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Upland rice yield as affected by *Brachiaria* coverage management

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Key words:
Oryza sativa
no-tillage system
glyphosate
cover crop

ABSTRACT
An important point in no-tillage system is the time between cover crop glyphosate desiccation and rice sowing. This study aimed to verify the effect of *Brachiaria ruziziensis* management time before rice sowing on rice yield and its components. The experiment was conducted under greenhouse conditions and consisted of four types of *B. ruziziensis* management: with *Brachiaria* and with herbicide (WBWH), without *Brachiaria* shoots and with herbicide (NBWH), without *Brachiaria* shoots and without herbicide (NBNH), and with *Brachiaria* and without herbicide (WBNH), at four times: 30, 20, 10, and 0 days, preceding the rice sowing. The amount of *B. ruziziensis* dry matter increased as the management was done closer to the rice sowing date. The WBWH and WBNH managements (this one causes the lowest rice grain yield) must be done 30 days before rice sowing; while NBWH management must be done ten or more days before rice sowing. On the other hand, NBNH management (this one favors the best rice grain yield) can be done until rice sowing day. Despite some reduction in rice yield caused by the *B. ruziziensis* management, when it was done at the proper time the rice grain yield was similar to the control (without *Brachiaria* sowing and without herbicide application).

Palavras-chave:
Oryza sativa
sistema de plantio direto
glifosato
cultura de cobertura

Produtividade do arroz de terras altas em função do manejo da cobertura de *Brachiaria*

RESUMO
No sistema de plantio direto é importante o tempo entre a dessecação da cobertura com glifosato e a semeadura do arroz. Este estudo objetivou verificar o efeito da época de manejo da *Brachiaria ruziziensis* antes da semeadura do arroz na produtividade do arroz e seus componentes de produção. O experimento foi conduzido em casa de vegetação, com quatro tipos de manejo da *B. ruziziensis*: com *Brachiaria* e com herbicida (CBCH), sem a parte aérea da *Brachiaria* e com herbicida (SBCH), com *Brachiaria* e sem herbicida (CBSH) e sem a parte aérea da *Brachiaria* e sem herbicida (SBSH), em quatro épocas: 30, 20, 10 e 0 dias anteriores à semeadura do arroz. A matéria seca de *B. ruziziensis* aumentou à medida que o manejo foi realizado próximo à semeadura do arroz. Os manejos CBCH e CBSH (este proporcionou a menor produtividade de arroz) devem ser feitos 30 dias antes da semeadura do arroz; já o manejo SBCH deve ser feito dez ou mais dias antes da semeadura. O manejo SBSH, que proporcionou a maior produtividade de arroz, pode ser feito até o dia da semeadura do arroz. Apesar de alguma redução na produtividade causada pelo manejo da *B. ruziziensis*, quando ele foi feito no momento adequado a produtividade do arroz foi semelhante ao controle (sem semeadura da *Brachiaria* e sem herbicida).

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Introduction

In no-tillage system (NTS) straw on the soil surface is an essential requirement before the deployment of crops (Dabney et al., 2001; Yahuza, 2011; Nascente et al., 2013a). Once the amounts of biomass produced by cash crops are not enough for an adequate ground cover, it is necessary to introduce cover crops to produce the required volume of biomass in the off-season (Crusciol et al., 2012; Nascente et al., 2013c). Then, soil will remain covered as long as possible until the following summer crop (Nascente et al., 2012b). Forage species such as *Brachiaria* genus is being used as a cover crop because it produces large amounts of biomass and persists longer on the soil surface, especially in times of shortage of rain (Valle & Pagliarini, 2009; Crusciol et al., 2013; Freitas et al., 2013).

An important point to be considered is the time between desiccation of the cover crops and main crop sowing (Nascente & Crusciol, 2012). Herbicide application on cover crops close to cash crop sowing has caused difficulties in sowing operations and in the early crop development, reducing crop grain yield (Grisso et al., 2009; Nascente et al., 2013b). It may happen because the systemic characteristic of glyphosate, the principal herbicide used in chemical management of cover crops, which take some days to dry completely the crops (Franz, 1985). Therefore, at the cash crop sowing day cover crops are not completely dry and with high amount of biomass it can cause difficulties to cut their leaves by the discs of the planter (Grisso et al., 2002; Nascente et al., 2013c). In addition, other factors such as an initial shading in the crops, possible translocation of herbicide from target plants (cover crops) to non-target plants (cash crops), increasing demand for nitrogen by decomposing microorganisms, allelopathic effects and other aspects still must be studied, understood and avoided (Weston, 1990; Miyazawa et al., 2002; Barbosa et al., 2008; Nascente et al., 2012a).

Despite of the importance of the subject, there are very few studies on this subject in upland rice (Nascente et al., 2013d). Identification of the correct interval between cover crops desiccation and rice sowing could be important to increase its grain yield adjust at NTS. This measure may provide greater availability of nutrients, greater presence of straw on the soil surface and less possible release of allelopathic substances to the soil (Weston, 1990; Barbosa et al., 2008, Zaidan & Carreira, 2008; Weih et al., 2008; Nascente et al., 2013d).

In this context, a test was performed under controlled conditions to verify the effect of *Brachiaria ruziziensis* management, with or without herbicide, in different times preceding upland rice sowing in the grain yield and its components.

Material and Methods

The study was performed in Santo Antônio de Goiás, GO, Brazil (16° 27' latitude, 49° 17' longitude and 823 m altitude) under greenhouse conditions between January and August of 2010. The experimental units consisted of PVC columns with 0.25 m in diameter and 1.0 m tall (0.25 m^3), filled with soil (35% sand, 12% silt and 53% clay), classified as a Rhodic Ferralsol, from the layer 0-20 cm deep, previously sieved through 5 mm mesh. Chemical analysis showed pH in H_2O = 5.0, Al^{+3}, $H^+ + Al^{+3}$, Ca^{+2} and Mg^{+2} was 0.2, 5.00, 0.45 and 0.14 $cmol_c\ kg^{-1}$, respectively, P = 9.2 mg kg^{-1}, K = 19 mg kg^{-1}, and soil organic matter = 16 g kg^{-1}. P and K were extracted by Mehlich 1 extracting solution (0.05M HC1 in 0.0125M H_2SO_4). In the extracted solution, phosphorus was determined colorimetrically and K by flame photometry. Calcium, Mg and Al were extracted with 1M KC1. Aluminum was determined by titration with NaOH and Ca and Mg by titration with EDTA from the extracted solution and pH was determined in water using pHmeter.

The experiment was conducted in four (managements) x four (times of *Brachiaria* drying/cutting) factorial + one control treatment (no-planting *Brachiaria* and no-herbicide application) in a completely randomized design with three replications, totaling 51 experimental units. Four types of *Brachiaria* management were established: with *Brachiaria* and with herbicide (WBWH), without *Brachiaria* shoots and with herbicide (NBWH), without *Brachiaria* shoots and without herbicide (NBNH), and with *Brachiaria* and without herbicide (WBNH).

The periods of drying/removal of the *Brachiaria* shoots were at 30, 20, 10 and 0 days before rice sowing.

In each column ten seeds of *B. ruziziensis* were sown. Fertilizer application consisted of 5 g per column with triple superphosphate (equivalent to 69.87 kg of P ha^{-1}), one day before forage sowing. At 60 days after germination, when *Brachiaria* plants had approximately three to four tillers, proceeded to the beginning of the forage management (30 days before rice sowing).

In NBWH management, 48 h after herbicide application a cutting was made at ground level with removal all shoots of *B. ruziziensis*. In NBNH management, at the same time, despite of not applying herbicide removal of the forage shoots was done and the sprout was removed weekly. In WBNH management, at the time of herbicide application in the other treatments, *Brachiaria* shoots were cut and put on the soil surface, removing sprouts weekly too.

The application of glyphosate (1.8 kg ha^{-1} acid equivalent) was done using a vacuum pump, stationary, with constant pressure of 207 kPa, equipped with a fan type tip (TeeJet XR 110.02) positioned 0.5 m from the target surface, applying the equivalent of 200 L ha^{-1} of spray.

In each column ten seeds of upland rice cultivar BRS Sertaneja were sown at a depth of 2 cm. Fertilization at sowing was 5 g per column equivalent to 20 kg ha^{-1} of N as urea, 52 kg ha^{-1} of P as triple superphosphate and 49.8 kg ha^{-1} of K as potassium chloride and 45 days after germination, 2.5 g per column of ammonium sulfate (equivalent to 40 kg ha^{-1} of N) was applied. At 5 days after germination thinning was done and three rice plants per column were left.

The amount of shoot dry matter produced by *Brachiaria* was assessed in each season of forage management (30, 20, 10 and 0 days before rice sowing). *Brachiaria* shoots were collected and packed in paper bags and dried in an oven with air circulation at 60 °C until constant weight. In addition the relative growth rate (RGR, g g^{-1} d^{-1}) of the grass was calculated, following the method proposed by Reader et al. (1994), using the formula:

$$RGR = \frac{\ln(M_2) - \ln(M_1)}{t_2 - t_1}$$

where:

M_1 and M_2 - weight of *Brachiaria* shoots dry matter (g) at times t_1 and t_2

t_1 and t_2 - time of sampling plants (30 and 0 d prior to rice sowing)

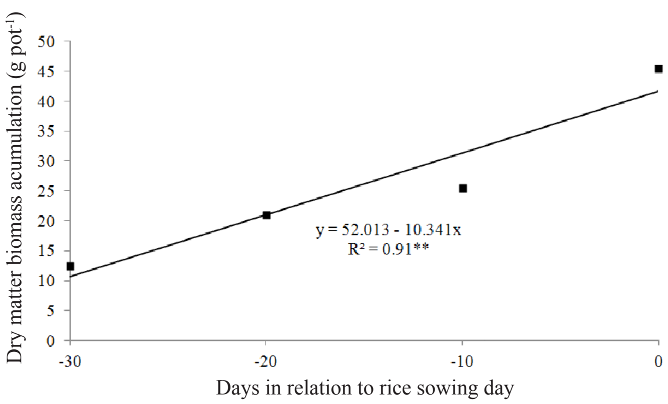
To evaluate rice yield all rice plants in each experimental plot were collected, grains were corrected to 13% moisture and then weighed. For yield components, the number of panicles per pot, spikelets per panicle, number of filled spikelets and 1000 grain weight were evaluated.

Data were subjected to variance analysis in a factorial design and means were compared by t test at $p < 0.05$. Regression analysis was carried out for the growth rate of *Brachiaria* and for rice grain yield and its components with the time of *Brachiaria* management, for each type of management. Comparison of treatments with control treatment was also performed by analysis of variance, and the means of the treatments were compared to control treatment by Dunnett's test at $p < 0.05$. All tests were performed using statistical program Statistical Analysis System (SAS, 1999).

Results and Discussion

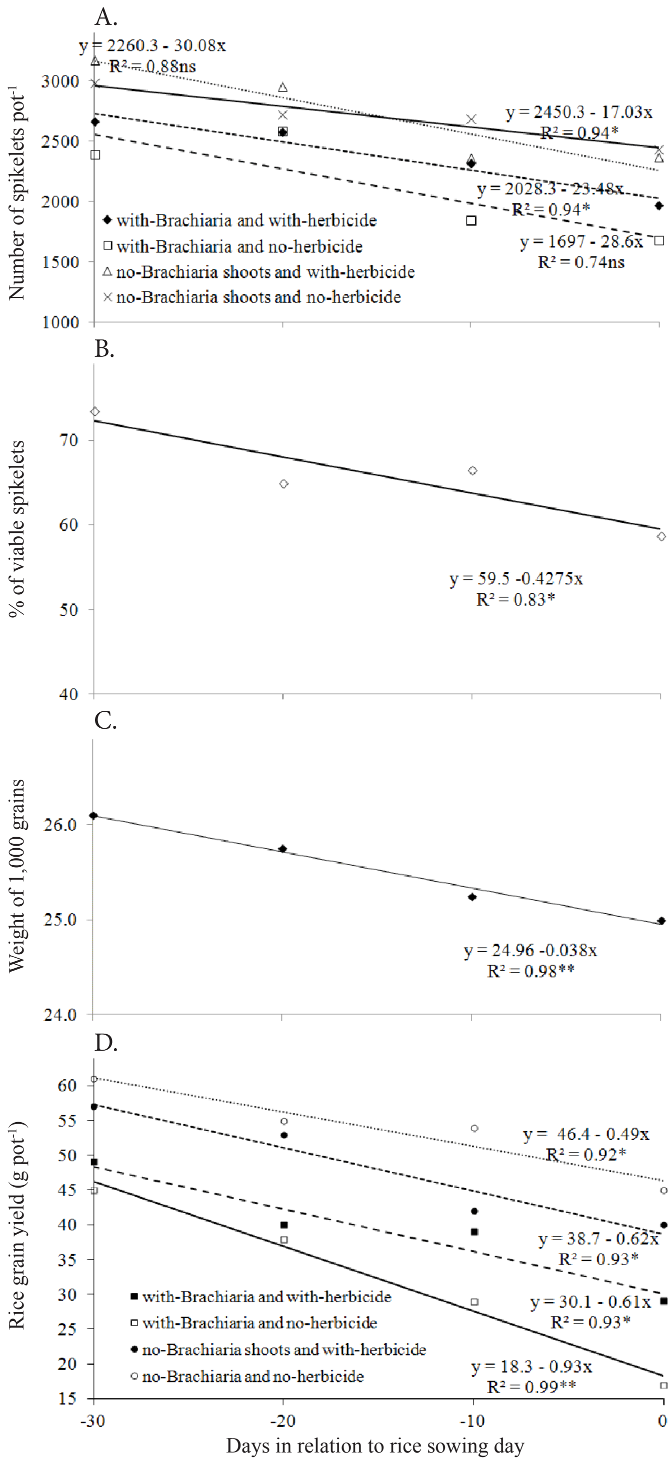
The amount of *Brachiaria ruziziensis* dry matter increased as the management was done closer to the rice sowing day, with a significant linear regression (Figure 1). Regarding yield components, they all had lowest values when the forage management was done closer to the rice sowing day (Figures 2A to 2D), although it was not significant for number of panicles. There were interactions between types and times of *Brachiaria* management for number of spikelets per pot (Figure 2A). Number of viable spikelets and 1000 grain weight were not affected by *Brachiaria* management but only by the management time (Figures 2B and 2C).

There was interaction between types and times of *Brachiaria* management in upland rice grain yield (Figure 2D). The lowest yields were observed when *Brachiaria* straw management was done on the rice sowing day. Treatments with *Brachiaria* cutting and maintenance of the shoots on the soil surface was the worst



** significant at $p < 0.01$

Figure 1. Shoot dry mass accumulation by *Brachiaria ruziziensis* plants, considering days before rice sowing



*Significant by $p < 0.05$; **Significant by $p < 0.01$, and ns – No significant

Figure 2. Number of spikelets per pot (A); Viable spikelets, % (B); 1000-grain mass (C); Rice grain (D) yield as a function of the day which was done *Brachiaria ruziziensis* management in relation to rice sowing

for rice yield. On the other hand, the highest grain yields were observed when grass shoots were removed and there was no application of herbicide. In the absence of *Brachiaria* shoots, the herbicide application also reduced the rice yield.

It was found by statistical analysis that there was high correlation between amount of dry matter produced by *Brachiaria* on the management day and rice yield, with value -0.57 (Table 1). The same happened to all yield components in relation to the grass biomass, with exception of 1000 grain

Table 1. Pearson correlation coefficient and p value among rice yield components, rice yield and *Brachiaria* dry matter at the management day during 2010 growing season

Variables	Number of grains	% Viable grains	1000 Grain weight	Number of panicle	Rice yield per pot (g)
Brachiaria dry matter	-0.57	-0.36	-0.16	-0.41	-0.57
(management day)	<.0001	0.0099	0.2571	0.0031	<.0001

weight. On the other hand, WBNH management at 30 days before rice sowing was satisfactory and rice grain yield did not differ from the control treatment (Table 2).

Regarding *Brachiaria* biomass accumulation, through the results it was observed that management with-grass and no-herbicide at sowing rice day, had the presence of 45 g of straw dry matter on the soil surface and it could hindered emergence of rice seedlings. This amount of straw on the soil surface is equivalent to 2.3 t of dry matter ha^{-1} and it is sufficient to cover about 40% of the soil (Miyazawa et al., 2002; Mauli et al., 2011). It is noteworthy that this value is even lower, considering that *Brachiaria* species have potential to produce 20 t ha^{-1} of dry matter (Fischer et al., 2001; Crusciol et al., 2012; Nascente et al., 2013a).

This small accumulation of *Brachiaria* biomass can be explained due to its slow initial growth (Valle & Pagliarini, 2009; Crusciol et al., 2012), that was observed by the relative growth rate (increase in grams of dry biomass per unit of material present in the observation period) which was 0.043 g g^{-1} (Figure 1). Similar values were obtained by Valle & Pagliarini (2009), 0.050 g g^{-1} at 60 days after grass germination, same time of onset *Brachiaria* management in our study. However, even this amount of *Brachiaria* dry matter on the soil surface was not beneficial for rice plants, once plots with lower levels of *Brachiaria* biomass (management carried out in a period larger in relation to rice sowing day) allowed higher rice yield (Figure 2D). On the other hand, as higher the amount of accumulated *Brachiaria* dry matter as lower was the rice yields in all types of *Brachiaria* management.

Fischer et al. (1995), Crusciol et al. (2012) and Nascente et al. (2013a) add that species of *Brachiaria* spp. produce large amount of biomass, which if not properly managed, can undermine emergence and establishment of rice plants. Corroborating this information, there was negative correlation between amount of *Brachiaria* dry matter with rice grain yield and all yield components, with exception of 1000 grain weight.

Treatment with-*Brachiaria* which keeps the shoots on the soil surface simulating mowing, was the most detrimental to the rice yield. According to Nascente et al. (2013c), mowing does not kill the plants and the grass keeps competing with the cash crop, with constant sprout, which can significant reduce grain yield. The application of herbicide in WBWH management minimized this effect. According to Dabney et al. (2001) and Nascente et al. (2013c,d) benefits of managing cover crops with herbicide or mowing before main crop sowing are: reducing competition for water in the early crop development, promotes decomposition of cover crop residues or weeds, which can provide nutrients to the crops, improves uniformity of sowing; reduce possible allelopathic effects of cover crops or weeds, and provides increased in crops yield. According to Nascente et al. (2013b) the time to apply herbicide will depend of the cover crop specie, for example for millet (*Pennisetum glaucum*) this time is around 10-14 days before sowing and for *Brachiaria* species this time is around 30 days before rice sowing.

The NBNH management, when grass straw was removed from the soil surface, allowed the greatest rice yield in comparison to all kinds of *Brachiaria* management. On the

Table 2. Evaluation of the rice yield and its components under different treatments in greenhouse conditions in comparison to the control treatment during 2010 growing season

Treatments	Managment time	Number of panicle	Number of grains	% Viable grains	1000 Grain weight	Rice yield per pot (g)
WBWH	0 DAH	15 (NS) +	1.967(NS)	56 (NS)	25 (NS)	29 (-)
	10 DAH	17 (NS)	2.317 (NS)	66 (NS)	25 (NS)	39 (-)
	20 DAH	19 (NS)	2.574 (NS)	64 (NS)	24 (NS)	40 (-)
	30 DAH	19 (NS)	2.664 (NS)	74 (NS)	25 (NS)	49 (NS)
NBWH	0 DAH	18 (NS)	2.364 (NS)	67 (NS)	26 (NS)	40 (-)
	10 DAH	20 (NS)	2.361 (NS)	64 (NS)	27 (NS)	42 (NS)
	20 DAH	19 (NS)	2.951 (NS)	68 (NS)	26 (NS)	53 (NS)
	30 DAH	20 (NS)	3.170 (NS)	71 (NS)	26 (NS)	57 (NS)
NBNH	0 DRB	19 (NS)	2.430 (NS)	70 (NS)	27 (NS)	45 (NS)
	10 DRB	19 (NS)	2.685 (NS)	78 (NS)	26 (NS)	54 (NS)
	20 DRB	22 (NS)	2.723 (NS)	62 (NS)	27 (NS)	55 (NS)
	30 DRB	20 (NS)	2.985 (NS)	77 (NS)	26 (NS)	61 (NS)
WBNH	0 DAH	14 (-)	1.682 (-)	42 (-)	24 (-)	17 (-)
	10 DAH	13 (-)	1.847 (-)	58 (NS)	25 (NS)	29 (-)
	20 DAH	18 (NS)	2.586 (NS)	56 (NS)	25 (NS)	38 (-)
	30 DAH	18 (NS)	2.389 (NS)	72 (NS)	25 (NS)	45 (NS)
Control treatment++		21	3.255	74	27	65
Coefficient of variation		18.00	15.19	19.04	4.21	22.11

+Means in column followed by (-) are lower than the treatment control and (NS) do not differ from absolute control by Dunnett's test at $p < 0.05$; ++ Treatment control - without herbicide treatment and no *Brachiaria ruziziensis;* WBWH – Treatment with-*B. ruziziensis* and with-herbicide to dry it; NBNH – Treatments no-*B. ruziziensis* shoots and no-herbicide; NBWH – Treatments with-herbicide and *B. ruziziensis* shoots were removed after two days; WBNH – Treatment with-*B. ruziziensis* and no-herbicides; DAH – Day of the herbicide application before upland rice sowing; DRB – Day of the elimination of *B. ruziziensis* shoots before upland rice sowing other hand, the WBNH management, when shoot straw was on the soil surface, caused greater reductions in rice yield and its components in management carried out on the days 20, 10, and 0 prior to sowing of rice. These results allow us to infer that shoots straw of *Brachiaria* has detrimental effect on rice plants. When we used the management that took out *Brachiaria* shoots the effects on rice yield and its components were smaller. According to Weston (1990), Barbosa et al. (2008), Zaidan & Carreira, (2008) and Weih et al. (2008) although there are many advantages for the presence of mulch on the soil over fallow, some types of coverage may have inhibitory effects on crops seedling emergence and these effects can be physical, allelopathic or biological (reduction of soil microbial population).

In the WBWH management the highest yields were obtained at treatments which management were done 30 days before rice sowing and were not different from the control treatment. In these treatments, herbicide reduced *Brachiaria* effect and had better rice yield and its components in comparison to treatments with only *Brachiaria* (no herbicide). According to Nascente & Crusciol (2012) and Nascente et al. (2013c) it is important to wait two or three weeks between the cover crop desiccation and annual crop sowing to avoid possible translocation of the herbicide from target (cover crop) to no-target plants (rice), possible release of allelopathic substances from the cover crop and shade in the seedling. Waiting a while before cash crop sowing could allow plants to have a rapid and vigorous initial development. For rice it seems that this period must be greater, about 30 days before rice sowing. Nascente et al. (2012a) under field conditions reported that *Brachiaria ruziziensis* desiccated 30 days before rice sowing allow the highest grain yield. Matallo et al. (2009) add that due to systemic nature of glyphosate its effect on plants is slow and coverage takes a few days to die completely. When using the system to apply this herbicide on cover crops close to sowing day, these plants are not yet completely dried and may impair the operations of sowing, and the initial crop development (Grisso et al., 2002; 2009; Nascente et al., 2012b; 2013c).

In NBWH management (herbicide application and removal of grass shoots two days after), to check the effect of the herbicide without *Brachiaria* shoots, management carried out 10 or more days before rice sowing had similar rice yields and not differ from control treatment. Without *Brachiaria* shoots glyphosate effect was fewer than in the management with only *Brachiaria* or with *Brachiaria* and herbicide. Again, it could see that something in the *Brachiaria* shoots are causing damage in rice and should be more understood.

Summarizing the results allow inferring that management of cover crops before rice sowing has significant effect on the grain yield and its components and therefore should be done at the correct time. In this sense, despite of some *Brachiaria* managements are harmful to rice yield and its components, it cannot eliminate the use of cover crops in a crop rotation management on rice crops, once cover crops in rotation with rice are very important to NTS and have many interesting features like nutrients cycling, protection against erosion, weed control and increase soil organic matter (Dabney et al., 2001; Filizadeh et al., 2007; Yahuza, 2011; Crusciol et al., 2012; Nascente et al., 2013d). When *Brachiaria* management was done at the correct time it allowed satisfactory results and it was enough to have rice yield similar to the control treatment. Therefore, farmers can chose all kind of management, but must pay attention to correct time to avoid damage in rice yield.

Conclusions

1. Management of *B.ruziziensis* with herbicide and without removing the straw must be done 30 days before rice sowing.

2. Chemical control of *B. ruziziensis* with removal of straw must be done ten or more days before rice sowing.

3. Management where *B. ruziziensis* straw is removed from the soil surface and without herbicide application is the best for rice yield and can be done until on the day of rice sowing.

4. Management that remained *Brachiaria* straw on the soil surface without herbicide application cause lowest rice yield and must be done 30 days before the rice sowing.

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