Effects of grain-producing cover crops on rice grain yield in Cabo Delgado, Mozambique

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ABSTRACT

Besides providing benefits to the environment such as soil protection, release of nutrients, soil moisture maintenance, and weed control, cover crops can increase food production for grain production. The aim of this study was to evaluate the production of biomass and grain cover crops (and its respective effects on soil chemical and physical attributes), yield components, and grain yield of rice in Mozambique. The study was conducted in two sites located in the province of Cabo Delgado, in Mozambique. The experimental design was a randomized block in a 2 × 6 factorial, with four repetitions. Treatments were carried out in two locations (Cuaia and Nambaua) with six cover crops: Millet (*Pennisetum glaucum* L.); namarra bean (*Lablab purpureus* (L.) Sweet), velvet beans (*Mucuna pruriens* L.), oloco beans (*Vigna radiata* (L.) R. Wilczek), cowpea (*Vigna unguiculata* L.), and fallow. Cover crops provided similar changes in chemical and physical properties of the soil. *Lablab purpureus*, *Vigna unguiculata*, and *Mucuna pruriens* produced the highest dry matter biomass. *Vigna unguiculada* produced the highest amount of grains. Rice grain yields were similar under all cover crops and higher in Cuaia than Nambaua.

Key words: sustainability; legumes; grain production; conservation agriculture.

RESUMO

Plantas de cobertura produtoras de grãos e a produtividade de arroz em Cabo Delgado, Moçambique

As plantas de cobertura, além de proporcionar benefícios ao ambiente como a proteção do solo, liberação de nutrientes, manutenção da umidade do solo e controle de plantas daninhas, pode servir para aumentar a produção de alimentos pela sua própria produção de grãos. O objetivo desse trabalho foi avaliar a produção de biomassa seca e de grãos de espécies de plantas de cobertura e seu respectivo efeito nos atributos químicos e físicos do solo, componentes de produção e produtividade de arroz em Moçambique. O trabalho foi desenvolvido em dois locais na Província de Cabo Delgado, em Moçambique. O delineamento experimental foi em blocos ao acaso no esquema fatorial 2 x 6, com 4 repetições. Os tratamentos foram compostos pelas 2 localidades (Cuaia e Nambaua) e 6 coberturas vegetais: Milheto (*Pennisetum glaucum* L.); Lablabe (*Lablab purpureus* (L.) Sweet), mucuna (*Mucuna pruriens* L.), feijão oloco (*Vigna radiata* (L) R. Wilczek), feijão caupi (*Vigna unguiculata* L.) e pousio. As plantas de cobertura proporcionaram alterações semelhantes nas propriedades químicas e físicas do solo. *Lablab purpureus*, *Vigna unguiculata* e *Mucuna pruriens* produziram a maior quantidade de biomassa seca. *Vigna unguiculata* foi a cultura de cobertura que produziu a maior quantidade de grãos. A produtividade de grãos do arroz foi semelhante em todas as culturas de cobertura e maior em Cuaia que Nambaua.

Palavras-chave: sustentabilidade; legumes; produção de grãos; agricultura de conservação.

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INTRODUCTION

About 270 million people living in Sub-Saharian Africa face problems of hunger and malnutrition (Balasubramanian *et al*., 2007). Despite having climate and soil conditions to produce their own food, countries of this region are characterized by being importers of foodstuff (Kijima *et al*., 2011; Benson *et al*., 2008; Ivanic & Martin, 2008). Therefore, there is a need for developing actions and technologies that effectively contribute to the increase of food production in this area.

Rice (*Oryza sativa* L.) is considered a staple food for countries worldwide (Nokkoul & Wichitparp, 2014; Nascente *et al*., 2013a; Nayar, 2014). Specifically in Mozambique, this grain can ease poverty of 3.1 million people directly dependent on rice grain production and 20 million Mozambicans indirectly dependent on it (IRRI, 2015). In 2010, rice was produced on 185,000 ha, resulting in a production of 180,000 tons of paddy rice in this country. However, this production was not enough to meet people's demand, which led to the importation of about 304,000 metric tons of rice (Ricepedia, 2015). Therefore, it seems that, despite the fact that climate and soil conditions are favorable for rice production, the yield is very low, ranging from 970 kg ha^{-1} (Ricepedia, 2015) to 1170 kg ha^{-1} (Faostat, 2015). The main reasons are the use of rudimentary techniques, limited knowledge, and inefficient management of water and infrastructure, which keeps rice production in Mozambique, and in several African countries, in family subsistence levels (Balasubramanian *et al*., 2007; Planeta Arroz, 2015). Thus, there is a need for developing farming techniques in these sites to take advantage of climate and soil favorable conditions and provide significant increases in the yield of rice grains.

The no-tillage system (NTS) can be a viable alternative to Mozambique and other countries in Africa, Latin America, and Asia. It is a technique that allows several environmental benefits, such as increasing levels of organic matter and biological activity of the soil, reduction of soil temperature fluctuations and laminar erosions. In addition, it reduces the carrying of fertilizers and pesticides to the watershed water, reductes the population of weeds and allows greater conservation of soil moisture, being therefore considered a sustainable production technique (Nascente *et al*., 2013b).

One of the premises of the NTS is the use of cover crops to form straw layers on the soil surface prior to deployment of the main crop (Crusciol *et al*., 2015). Among many benefits, cover cops can significantly affect the chemical properties of the soil (Boer *et al*, 2007; Carpim *et al*., 2008; Garcia *et al*., 2008; Torres & Pereira, 2008; Cunha *et al*., 2011; Nascente *et al*., 2015). Sá (1993) reported the use of cover crops for 16 years and the increase in phosphorus concentration from 29 to 129 mg kg^{-1}. Sá (1993), Crusciol *et al*. (2015), and Nascente *et al*. (2015) showed increases in K^+ levels in NTS because of the use of cover crops. Other studies also showed accumulations of Ca^{2+}, Mg^{2+} (Falleiros *et al*., 2003), Zn^{2+}, Mn^{2+}, Fe^{2+}, and Cu^{2+} (Franzluebbers & Hons, 1996), increases in cation exchange capacities, in soil organic matters, and in P and K^+ (Crusciol *et al*., 2015; Nascente *et al*., 2015), and also changes in pH and reductions of Al saturation (Cunha *et al*., 2011) due to cover crops in NTS.

The inclusion of cover crops before rice cultivation can contribute to sustainable development (Filizadeh *et al*., 2007; Nascente *et al*., 2013a). The increased diversity of plant species in the environment provides benefits such as better use of soil nutrients, minor attacks of pests, lower incidence of pathogens, greater weed control, increased crop yields, and greater yield stability (Mahmoudi *et al*., 2011; Yahuza, 2011).

The use of cover crops can also serve as a source of food for farmers, especially when using grain-producing species (Filizadeh *et al*., 2007). This feature is very important for family farmers – especially in Latin America, Africa, and Asia – that face problems of malnutrition and starvation, once they can enrich the family diet by including more food without the need to enlarge the area. However, considering the peculiarities of each region, there is still little knowledge on the main characteristics of cover crops with the production of biomass and grains (Oliveira *et al*., 2002). In this sense, the objective of this study was to evaluate the production of biomass and grains by cover crops and its effects on soil chemical and physical properties, yield components, and grain yield of rice in Mozambique.

MATERIAL AND METHODS

The study was conducted in two districts of the Province of Cabo Delgado, in Mozambique, namely Metuge and Macomia. In Metuge, the trial was carried out in an experimental field in the village of Cuaia (40°23'47" E and 12°58'17" S), while in the district of Macomia, it was carried out in the village of Nambaua (40°25'54" E and 11°45'11" S). The climate is Tropical Savanna, considered as Aw according to Köppen's classification. There are two distinct seasons, usually the dry season from May to September (fall/winter) and the rainy season from October to April (spring/summer). Cuaia has an altitude of 100 m and average annual rainfall varies from 800 to 1000 mm, with an average annual temperature of 25 °C. In Nambaua, the altitude is 1000 m, the average annual rainfall varies from 1000 to 1300 mm, and the average temperature is 22 °C. Besides, from the "Instituto Nacional de Meteorologia de Moçambique (INAM)" we got information from medium temperature and rain in both sites (Figures 1 and 2). The soil in Cuaia is classified as Ferralic arenosol (FAO, 2014).

The values of the soil texture in the 0-0.20 m layer were 672.7 g kg^{-1} sand, 148.3 g kg^{-1} silt, and 179.0 g kg^{-1} clay. In Nambaua, the soil is classified as Haplic lixisol (FAO, 2014). The values of the soil texture in the 0-0.20 m layer were 728.3 g kg^{-1} sand, 106.1 g kg^{-1} silt, and 165.6 g kg^{-1} clay.

Before the application of treatments in March 2014, the chemical characteristics of the soil were determined according to the methods described by Donagema *et al*. (2011). The results for Cuaia were: pH (H_2O) = 6.35, Ca^{2+} = 5.8 $cmol_c$ kg^{-1}, Mg^{2+} = 4.2 $cmol_c$ kg^{-1}, K^+ = 0.70 $cmol_c$ kg^{-1}, $H^+ + Al^{3+}$ = 0.64 $cmol_c$ kg^{-1}, Na^+ = 0.69 $cmol_c$ kg^{-1}, $cmol_c$ kg^{-1}, P = 9.25 mg kg^{-1}, and soil organic matter = 27.7 g kg^{-1}. The results for Nambaua were: pH (H_2O) = 6.21, Ca^{2+} = 5.3 $cmol_c$ kg^{-1}, Mg^{2+} = 6.5 $cmol_c$ kg^{-1}, K^+ = 1.20 $cmol_c$ kg^{-1}, $H^+ + Al^{3+}$ = 0.87 $cmol_c$ kg^{-1}, Na^+ = 0.30 $cmol_c$ kg^{-1}, P = 40.83 mg kg^{-1}, and soil organic matter = 17.0 g kg^{-1}.

The experimental design was a randomized block in a 2 × 6 factorial with four repetitions. Treatments were composed of two environments (Cuaia and Nambaua) and six vegetation covers: *Pennisetum glaucum* L., *Lablab purpureus* (L.) Sweet, *Mucuna pruriens* L., *Vigna radiata* (L.) R. Wilczek, *Vigna unguiculata* L., and fallow. The plots had the dimension of 2 × 5 m. The usable area was considered the two central rows of the plot, disregarding 0.50 m by the end on each side of both plots following methods proposed by Nascente *et al*. (2013b). There was a 1 m wide alley between each plot.

Cover crops were sown on April 30^{th,} 2014 in Cuaia, and on July 18th, 2014 in Nambaua (this area was flooded and then we had to wait the natural drainage before sowing cover crops). The row spacing used was of 0.40 m between plants with density of 10 seeds per meter. Fertilization was

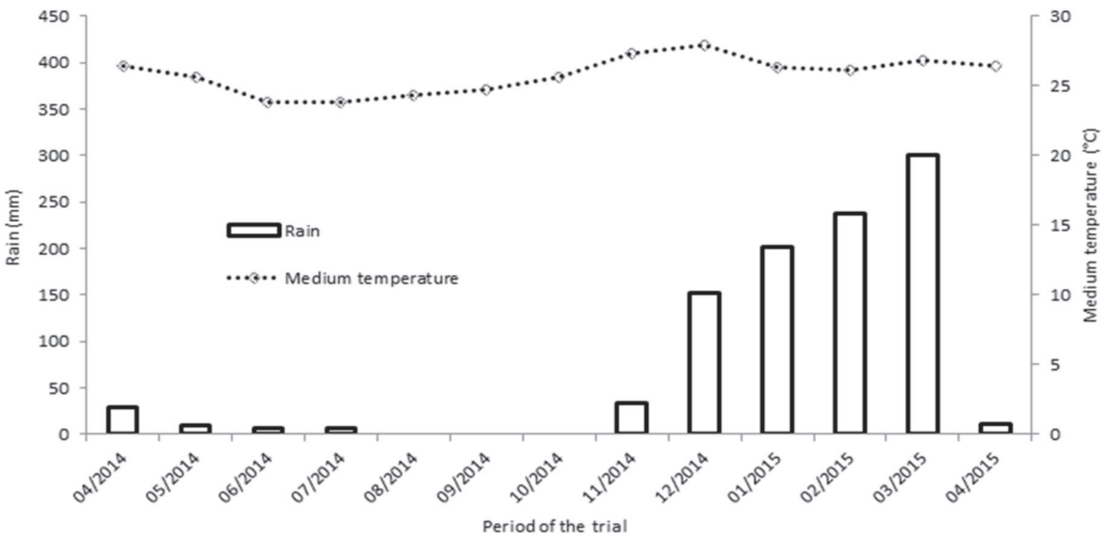

Figure 1: Mean temperature and rain during the trial period in the Cuaia Site.

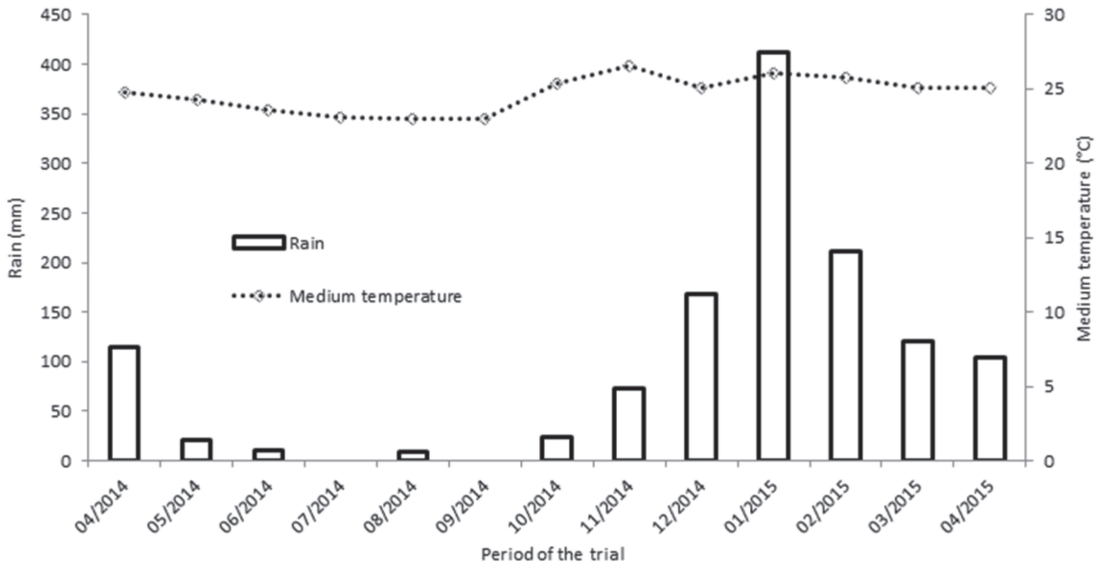

Figure 2: Mean temperature and rain during the trial period in the Nambaua Site.

not carried out in the plots. The weed control was manual with the aid of hoes; there were weed problems (*Cyperus rotundus* L.) especially in Nambaua,. Control of insect plagues and diseases was not performed. Harvest of cover crops took place on August 30th in Cuaia and on December 5th in Nambaua. The grains were manually harvested and the aboveground plants were cut and placed to dry until reaching constant weight. Data concerning the production of dry biomass and grains of cover crops were collected. After weighing the dry matter, biomass was placed on the soil surface in the respective plots.

In both locations, rice cultivar Macassane was sown in nursery (January 1st, 2015 in Cuaia and January 2nd, 2015 in Nambaua) and manually transplanted 15 days after emergence, with a space of 0.40 m between rows and 0.20 m between plants. Cultivar Macassane was developed by the Mozambique Agricultural Research Institute (IIAM); this cultivar, very known by the Mozambique farmers, has a life cycle of around 90 days, low plant height (< 0.90 m), and long aromatic grain (IIAM, 2015). No fertilizations and control of insect plague and diseases were implemented. Weed control was carried out by weeding; in Nambaua, there was a great infestation of *Cyperus rotundus*.

Rice harvesting in both locations was done manually after physiological maturity (April 4th, 2015 in Cuaia and April 6th, 2015 in Nambaua). The following data were collected in each plot: number of tillers, determined by measuring 10 plants per plots at the full flowering stage; plant height (m) was determined by measuring 10 plants per plot at the time when the crop was at the phenological stage of pasty grains and, by recording the distance between the soil surface and the top end of the highest panicle; number of panicles m^{-1} was determined by counting the number of panicles within 1.0 linear meter of one of the rows in the useful area of each plot; number of grains $panicles^{-1}$ was determined by counting the number of grains in 10 randomly collected panicles and by calculating their average; mass of 1000 grains was randomly evaluated by collecting and weighing two samples of 1000 grains from each plot and then corrected to 13% of water content; and grain yield was determined by weighing the harvested grains in the usable area of each plot, corrected to 13% of water content, and converted to kg ha^{-1}.

The soil was sampled before sowing cover crops on April 3rd, 2014 in Nambaua and on April 2nd, 2014 in Cuaia and before rice transplanting on December 22nd, 2014 in Nambaua and December 20th, 2014 in Cuaia. Eight single soil samples were collected from each plot in the 0-0.20 m layer, being manually mixed and homogenized to form a composite sample of each plot. These samples were packed separately in plastic bags and sent for chemical and physical analysis, according to the methodology of Embrapa (Donagema *et al*., 2011).

The pH was determined in water by using a soil solution ratio of 1:2.5. Phosphorus and K^+ were extracted by Mehlich-1, Ca^{2+}, Mg^{2+}, Na+, and Al^{3+} with 1 mol L^{-1} KCl. In the extracted solution, P was determined by colorimetry and K^+ by flame photometry. Ca^{2+} and Mg^{2+} were determined by EDTA titration and Al^{3+} by NaOH titration from the extract. Soil organic matter was determined by Walkley & Black's method (Walkley & Black, 1934).

Soil bulk density of the soil was calculated by the relation between the mass and the volume of the soil using the volumetric ring (50 cm^3). Soil texture (sand, silt, and clay) was calculated by the Pipette method.

Variance analysis was performed with the data of physical and chemical soil properties, dry biomass and grain production of cover crops, plant height, yield components, and grain yield of rice. Cover crops and locations were considered fixed effects, while blocks and interactions were considered random effects. In the data with significant effects, a mean comparative Tukey test was carried out at $P < 0.05$, using the statistical package SAS (SAS, 1999).

RESULTS

In Cuaia, no differences were found among cover crops for chemical characteristics values of pH, Na, Ca, Mg, H + Al, K, P, and soil organic matter (Table 1), and neither for the physical attributes of the soil: particle density, sand, silt, and clay contents. In Nambaua, no differences were found among cover crops for chemical and physical properties of the soil (Table 2).

There was a significant interaction between cover crops species and locations regarding dry biomass (Table 3). Concerning the production of grains, only effects of cover crops species were found. *Vigna unguiculata* achieved the highest grain yield (1793 kg ha^{-1}) and differed from all other species.

In the interaction between cover crops and locations in relation to dry biomass of cover crops, *Pennisetum glaucum*, *Lablab purpureus*, *Mucuna pruriens*, and *V. radiata* produced more in Nambaua than in Cuaia (Table 4). In Cuaia, *V. radiata* had the highest biomass production and differed from the other cover crops. In Nambaua, *L. purpureus* produced more biomass and differed from the other cover crops.

Cover crops did not significantly affect tillering, plant height, number of panicles and number of grains per panicle, mass of 1000 grains, and grain yield of rice (Table 5). On the other hand, there were effects of cropping location on tillering, plant height, number of panicles, number of grains per panicle, and grain yield and for all these variables and, values were higher in Cuaia than in Nambaua.

DISCUSSION

Cover crop plants were grown for a period of 120 days in Cuaia and for 137 days in Nambaua. Based on the results, we can infer that the period for development of cover crops was not enough to provide significant differences in chemical and physical properties of the soil in relation to the control treatment (fallow). Nevertheless, the use of cover crops may be advantageous since the fallow treatment favors the spread of weeds (Nascente *et al*., 2013b).

Cover crops produced low amounts of dry biomass, between 350 and 3213 kg ha^{-1} on average, in both locations (Table 3); therefore, we can assume that the few months of

Table 1: Soil chemical and physical attributes at cover crops sowing day (CCD) and at rice transplantation day (RTD) at the 0-0.20 m layer as a function of cover crops (CC). Cuaia site, Province of Pemba, Moçambique

	Chemical attribute							
	pH (water)		**Na (cmol$_c$ kg^{-1})**		**Ca (cmol$_c$ kg^{-1})**		**Mg (cmol$_c$ kg^{-1})**	
CC[1]	**CCD**	**RTD**	**CCD**	**RTD**	**CCD**	**RTD**	**CCD**	**RTD**
	Average		**Average**		**Average**		**Average**	
1	6.24		0.69		6.88		5.39	
2	6.51		0.70		6.80		3.75	
3	6.35		0.69		6.57		3.67	
4	6.52		0.91		5.71		4.14	
5	6.28		0.88		5.16		4.38	
6	6.18		0.80		6.80		2.97	
Average	6.44	6.25	0.76	0.80	5.99	6.64	4.69	3.41
	H+Al (cmol$_c$ kg^{-1})		SOM (g kg^{-1})		K (mg kg^{-1})		P (mg kg^{-1})	
1	0.71		25.50		0.97		19.38	
2	0.70		23.49		1.05		20.00	
3	0.72		25.56		0.96		19.38	
4	0.73		25.48		0.84		10.88	
5	0.84		28.05		1.09		9.75	
6	0.65		25.69		0.94		15.00	
Average	0.73	0.72	25.97	25.28	0.96	0.99	14.95	16.50
Factor	ANOVA (F probability)							
	pH	Na	Ca	Mg	H+Al	MO	K	P
CC	0.5388	0.5018	0.4081	0.8422	0.7154	0.8575	0.6315	0.7249
Time (T)	0.1508	0.0589	0.2613	0.2303	0.0784	0.7217	0.0574	0.0963
CC × T	0.1576	0.5883	0.9528	0.6765	0.4173	0.1905	0.1829	0.7312
	Physilcal attribute							
CC	SBD (g kg^{-1})		Sand (g kg^{-1})		Silt (g kg^{-1})		Clay (g kg^{-1})	
	CCD		RTD		CCD		RTD	
CCD	RTD		CCD		RTD			
	Average		Average		Average		Average	
1	1.26		712.5		145.0		142.5	
2	1.24		725.0		157.5		118.8	
3	1.31		728.8		145.0		123.8	
4	1.36		741.2		97.50		160.0	
5	1.29		755.0		113.8		132.5	
6	1.24		662.5		167.5		172.5	
Average	1.27	1.28	682.5	759.2	166.7	108.8	150.8	132.5
Factor	ANOVA (F probability)							
	SBD		Sand		Silt		Clay	
CC	0.5961		0.7164		0.6220		0.2858	
Time (T)	0.8574		0.0629		0.0687		0.2319	
CC × T	0.5074		0.3225		0.1915		0.0897	

[1]1 - millet (*Pennisetum glaucum* L.); 2 – namarra beans (*Lablab purpureus* (L.) Sweet), 3 - velvet bean (*Mucuna pruriens* L.); 4 - oloco beans (*Vigna radiata* (L.) R. Wilczek); 5 - cowpea (*Vigna unguiculata* L.); and 6 - fallow.
SOM - soil organic matter; SBD - soil bulk density.

growing cover crops was not enough to provide significant differences in soil properties. Nascente *et al.* (2015) observed significant increases in soil nutrient levels, soil organic matter, cation exchange capacity, and base saturation after two years of cultivating cover crops by following rice crops. Cover crops such as grasses *Panicum maximum*, *Brachiaria ruziziensis*, and *Brachiaria brizantha* produce large amounts of dry biomass (> 10 Mg ha^{-1}) and provide significant increases in soil fertility (Moreti *et al.*, 2007; Rosolem *et al.*, 2010; Pacheco *et al.*, 2011; Nascente *et al.*, 2015). However, despite not having significant changes in the chemical and physical properties of the soil, due to the

Table 2: Soil chemical and physical attributes at cover crops sowing day (CCD) and at rice transplantation day (RTD) at the 0-0.20 m layer as a function of cover crops (CC). Nambaua site, Province of Pemba, Moçambique

	Chemical attribute							
	pH (water)		**Na ($cmol_c$ kg^{-1})**		**Ca ($cmol_c$ kg^{-1})**		**Mg ($cmol_c$ kg^{-1})**	
CC[1]	**CCD**	**RTD**	**CCD**	**RTD**	**CCD**	**RTD**	**CCD**	**RTD**
	Average		Average		Average		Average	
1	6.17		0.35		5.00		4.22	
2	6.44		0.45		5.32		4.92	
3	6.18		0.58		5.08		3.60	
4	6.31		0.52		5.08		6.02	
5	6.25		0.44		3.60		3.91	
6	6.23		0.37		4.30		5.94	
Average	6.16	6.37	0.42	0.48	4.92	4.44	5.11	4.43
	H+Al ($cmol_c$ kg^{-1})		SOM (g kg^{-1})		K (mg kg^{-1})		P (mg kg^{-1})	
1	0.83		18.96		0.81		38.00	
2	0.84		23.69		1.04		39.88	
3	0.83		22.79		0.87		38.25	
4	0.74		21.53		0.85		40.00	
5	0.63		18.96		0.91		34.38	
6	0.79		22.68		0.80		51.00	
Average	0.79	0.76	21.32	21.58	0.90	0.86	43.21	37.29
Factor	ANOVA (F probability)							
	pH	Ca	Mg	Na	H+Al	K	P	MO
CC	0.7558	0.0701	0.6298	0.4729	0.2934	0.8282	0.6118	0.7836
Time (T)	0.0722	0.0604	0.5088	0.0847	0.0682	0.1541	0.1102	0.1816
CPC × T	0.8010	0.1379	0.7829	0.7053	0.8698	0.7918	0.6066	0.5990
	Physical attribute							
CC[1]	SBD (g kg^{-1})		Sand (g kg^{-1})		Silt (g kg^{-1})		Clay (g kg^{-1})	
	CCD	RTD	CCD	RTD	CCD	RTD	CCD	RTD
	Average		Average		Average		Average	
1	1.22		755.0		107.5		136.3	
2	1.17		728.8		145.0		125.0	
3	1.17		750.0		117.5		135.0	
4	1.20		737.5		110.0		152.5	
5	1.21		776.3		112.5		111.3	
6	1.19		780.0		93.8		122.5	
Average	1.21 A	1.19 A	734.5 A	774.6 A	102.9 A	125.8 A	162.0 A	98.8 A
Factor	ANOVA (F probability)							
	PD		Sand		Silt		Clay	
CC	0.7878		0.6037		0.4351		0.2362	
Time (T)	0.1059		0.0585		0.1086		0.0894	
CC x T	0.7674		0.9807		0.6585		0.6154	

[1] 1 - millet (*Pennisetum glaucum* L.); 2 – namarra beans (*Lablab purpureus* (L.) Sweet), 3 - velvet bean (*Mucuna pruriens* L.); 4 - oloco beans (*Vigna radiata* (L.) R. Wilczek); 5 - cowpea (*Vigna unguiculata* L.) and 6 - fallow.

SBD - soil bulk density; SOM - soil organic matter.

Means followed by the same letter, uppercase vertically or lowercase horizontally, do not differ by Tukey test at $p \geq 0.05$.

use of cover crops in our trial, this practice should be continued because, ,on the long run, it can provide cycling nutrients and other benefits such as maintenance of soil moisture, protection against erosion, and lower oscillation of soil temperature (Crusciol *et al*., 2015; Nascente *et al*., 2015) and can produce grains. Moreti *et al*. (2007), Cunha *et al*. (2011), and Nascente *et al*. (2015) added that by using cover crops, the chemical properties of soil are enhanced with their regular use, i.e., it is interesting to use cover crops every year before rice cultivation.

It is important to highlight that we did not use any fertilization. However, it is important to supply the soil with nutrients that were removed in the harvesting, especially with cash crops to avoid reductions in soil fertility. In this sense, soil fertilization with the use of cover crops would help to increase nutrient efficiency once nutrients lost by leaching could be uptaken by cover crop roots and returned to the topsoil after harvesting (Crusciol *et al*., 2015).

Table 3: Biomass dry matter (BDM) and grain yield (YIELD) of cover crops cultivated before rice crops. Cuaia and Nambaua sites, Pemba city, Province of Cabo Delgado Moçambique, Growing season 2014

Factor	BDM	YIELD
Cover crop	kg ha^{-1}	
Pennisetum glaucum	1000 b	238 c
Lablab purpureus	3188 a	700 b
Mucuna pruriens	3213 a	800 b
Vigna radiata	350 b	209 c
Vigna unguiculata	3163 a	1793 a
Site		
Cuaia	1815 b	780 a
Nambaua	2550 a	716 a
Factor	ANOVA (F probability)	
Cover crop (CC)	< 0.001	0.0307
Site	0.0109	0.9027
CC× site	0.0271	0.5548

*Means followed by the same letter vertically, do not differ by the Tukey test at $p \geq 0.05$.

Table 4: Interaction between biomass dry matter of cover crops and sites. Cuaia and Nambaua sites, Pemba city, Province of Cabo Delgado Moçambique, Growing season 2014

Factor	Cuaia	Nambaua
Cover crop	kg ha^{-1}	
Pennisetum glaucum	875 cdB	1125 dA
Lablab purpureus	2000 bcB	4375 aA
Mucuna pruriens	2750 bB	3675 bA
Vigna radiata	200 dB	700 dA
Vigna unguiculata	3450 aA	2875 cB

*Means followed by the same letter, uppercase horizontally or lowercase vertically, do not differ by the Tukey test at $p \geq 0.05$.

From our results, *Vigna unguiculata* stood out because, on average, it produced a higher amount of biomass in relation to the other cover crops and produced the highest amount of grains that can be used as food by family farmers. According to Andrade Junior *et al*. (2002), *V. unguiculata* has a short cycle, low water requirement, and rusticity to develop in low fertility soils and, its grain is an excellent source of protein, carbohydrates, vitamins, and minerals. Because of these features, *V. unguiculata* becomes an important alternative for food production preceding rice cultivation.

Plants differ in developing specific conditions (Oliveira *et al*. (2002), being, therefore, interesting to evaluate different locations. Based on the results, we found that *V. unguiculata* grew more in Cuaia. On the other hand, *Lablab purpureus* and *Mucuna pruriens* grew better in Nambaua. This could be because in Nambaua, the soil had 34.38 mg kg^{-1} of P and in Cuaia, 9.75 mg kg^{-1}. Therefore, it is likely that the other cover crops develop better in places with high level of P. However, *Vigna unguiculata*, among the cover crops tested, seems to have higher response to K in the soil, once in Cuaia, the level of this nutrient was higher than in Nambaua. According to Oliveira *et al*. (2009), the cover crop *V. unguiculata* increased plant growth and grain yield with the increase of K fertilization.

Considering that productivity of rice grains is determined by three yield components, namely the number of panicles m^{-2} and of filled grains and the mass of 1000 grains (Yoshida, 1981), from the results obtained in the yield components, we can explain the higher grain yield in Cuaia compared with Nambaua.

In both sites, rice grain yields were high considering the yield average in Mozambique in the growing season of 2013, 1170 kg ha^{-1} (Faostat, 2015). Therefore, grain yield obtained in Nambaua was more than twice the national average and grain yield achieved in Cuaia was almost four times higher than the rice grain yield in Mozambique. These data are promising and may contribute incisively to increase food production in Africa and could be used in other countries of Asia and Latin America. Allied to this, there is the production of grains from the cover crops that can be grown before rice cultivation. Therefore, aiming to achieve a sustainable development by including more species in agricultural systems, we observed that the use of cover crops, especially *V. unguiculata*, followed by rice cultivation, could contribute to increase grain production (from cover crop and from rice), resulting in much higher food per area. Furthermore, cover crops provided nutrient cycling, which could allow better development of the following rice crop. These data become more important considering that around 270 million of inhabitants living in sub-Saharan Africa have problems with hunger and malnutrition (Sanchez & Swaminathan, 2005; Balasubramanian *et al*., 2007).

Table 5: Plant height (PH), number of tillers (NT), number of panicles (PAN), number of grains per panicle (GRAIN), mass of 1000 grains (MGRAIN), and grain yield of rice as affected by cover crops and sites. Cuaia and Nambaua sites, Pemba city, Province of Cabo Delgado Moçambique, Growing season 2014/2015

Cover crop	**PH** cm	**NT** n. m^{-1}	**PAN** n. m^{-1}	**GRAIN** n. $panicle^{-1}$	**MGRAIN** grams	**YIELD** kg ha^{-1}
Pennisetum glaucum	56.1	18.5	14.0	141	24.7	3248
Lablab purpureus	55.0	20.6	13.9	158	23.8	3499
Mucuna pruriens	55.4	20.6	13.4	151	25.5	3586
Vigna radiata	57.9	21.5	16.3	147	25.6	3700
Vigna unguiculata	62.6	18.6	13.8	146	25.3	3816
Fallow	60.4	20.4	13.3	145	23.9	3586
Site						
Cuaia	74.7 a	22.0 a	15.3 a	158 a	24.9 a	4509 a
Nambaua	40.3 b	18.0 b	12.9 b	139 b	24.8 a	2594 b
Factor			ANOVA (F probability)			
Cover crops (CC)	0.8758	0.8724	0.2055	0.7925	0.1368	0.8545
Site	< 0.0001	0.0231	0.0024	0.0127	0.9835	< 0.001
CC×Site	0.7905	0.2963	0.1669	0.1629	0.2411	0.3655

*Means followed by the same letter vertically do not differ by the Tukey test at $p \geq 0.05$.

CONCLUSION

Cover crops and fallow resulted in similar chemical and physical properties of soil and rice grain yield;

Lablab purpureus, *Vigna unguiculata*, and *Mucuna pruriens* provide higher production of biomass;

Vigna unguiculada produce the highest grain yield;

The location of Cuaia allows higher rice grain yield than the location of Nambaua.

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