O.36 - Toward an integrated strategy to limit blast disease in upland rice

Sester M.[1], Raboin L.M.[1], Ramanantsoanirina A.[2], Tharreau D.[3]

[1] CIRAD, URP SCRiD, BP 230, Antsirabe 110, Madagascar
[2] Fofifa, URP SCRiD, BP 230, Antsirabe 110, Madagascar
[3] UMR BGPI, CIRAD TA 41/K Campus international de Baillarguet 34398 Montpellier Cedex 5

Contact: sester@cirad.mg

Abstract

In the Highlands of Madagascar, rice is the staple crop and food. To face the growing demand for rice, CIRAD and Fofifa developed upland rice varieties adapted to the conditions of high elevation areas. However, upland rice was more susceptible to bio-aggressor attacks than rainfed lowland rice, and especially susceptible to *Magnaporthe oryzae*, the causal agent of blast disease. Due to the economical situation of Madagascar farmers, the use of pesticides is limited. Integrated strategies have to be built for the management of the blast disease. Based on results obtained on rice or other crops, we considered two directions: a) the effect of direct-seeded, mulch-based cropping systems, first used in Madagascar to reduce erosion and soil degradation, b) the effect of cultivar mixtures. Our first results show a significant slow-down of the dynamic of blast epidemic with both management practices. However, no significant difference was detected when the final sanitary state of the crop is considered. This is probably due to the very high susceptibility of the cultivar examined. Nevertheless, it seems possible to improve the system in order to achieve an efficient and sustainable management of the disease. Modelling approaches will be helpful to optimize the cropping systems and the cultivar mixture arrangements.

In Madagascar, rice is the staple crop and food. The Highlands are densely populated and farmers traditionally grow irrigated or rain-fed lowland rice wherever possible, with admirable developments in inland valleys and terraces on hillsides. At the end of the 1970s, the population had to face the challenges of a growing demand for rice, the stagnation of rice yields in irrigated lowlands, and the scarcity of new lowland areas which could be devoted to rice cultivation. Because of the lack of suitable varieties, they could not grow upland rice on their vast upland stretches. Indeed, upland rice growing was limited to altitudes lower than 1,200m.

In the mid-1980s, CIRAD and FOFIFA launched a research programme for the Highlands with the aim of pushing forward the frontier of upland rice growing areas in high elevation areas of the tropics. This programme was then consolidated with research on cropping practices that ensure the sustainability of upland rice-based cropping systems, especially in this poor and fragile environment. New varieties were obtained and adapted for use in altitudes up to 1800m (Dzido *et al.*, 2004).

However, upland rice is subject to much more pressure from bio-aggressors than rain-fed lowland rice. The farmers had to face attacks of white grubs and black beetles and the expansion of blast disease, caused by the fungus *Magnaporthe oryzae*. Blast disease develops on panicle stems and prevents grain filling. Due to the small genetic basis of the varieties adapted to upland conditions of the Highlands of Madagascar, the fungus quickly overcomes resistant or tolerant lines selected by breeders. The economic situation of Madagascan farmers limits the use of pesticides.

In such a context, new integrated strategies have to be thought-out and evaluated in order to durably control blast epidemics and ensure sustainable upland-rice production. We started investigating in two directions:

The effect of new crop management through direct-seeded, mulch-based cropping systems, first used in upland conditions to prevent erosion and soil degradation. The permanent mulch on the ground has many consequences on the rice crop: it reduces drought periods and ensures a better mineral equilibrium in the plant. Indeed, it could be an interesting way to limit epidemic expansion (Seguy *et al.*, 1999, Ratnadass *et al.*, 2006).

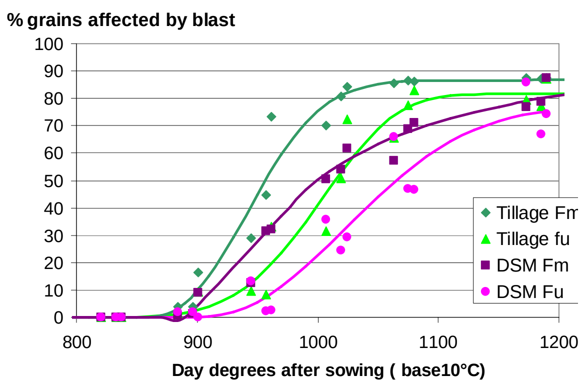
The effect of cultivar mixtures which have already demonstrated their efficiency for the control of rusts and mildews of small grain crops (Wolfe, 1985). This approach was also successful against blast disease in the irrigated rice fields of Yunnan where a susceptible traditional glutinous variety can be grown in mixture with resistant varieties without the need for fungicides (Zhu *et al.*, 2000). The question we would like to address is whether this strategy may efficiently contribute to blast reduction in the difficult epidemiological context of upland rice in the Highlands of Madagascar.

We present here the first results of our investigations in these two directions.

Direct-seeded, mulch-based (DSM) cropping systems

Over three years, a susceptible variety (Fofifa 154, a variety that contributed to the success of upland rice in the Highlands of Madagascar but whose resistance broke down over recent years) was sown in two cropping systems, in randomised block design experiments with 4 repetitions in Andranomanelatra (in the Highlands of Madagascar). A direct-seeded (no tilling) mulch-based cropping system was compared to the traditional system involving manual tillage and exportation of crop residue. Two fertilisation levels were used: organic fertilisation (zebu manure at 5t per hectare) with or without mineral fertilisation (300 kg NPK 11/22/16 per hectare), coded Fm and Fu respectively in figure 1. For the first two years, dynamic studies were performed with one observation per week. The results of panicle blast are shown on figure 1. In 2004-2005, blast symptoms were significantly lower in the direct-seeded cropping system and especially with Fu fertilisation for each date except the last one where disease levels were not statistically different. In the second year, a significant difference was observed until the last date and the effect of fertilisation was quite low in the direct-seeded cropping system.

2005-2006:



2006-2007:

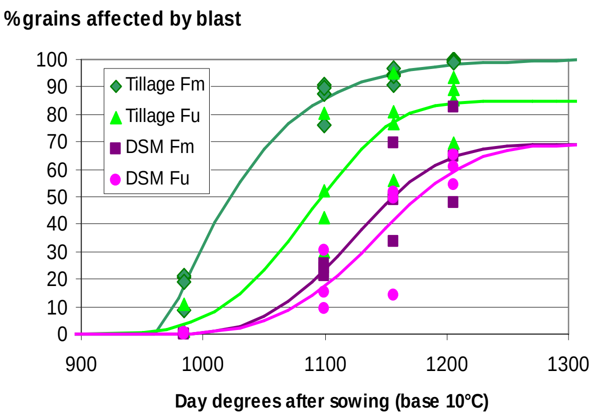


Figure 1: Dynamical studies on blast disease in upland rice fields in 2004-2005 and 2005-2006. Mean percentage of grains affected by the disease (mean rate of sick panicles x percentage of sick grains per sick panicle).

These experiments clearly show the potentialities to use direct-seeded cropping systems to limit the progression of blast disease and to reduce the effects of fertilisation on disease susceptibility. Nevertheless, these systems need a good management of the mulch and their performances are bound to the success of the previous crops. In our experiment, mulch was quite sparse and did not manage to cover the ground. That could be the reason why the effect of the cropping system on the reduction of blast disease was moderate.

Our research will now focus on an overall improvement of the cropping system with a stimulation of its useful components. To detect mechanisms involved, explain them and propose new strategies to limit blast, modelling approaches will be used so that a large range of combination of cropping practices could be virtually tested and their effects on blast epidemics could be assumed. Such models will need a characterisation of the effect of each practice individually or a mechanistic modelling of the phenomena involved.

Cultivar mixtures

In 2007-2008, we carried out an experiment on cultivar mixtures involving a highly susceptible variety (Fofifa 154) and a resistant variety (Fofifa 172). Three mixture arrangements were compared to the monoculture of the susceptible variety as a control: one row of the susceptible variety planted every one row of the resistant variety (1/2 row mixture), one row of the susceptible variety every five rows of the resistant variety (1/6 row mixture) and the complete randomisation of the hills of the susceptible cultivar with an overall ratio of one susceptible hill for 5 resistant hills (1/6 random mixture). This trial was a randomised block design with four replications. Individual plots of 6x6 metres were separated one from the other by a 4m band of the resistant variety in order to limit inter-plot interactions.

The results presented in figure 2 clearly demonstrate a slowing down of the blast epidemic when mixtures are grown. The most diluted 1/6 rows or 1/6 random mixture arrangements appear more efficient than the ½ rows mixture. However, at the end, nearly all panicles were attacked whatever the dilution and final yields were almost nil (150kg per hectare on average for the susceptible component of the mixture compared with 4,600kg per hectare on average for the resistant component) and not statistically different between the treatments.

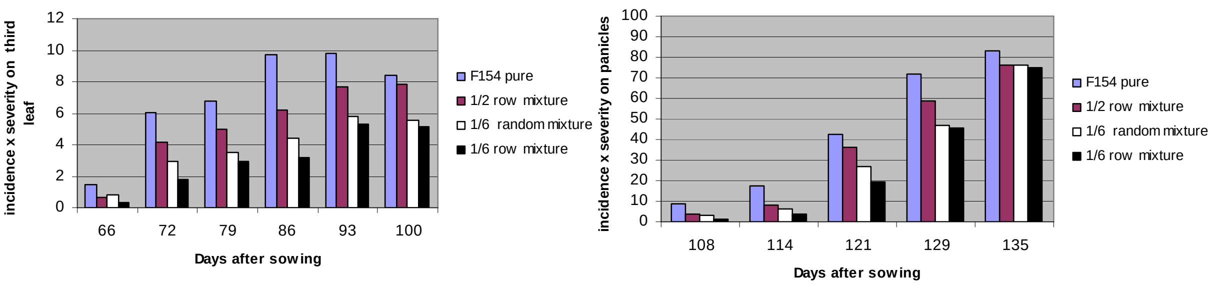


Figure 2: Incidence x severity of blast disease observed across 2007-2008, first on leaves and then on panicles, in different mixture arrangements compared to the monoculture of the susceptible variety

Other mixtures should be tested: mixtures involving a less susceptible variety than Fofifa 154 which could better benefit from the epidemic slowdown we observed and mixtures of varieties with a complementary resistance spectrum in order to take advantage of induced resistance in addition to the dilution effect we tested in this experiment (Lannou et al., 1994). In fact, the effect of the number, proportions and resistance levels of the mixture components should be anticipated through modelling approaches and the expected better combinations tested in the field.

Beyond these practical experiments, we also would like to address the tricky question of whether resistances may be more durably managed through the implementation of genetic diversification at the field or regional level.

Conclusion

In Madagascar, the integrated management of blast disease is a crucial challenge for the success of upland rice in the Highlands. The first results presented here show a potential for the use of cropping system and cultivar mixtures that need to be optimised and should be tested in combinations afterwards. Moreover, further studies based on a modelling approach will start now to test virtually many situations and guide future experiments.

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