Field Crops Research 217 (2018) 20–31

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Is mulching an efficient way to control weeds? Effects of type and amount of crop residue in rainfed rice based cropping systems in Madagascar

Lalaina Ranaivoson[a,b,*], Krishna Naudin[b,c], Aude Ripoche[b,d], Lilia Rabeharisoa[e], Marc Corbeels[b,f]

[a] Centre National de Recherche Appliquée au Développement Rural (FOFIFA), BP 1690, Antananarivo, Madagascar
[b] Centre de coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), UPR AIDA, F-34398 Montpellier, France. AIDA, Univ Montpellier, CIRAD, Montpellier, France
[c] Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), Cerrados, Planaltina, DF 73310-970, Brazil
[d] Centre National de Recherche Appliquée au Developpement Rural (FOFIFA), SRR, BP 230, Antsirabe, Madagascar
[e] Université d'Antananarivo, LRI, 101, Antananarivo, Madagascar
[f] International Maize and Wheat Improvement Center (CIMMYT), Sustainable Intensification Program, P.O. Box 1041-00621, Nairobi, Gigiri, Kenya

ARTICLE INFO

Keywords:
Weed emergence
Weed biomass
Rainfed rice
No till
Conservation agriculture
Smallholder farms

ABSTRACT

Weeds are a major constraint to crop yields in tropical production systems, especially for smallholder farmers who cannot afford to purchase herbicides. It has been argued that the practice of mulching with crop residues can suppress weeds in conservation agriculture systems. However, few data are available on the effect of crop residue mulching on weed infestation. In this study we quantified the effect of increasing amounts of surface crop residues on weed emergence, weed biomass production and rice yield. The experiment was conducted during four growing seasons in the Lake Alaotra region, Madagascar. Two types of mulch were applied on a no-tilled soil, *Stylosanthes guianensis* and a mixture of maize and *Dolichos lablab*, with different amounts ranging from 0 to 45 Mg dry matter ha^{-1}. Weed emergence was measured every week from the day of the first rain that triggered weed germination to 100 days thereafter, and weed biomass was monitored at four dates during the cropping season. Our results show that weed emergence and weed biomass decreased with increasing amount of residue. More than 10 Mg ha^{-1} was, however, needed to significantly reduce weed emergence and weed biomass as compared to the bare soil treatment without surface residues. Rice grain yields decreased by 16% for an increase in weed biomass of one Mg ha^{-1}. Our results indicate that mulching is not a viable option of weed control for smallholder farmers, given the low amounts of residue currently retained on their fields, which is at best about 4 Mg ha^{-1} in the case of a stylosanthes crop and about 5 Mg ha^{-1} in case of dolichos intercropped with maize.

1. Introduction

Weeds are one of the most severe biotic constraints to food production (FAO, 2017). They act as competitive plants to the cultivated crop for several resources, such as light, water and nutrients, which may result in important crop yield losses (Oerke, 2006). Moreover, their control increases labor demand and inflates the crop production costs. Smallholder farmers in developing countries generally lack adequate access to external inputs, such as herbicides or mechanization, to control weeds. They mostly rely on hand weeding which is an effective method and does not require extensive knowledge, but is highly time consuming and labor intensive (Tu et al., 2001).

The Lake Alaotra region in Madagascar has a great agricultural potential with a predominance of rice farming and livestock keeping. This region is the second largest area of rice production in Madagascar with more than 100 000 ha of cultivated rice. Because of limited availability of land in the irrigated plains, rice production in this region has expanded into the rainfed upland areas. These areas are generally characterized by low crop productivity, mainly due to low soil fertility, low access to fertilizers and high weed infestation. In contrast to the irrigated lowlands, use of flooding is not an option to control weeds. Moreover, upland rice production suffers from labor shortages and limited access to mechanized equipment and herbicides for weed control. In general, available farm labor and capital are preferably used on the more productive lowland fields to optimize resource use and minimize risks on the farms (Lallau, 2008). Therefore, there is a need for alternative methods of weed management in upland rice fields.

Conservation agriculture has been introduced in the Lake Alaotra region in the late 90s to improve crop productivity of rainfed agriculture (Husson and Rakotondramanana, 2006). Conservation agriculture is based on three principles: minimum soil disturbance, permanent organic soil cover and diversification of crop species grown in

* Corresponding author at: Centre National de Recherche Appliquée au Développement Rural (FOFIFA), BP 1690, Antananarivo, Madagascar.

https://doi.org/10.1016/j.fcr.2017.11.027
Received 22 August 2017; Received in revised form 25 November 2017; Accepted 27 November 2017

rotations and/or associations (FAO, 2015). One of the expected functions of the soil cover or mulching is to reduce weed infestation. Crop residues that are retained on the soil surface can interfere with weed establishment by physically impeding their emergence (Teasdale and Mohler, 2000), creating a microclimate that disturbs weed germination and weed development (Teasdale and Mohler, 1993) or by releasing allelopathic substances that inhibit weed germination and growth (Liebman and Mohler, 2001). The efficiency of weed control through mulching depends on the type of crop residue and the amount of residue left on the field (e.g. Ranaivoson et al., 2017; Teasdale and Mohler, 2000; Radicetti et al., 2013; Ngwira et al., 2014). There is, however, a lack of information on the amount of residue required to effectively reduce weed infestation.

This study aims to quantify the effect of the type and amount of crop residue on weed emergence, weed biomass production and rice yield under no-tillage in upland fields in the Lake Alaotra region of Madagascar.

2. Material and methods

2.1. Study site

The study was carried out on the research station of the National Research Center for Rural Development (FOFIFA) located at Ambohitsilaozana (17°30′S; 48°30′E, 780 m asl) in the Lake Alaotra region, Madagascar. This region is characterized by a mid-altitude tropical climate, Cfa (Köppen classification), with a mean annual temperature of 22 °C. The cropping season starts at the end of November with the onset of the rains and ends in April. The mean seasonal rainfall recorded between 2004/05 and 2014/15 was 1040 mm. The soil of the experimental site is an Orthic Ferralsol (FAO classification). Selected physical and chemical properties of the topsoil layer (0–20 cm) are shown in Table 1.

2.2. Field experiment

An experiment was conducted to study the effects of surface crop residues on weed dynamics and rice yield. Field trial were set up during four growing seasons, from 2010 to 2015 (season 2010/11 = year 1; 2011/12 = year 2; 2013/14 = year 3 and 2014/15 = year 4 in this paper). Each year, a trial was established on a different part of the experimental field to eliminate residual treatment effects on weed dynamics and on the soil seed bank from one year to another. At the start of each trial, existing aboveground biomass was removed from the site. A trial was located at a maximum distance of 10 m from the previous one.

The experimental design for each trial was a randomized complete block with four replications. Treatments consisted of two types of crop residue mulches, *Stylosanthes guianensis* (S) and a mixture of maize (*Zea mays*) and *Dolichos lablab* (MD), and different amounts of these residues, ranging from 0 to 45 Mg dry matter ha^{-1} (Table 2). The corresponding proportions of soil cover were calculated using the equation described in Gregory (1982):

$$F_c = 1 - e^{-A_r * M} \quad (1)$$

where F_c is the proportion of soil covered, A_r is the area-to-mass ratio of the residue in $m^2\ kg^{-1}$ (0.377 for S residue and 0.251 for MD residue, Naudin et al., 2012) and M is the amount of residue in kg m^{-2}.

During the first two growing seasons (year 1 and 2), 15 treatments were studied corresponding to seven levels of soil cover for each type of crop residue and a bare soil treatment (Table 2). The crop residues were brought from a nearby field. Amounts of crop residue covered a wide range, including large quantities, to determine the potential effects of surface residues on weed emergence and weed biomass production. No crop was grown during year 1 and year 2. During the 2013/14 and 2014/15 seasons (year 3 and 4) we reduced the number of treatments (levels of soil cover) based on the results of the previous years, whilst still encompassing a range from 0 to 99.9% soil cover (Table 2). Four levels of soil cover were applied for each type of residue along with a bare soil treatment, and a rice crop was grown. The rice cultivar used was B22, a short-duration (120 days) upland rice variety from the Brazilian Agricultural Research Corporation (EMBRAPA) that is adapted to the agro-ecological conditions of the Lake Alaotra region. Rice was sown manually under no-tillage using a planting stick with an inter-row spacing of 40 cm and intra-row spacing of 20 cm. No fertilizer, herbicides or pesticides were applied on the treatments. Weeding was done manually (Table 3).

The individual plot sizes in each trial were 4 m^2 (2 × 2 m). Each year, crop residues were brought on the soil surface during the last week of November, which corresponds to the start of rainy season.

2.3. Measurements

Weed emergence (number of seedlings m^{-2}) was measured during the four growing seasons of the experiment, following a method used by Jodaugienė et al. (2006); Moore et al. (1994); Teasdale and Mohler (2000); Webster et al. (2016). Measurements were done on a single fixed quadrat of 0.25 m^2 (0.5 × 0.5 m) in each individual plot of the trials. Emerged seedlings (monocots and dicots) were counted and removed from the quadrats at 7-day intervals from the day of the first rain that triggered weed germination to 100 days after the first rain (DAF).

Weed biomass production (Mg dry matter ha^{-1}) was measured during year 3 and year 4. Measurements were done on a single fixed quadrat of 1 m^2 (1 × 1 m) in each individual plot of the trials at each weeding operation and at rice harvest (Table 3). Weeds were cut at soil level, oven-dried at 70 °C for 48 h and weighted to obtain dry matter contents. Monocots and dicots were weighted separately.

Rice grain yields (Mg dry matter ha^{-1}) were determined during year 3 and year 4. Measurements were done at physiological maturity on the quadrats of 1 m^2 (1 × 1m) that were used for the weed biomass measurements. Panicles were hand-threshed; all spikelets were stripped from panicles. Unfilled spikelets were removed and filled spikelets were weighted to estimate grain yield. Moisture content of filled spikelets was determined by oven-drying at 70 °C for 48 h. All results were expressed as dry matter on hectare basis.

2.4. Residue decomposition

Decomposition of both types of crop residue (S or MD) was measured in 2011/12, 2013/14 and 2014/15 using a litterbag experiment (Maltas et al., 2009) that was set-up in a rice field under no-tillage located near the weed trial sites. Each year, air-dried samples of S and MD residues were collected randomly from a field experiment where respectively stylosanthes, and dolichos intercropped with maize were grown. The residues (stems and leaves) were chopped into pieces with length of less than 20 cm. Nylon litterbags (20 × 25 cm) with a mesh size of 2 mm were filled with an amount of residue that corresponded to about 6–7 Mg dry matter ha^{-1}. The two residue treatments were

Table 1
Selected physical and chemical properties of the 0–20 cm topsoil layer of the experimental field at the FOFIFA research station located in Lake Alaotra, Madagascar; SD: standard deviation; n: number of samples.

	mean	SD	n
pH (H_2O)	5.2	0.2	60
Clay (%)	31.2	6.2	60
Silt (%)	41.9	3.4	60
Sand (%)	26.9	4.7	60
Olsen P (mg kg^{-1})	316.3	41.4	60
CEC (meq 100 g^{-1})	7.0	2.8	60
Organic C (g kg^{-1})	34.7	4.3	8