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# Upland rice varieties for smallholder farming in the cold conditions in Madagascar's tropical highlands

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ABSTRACT

Upland rice cropping has become a familiar part of the landscape in Madagascar's central highlands, a densely populated region mainly characterized by resource poor family farmers and cold climatic conditions. A survey of 485 farmers conducted in 2011–2012 revealed that 71% of them cultivated upland rice although the crop was absent in this region before the first cold tolerant varieties were released in 1995. It also revealed that a single variety, Chhomrong Dhan (CD) originating from Nepal and released in 2006 was by far the most widely cultivated variety and accounted for 82.5% of the total acreage of upland rice. Farmers appreciate CD for its relatively high yield under low input conditions. However, this dominance raises concerns about the resilience of upland rice agro-systems in the face of changes in climatic conditions or in pathogen populations. To identify key varietal adaptive traits that should be taken into account in the breeding of new upland rice varieties in this context, we compared a panel of improved varieties including CD under low input management over two cropping seasons. A strong positive correlation between leaf area index (LAI) before harvest and yield was observed. Varieties with the highest yield, including CD, are of long duration, produce high biomass yields, have a high LAI and the highest harvest index. A significant negative correlation was observed between the LAI of rice varieties and that of weeds, showing that a high LAI also helps limit competition for resources by weeds. In the context of subsistence family farming and in the cold conditions of Madagascar's tropical highlands, new improved varieties should combine high LAI, high harvest index and long duration, as these traits help compete with weeds and contribute to high yield potential under low input management, on the one hand, and resistance to blast, cold tolerance and reduced crop duration, traits that prevent yield losses, on the other hand. The trade-off between crop duration and the risk of cold-induced sterility specific to the cold conditions of Madagascar highlands has to be taken into account.

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## 1. Introduction

Rice is the staple crop in Madagascar and there is a long tradition of rice cultivation. Per capita rice consumption is the highest in Africa and the rice supply was estimated to be 154 kg/per capita/year (paddy equivalent) in 2009 (FAO-STAT, 2014). Back in the 1970s, Madagascar exported rice but has since become a rice importer. In the central highlands of Madagascar, which have the country's highest population density, the development of new lowland paddy fields is not possible. On the other hand, rainfed upland rice (UR) can be cultivated provided cold tolerant UR varieties are available. The region is characterized by a cold tropical highland climate with minimum temperatures that can fall below 10 °C and maximum temperatures that rarely reach over 30 °C (at 1650 m asl) between October and April during the rainy season corresponding to the upland rice cropping season. In the mid-1990s, the first varieties suitable for cultivation at high altitudes (from 1250 to 1800 m asl.) were released by FOFIFA (Madagascar national center of applied research and rural development) and CIRAD (Centre de coopération Internationale en Recherche Agronomique pour le Développement) paving the way for rice cultivation on the hillsides where farmers previously grew corn, beans or cassava (Dzido et al., 2004). Since then, the cultivation of UR has expanded very rapidly in the region, mostly among resource poor farmers.

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The most successful varieties from this early release were all obtained through pedigree breeding performed at 1500 m asl. on progeny of crosses between a local temperate *japonica* landrace (Latsika), cultivated in the lowlands, as cold-tolerance donor, and improved UR varieties developed for medium altitude areas. Unfortunately, the resistance to rice blast (disease caused by *Magnaporthe oryzae*) of these varieties, of narrow genetic base, was overcome within a few years (Raboin et al., 2011). The first blast outbreaks were observed in the 2002–2003 cropping season. New blast resistant varieties were needed and among the new material evaluated in participatory trials, a Nepalese variety Chhomrong Dhan (CD) was officially released in 2006 and rapidly adopted by farmers (Raboin et al., 2013). While in Nepal CD is exclusively grown in irrigated lowlands and was introduced in Madagascar as a cold-tolerance donor (Vales and Razafindrakoto, 1997), it proved to be well adapted to the rainfed upland cropping conditions of Madagascar's highlands where rainfall is not limiting during the cropping season. CD is a pure line selected at Lumle Agricultural Research Center, Nepal, from a cold tolerant irrigated landrace originating from a high elevation (2000 m asl.) village called Chhomrong (Sthapit et al., 1996). Interestingly, high pressure of both bacterial sheath brown rot caused by *Pseudomonas fuscovaginae* and blast to which the CD variety happens to be resistant, was also reported in Chhomrong village (Sthapit et al., 1995).

Eighteen years after the release of the first set of UR varieties, upland rice fields have become a familiar part of the landscape of Madagascar's central highlands. However, the successful expansion of UR cropping now relies on the adoption and cultivation of one dominant variety (CD), raising concerns about the sustainability of upland rice cropping systems in this region if conditions (climate, blast populations, etc.) change. Genetic uniformity increases the vulnerability of crops to pathogens or abiotic stresses (Strange and Scott, 2005; Frison et al., 2011). The purpose of this study was thus to (i) document the extent of UR cultivation in the central highlands of Madagascar (ii) document the share of CD among the UR varieties used by farmers and (iii) identify varietal adaptive traits to the low input conditions and to the climatic conditions that characterize the region's resource poor family farming. The study was based on the phenotypic dissection of the CD variety and comparison with other released or soon to be released varieties in low input trials over two cropping seasons.

## 2. Materials and methods

### 2.1. Survey of UR cultivation and UR varieties

#### 2.1.1. Sampling method

Sixteen villages in the Vakinankaratra region in Madagascar's central highlands, all situated at altitudes above 1250 m asl. (Fig. 1), and already surveyed in 2005 for UR cultivation and for the names of the UR varieties (Radanielina, 2010; Radanielina et al., 2013) were surveyed anew during the 2011–2012 cropping season. A total of 485 farmers (29–35 per village) were interviewed of whom 60% had already been interviewed in 2005 (Radanielina, 2010). The questionnaire included a request for information on (1) the area dedicated to lowland rice cultivation, (2) the number of plots and the area dedicated to UR cultivation, (3) the area dedicated to other upland crops and (4) a list of the UR varieties they cultivated. For each UR plot cultivated in the 2011–2012 cropping season, the farmers were also asked for (1) the size of the plot, (2) the UR variety used, (3) the preceding crops, (4) the use of organic fertilizers, (5) the use of mineral fertilizers and (6) the sowing date.

#### 2.1.2. Collection and identification of varieties

All UR varieties cultivated in the region are assumed to be one of the 16 varieties released by FOFIFA–CIRAD before 2012 (Table 1) as no UR had previously been cultivated in the region. However, the varieties were often renamed by farmers, and sometimes different names were given to the same variety in different villages. The lists of the UR varieties collected during the survey were used to draw up a consolidated list of the names of varieties found in each village, and one sample of seeds of each name was collected in each village. Given the unexpected variety of names, each seed sample was compared to the reference seed samples of the 16 varieties for a preliminary identification. To refine the preliminary identification,

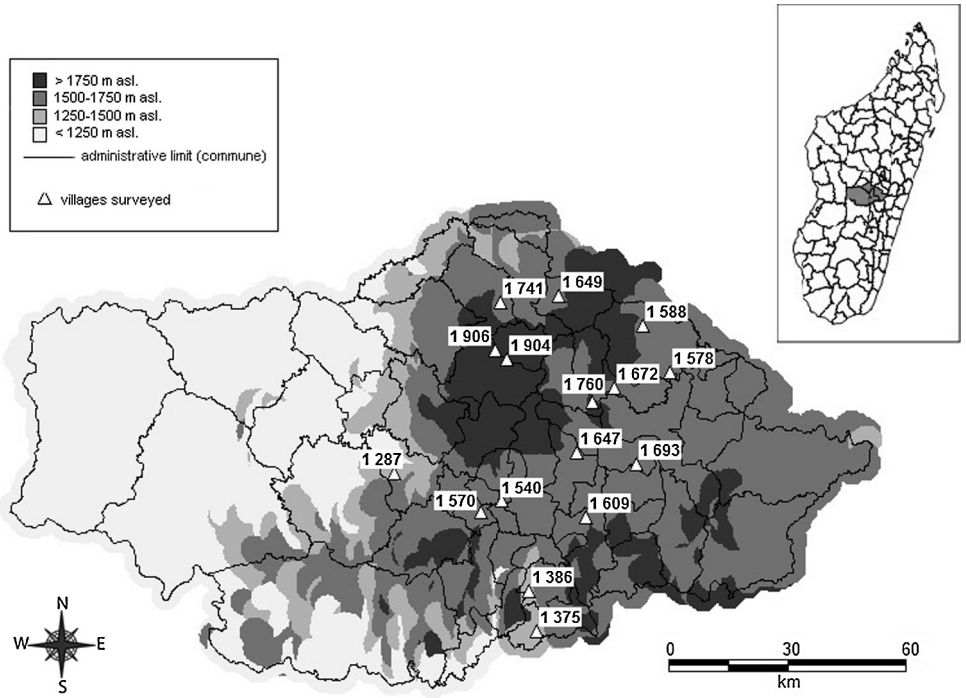


**Fig. 1.** Location and altitude of the villages surveyed in 2011–2012 in the Vakinankaratra region.

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