generation of resistance, as IRGA 422, do not provide consistent tolerance to IMI herbicides, and CL161, that has high level of resistance, has limited yield potential. INIA introduced IMI-tolerant germplasm, under research agreements with BASF Corporation, in 1998 and 2001, with the purpose of developing Clearfield cultivars adapted to local conditions. Introduced material was used in selection and in crosses with local germplasm, either of indica and tropical japonica background. After discarding 1st generation germplasm in 2003, cultivar development was focused on 2nd generation (from PWC-16). The purpose of this paper is to present the first results from yield trials of those locally developed IMI-resistant experimental lines.

II. MATERIAL AND METHODS

In 2005/06 crop season, 172 breeding lines, originated from selection in introduced material and local crosses, were tested in preliminary yield trials in the experimental field. Cultivars were distributed in 3 experiments with 2 replications each. Plots had 6 rows of 3.5 m, with 0.2 m between rows. Plots were sprayed with imazapyr + imazapic (74 + 25 g/ha) in post emergence. Check varieties were the introduced IMI-resistant CL161 and Puitá INTA CL. The experiments were sowed on November 7, 2005. Determinations included grain yield,

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agronomic traits, disease incidence and milling quality. Materials included in experiments 1 and 2 were tropical japonica and in experiment 3 were indica.

III. RESULTS AND DISCUSSION

A. Experiment 1

All cultivars had good tolerance to the herbicide and grain yield of the test ranged between 6,330 and 9,863 kg/ha, with an average of 7,924. A group of 25 experimental lines and the variety Puitá (8,215 kg/ha) presented significantly higher grain yields than that of CL161 (6,429 kg/ha). Both check varieties had good milling quality, as most of the breeding lines (Table 1). Cultivars had moderate to high infection with Stem rot (*Sclerotium oryzae*), but the disease developed late in the season and grain yield was not severely affected.

Table 1. Grain yield, days from seeding to heading, Stem rot incidence and milling of varieties CL 161, Puitá CL, and selected breeding lines in Exp. 1.

N°	Cultivar	Grain yield kg/ha	Heading days	Stem rot (1)	Whole kernels %	Chalkiness %
50	INIA CL50	9863	90	8.0	64.4	4.5
29	INIA CL29	9786	89	7.0	61.5	5.1
54	INIA CL54	9703	93	6.5	64.7	2.9
43	INIA CL43	9666	90	8.1	67.1	2.9
27	INIA CL27	9363	90	7.5	63.4	6.0
51	INIA CL51	9200	92	6.5	65.0	3.5
41	INIA CL41	8684	89	7.0	66.5	2.0
49	INIA CL49	8657	90	6.5	67.3	1.4
63	**Puitá**	**8215**	**93**	**8.0**	**60.6**	**2.1**
61	**CL161**	**6429**	**95**	**7.5**	**66.6**	**2.0**
Mean		7924	93	6.9	64.9	3.0
P Cult.		0.000	0.000	0.000	0.099	0.000
CV%		10.6	1.6	7.9	5.0	21.6
LSD 0.05		1681	3.0	1.1	6.5	2.9

(1) Std. Evaluation System for rice: 0 no incidence, 9 highly susceptible

B. Experiment 2

Average grain yield of the experiment was 6,650 kg/ha, with wider variability among cultivars (912 to 10,006 kg/ha) than in the previous one. A group of 16 breeding lines had grain yields (8,000-10,000 kg/ha) significantly higher than that of CL161 (6,350 kg/ha). Grain yield of CL104 was also higher than that of Puitá (7,613 kg/ha) (Table 2). Best yielding lines showed good milling, but some of them had high incidence of chalky grains. In most of the cases, low grain yield was associated with high Straighthead incidence and sterility.

C. Experiment 3

Grain yield ranged from 4,507 to 8,754 kg/ha and a group of 26 indica breeding lines, originated from local crosses, as well as the variety Puitá, presented significantly higher yields than that of CL161. This check variety was affected by Straighthead and had important spikelet sterility. Most breeding lines showed excellent vigor and good herbicide resistance, however, milling quality was lower than that of tropical japonica materials included in previous experiments (Table 3).

Table 2. Grain yield, days from seeding to heading, Stem rot incidence and milling of varieties CL 161, Puitá CL, and selected breeding lines in Exp. 2.

N°	Cultivar	Grain yield kg/ha	Heading days	Stem rot (1)	Whole kernels %	Chalkiness %
46	INIA CL104	10006	90	7.0	67.5	9.7
57	INIA CL115	9217	86	6.5	62.0	13.2
51	INIA CL109	9207	90	7.5	66.4	6.7
43	INIA CL101	8730	89	6.5	66.9	5.7
35	INIA CL93	8657	91	6.5	67.8	4.4
11	INIA CL69	8192	96	6.5	67.1	1.8
40	INIA CL98	8102	94	7.5	65.6	5.4
48	INIA CL106	8081	93	6.0	67.7	4.1
63	**Puitá**	**7613**	**94**	**8.0**	**61.8**	**3.2**
61	**CL161**	**6350**	**95**	**6.5**	**67.8**	**2.4**
Mean		6650	91.8	6.9	58.1	6.5
P Cult.		0.000	0.000	0.001	0.000	0.000
CV%		12.0	2.0	10.4	8.9	41.1
LSD 0.05		1613	3.7	1.4	10.4	5.3

(1) Std. Evaluation System for rice: 0 no incidence, 9 highly susceptible

Table 3. Grain yield, days from seeding to heading, Stem rot incidence and milling of varieties CL 161, Puitá CL, and selected breeding lines in Exp. 3.

N°	Cultivar	Grain yield kg/ha	Heading days	Stem rot (1)	Whole kernels %	Chalkiness %
40	INIA CL155	8754	88	7.0	61.7	9.9
38	INIA CL153	8590	89	6.5	62.6	8.4
3	INIA CL118	8586	90	8.0	52.6	3.5
27	INIA CL142	8530	88	7.0	56.7	5.8
24	INIA CL139	8392	87	7.0	55.2	2.8
39	INIA CL154	8263	88	7.0	63.6	9.8
8	INIA CL123	8051	85	8.0	58.1	5.8
13	INIA CL128	7808	78	7.5	58.9	1.7
63	**Puitá**	**7529**	**94**	**6.5**	**59.5**	**2.0**
61	**CL161**	**5563**	**95**	**7.5**	**63.4**	**2.0**
Mean		6920	90	7.2	55.9	4.2
P Cult.		0.000	0.000	0.001	0.025	0.000
CV%		11.3	2.2	10.5	10.3	13.9
LSD 0.05		1566	3.9	1.5	11.6	2.4

(1) Std. Evaluation System for rice: 0 no incidence, 9 highly susceptible

IV. CONCLUSION

In preliminary trials, some IMI-resistant breeding lines showed higher yield potential than introduced variety CL161, good herbicide resistance and milling quality, and 96 were selected for further testing in 2006/07 crop season.

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