Resistance to neck blast caused by *Pyricularia oryzae* in Italian rice cultivars

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Abstract Very little information is available on neck blast resistance in Italian rice varieties under field conditions. In order to provide these data, 105 cultivars were tested under very favourable conditions for the disease development; the cultivars' response to a single treatment of tricyclazole was also evaluated. Among tested varieties, 15 % showed resistance to the disease, 17 % moderate resistance, 30 % moderate susceptibility and 38 % susceptibility. Generally, recently developed cultivars were more tolerant to neck blast, compared to the oldest ones. Furthermore, cultivars with Long A grain shape are the most susceptible to neck blast, followed by medium grain type, round grain and Long B grain shape. A single spray of tricyclazole (450 a.i. g/ha) was effective in reducing disease incidence (55 % average reduction). It was also observed that there was a reduction in severity of symptoms. The majority of rice Italian cultivars are susceptible to neck blast disease. This study underlines the importance of field tests as useful tool for researchers, breeders and growers, combining scientific value with impact in application, giving valuable information to improve disease control.

Keywords Neck blast · *Oryza sativa* · Variety · Resistance · Disease incidence · Tricyclazole

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Introduction

Italian rice culture represents 55 % of the entire European Union's production (Casati 2013) and comprises more than 50 % of the rice cultivars listed in the "Common catalogue of varieties of agricultural plant species" (206 varieties out of 384) (Commission 2013). In 2012, the area planted to rice in Italy was 235051.96 ha; a slight reduction of such area (−8 %) was recorded in 2013 (Ente Nazionale Risi 2013).

Rice blast, caused by *Magnaporthe oryzae* B. Couch (anamorph *Pyricularia oryzae* Cavara) (Couch and Kohn 2002), is considered a major disease of rice because of its wide geographic distribution and destructiveness under favorable conditions (IRRI 2013). A disease resembling blast was described in Italy in 1775 (Gallo 1775) in a treatise on rice cultivation and agriculture. For almost three centuries, under the name of "Brusone", several plant diseases that cannot all be attributable to *M. oryzae* were mentioned. In 1828 was published a book about blast disease and the farming techniques for its management (Astolfi 1828). In Northern Italy, documented epidemics attributed to this pathogen occurred from 1820 to 1827 (Re 1826) and thereafter for twenty consecutive years, from 1875 to 1895, in all cultivated areas. It is important to note that blast disease induced the development of Italian rice cultivars over the centuries (Buffà 2000).

Symptoms can develop on the whole plant (TeBeest et al. 2007; Faivre-Rampant et al. 2011; Faivre-Rampant et al. 2013) but, in Italy, environmental conditions for rapid growth of the pathogen mainly occur between the second half of July and the first 10 days of August

(Rodolfi et al. 2006); for this reason, the most severe outbreaks are observed starting from inflorescence emergence stage and eventually show neck blast symptoms (Cortesi and Giuditta 2003). When severely affected, rice display both yield and quality reduction (Moletti et al. 1988). Losses in grain and milling yields (rate of polished white rice obtained from unhusked rough rice) can vary from minimal to 85 % of production depending on inoculum pressure, crop growth stage at the time of infection, environmental conditions, cultivar resistance and agronomic practices (IRRI 2013). Milling yield strongly affects economic aspects. In Italy, a significant reduction in milling yield (e.g., 20 %) may lead to a decrease up to 50 % of the market value (unpublished data).

Most evaluations of blast resistance under field conditions are made at the nursery stage following the International Rice Research Institute Standard Evaluation System (IRRI-SES) (IRRI 2002; Aram et al. 2013; Shafaullah et al. 2011; Marchetti 1983), which provides data in a relatively short time, since this method does not require cultivation until ripening stage. This method, however, is not always representative of what happens at the time of heading or later, when blast can infect the neck and directly compromise yield (Webster and Gunnell 1992). In a long term study carried out from the Ente Nazionale Risi under Italian field conditions (19 years), leaf blast assessments underestimated neck blast disease in 12 % of cases (Biloni and Lorenzi 2002).

Disease management is based mainly on efficient use of nitrogen fertilization (Webster and Gunnell 1992; Long et al. 2000), use of resistant cultivars, crop rotation, maintaining a proper flood level and treatment with fungicides (TeBeest et al. 2007; Maciel 2011). Surveys conducted in 2009 showed that in Italy the 75 % of the rice area is treated against blast disease and the 94 % of treated surface is treated with tricyclazole, mainly by a single treatment (Di Tullio and Baldi 2011). Tricyclazole is a systemic fungicide commercialized since 1970s (Floyd et al. 1976) and registered in Italy in the 1998; in 2008 the Commission of European Communities approved the withdrawal of authorizations for plant protection products containing that active ingredient. In order to firstly evaluate the resistance of Italian rice cultivars to neck blast disease and then the response of cultivars to a single treatment of tricyclazole against neck blast disease in Northern Italy (with a view to its possible future inclusion in Annex I to Directive 91/414/EEC), we tested 105 cultivars registered in

Italian Rice Catalogue, representing the 98 % of the cultivated rice area in 2012. Cultivars were chosen among those traditionally most important registered in National list before 2005 (Tamborini and Legnani 2005), and all cultivars registered from 2005 to 2013 (SIAN 2013).

Materials and methods

Trials were performed during 2011 and 2012 on Olai farm (45° 16' N 8° 39' W, 109 m a.s.l., Ceretto Lomellina, Lombardy Region), in the main area of rice cultivation in Italy. The chosen location has a long history of strong neck blast disease presence and has sandy soil. Sowing was done on dry soil, on 5 May 2011 and on 7 May 2012 with pneumatic seed drill. Once rice reached the 3rd leaf stage, the field was permanently flooded until beginning of the ripening stage. High rates of nitrogen fertilizer were applied 3 times, twice between 3rd leaf unfolding and tillering stage (210 kg ha⁻¹ of 46 % urea applied two times, equal to 97 kg N ha⁻¹ per application) and after stem elongation (300 kg ha⁻¹ of 13–5–20 mineral complex equal to 39 kg N ha⁻¹).

Plant material

A total of 105 varieties belonging to different commercial groups (Round, Medium, Long A and Long B) were evaluated for panicle blast resistance under flooded field conditions. Product category with Long A grain was further divided into “parboiled” grain (LA-PB) and “internal consumption” grain (LA-IC). The latter refers to those varieties that are marketed almost exclusively in Italy for the preparation of “risotto”. Varieties were chosen from among the most important Italian cultivars; they represent the 98.4 % of the Italian cultivated area in 2012 (Tables 2, 3, 4 and 5).

Experimental design

A randomized split plot design was used, consisting of four replicates of treated and untreated plot. These main plots were split among the 105 varieties. The experimental unit was a 2-m row; distance between rows was 20 cm; tested rows were interspersed with rows of a highly blast-susceptible Italian rice cultivar, “Deneb”, used as “spreader” row.

Evaluation for blast resistance

Rice cultivars were classified on the base of incidence (percentage of infected panicles) and severity (part of panicle exhibiting blast symptoms) of the disease, evaluated in untreated block 3 weeks after heading. Based on the incidence rates of panicles exhibiting neck blast symptoms, cultivars were classified as follow: Resistant (R) with 0 to 15 % of infected panicles, Moderately Resistant (MR) with 15.1 to 30 %, Moderately Susceptible (MS) with 30.1 to 50 %, and Susceptible (S) with 50.1 to 100 % (Puri et al. 2009). Severity of symptoms was rated on infected panicles using a 0 to 9 ordinal scale (IRRI 2002), where: 0 indicates no lesions or lesions only on pedicels, 1 indicates lesions on several pedicels or secondary branches, 3 indicates lesions on a few primary branches or the middle part of panicle axis, 5 indicates lesions partially around the base or the uppermost internode or the lower part of panicle axis, 7 refers to a lesion completely around panicle base or uppermost internode or panicle axis near base with more than 30 % of filled grains, 9 indicates lesions completely around panicle base or uppermost internode or the panicle axis near the base with less than 30 % of filled grains. Symptom scores were attributed as average symptom observed in each experimental unit. Cultivar Vialone Nano was used as susceptible control and two varieties were considered as resistant control: cv. Arsenal and cv. CLXL745. Leaf blast was not recorded as it was not sufficiently developed.

Evaluation of treatment with tricyclazole

A single spray of tricyclazole at the recommended rate (450 g/ha of tricyclazole, corresponding to 0.6 kg/ha of Beam 12) was applied at the flowering stage to treated plots; the other plots were used as untreated control. Effect of fungicide treatment was evaluated comparing the average of panicle blast incidence obtained in treated and untreated block.

Data analysis

Incidence rates were subjected to a multi factorial ANOVA, after angular transformation ($Y = \arcsine p^{0.5}$). The model included: treatment, *cultivar*, block, year, *cultivar*-year interaction, treatment-year interaction and *cultivar*-treatment interaction. Furthermore, after founding significant differences between *cultivars*,

LSD (with Bonferroni correction) was calculated for comparison of cultivar incidence means. Since there is an equal number of observation per group, a single value was calculated. Statistical analysis was performed using SPSS software (version 21.0 for PC) and Microsoft Excel 2013.

Results

Effects of *cultivar*, treatment and year were statistically significant at the 0.05 significance level (Table 1). As indexed by the R^2 statistic, this multi-factorial ANOVA accounted for 74 % of the total variation in the incidence variable.

Variability in panicle blast resistance

Tested cultivars were evaluated in untreated block for panicle blast incidence and severity and separated in resistance classes (Tables 2, 3, 4 and 5). The ANOVA showed significant differences in incidence of diseased panicles among cultivars, ($p < 0.001$).

Only two cultivars were asymptomatic; 15 % of tested cultivars were Resistant, 17 % Moderately Resistant, 30 % Moderately Susceptible, and 38 % Susceptible. Cultivar CLXL745, used as resistant control, was confirmed to be highly resistant and in both years of test it was asymptomatic. Cultivar Arsenal, also considered as resistant control, was placed in the resistant class with 8 % of infected panicles, showing slight lesions. Cultivar Vialone Nano, used as susceptible control, was severely infected by the pathogen (98 % incidence), confirming that it is a highly susceptible cultivar that, without disease management can lose the whole yield.

Table 1 Results of the multi factorial ANOVA performed on incidence rates with $\alpha = 0.05$

Source of variation	df	F	Sig.
Cultivar	104	21.45	.000
Block	3	67.95	.000
Treatment	1	777.41	.000
Year	1	4.70	.030
Cultivar * Year	104	3.61	.000
Treatment * Year	1	0.24	N.S.
Cultivar * Treatment	104	2.26	.000

Table 2 List of Resistant varieties (R), with 0–15.0 % incidence of panicles showing neck blast symptoms; results expressed as average of incidence and severity score assessed in 2011 and 2012 in treated and untreated plots

Cultivar	Untreated		Treated		Mean Incidence ^a	Registration year	2012 area ^b (ha)	Grain shape
	Incidence (%)	Severity (0–9)	Incidence (%)	Severity (0–9)				
CL46	0	0	0	0	0.00000	2012	59	Long B
CLXL745	0	0	0	0	0.00000	2011	1302	Long B
Libero	1	1	1	0	0.04022	2005	–	Long B
Atlantis	2	1	4	2	0.08329	2006	11	Long B
Oceano	3	2	0	0	0.04307	2012	43	Long B
CL71	4	1	4	2	0.09817	2011	16,986	Long B
Wang	6	4	4	3	0.16373	2013	22	Medium
CRW3	7	4	9	2	0.18147	2007	–	Round
Mare CL	8	1	1	0	0.08357	2012	906	Long B
Arsenal	8	3	3	1	0.15249	2008	933	Long B
Teseo	9	3	1	0	0.12553	2012	–	Long B
CL26	9	3	6	3	0.23562	2011	5653	Long B
Sagittario	11	2	5	2	0.19758	2012	13	Long B
Vulcano	13	4	6	2	0.21292	2010	6	Long A (IC)
Falco	13	3	9	4	0.26279	2012	6	Long A (IC)
CL80	13	3	3	0	0.15249	2012	214	Long B

^a Mean calculated after angular transformation. LSD=0.39964

^b Italian Cultivated Area in 2012. Data provided by Ente Nazionale Risi

The most widely cultivated cultivars within the R and MR groups are CL71 (Long B), Luna CL (LA-PB) and CL26 (Long B); they represent 13 % (30471 ha) of the cultivated area, they are resistant to imidazolinone herbicides (Clearfield® technology) and they have been recently registered (2011). Within the R and MR cultivars 4 out of 34 varieties belong to LA-IC grain shape group and only one, Roma, an historical variety released in the market in 1931, is cultivated on a significant area (3840 ha). In MS group, the three most cultivated varieties have a LA-IC grain shape: S. Andrea (10796 ha), Carnaroli (9003 ha) and Karnak (7796 ha). No Clearfield® varieties resulted MS. Almost 60 % of the Italian rice production area is cultivated with susceptible varieties; adding Moderately Susceptible cultivars the involved area reaches 80 %. In fact, the three most cultivated varieties in 2012, Centauro, Volano and Sirio CL, resulted Susceptible and, despite this characteristic, they are extensively cultivated for their agronomic characteristics and, respectively, for high yield, organoleptic qualities or resistance to imidazolinone herbicides. Furthermore, Sirio CL is the only

Clearfield® variety classified Susceptible (S) to neck blast.

The 88 % of LA-PB grain shape cultivars were Moderately Susceptible or Susceptible, followed by Medium grain shape (80 %), LA-IC grain shape (78 %), Round grain shape (68 %), and Long B grain shape (37 %) (Fig. 1).

Dividing cultivars depending on the year of registration on Italian catalogue of rice varieties and calculating average incidence and severity in untreated block, we observed that the most recently developed cultivars are more resistant to the disease. In fact, mean incidence (%) and severity (0–9 scale) for the varieties bred before 1970s is 71 % and 8 respectively, instead of cultivars registered after 2010, which have 30 % mean incidence and an average of severity score of 5 (Table 6).

Treatment effect

Treatment with tricyclazole at the flowering stage significantly reduced incidence of diseased panicles (55 % mean reduction) ($p<0.001$). It also reduced severity of

Table 3 List of Moderately Resistant varieties (MR), 15.1–30.0 % incidence of panicles showing neck blast symptoms; results expressed as average of incidence and severity score assessed in 2011 and 2012 in treated and untreated plots

Cultivar	Untreated		Treated		Mean Incidence ^a	Registration year	2012 area ^b (ha)	Grain shape
	Incidence (%)	Severity (0–9)	Incidence (%)	Severity (0–9)				
Orione	16	4	4	1	0.22154	2010	82	Medium
Elettra	16	2	9	1	0.25661	2012	5	Long B
Vasco	16	2	8	2	0.26481	2013	11	Long A (PB)
Thaibonnet	18	4	13	4	0.33096	1992	535	Long B
Giglio	18	2	4	1	0.21769	2011	319	Long B
Sole CL	19	3	9	3	0.31081	2012	260	Round
Fedra	20	6	12	6	0.36305	2012	3	Long A (IC)
Brezza	20	3	9	2	0.30827	2013	3	Long B
Tigre	20	6	11	3	0.35467	2012	4	Long B
Ercole	23	7	5	2	0.30902	2005	98	Long A (PB)
CL12	23	5	5	2	0.30834	2012	1238	Round
Ellebi	23	7	4	3	0.30111	2007	1147	Long B
SP55	25	8	13	6	0.41139	2008	164	Round
Castore	28	6	9	5	0.35553	2013	–	Round
Roma	29	7	20	4	0.47920	1967	3840	Long A (IC)
Yume	29	7	14	2	0.39338	2007	544	Round
Fast	30	4	19	4	0.46670	2012	4	Long B
Luna CL	30	4	11	3	0.41146	2011	7832	Long A (PB)

^a Mean calculated after angular transformation. LSD=0.39964

^b Italian Cultivated Area in 2012. Data provided by Ente Nazionale Risi

symptoms (Fig. 2). This incidence reduction is stable and it is verified in each resistance class (Fig. 3). The interaction effect between treatment and year was non-significant while interaction effect between cultivar and treatment was highly significant ($p<0.001$).

Discussion and conclusions

The relative field resistance of Italian rice cultivars to neck blast disease is not well known; for this reason, cultivars were chosen among those traditionally most important registered in National list before 2005 (Tamborini and Legnani 2005), and all cultivars registered from 2005 to 2013 (SIAN 2013).

Recent studies identified the presence of resistance genes to the three lineages of *P. oryzae* reported in Italy. Among the cultivars considered in the present study, 42 have been characterized for resistance genes Pi-ta, Pi-B, Pk^h and Pi-z (Gironi et al. 2010), which have been

proven to determinate complete resistance to all (Pi-ta and Pi-b) or most (Pi-kh and Pi-z) of Italian strains (Roumen et al. 1997). Screening results showed that 38 cultivars have no resistance genes, while four cultivars have one or two resistance genes: Arsenal and Atlantis (Pi-z and Pi-k^h), Libero (Pi-k^h), Augusto (Pi-z) (Gironi et al. 2010). Arsenal, Atlantis and Libero resulted resistant in our test, instead of Augusto, which appeared to be MS (33 % of infected panicles). Moreover, Faivre-Rampant et al. (2011) tested the resistance of several varieties to leaf-blast using nursery method and artificial inoculation with three isolates representative of the three lineages of *M. oryzae* reported in Italy (Roumen et al. 1997). For varieties tested in both this study and Faivre-Rampant et al. trials there's generally a good correspondence, despite the different method of resistance class assignment. The majority of varieties that in Faivre-Rampant's study showed different degrees of resistance to the three different pathotypes have at least a response consistent with that in our study.

Table 4 List of Moderately Susceptible varieties (MS), 30.1–50.0 % incidence of panicles showing neck blast symptoms; results expressed as average of incidence and severity score assessed in 2011 and 2012 in treated and untreated plots

Cultivar	Untreated		Treated		Mean Incidence ^a	Registration year	2012 area ^b (ha)	Grain shape
	Incidence (%)	Severity (0–9)	Incidence (%)	Severity (0–9)				
Teti	31	6	9	4	0.40275	2013	2	Long A (PB)
SIS R215	31	4	10	3	0.41730	2003	40	Long A (PB)
Augusto	33	7	12	4	0.44234	2002	4610	Long A (PB)
Antares	33	6	11	3	0.40864	2010	158	Long A (PB)
Rombo	34	4	14	5	0.44037	2011	1	Long A (PB)
Ronaldo	34	5	8	2	0.40118	2010	5844	Long A (PB)
Centro	35	5	7	2	0.39988	2012	131	Long B
Onice	35	7	16	5	0.50558	2011	372	Long A (PB)
Samba	35	5	20	5	0.52710	2008	96	Long A (IC)
Sfera	38	6	6	2	0.40159	2012	36	Round
Gloria	38	6	19	4	0.51846	2010	486	Long A (IC)
Corimbo	38	6	19	5	0.52683	2013	1	Long B
Agata	39	7	6	3	0.40720	2012	6	Round
Cerere	39	5	14	2	0.48953	2009	919	Round
Ninfa	40	7	6	2	0.39387	2012	0.2	Long B
Bacco	41	7	24	5	0.57906	2011	80	Long A (IC)
Lince	41	5	20	4	0.51098	2011	510	Long A (PB)
Virgo	41	6	21	6	0.57858	2011	939	Round
Aiace	41	6	27	5	0.59743	2002	933	Long A (PB)
Ducato	44	6	18	5	0.57641	2011	196	Round
Carnaroli	44	8	20	5	0.57356	1983	9003	Long A (IC)
S. Andrea	44	7	20	5	0.57803	1974	10,796	Long A (IC)
Opale	45	7	23	4	0.56591	2008	1688	Long A (PB)
Crono	46	7	14	3	0.53788	2010	584	Medium
Scudo	46	5	12	5	0.52528	2005	54	Long B
Proteo	46	7	13	3	0.54580	2013	1	Long A (PB)
Galileo	48	7	21	6	0.61663	2002	4228	Long A (IC)
Urano	48	6	8	3	0.50166	2009	499	Long B
Medea	48	5	19	3	0.57555	2013	1	Medium
Karnak	48	7	14	4	0.52222	2002	7796	Long A (IC)
Puma	48	6	21	4	0.61499	2011	2981	Long A (PB)

^a Mean calculated after angular transformation. LSD=0.39964^b Italian Cultivated Area in 2012. Data provided by Ente Nazionale Risi

Where the response within the two studies is very different, it could be likely the lack of complete correspondence on disease severity between evaluations made at nursery stage and field evaluations during ripening stage. This can clearly be observed on Augusto and Argo cultivars, that resulted in resistance to leaf blast (Faivre-Rampant et al. 2011) while being susceptible to neck blast. It is also

possible to observe the opposite; Orione and Roma are reported to be highly susceptible to leaf blast while being moderately resistant to neck blast disease. Finally, the mismatch in results on neck and leaf blast resistance could be explained thanks to new advances in molecular characterization of *M. oryzae*. In fact, the analysis of more than 200 strains collected in Lombardy Region suggests the

Table 5 List of Susceptible varieties (S), 50.1–100.0 % incidence of panicles showing neck blast symptoms; results expressed as average of incidence and severity score assessed in 2011 and 2012 in treated and untreated plots

Cultivar	Untreated		Treated		Mean Incidence ^a	Registration year	2012 area ^b (ha)	Grain shape
	Incidence (%)	Severity (0–9)	Incidence (%)	Severity (0–9)				
Centauro	51	6	14	5	0.56591	2002	27,290	Round
Scirocco	51	7	9	3	0.51810	2004	11	Long A (PB)
Argo	53	7	14	4	0.57152	1978	309	Round
Febo	53	7	21	5	0.60651	2012	1	Long B
Dardo	55	8	34	5	0.74947	2010	8052	Long A (PB)
Neve	55	8	34	5	0.73916	2013	24	Long A (IC)
Musa	55	6	34	4	0.72305	2011	202	Medium
Meco	56	7	13	5	0.57720	2012	90	Long A (PB)
Brio	56	6	22	3	0.69037	2005	3401	Round
Albatros	59	6	14	3	0.58685	2000	22	Long B
Gladio	59	8	32	4	0.73287	1998	11,719	Long B
Selenio	59	7	20	2	0.64397	1987	13,696	Round
Baldo	59	8	30	6	0.72811	1977	7705	Long A (IC)
Ulisse	60	8	17	6	0.62596	2007	2603	Long A (IC)
Carnise	60	7	28	6	0.70952	2008	1382	Long A (IC)
Flipper	61	8	33	5	0.74783	1997	228	Medium
Nuovo Maratelli	61	7	39	5	0.75412	2000	124	Medium
Sirio CL	63	8	21	5	0.69266	2009	17,739	Long B
Volano	63	8	40	7	0.80192	1972	19,550	Long A (IC)
Eridano	63	6	33	3	0.77753	2012	40	Round
Nembo	65	7	33	5	0.75738	1999	2346	Long A (PB)
Lido	68	7	28	6	0.74660	1976	–	Medium
Ariete	69	7	33	4	0.79456	1985	311	Long A (PB)
CRLB1	70	8	48	6	0.92378	2007	540	Long B
Carmen	71	7	34	5	0.82326	2005	17	Long A (IC)
Creso	73	7	15	5	0.69087	2004	1717	Long A (PB)
Delfino	76	8	30	6	0.81364	2001	362	Long A (PB)
Eurosis	76	5	44	6	0.93772	2002	282	Long A (PB)
Balilla	76	7	45	6	0.91397	1967	3649	Round
Presto	78	6	29	4	0.82787	2012	–	Long A (PB)
Nerone	79	8	26	5	0.85909	2009	14	Long A (PB)
Loto	80	8	25	6	0.83118	1988	6135	Long A (PB)
Luxor	81	8	41	7	0.93675	2008	60	Long A (PB)
Arborio	83	8	46	7	0.97584	1967	867	Long A (IC)
Sprint	88	8	73	6	1.19096	2002	203	Long B
Elio	91	6	36	4	0.95507	1985	173	Round
Deneb	95	9	70	8	1.21357	2007	41	Medium
Carnise Precoce	96	8	50	8	1.12671	2008	809	Long A (IC)
Ambra	98	9	46	6	1.11681	1999	208	Round
Vialone nano	98	9	64	7	1.22623	1967	4140	Medium

^a Mean calculated after angular transformation. LSD=0.39964^b Italian Cultivated Area in 2012. Data provided by Ente Nazionale Risi

Fig. 1 Percentage of Resistant (R), Moderately Resistant (MR), Moderately Susceptible (MS) or Susceptible (S) varieties belonging at each grain type

presence of new haplotypes, different from those reported by Roumen in 1997 (Abbruscato et al. 2014).

Sixteen varieties out of 105 exhibited incidence lower than 15 %; since we worked under favourable environmental conditions for the pathogen, they were classified as Resistant. Medium and Long A for internal consumption grain shape varieties (to which belong most traditional cultivars) were determined to be highly susceptible to the disease with 80 % and 78 % of MS+S cultivars respectively. This result agrees with what is commonly reported; in fact, traditional cultivars, are preferred in the Italian market for their qualitative and organoleptic characteristics despite their high susceptibility to the disease and, for some varieties, despite their agronomic problems (long stem, late time of maturity, difficulties on red rice control). High susceptibility of

some of these cultivars can also be due to the fact that they had been bred at the beginning of last century for cultivation with reduced nitrogen rates than those currently suggested.

Type of incidence and severity in cultivars of recent introduction are less severe. This can be due to different factors. First, one of the main goals in Italian rice breeding has always been to select varieties with genetic resistance to neck blast disease; second, after 1990 in Italy were introduced varieties from the US with good blast disease resistance, that were integrated in rice breeding programs (Faivre-Rampant et al. 2011); third, cultivars registered in National list in 1967 (the year of constitution of the official National list) were actually selected between 1920 and 1940 (Tamborini et al. 2008) and in almost a century of cultivation the pathogen could have overcome host resistance. Moreover, the ability of the fungus to mutate and quickly overcome host resistances is well known and is a major problem for rice breeders (Bonman 1992; Araujo et al. 2000; Conaway-Bormans et al. 2003; Faivre-Rampant et al. 2011).

Tricyclazole was effective in reducing the neck blast disease. For Moderately Susceptible or Susceptible cultivars, a single treatment reduced incidence and severity of disease but the infection was still high after the treatment, confirming that a single treatment in presence of conducive conditions and susceptible cultivars is not enough to control the disease (Moletti et al. 1988). In

Table 6 Evolution of incidence and severity of symptom of neck blast disease in tested cultivars, according to the year of registration in National list; data collected in untreated block

Years of subscription	Incidence (%)	Severity (0–9)
1960–1969	71	8
1970–1979	57	7
1980–1989	69	7
1990–1999	60	7
2000–2009	50	6
2010–2013	30	5

Fig. 2 Incidence of infected panicles (%) and severity score (0–9) observed in 2011 and 2012; results expressed as average of data collected in treated and untreated plots

such conditions, good agronomical practices (especially application of reduced nitrogen rates) are recommended (Bonman and Garrity 1992; Webster and Gunnell 1992; Long et al. 2000; Ballini et al. 2013). In Italy, under favourable conditions for blast disease, cultivar classified as Resistant could be grown even without fungicide protection; this group consists mainly of Long B grain shape varieties (14 out of 16). Under favourable conditions, all cultivars belonging to MR group could be

cultivated without risk of high yield losses if a reduced nitrogen rate or fungicide treatment is applied. For MS cultivar reduced nitrogen supply and fungicide treatment should be carefully considered by the grower. On the other hand, S cultivars should be avoided for cultivation under favourable conditions unless supplied nitrogen is reduced and at least one fungicide treatment is applied. It is impossible to suggest the best cultivar to be grown in favourable condition for neck blast disease but

Fig. 3 Mean of incidence (%) among the different resistance classes compared in treated and untreated plots

following the above recommendations combined with other fundamental cultivar parameters, such as time of maturity, grain and milling yield, and considering market price, farmers could make the best choice in their situation.

Tricyclazole still remains a valuable tool to control the disease especially considering that, in 2012, the 80 % of the Italian rice area is cultivated with Moderately Susceptible or Susceptible cultivars. Furthermore, given the strong ability of the fungus to overcome host plant resistance, tricyclazole is even more useful especially for varieties that have high commercial value. On the other hand, an eventual genetic resistance would constitute a valid alternative both from economic and environmental point of view.

Considering that there isn't always a correlation between symptoms observed on leaves and then on panicles and despite the huge amount of study on resistance genes, host-pathogen interaction, selection of resistant cultivar (Dean et al. 2005; Jia et al. 2000, 2009; Bagnaresi et al. 2012; Campos-Soriano et al. 2013; Miah et al. 2013; Wu et al. 2013) it is still important to confirm in-field the expression of any possible resistance on the basis of the environment and agricultural techniques used. The availability of data about the field resistance is an important tool for researchers, breeders and growers, combining scientific value with impact in applications. At global level many researches are focused on how climate changes can impact on the future ability of agriculture to provide food and feed (Climate Change Position Statement Working Group 2011). In this sector, the forecast models play a fundamental role, but the improvement of existing models needs precise information such as varietal field resistance to main diseases that cause yield losses. Breeders can use this information to focus their research of new resistant varieties, considering that in Italian rice growing area the main blast symptom concern the panicle, instead of other environmental condition, where the leaf blast is the most spread symptom. The impact of this work in application is evident, as the choice a variety to be grown is driven by many factors, at the base of which there is always the goal of an economic return. Losses caused by diseases result in economic losses, so the variety choice must be done consciously, even considering the economic impact that diseases may have, in order to prevent damages and to adopt any possible countermeasures.

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