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RESEARCH PAPER

Farmers' perception, cropping patterns and weed management in rice (*Oryza sp.*) growth in Burkina Faso

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Abstract

Rice consumption is increasing because of the high population growth and the populations changing food preferences. Rice is mainly grown in three ecologies (irrigated, lowland and upland) where weeds affect its productions and therefore constitue the second limiting factor after water stress. This study aims to characterize rice cropping systems along with indigenous technical knowledge and introduced relevant technologies to rice growth and weed management. Farmers survey was conducted with 330 rice farmers in 7 sites located in the 3 rice growing ecologies. It appears that rice crop patterns are mainly based on a continuous rotation of rice. But in irrigated rice system during the dry season we noticed some crop rotation practices during dry season. Weed constraints are highly dependent on the 3 types of rice cropping patterns. Indeed, the most feared weeds according to rice farmers belong to *poaceae* (53%) family in irrigated rice, *cyperaceae* in upland rice (41.4%) and finally broad-leaved weeds in lowland rice ecology (57.8%). However, lowland rice ecology requires more weeding than other types of rice ecology. Irrigated rice has recorded the most technologies introduced, namely: composting with rice straw and 12 NERICA rice varieties associated with regular manual weeding for weed control.

Key words: Survey; Lowland; Upland; Irrigated rice; Farmers' practice

Introduction

Rice is the world's most important staple food grown over 100 countries, consumed regularly by over two billion people and the primary source of carbohydrate (Dibyendu *et al*., 2017). Asia is the largest growers of rice, with nearly 90% (738.2 Mtonnes of paddy) of world production (Rio and Brent, 2014; FAO, 2016). Rice demand in West Africa is increasing by 6% per year (Rio and Brent, 2014). Driven by food changing preferences in the urban and rural areas and compounded by high population growth rate (3.2 %) and rapid urbanization. Rice is ranked 4th among the cereals grown in Burkina Faso in terms of area, production and annual human consumption Ouedraogo and Dakuo (2017). Annual consumption per capita therefore increased from 18.2 kg in 1999 to 35 kg in 2013 and reached 50 kg per person in the two major urban centres (Ouagadougou and Bobo-Dioulasso) of the country (Bazié *et al.* 2014). In Burkina Faso, rice is a strategic sector despite low national production, which has only met 47% of national needs in rice grains since 2010 (National Rice Development Strategy (NRDS), 2011). Rice production in 2014 was estimated at 347,500 tonnes, an increase of 28.7% over the five-year average (Direction générale des études et des statistiques sectorielles (DGES), 2015). However, this increase does not cover the deficit of 53% of the national demand in rice grains. The country's rice policy aims to increase rice grain production so as to reduce imports amounted 37.8 billion CFA/year (Traoré *et al.*, 2015).

Considered as rice growing ecologies,rice is grown in irrigated land, lowland and upland,. Rice yield is less than 1 t/ha in upland (NRDS, 2011), 1.5 tons/ha in lowland areas and varied from 4 to 7 t/ha in irrigated areas (Guissou and Ilboudo, 2012). There is therefore a wide yield gap, especially in upland where potential yields are in the order of 4 to 5 t/ha (Traore, 2016).

The main constraints of rice cultivation are due to abiotic and biotic factors (Tibaldeschi and Boulenger, 2001). Drought is one of the major abiotic constraints and weeds are the second most important limiting factor after water stress (Deuse *et al.,* 1980). Yield losses due to weed competition can reach 15% for irrigated rice, 30% for lowland rice and 84% for upland rice (Diarra, 1992). The extent of yield losses depends on the weed density, rice variety planted and soil moisture conditions (WARDA, 2008; Dogbe and Aboa, 2002). The low rice productivity in Africa is correlated to the low dissemination and/or adoption of novel technologies to rice growers (Seck *et al.* 2013). However, African States have invested $420 million in the research and development of appropriate technologies to boost rice production for the- period of 2011-2015 (AfricaRice, 2011). Their adoption should increase productivity, income and improve household food security. Currently, the observation that emerges is that many rice innovations have actually been developed by national and international Institutions of agricultural research. but the question is how their efficient dissemination and adoption are ensured at the farmers' level in considering the socio-economic characteristics and indigenous knowledge of farmers.

The objective of the study is to highlight rice cropping patterns, indigenous technical knowledge (ITK) and introduced technologies for rice growth and the coping of weed management in rice agroecologies. The ouputs should prospect alternative farming innovations, technically and economically accessible to farmers; for weed and other constraint management in rice cultivation in Burkina Faso.

Material and Methods

Study sites

Farmers's survey was conducted in seven (07) sites belonging to three rice growing ecologies that are upland, lowland and irrigated scheme located in the three agro-ecological areas of Burkina Faso. The upland sites were chosen around lowland and irrigated sites (Figure 1). The seven (07) sites were as follows:

a. Kou Valley site is about 30 km northwest of Bobo-Dioulasso in the village of Bama (4° 22' W and 11 °22' N with an altitude of 300 m). It"s located in western Burkina,in the Hauts-Bassins Region ,in the Houet Province . This site is an irrigated land with total water control on an area of 1200 ha for 1300 rice farmers during 2016-2017 season.
b. Bagre site is located in Boulgou Province and in the Central-East region of Burkina Faso (0°30' W and 11 °27' N). Among 1680 plot users, the men constitue the majority;
c. Oueleni site (10° 51′ N, 5° 21′ O.) covers an area of 2810 km^2, it's located in Leraba province, in the Cascades region;
d. Tougouri site is located in Namentenga Province in the Central north region of Burkina Faso (12° 40 N and 14° S) and covers an area of 6168 km^2.
e. Niena Dionkele site (4°40' - 5° W and 11°30'- 12° N) is a developed lowland located in the Kenedougou Province, in Hauts-Bassins region. Its cultivable potential is estimated at 46,000 ha.
f. Sourou site (03° 20' W and 13° 00' N) is located in the northwest part of Burkina Faso, about 270 from Ouagadougo;
g. Bazon site (4°48' W and 11°19' N) is located in Kenedougou province, 63km from Bobo Dioulasso (10° 51′ N, 5° 21′ O.) .

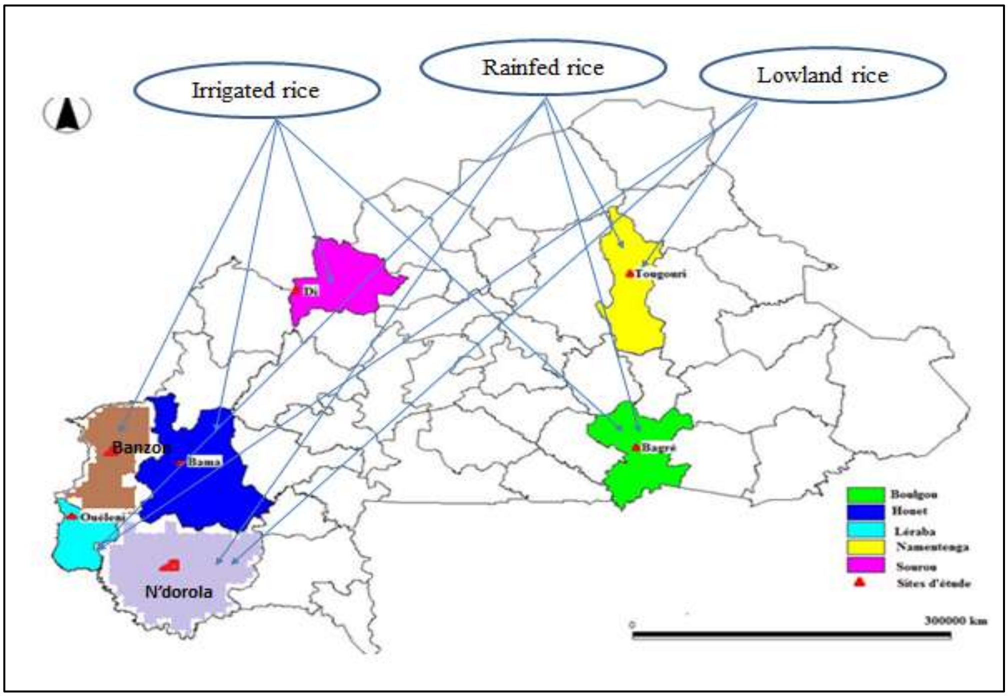


Figure 1: Geographic distribution of study sites in Burkina Faso

Methods

Farmers Sampling

Sampling of rice farmers was carried out randomly with the contribution of extension services and group leaders or cooperatives working in the plains or villages. At each selected site, 60 rice farmers were surveyed except Bama, Bazon and N'dorola sites where 30 farmers were sampled to balance the total population between the three rice growing ecologies.

Survey

About total of 330 rice farmers were interviewed during the 2016 rain season and 2017 dry seasons. The questionaire was designed using the Sphinx plus² software (Moscarola and Baulac, 1985) with questions on socio-economic data and farmers' weed management practices in each site. With a total of seventy-five (75) questions which were composed of closed-ended, numerical and text questions. The pre-survey consisted in seeking information to identify the main rice sites and resource persons for the implementation of the survey. It made it possible to explain the objectives of the study to the heads of farmer groups and plain leaders and to adjust the questionary.

Statistical analysis

The data were analyzed with the Sphinx plus² software version 5 (Moscarola and Baulac, 1985). The calculation of frequency distributions was performed using the Khi-2 independence test at the threshold of 5%. Data analysis was carried out on three population strata according to type of rice ecology: lowland (119 individuals), strict rainfed (120 individuals), and irrigated (161 individuals) rice farmers. the number of responses (402) is higher than the number of respondents (330) because some farmers interviewed practice more than one type of rice cultivation. The dependence level between variables is a function of the p probabality: p< 1% very significant; 5% < p < 1% significant; 5% < p < 20% not very significant; p > 20% not significant.

The rice area data (RA) and herbicide cost (HC) were combined to create a new data called average herbicide investment cost (AIC). The AIC for each ecology was calculated using the below formula.

$$\text{AIC} = \frac{HC}{RA} * \alpha \ (\alpha = 1 \text{ ha;})$$

Results

Socio-economic features of rice farmers

Few women are rice farmers regardless of the rice growing ecology. The high percentage of rice farmers women (31.1%) is recorded in lowland ecology while their proportion is less than 1% in irrigated ecology. The percentage of illiterate farmers is high for both men and women (44.5%). According to rice growing ecology, at least 10% of literate are counted in irrigated ecology in Arabia (20%), in upland ecology in Dioula (12%) and in lowland ecology in Moore (10%). With regard to formal schooling, only 19% of rice farmers have on average been enrolled in primary school. while 4.9% have a secondary level,.

Training in Rice farming and education levels of rice farmers is highly related to the rice growing ecology (p<1%) (Table 1). On average, the three rice ecologies registered less than 50% of farmers (36.3%) trained in rice production. . However, 49.6% of rice growers in irrigated areas gained trainings such as Système of Rice

Intensification (SRI), compost production and deep placement of urea.

The plot size significantly (p<1%) varies according to the rice growing ecology. From each rice growing ecology, the areas cultivated by the majority of rice growers are less than 1 ha. Indeed it's respectively the case of 58.5%, 57.7% and 78% in irrigated, upland and lowland ecologies. Plots of 1-3 ha are cultivated by 35.2% in irrigated ecology, 40.2% in upland ecology and 18.6% in lowland ecology. Plot owners of 7-8 ha are about 1% in irrigated ecology and 2% in upland and lowland ecologies Plot seize of 4-6 ha (5%) and over 8 ha (0.8%) are respectively recorded only in irrigated and lowland ecologies,.

In addition to rice farming, livestock is practiced by rice growers as a social and economic activity. More than 50% of rice growers are therefore cattle-breeders in upland (54%) and lowland (62%) ecologies against 44% in irrigated ecology.

Agricultural equipment used over the last five years on rice farms consisted of plough, cart for transporting the material, the chemical sprayer and the threshing machine. Rotary hoe and harrow are specific weeding tools inventoried in irrigated rice ecology.

Cropping patterns and induced technologies in rice cropping

In the rice plots, the dominant soil is clayey according to 70% of rice growers working in irrigated ecology, 61% in upland ecology and 72% in lowland ecology. They reported that the second dominant soil is silty namely 17% in irrigated ecology, 26% in in upland ecology against 28% in lowland ecology. Sandy is considered as the third soil by 13% of rice growers in both irrigated and upland ecologies while only 0.9% mentionned it in lowland ecology.

In rice farms, sorghum is the main (p <1%) cereal grown in addition to rice.In addition to sorghum, maize is mostly grown in irrigated areas while millet and cotton are cropped in lowlands. Crop rotation is practiced by rice farmers, 40.8% in upland, 8,4 % in lowland and 43.5% in irrigated areas. Concerning the type of crop rotation, there are 14 types (Figure 2) and the main ones for each ecology are the rotation between rice-maize and rice-sorghum. Some are specific such as the rotation of rice-ginger, rice-*cyperus* in upland and the rotation of rice-onion, rice-sweet potato in irrigated rice.

The choice of varieties by rice growers is highly dependent (p<1%) on the type of rice ecology (Figure 3). Irrigated rice has the highest number of varieties used (12 varieties) compared to the strict rainfed rice, where only one variety is used (FKR 45 N). In addition some rainfed rice growers, use irrigated variety (FKR 56 N) in their field. This is the non-respect of the principles of the rainfed rice cropping system.

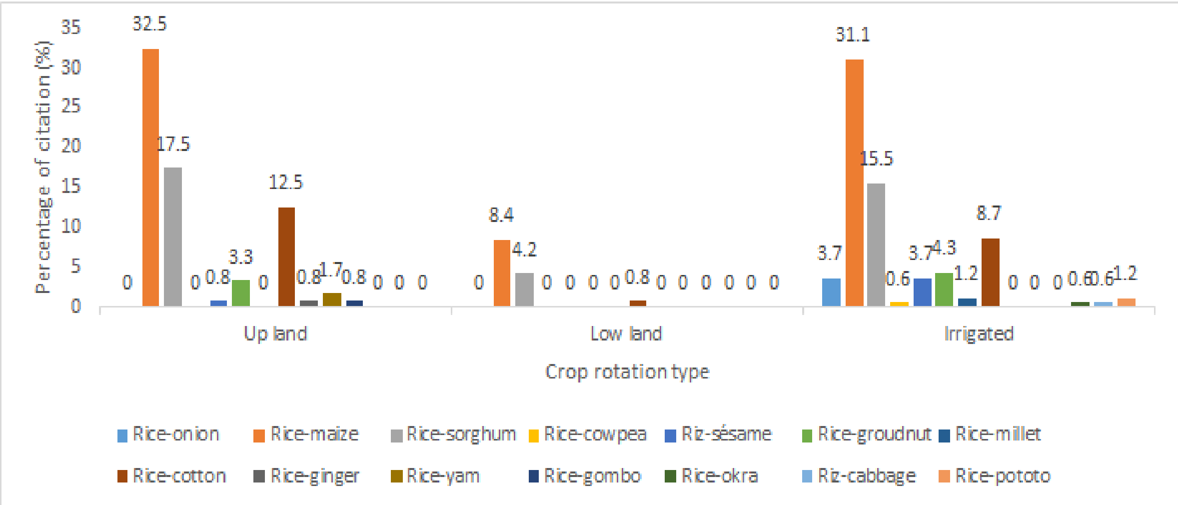
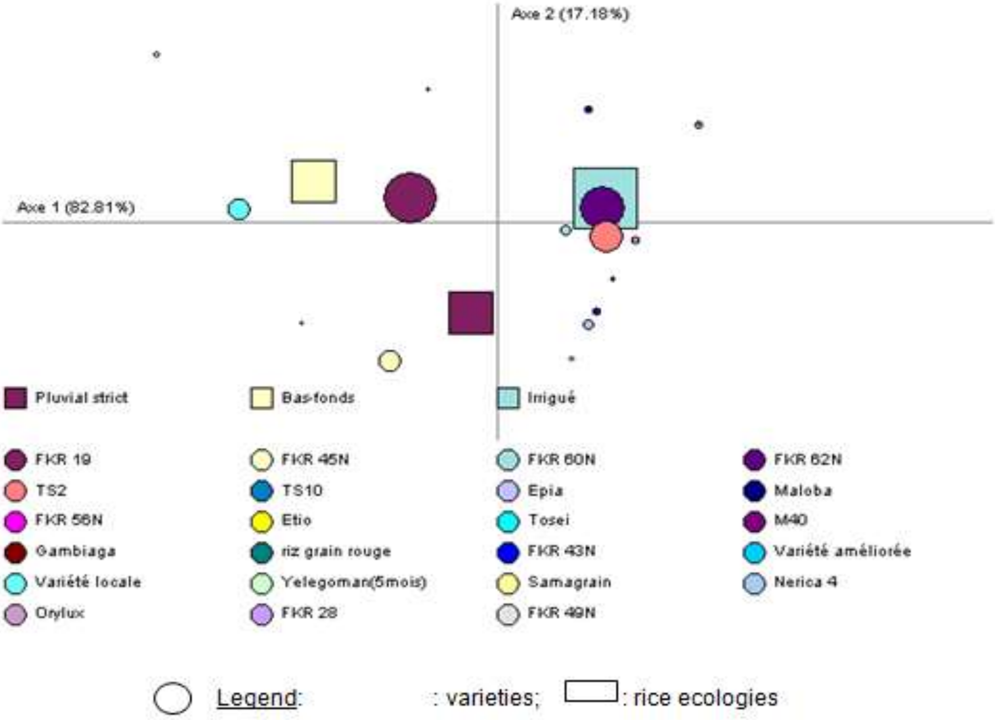


Figure 2 : Type of crop rotation according to the type of rice ecology in Burkina Faso. Les speculations sont en français

Legend:The dependence level between rice ecology and crop rotation type is: very significant (p< 1%)



The dependence level between rice ecology and varieties used type is: very significant (p< 1%)

Figure 1 : The Facoriel correspondence analysis of varieties used by rice farmers according to the type of rice ecology in Burkina Faso

Farmer's characterization and practices of rice weed control

- ***Identification of the most harmful weeds group and source of infestation***

Farmers highly correlated the most harmful weed families growing in rice (p <1 %) to rice ecology (Figure 4). Based on weed groups suggested by Defoer *et al.* (2004), rice farmers (41.3%) consider dicotyledons as the most harmful weeds to rice in lowland ecology. Surveyed farmers (57.8%) mentioned that the weeds affecting rice growth in upland ecology and withstand to local weeding options belong to *Cyperaceae* family. Farmers (53.2%) consider broad-leaved weeds are manageable in irrigated ecology while weeds of *Poaceae* family are most noxious to rice production.

Farmers emphasized that runoff is the main contamination source of rice fields by weed species in all rice ecologies. The other contamination sources vary according to rice ecology (p <1 %) . Indeed in lowland ecology respectively, 23.5% and 16.8% of farmers reported the working tools and the animal roaming as weed contamination sources, respectively. Impurity of rice seeds infeste rice fields in irrigated (24.2%) and upland (26.7%) ecologies while 14.2% of farmers consider animals roaming as weed contamination in upland ecology.

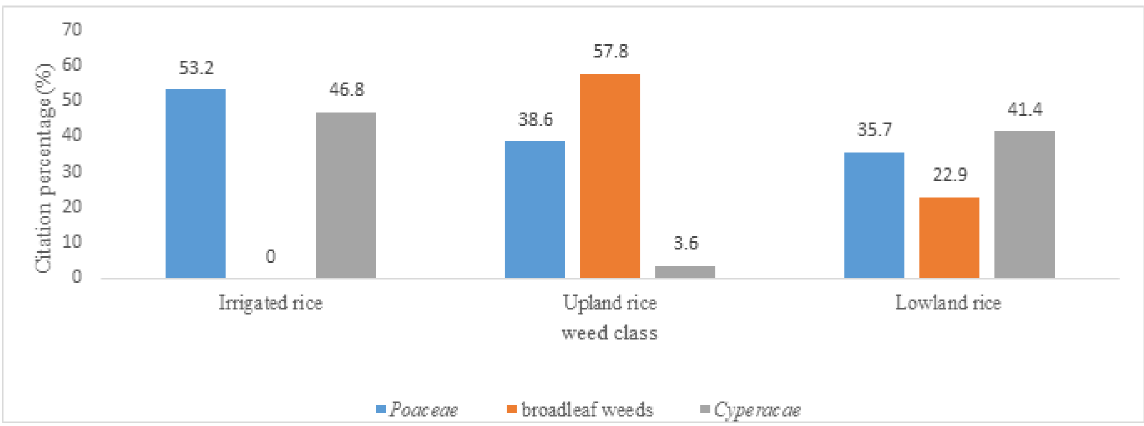


Figure 4: Farmers' perception of main weed pest class according to rice ecologies in Burkina Faso

Legend:The dependence level between rice ecology and most harmful weed families *is: very significant*(p <1 %)

- ***Indigenous weed control options in rice growth***

Statistical analysis showed that farmers' methods used for weed control vary according to rice ecology (p <1 %). Farmers use mineral fertilizers in upland (54.5%), lowland ecology (31.4%) and irrigated (43.6%) ecologies to break down competitiveness in rice fields. All farmers used to conserve water blade in irrigated ecology as a preventive and hydrophobic weed control. Improved varieties (64.8%), manure (compost) (73.3%) and crop rotation (75%) between rice and other crops (maize, potato, groundnut) and water level maintenance (100%) are predomnally used as preventive weed control in irrigated ecology (Figure 5). In addition, with regard to curative weed control, pulling is the most practiced in lowland ecology(43.8%) (Figure 6). Chemical herbicide is most used in irrigated ecology (34.1%) followed by the rotary hoeing (21.6%) as a mechanical control. Manual hoeing is the most common weeding in upland ecology (40.3%).

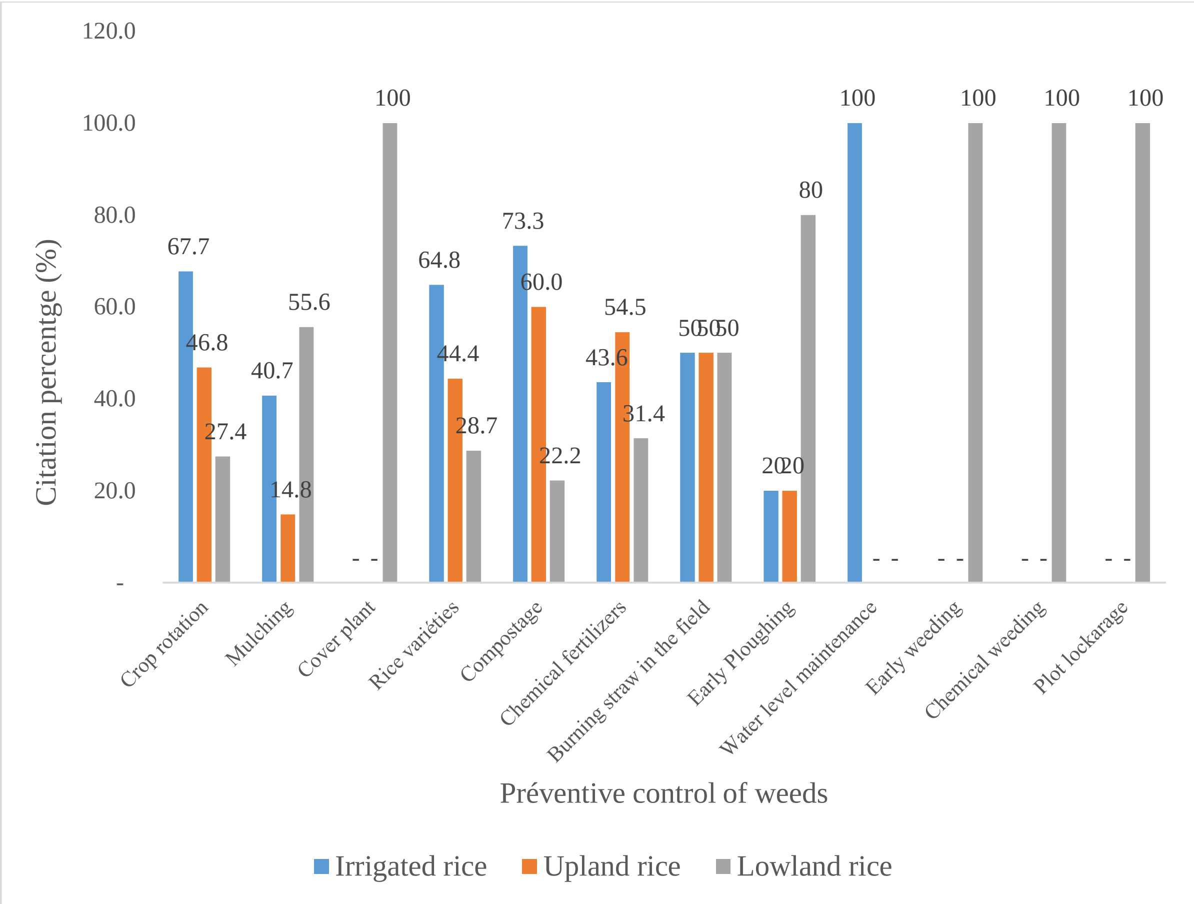


Figure 5: Farmers preventives methods of weed control according to the type of rice ecology

Legend : The dependence level between rice ecology and preventive control of weed *is very significant* (p <1 %)

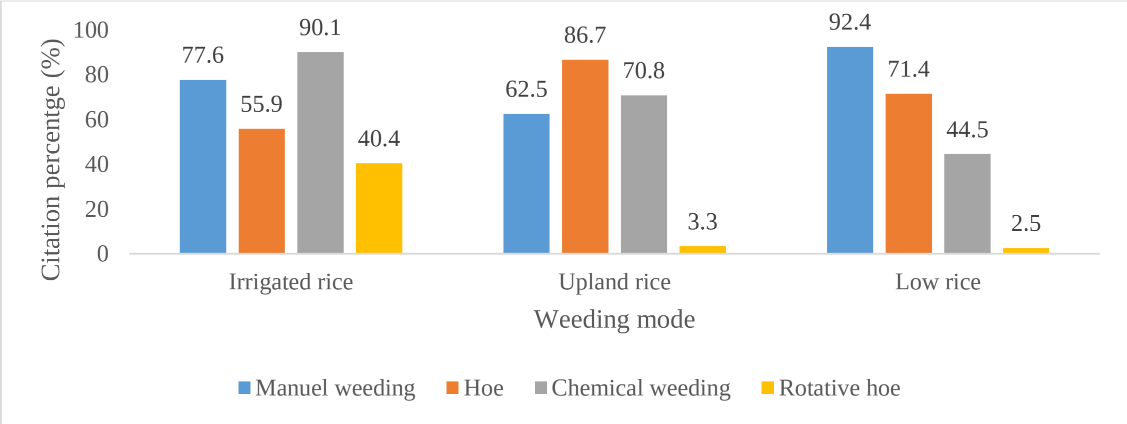


Figure 6: Farmers' weeding approach according to the type of rice ecology

Legend : The dependence level between rice ecology and weeding mode *is very significant*(p <1 %)

The number of weedings is also highly dependent on the type of rice ecology (p <1 %). The frequency of the weeding is higher in lowland ecology and more than four weeding operations are carried out during the crop cycle (Figure 7). But this weeding frequency (4 times) is carried out by only 7.6% of farmers compared to 54.6% who weed three (3) times from sowing to harvesting. For 56.9% (irrigated rice) and 53.2% (Up land rice) the rice field is weeded only twice, from sowing to harvesting.

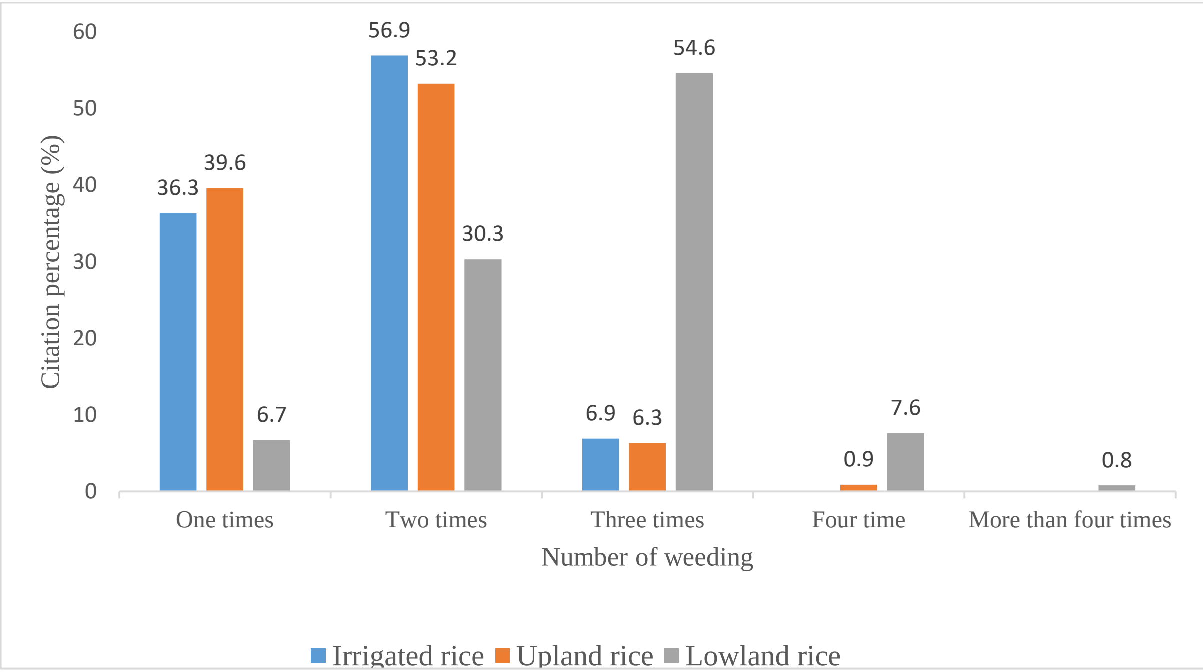


Figure 7: Number of weeding per cycle according to the type of rice ecology in Burkina Faso

Legend : The dependence level between rice ecology and most harmful weed families *is very significant*(p <1 %)

The criteria for herbicide selection by rice farmers is also highly dependent on the type of rice ecology (p <1 %). In irrigate rice production, 43.2% of farmers prefered selective post-emergence herbicide. for lowland (47.5%) and upland (39.3%) ecology, farmers prefer using total herbicides.

The average investment cost in herbicides for weed control was 37 USD/ha for the majority of farmers interviewed, regardless of the type of rice ecology (Figure 8). However, in irrigated rice production, more than 30% of farmers invest between 37 and 74 USD/ha. In lowland ecology, investment peaks are recorded with more than 146 USD/ha for about 4% of farmers.

Farmers propose differents solutions depending on the type of rice ecology when facing high weed infestation. However, the dependence of these proposed weed control solutions by farmer's according to the type of rice ecology was not statistically significant (p = 32.43%). Lowland farmers made more proposals, the main ones being: weed control (early and regular); technical itinerary compliance and herbicide use. For irrigated ecology, composting and ploughing are considered the best technics to control the weeds. For upland rice farmers, the use of improved varieties is the most important solution to reduce weed infestation.

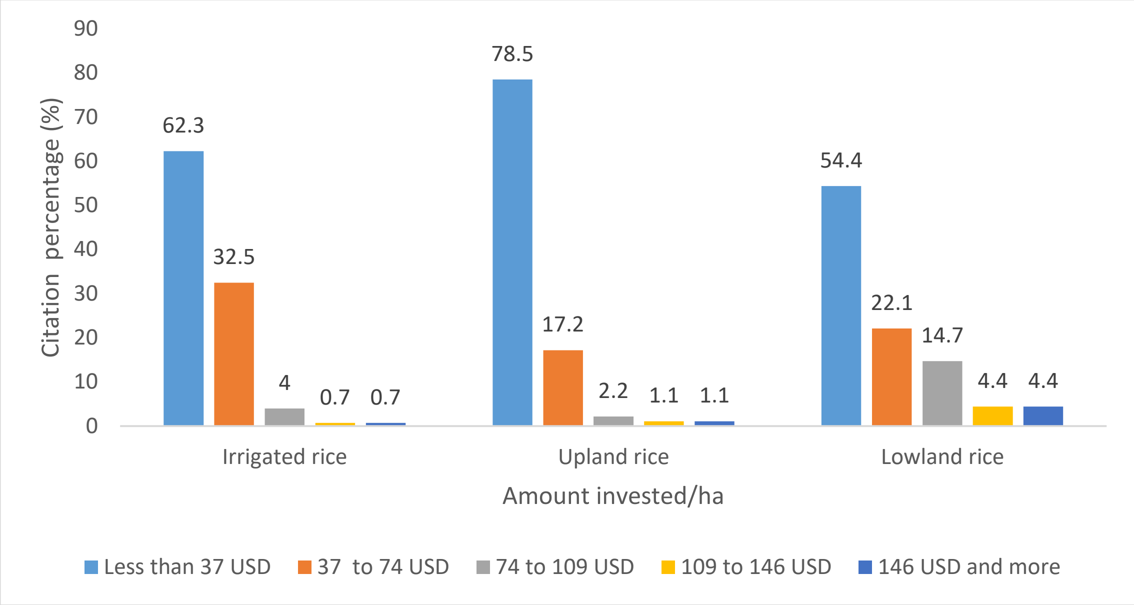


Figure 8: Average herbicide investment cost (AIC) per hectar according to the type of rice ecology in Burkina Faso

Legend: *The dependence level between rice ecology and* amount invested/ha for herbicides *is: very significant*(p <1 %)

Discussion

Socio-economic and technical characteristics of the farms

The descriptive statistics showed that the interviewees were composed of 78.8 % men and 20.9 % women. These results show that women are less involved in rice production in the four regions taken into account in this study. The results of this study are closed to those of Ouedraogo and Dakuo (2017), who reported that 35% of women in rice farms in western Burkina Faso. Moreover, most of the time, the rice income belong to the men (FAO, 2015). Secondary income from rice farms is mainly provided by livestock. Sanou (2014) in a survey conducted in the Western and Central-North-region of Burkina Faso showed that 75.7% of farms practice livestock farming as a secondary activity. The results showed that soil texture does not change fundamentally depending on the type of rice ecology. Indeed, the soil texture chosen by rice farmers is preferably clayey, which preserves soil moisture.

Cropping pattern and induced technologies

The three cropping systems studied in this survey showed that rice and sorghum are the main crops on rice farms. Specifically, irrigated ecology combines maize cultivation while lowland ecology combines millet and cotton. These are crops that need a lot of workforce and could explain the difficulties in terms of weed management in these two rice growing systems.

Main crop rotation are respectively rice-maize, rice-sorghum for irrigated and upland ecology respectively. However in irrigated rice, crop rotation could be explained by the fact that water amount decreases during the dry season. Indeed in Kou valley from 1992, when the water level began to fall in the dry season, a water turn was set up for two major sectors of the perimeter sharing water (Dicko, 2004). In order to avoid unnecessary crop rotation in irrigated rice, the alternate wetting and drying, which is the irrigation mode of the Rice Intensification System (Stoop *et al.* 2002), could be adopted. However we noticed that crop rotation is rarely practiced in lowland ecology and especially in upland conditions. These results are in agreement with those of Traoré (2017) who described in a survey in upland ecology that crop rotation is low and irregular.

In addition to the common equipment rotary hoe and harrow are specific to irrigated ecology. However rotary hoe is not efficience against *poaceae* (Schaub, 2010) the most harmful family in irrigated rice. it's very necesary to introduced the news rotary hoe models with more large efficacity and adapted to other ecology.

In terms of quantity and quality, irrigated rice has recorded the most technologies introduced, including rotary hoe, composting and improved rice varieties. Indeed, 12 different varieties, including NERICAs, are used by irrigated rice farmers. According to Ouedraogo and Dakuo (2017), the high number of improved varieties used is due to the frequent contact of these irrigated rice farmers with researchers. In addition, 49.1% of rice farmers have received training in rice production. However, Kaboré (2007) and Bouré and Samedi (2010) consider that capacity building for rice farmers is one of the major solutions to improving rice productivity.

Nerica are screened for weed resistance and Nerica 4 which is recorded in this study at upland ecology is anyway resistant variety to *Striga hermonthica* (Rodenburg *et al.* 2015). In addition according to Unachukwu *et al* (2017), efforts should also be made to develop relevant control technologies for areas infested with rice-specific *Striga* spp. populations. It can also be noticed that other varieties of Nerica (FKR 56N, FKR 60N et FKR 62N) used in irrigated rice production are resistant to weed infestation due to their good tillering. It is therefore a good agricultural practice that must be encouraged and integrated it into a good technical itinerary. However, NERICAs are poorly adopted, with a low adoption rate of 17% out of a 37% potential due to their incomplete dissemination (Ouédraogo and Dakuo, 2017).

This study showed that the number of weedings varies according to the type of rice ecology. Indeed The highest number of weeding is four (4) and is recorded in lowland ecology Traoré and Yonli (2001) reported that a high weeding number can disrupt the rice root system. So in lowland ecology, farmers faced the high duration needed for weed control and the bad rice plant nutrition as constraints due to weed thriving.The choice of herbicide type depends strongly on the type of rice ecology. Selective herbicides are preferred in irrigated rice production. This fact could be explained by the homologation over the last five years of selective herbicides by the Sahelian Committee of Pesticides (SCP). In fact, the use of pre-emergence and post-emergence herbicides improves weed control efficiency (Grey *et al*., 2014). There is therefore a change in practice that would be better adapted to the specific weed spectrum of irrigated rice ecology. Lowland rice farmers use more pre-plant herbicides. These results are similar with those of Oyebanji and Oluyemisi, (2018) who found out that farmers use more pre-plant herbicides in lowland rice ecology in western Nigeria.. The case of Burkina Faso is explained by the lack of training of this category of farmers. It is therefore necessary to train them in the use of herbicides in combination with other cultural practices. Indeed, an integrated approach of weed control could allow a rational use of herbicides, environmental protection and make rice production more profitable.

The average investment for herbicide per ha by farmers is 37 USD. However, bad agricultural practices are identified, especially in lowland rice ecology where 4% of farmers use large quantities of chemical herbicides for small areas, more than 182 USD of investment per hectare. However, the resolution of production constraints must be participatory, because according to Ouédraogo *et al*, (2017) farmers can have effective empirical solutions to production constraints.

Weed characteristics in rice cropping and farmer's control methods

According to the farmers interviewed, *Poaceae* are the most harmful (45.8%), followed by *Cyperaceae* (41.9%) and broad-leaved weeds or dicotyledons (12.3%). These results are in agreement with those of Houma (1993) who found that 98% of rice plots are infested by the grass *Echinochloa colona* (L.) Link. Moreover, these results corroborate those of Traore *et al*, (1992) who highlighted the fact that twenty weed species of annual cereal ecology of Burkina Faso belong to the group of *Poaceae*. Rice ecologies in Burkina Faso are therefore confronted with weeds of high abundance and very competitive for nutrients in the sense that rice is also a *Poaceae*, especially in irrigated rice ecology. However, specifically, dicotyledons are considered a very constraining group in lowland rice ecology. So, a lowland chemical removal program should be a combination of graminicide and broad-leaved weeds control active ingredients.

In view of the high dependence of farmers on weed infestation sources and the type of rice ecology, it can be said that farmers are aware of the grass cover problem. Indeed, they mainly indicate runoff as source of rice weeds infestation. Water runoff increases rice field seed bank which is the most important rice weed source (Mesquita, 2017). But specifically the use of poorly decomposed organic matter, the lack of maintenance of plots and the non-use of pure seeds are respectively cited in irrigated rice ecology, lowland and strict rainfed agriculture.

However, there is a low dependence between farmers weed control methods and the type of rice ecology. Thus, farmers' solutions would not be well adapted to the specificities of each type of rice ecology. Specific technical advice with integrated pest management approaches would then be required. Indeed, integrated pest management consists of a strategic combination of several techniques whose synergy can produce a significant effect (Traoré *et al.,* 2006) from both an agronomic and an economic point of view.

Conclusion

This study shows that rice farmers are mostly young with a significant endogenous experience in rice cultivation. However, their level of equipment is rather low, particularly in strict rainfed and lowland rice cultivation. Indeed, the high number of weedings and rudimentary weeding tools is an indicator of the high level of stress associated with weed infestation and the low technicality of farmers. Thus, lowland rice cultivation can be considered as the most constraining rice cultivation system in term of grass cover due to the high number of weedings required. It should be noted that lowland rice farmers are more exposed to broadleaf weeds but preferably use non-selective herbicides (pre-plantation). It would therefore be necessary to propose appropriate agronomic practices

To overcome the constraint of manual weeding, irrigated rice farmers who have the highest level of technicality due to training in rice cultivation use herbicides. They are much more exposed to grasses and cyperaceae and choose post-emmergence herbicides as a priority.

Up land rice cultivation recorded the smallest areas devoted to rice compared to other types of rice cultivation due to unfavourable hydrological conditions and the low availability of improved rainfed rice varieties.

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