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Moletti M., Giudici M.L., Villa B.

in

Chataigner J. (ed.).
Maladies du riz en région méditerranéenne et les possibilités d'amélioration de sa résistance

Montpellier : CIHEAM
Cahiers Options Méditerranéennes; n. 15(3)

1997
pages 79-85

Rice Akiochi-brown spot disease in Italy: Agronomic and chemical control

M. Moletti, M.L. Giudici and B. Villa
Centro di Ricerche sul Riso, ENR (Italy)

Abstract. As it is well known, Akiochi is a nutritional disorder typical of sandy soils with low CEC and a low content of Fe, Mn, K, Mg, Si, etc. This disease is mainly caused by H2S and by other reduced substances produced under reductive conditions which affect the nutrient absorption; by silica and bases deficiencies as a consequence of soil and water high temperatures; by N and K deficiencies at later stages of growth. Plants damaged by Akiochi are consequently susceptible to *Bipolaris oryzae*, the pathogen of the rice Brown spot disease which develops profusely in rice fields on sandy soils.

In Italy, this disease has become important since about 10-12 years in lighter textured soils as a consequence of rather high temperatures, with values higher than usual in July and in August, and it concerns more than 50% of the rice fields.

In order to control this disease, a sub-plot experiment was carried out to evaluate some agronomic practices (later applications of N, N+K and K in mid-July) and some fungicides (Iprodione and Propiconazole) applied once (22/7) or twice (13/7 and 5/8) at the beginning of the Brown spot development (in the sub-plot), both not draining and draining long the rice field in mid-July to oxidize the soil (in the plot). The susceptible cultivar Elio was sown in a sandy soil in which this disease has always developed widely in the last years as well as in the year of this trial. The brown-spot development was recorded weekly as soon as the first symptoms appeared from flowering to harvesting.

The results of this trial can be summarized as follows:

- later N and N + K applications were positive because they delayed the Akiochi Brown spot development;
- the later K application did not affect positively this disease;
- the fungicides treatments, particularly the double application, reduced and/or delayed the infections of *Bipolaris oryzae* in both the edaphic conditions;
- drying the rice field in July was very useful because this delayed the Brown spot development.

The treatments which reduced or delayed the Akiochi brown spot development gave higher productions in t/ha:

N = 5.17 b; N + K = 5.27 b; K = 4.44 c; Iprodine = 5.59 ab; Iprodione + Iprodione = 5.79 a; Propiconazole = 5.15 b; Propiconazole + Propiconzole = 5.63 ab; Check = 4.93 c; Draining = 5.33 a; Not draining = 5.06 b.

I – Introduction

Akiochi, as it is well known, is a nutritional disorder. It is typical in well-drained sandy soils lacking in free iron, entailing accumulation of hydrogen sulphide, with low cation exchange capacity and low content of K, Si, Mn, Mg, etc., and also in ill-drained organic soils, rich in reduced compounds like ferrous iron, organic acid (butyric and acetic) and hydrogen sulphide (Baba et al., 1965). This disease is mainly caused by the toxicity of the hydrogen sulphide and of other reduced substances, produced, particularly when temperatures are high in summer, under reducing conditions which affect the nutrient absorption; by silica and bases deficiencies as a consequence of soil and water high temperatures; by nitrogen and potassium deficiencies at later stages of growth (Baba et al., 1965; Tanaka and Yoshida, 1970). The toxic substances start to be noxious to rice plants in July when the temperature raises and when rice begins its reproductive stage and its capacity for supplying oxygen to the rhizosphere decreases: therefore soil conditions become more reducing (Yoshida, 1981). Akiochi does not occur in heavy clay soils with high cation exchange capacity and rich in several nutrients, particularly in active iron which reacts with hydrogen sulphide to form insoluble ferrous sulphide (Baba, 1965).

Plants affected by Akiochi become susceptible to *Bipolaris oryzae* (Breda de Haan) Shoem., the pathogen of the rice Brown spot disease which was used as an index of Akiochi (Baba, 1965; Ou, 1985). Brown spot develops profusely in rice fields on sandy soils, where it causes great damage decreasing both the grain yield and the grain quality (Ou, 1985).

In Italy, this disease has become important since 1982-1983 (Moletti, 1984) in lighter textured soils as a consequence of rather high temperatures, with values higher than usual in July and in August (Table 1), and also as a consequence of the spreading of very susceptible rice varieties like Lido, of the greater soil compaction (which decreases the water movement in and on soil), of the continuous rice cropping and of the replacement of organic manure with mineral fertilizers. This disease, with different crop damage, concerns about 50% of the Italian rice fields.

Table 1. Average temperatures in May-September recorded at CRR Station at Castello d'Agogna (Pavia), Growing Degree Days (GDD) and Akiochi-Brown spot incidence in the period 1982-1993, in lighter textured soils in Italy

Years	Average Temperature °C					GDD (*)	Akiochi Brown spot incidence
	May	June	July	August	September		
1974-1981	15.2	19.1	20.7	20.1	16.5	967.0	
1982	18.8	23.2	24.9	23.1	21.3	1566.4	Severe
1983	15.8	21.0	25.5	21.9	18.8	1319.0	Severe
1984	14.2	21.0	24.0	22.2	17.6	1195.6	Low
1985	16.8	19.6	24.1	21.9	19.5	1285.3	Mild
1986	18.6	20.0	21.1	22.0	17.9	1215.3	Mild
1987	15.4	19.5	23.5	22.0	20.8	1257.9	Mild
1988	17.4	19.4	23.0	22.3	18.7	1250.4	Mild
1989	18.8	20.4	23.3	23.0	18.3	1342.5	Mild
1990	19.4	21.1	23.5	23.1	18.8	1408.5	Mild
1991	15.7	20.9	25.1	23.8	19.7	1380.0	Mild
1992	19.8	20.1	23.5	24.4	18.6	1425.3	Severe
1993	19.0	22.2	22.1	24.1	18.5	1404.4	Severe
1974-1993	16.5	20.0	22.5	21.7	18.0	1189.3	

(*) GDD = ∑ (daily mean temp. 0°C-12°C), from May to September.

Different kinds of control measures against the Akiochi-Brown spot have been suggested: the varietal one, employing resistant genotypes; the agronomical one, adopting cultivation practices to decrease the toxic substances in soil; the chemical one, using fungicides against *Bipolaris oryzae* (Moletti, 1984; 1989). As regards the resistant rice genotypes, among the Italian and foreign varieties tested as well as among some pure lines, most were severely damaged and only few genotypes were not very affected (Moletti, 1989; Moletti et al. 1983; Moletti et al. 1988-1992).

In order to control this disease, a trial was carried out to evaluate some agronomic practices (later applications of N, N + K and K) and some fungicides (Iprodione and Propiconazole) applied 1 and 2 times at the beginning of the Brown spot development, both not draining and draining long the rice field in mid-July to oxidize the soil.

II – Materials and methods

The trial was performed in 1993 at Tromello (Pavia), in a sandy soil in which Akiochi-Brown spot has always developed profusely in previous years. The physical and chemical characteristic of this soil were the following: sand = 81.3%; loam = 15.2%; clay = 3.5%; pH = 5.3; organic matter = 2.65%; total N = 0.112%; cation exchange capacity = 3.1 me/100 g soil.

In this experiment, the eight treatments shown in Table 2 were compared in plots separated by levees, both not draining and draining in the whole second decade of July. A strip-plot experiment with four replications was chosen, with the treatment in the plot and the not draining or draining in the sub-plot, which measured 50 m^2.

Table 2. Agronomic and chemical treatments to control the Akiochi-Brown spot disease

Treatments		Doses per hectare	Application time
	N	30 kg	July 14
	K_2O	54 kg	July 12
	N + K_2O	30 kg + 54 kg	July 14
Not drained rice field	Rovral FL	1.6 l	July 22
in mid-July	Rovral FL + Rovral FL	1.6 l + 1.6 l	July 13 and August 5
	Tilt 25 EC	0.5 l	July 22
	Tilt 25 EC + Tilt 25 EC	0.5 l + 0.5 l	July 13 and August 5
	Check	-	-
	N	30 kg	July 14
	K_2O	54 kg	July 12
	N + K_2O	30 kg + 54 kg	July 14
Drained rice field	Rovral FL	1.6 l	July 22
from 10 to 20 July	Rovral FL + Rovral FL	1.6 l + 1.6 l	July 13 and August 5
	Tilt 25 EC	0.5 l	July 22
	Tilt 25 EC + Tilt 25 EC	0.5 l + 0.5 l	July 13 and August 5
	Check	-	-

Heading August 4-6
Rovral FL containing 25% of Iprodione; Tilt 25 EC containing 25.25% of Propiconazole. Fungicides were mixed with 400 l/ha of water and applied with an experimental sprayer similar to the farm sprayers.

The susceptible short grain cultivar Elio was sown at the end of April distributing 180 kg/ha of seed. The mineral fertilization was carried out some days pre-sowing with basal application of 80-80-150 kg/ha of N, P_2O_5, and K_2O respectively and again 40 kg/ha of N as topdressing in June, during the tillering stage. The other cultural practices were as the traditional ones.

The symptom severity of Brown spot was recorded weekly from the beginning of August, some days after the symptom appearance, until harvest at the end of September. Symptoms were scored according to the IRRI (International Rice Research Institute) scale from 0 to 9 evaluating the affected leaf area as follows: 0 = no incidence; 1 = less than 1%; 2 = 1-3%; 3 = 4-5%; 4 = 6-10%; 5 = 11-15%; 6 = 16-25%; 7 = 26-50%; 8 = 51-75%; 9 = 76-100%. Moreover, the following cultural parameters were evaluated: plant height on 20 records per plot; panicle density, dry matter and grain yield straw ratio on four samples of 0,25 m^2 per plot; grain yield by harvesting the whole plot; 1000 seed weight and head rice (with Satake testing-mill on 200 g of rough rice) on a sample per plot; kernel discoloration on the sample of head rice.

Rice was harvested with a plot combine at the end of September.

III – Results and discussion

In 1993 the weather was favourable to Akiochi-Brown spot. In fact, in the second and third decades of June, temperatures were higher than usual and favoured the disease development. At the beginning of July, in advance than usual, the disease symptoms were already observed on the lower leaves, particularly in cultivation lacking in nitrogen. However, the fall in temperature in the second and third decades of July slowed down the epidemic which increased again at the beginning of August, when the temperature rose again, and damage was severe, as shown in Table 1.

The disease progress curves of the different treatments and of the two soil conditions (not drained and drained) are shown in Figures 1 and 2: some treatments gave good results decreasing or delaying the disease development, whereas some others did not affect the disease behaviour. The double application with Iprodione (Rovral) was the best in the control of *Bipolaris oryzae* and the double application of Propiconazole (Tilt) comes just after. On the other hand also the single applications of this two fungicides were useful. Interesting results were given also by the later application of N + K or N which delayed the disease development, while the later application of K did not influence the epidemic. With regard to draining in mid-July, its effect was positive because it decreased the Akiochi-Brown spot severity.

Figure 1. Disease progress curves of different treatments

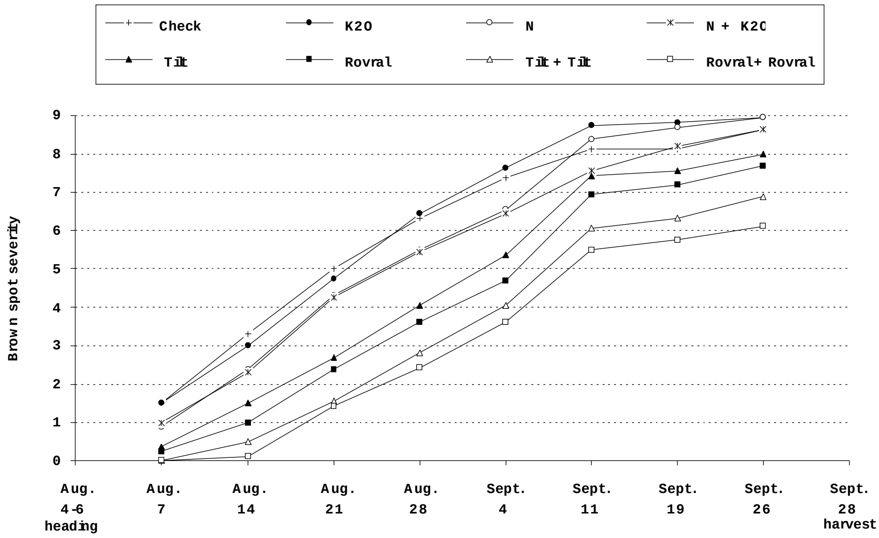
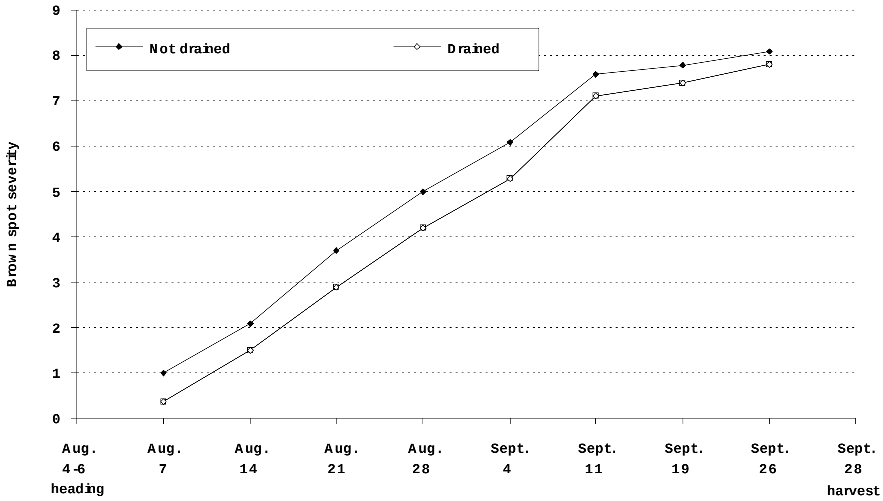


Figure 2. Disease progress curves in not drained and drained rice fields in mid-july



Scale (Brown spot affected leaf area): 0 = no incidence; 1 = less than 1%; 2 = 1-3%; 3 = 4-5%; 4 = 6-10%; 5 = 11-15%; 6 = 16-25%; 7 = 26-50%; 8 = 51-75%; 9 = 76-100%.

Values of the recorded main cultural traits are shown in Table 3 as well as the disease severity at the dough stage when most of the reserves are already stored in the grain (the record at this stage is the one which better evidences the relation between the symptom severity and the yield values of the various treatments). The analysis of the data indicates that treatments with fungicides and with N + K or N, which decreased or delayed the disease development, gave higher grain yield in both soil conditions, with increases between 11 and 33%. The highest grain yields were given by the theses with the double fungicide treatment (increase 20-33%), but the increases obtained were lower than our expectations based on the good plant appearance related to less *Bipolaris oryzae* infections. The applications of N + K or N, as well as draining, favoured the plant growth measured by plant height, panicle density and dry matter production.

An interesting trait to which attention should be paid is kernel discoloration: the amount of blotches due to infecting fungi on milled rice was higher in the theses (fungicide treatments, with values between 2.5 and 3.2%) where the infection of *Bipolaris oryzae* on leaves and on glumes was fewer; on the contrary it was lower in the theses (Check and K, with values from 1.6 to 2.1%) in which the lesions of Brown spot on leaves and on glumes were more numerous. In the theses N and N + K with the same trend of the disease development on leaves and on glumes for most of the cycle, the amount of blotches on milled rice was higher in N (2-2.5%) and lower in N + K (1.5-2.1%). It is important to point out that in Italy milled rice can be traded only if damage (discoloration and spots) on milled rice is less than 1.5% (this value can be raised to 2-2.25%, according to the variety, in particular years with severe damage). Therefore a treatment which, besides allowing grain yield increase, entails more blotches on milled rice is less useful.

Table 3. Disease severity and values of the main agronomic traits got with different cultural and chemical treatments

Treatments	Disease severity (1)	Grain yield (2) t/ha	Grain yield % of check	Head rice %	Kernel discolo-ration %	Plant height cm	Panicle density no./m^2	Dry matter g/m^2	1000 seed weight g	Grain yield/ straw
Not drained rice field in mid-July										
Check	7.5	4.38	100.0	63.3	1.6	73.5	364	1003	25.2	0.80
K_2O	8.3	4.20	95.9	64.9	1.6	71.3	383	995	25.1	0.77
N	7.3	4.87	111.2	62.7	2.0	78.0	415	1181	25.2	0.73
N + K_2O	6.9	4.99	113.9	63.0	1.5	76.5	398	1124	25.1	0.78
Tilt	5.9	4.99	113.9	62.7	2.5	71.9	361	1093	25.5	0.95
Rovral	5.1	5.58	127.4	63.8	2.5	74.2	419	1246	25.2	0.82
Tilt + Tilt	4.4	5.64	128.8	62.5	2.7	75.3	401	1246	25.5	0.86
Rovral + Rovral	3.9	5.83	133.1	62.2	2.5	75.2	376	1186	25.7	0.88
Drained rice field in mid-July										
Check	7.3	4.68	100.0	64.3	2.1	73.8	379	1055	25.6	0.79
K_2O	7.0	4.67	99.8	63.6	2.0	74.3	398	1057	25.1	0.79
N	5.9	5.47	116.9	64.2	2.5	77.2	465	1312	25.2	0.82
N + K_2O	6.0	5.55	118.6	64.3	2.1	79.1	447	1237	25.3	0.74
Tilt	4.9	5.30	113.2	63.2	3.0	73.2	407	1204	25.5	0.86
Rovral	4.3	5.59	119.4	64.2	3.2	74.3	417	1304	25.5	0.83
Tilt + Tilt	3.8	5.61	119.9	64.9	3.2	74.2	386	1205	25.4	0.82
Rovral + Rovral	3.4	5.75	122.9	65.2	3.2	74.7	389	1268	25.8	0.77
Means										
Check	7.4	4.53 c	100.0	63.8 a	1.9 c	73.6b	371 c	1029 c	25.4 a	0.80a
K_2O	7.6	4.44 c	98.0	64.2 a	1.8 c	72.8b	390 bc	1026 c	25.1a	0.78a
N	6.6	5.17 b	114.1	63.5 a	2.2 bc	77.6a	440 a	1247 ab	25.2 a	0.77a
N + K_2O	6.4	5.27 b	116.3	63.7 a	1.8 c	77.8a	422 ab	1180 ab	25.2a	0.76a
Tilt	5.4	5.15 b	113.7	62.9 a	2.8 ab	72.5b	384 bc	1148 b	25.5a	0.90a
Rovral	4.7	5.59 ab	123.4	64.0 a	2.9 a	74.2b	418 ab	1275 a	25.3 a	0.83a
Tilt + Tilt	4.1	5.63 ab	124.3	63.7 a	3.0 a	74.7b	393 bc	1226 ab	25.4a	0.84a
Rovral + Rovral	3.6	5.79 a	127.8	63.7 a	2.8 ab	74.9b	382 bc	1227 ab	25.7 a	0.83a
Not drained rice field	6.1	5.06 b	100.0	63.1 a	2.1 b	74.5b	389 a	1134 a	25.3 a	0.82a
Drained rice field	5.9	5.33 a	105.3	64.2 a	2.7 a	75.1a	411 a	1205 a	25.4a	0.80a

(1) On 4 September at dough stage.
(2) Data at 14% moisture content.
Means followed by the same letter are not significantly different at $P < 0.05$ (Duncan's test).

In order to better understand these different results, the samples of rough rice of the treatments were observed. It emerged that blotches on dehulled rice occurred in the centre of the kernel surface or near the apex, under the gaps where lemma and palea hook each other. Moreover the more numerous gaps were, the more numerous blotches were, which were absolutely unrelated to the disease development on leaves and on glumes.

Fungi found on blotches were mostly the following: *Bipolaris oryzae*, *Alternaria* spp., *Curvularia* spp., *Epicoccum purpurascens*, *Nigrospora oryzae*.

With regard to the gaps of hulls, it is necessary to point out that they are not attributable to the storage of greater amount of reserves in spikelets, because the 1000 seed weight was almost the same in all the treatments. More likely the greater number of gaps in some theses is attributable to a lower silicization of hulls (Bechtel and Pomeranz, 1978).

Records on rough rice show that gaps of hulls and consequently also kernel discoloration were more frequent in the theses in which plants had more vegetative vigour (thus with less silicized tissues) and remained green longer because of the application of N or of fungicides, as well as owing to the effect of draining in mid-July. However, it is interesting to point out that in the theses in which potassium was applied singly or mixed with nitrogen the amount of blotches was smaller than in the check and in the thesis with only N respectively.

On the basis of these data, it could be supposed that the later K application, probably, helped in improving the hooking between lemma and palea which consequently opened less. This hypothesis agrees with Noguchi and Sugawara (1966) who observed that potassium deficiency decreases the silica accumulation in cells. On the contrary, the content of silica in the plant increases with the level of supplied potassium.

With regard to the relation between nitrogen and silicon, it is known that if the former increases in the plant, the latter decreases (Yoshida, 1981). As a consequence, the increasing of blotches with the increasing of the nitrogen application could be explained by the less silicization of hulls which consequently open more.

The nitrogen application is negative for the kernel discoloration, but it is positive because it delays or decreases the Akiochi-Brown spot development: in fact it has been reported that nitrogen deficiency in soil after the middle of the growth period favours the early appearance of hydrogen sulphide; on the contrary, the nitrogen presence delays the hydrogen sulphide formation, therefore also the disease development (Yoshida, 1981; Ou, 1985).

IV – Conclusions

The results of this experiment seem to be rather useful in practice and they can be summarised as follows:

❑ The fungicide treatments of plants, both with the single and the double application, controlled *Bipolaris oryzae* well and gave an interesting grain yield increase which varied from 13 to 33%; obviously, the double application gave the best results. Iprodione (Rovral) worked a little better than Propiconazole (Tilt). As regards the application time, the results attained in this and in other trials show that the best period for treatments is the second half of July, as soon as the symptoms appear on the lower leaves. An unresolved problem about the fungicide treatments is the increase of kernel discoloration.

❑ The various agronomic practices were positive because they delayed the disease development. Some of them (N + K and N) gave grain yield increases between 11 and 18%, another (K) did not affect the grain yield positively. Potassium, however, gave some positive effects because it decreased kernel discoloration. The best result was obtained by the application of N + K owing to the grain yield increase related to nitrogen and owing to the fewer kernel discoloration related to potassium.

The effect of draining in mid-July was also positive because it decreased the Akiochi-Brown spot severity and increased the grain yield.

Anyhow further trials have to be carried out also with other varieties to confirm the already attained results, to verify the hypotheses put forward and to clarify the unresolved problems.

In conclusion, if in Italy weather went on being warmer than in the past, besides using varieties less susceptible, in order to decrease the Akiochi-Brown spot damage to rice, it is advisable to adopt the following agronomic practices: draining long in mid-July, later N + K application, organic manure utilization, use of fertilizers containing iron, magnesium, manganese, silicon, etc. (furnace slag), less soil compaction, deep and running water in warm months, delay sowing so that the reproductive stage and the ripening occur with temperatures not too high. Moreover, obviously, the fungicides Iprodione and Propiconazole, which control *Bipolaris oryzae*, could be applied; their use, however, might be integrated with the overmentioned cultivation practices directed to improve the soil conditions, which are the primary factor inducing the disease development.

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