VOLUNTEER RR® CORN MANAGEMENT IN ROUNDUP READY® SOYBEAN-CORN SUCCESSION SYSTEM[1]

Manejo do Milho RR® Voluntário em Sistema de Sucessão Soja-Milho Roundup Ready

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ABSTRACT - The present study evaluated the effects of cover crops (*Pennisetum glaucum*, *Crotalaria spectabilis* and *Urochloa ruziziensis*) associated with the application of herbicides {glyphosate; (glyphosate + haloxyfop-R); (glyphosate + fluazifop-p-butyl); (glyphosate + imazethapyr) and (glyphosate + imazaquin)} in soybean desiccation management for volunteer RR® corn control. The experiment was conducted under field conditions at Sinop-MT, during the 2013/2014 crop season, in a randomized complete blocks design with factorial scheme and four replications. The following parameter were evaluated: dry matter of cover crops and ground coverage rate, control of volunteer RR® corn present at the time of desiccation, dry matter, height and intoxication level on soybean plants caused by herbicides at 7, 14 and 28 days after emergence (DAE), control of volunteer RR® corn derived from emergence fluxes subsequent to desiccation management and soybean yield. The joint application of (glyphosate + haloxyfop-R) provided the best level of volunteer RR® corn control present at the time of desiccation. Satisfactory control (80%) of volunteer corn was obtained with the application of (glyphosate + imazethapyr). This treatment displayed an additional residual effect of imazethapyr, which efficiently controled volunteer RR® corn derived from fluxes subsequent to desiccation management, especially in treatments performed under *U. ruziziensis* straw. None of the herbicides used in desiccation management caused any significant effect on dry matter, height and phytotoxicity of soybean plants at 7, 14 and 28 DAE nor on grain yield.

Keywords: *Zea mays*, *Glycine max*, cover crops, herbicides.

*RESUMO - Avaliaram-se nesta pesquisa os efeitos de plantas de cobertura (**Pennisetum glaucum, Urochloa ruziziensis** e **Crotalaria spectabilis**) associadas à aplicação de herbicidas {glyphosate; (glyphosate+haloxyfop-R), (glyphosate+fluazifop-p-butil), (glyphosate+imazethapyr) e (glyphosate+imazaquin)} no manejo de dessecação na cultura da soja, visando o controle do milho RR® voluntário. O experimento foi conduzido em campo no município de Sinop-MT, na safra 2013/2014, no delineamento experimental de blocos casualizados, em esquema fatorial, com quatro repetições. Foram avaliados: matéria seca das plantas de cobertura e cobertura do solo, controle do milho RR® voluntário presente no momento da dessecação, matéria seca, altura e intoxicação das plantas de soja pelos herbicidas aos 7, 14 e 28 dias após a emergência (DAE), controle do milho RR® voluntário oriundo de fluxos de emergência posterior ao manejo de dessecação e produtividade da soja. A aplicação conjunta de (glyphosate+haloxyfop-R) proporcionou o melhor nível de controle do milho RR® voluntário presente no momento da dessecação. Controle satisfatório (80%) do milho voluntário foi obtido com a aplicação de (glyphosate+imazethapyr). Este tratamento teve como adicional o efeito residual do imazethapyr, que controlou de maneira eficiente o milho RR® voluntário oriundo de fluxo posterior ao manejo de dessecação, principalmente nos tratamentos cultivados sob palhada de **U. ruziziensis**. Não houve efeito significativo dos herbicidas utilizados no manejo de dessecação na matéria seca, altura e fitotoxicidade das plantas de soja aos 7, 14 e 28 DAE e na produtividade de grãos.*

Palavras-chave: *Zea mays*, *Glycine max*, plantas de cobertura, herbicidas.

[1] Recebido para publicação em 26.8.2014 e aprovado em 22.9.2014.
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INTRODUCTION

The State of Mato Grosso currently occupies a prominent position in terms of grain production, with an area planted to soybean (*Glycine max*) and corn (*Zea mays*) of 8.62 and 3.28 million hectares respectively, representing 28.6 and 20.8% of the total area of these crops in the country (CONAB, 2014).

Since its introduction in Brazil, soybean and corn planting has undergone several changes, such as modifications in management techniques. Among the innovations included in the technological package are the no-till system (NTS) and the introduction of RR® transgenic soybean and maize. The first one endorses the preservation and maintenance of the physical, chemical and biological characteristics of the soil by the formation of straw, crop rotation and no soil disturbance. The second aims at the use of the post-emergence herbicide glyphosate, controlling weeds in soybean and corn crops.

According to Petter et al. (2007), with the authorization for Roundup Ready® soybean cultivars planting in Brazil, the intensity of glyphosate use at planting, which was already great due to the applications for desiccation management, became even greater with the possibility of performing post-emergence applications. Recently, the use of this herbicide has conquered more and more of the market after the release of commercial-scale planting of maize resistant to glyphosate. In sensitive plants, glyphosate inhibits the activity of the key enzyme (5-enolpyruvylshikimate-3-phosphate synthase –EPSPs) (Zuffo et al., 2014) of aromatic amino acids tryptophan, phenylalanine and tyrosine synthesis process.

Given the characteristics of glyphosate, which is the only one that has this mechanism of action, and with continued use of this herbicide in corn-soybean succession cropping system, there is need for a proper chemical weed control; otherwise, an increase of selective pressure and the emergence of faster herbicide-resistant weeds may occur. The cultivation of these two crops is closely associated, since that in regions where there is a better rainfall distribution pattern, soybeans are typically grown in the summer harvest, and corn during the off-season.

In this sense, it has been observed in the field, in addition to resistant weed populations, the occurrence of volunteer RR® corn derived from the previous off-season amid soybean crops in the subsequent summer harvest. This situation has been observed in several regions where the succession system and/or the soybean-corn rotation system are predominant. This fact has hampered the management of soybean production, since that there is an intraspecific competition with maize, besides impairing post-harvest operations, thus resulting in grain losses during this process.

Confronted with the difficulty in the herbicide portfolio that meets, in an associative manner, the needs of both crops and due to the undesirable effects of volunteer corn plants in soybean plantations, many farmers are already using soybean/corn conventional varieties. Some herbicides, as diclosulam, that could play a preventively role in the control of volunteer corn may have phytotoxic effect on maize in the off-season when applied in desiccation management for soybean plantation (Artuzi & Contiero, 2006; Dan et al., 2011).

If we consider that for grain producers chemical control is the main form of weed management, it becomes clear that it is necessary to obtain information on the potential of sustainable and economic techniques that can be applied in the integrated weed management, like the benefits of no-till farming with the presence of dry matter of cover crops on the soil surface (Gimenes et al., 2011). Thus, one alternative is to combine the use of herbicides with cover crops management.

Dry matter production and soil coverage provided by cover crops are factors that can help control weeds by physical and chemical processes (allelopathy) (Pacheco et al., 2013b; Petter et al., 2013). The physical effect of mulch helps to shade the soil, inhibiting seed germination and infestation of some troublesome weeds, thus allowing the crop to develop free of initial competition (Queiroz et al., 2010). This effect may be extended to volunteer corn, providing effective preventive control of those plants in soybean crops. However, responses obtained with the use of plants for soil coverage and the production of direct effects on weed and corn germination depend on the species, quantity and distribution of residues (Chauhan et al., 2012).

Therefore, the objective of this work was to evaluate the effects of herbicides associated with cover crops in desiccation management, aiming at a chemical and cultural volunteer RR® corn control in soybean crops in a preventive manner.

MATERIALS AND METHODS

The field experiment was conducted at the Federal University of Mato Grosso, Sinop campus, during the 2013/2014 season, whose geodetic location is 11º51'52" latitude, 55º29'03" longitude and altitude of 374 m, on soil classified as dystrophic Yellow Oxisol ("Latossolo Amarelo distrófico", or LAd) (Embrapa, 2013). Soil textural analysis at 0-20 cm revealed 540 g kg^{-1} of clay content, 56 g kg^{-1} of silt, and 400 g kg^{-1} of sand. Soil chemical properties are presented in Table 1.

The climate is Aw, according to Köppen global climate classification, characterized by two distinct seasons: a dry season from May to September, and a rainy season from October to April.

We used a randomized complete blocks experimental design, in a 3 x 5 factorial scheme, with three cover crops (*Pennisetum glaucum*, *Urochloa ruziziensis* and *Crotalaria spectabilis*), five herbicides [glyphosate (1,080 g ha^{-1}); glyphosate (1,080 g ha^{-1}) + haloxyfop-R (260 g ha^{1}); glyphosate (1.080 g ha^{-1}) + fluazifop-p-butyl (187 g ha^{-1}); glyphosate (1,080 g ha ^{1}) + imazethapyr (106 g ha^{-1}); glyphosate (1,080 g ha^{-1}) + imazaquin (160 g ha^{-1})], and four replications. Each plot consisted of 4 m wide and 5 m long. For an useful area, 0.5 m on each side of the plot and 0.5 m at the ends were discarding, with a total floor area of 12 m².

The cover crops were grown after corn harvest, i.e. during the off-season, to serve as straws in a subsequent soybean desiccation management (2013/2014 season) and to control volunteer RR® corn and weed present in the growing areas. AG 7088RR maize cultivar was sown during the off-season, in February 2013, at density of 60,000 plants ha^{-1}, with 0.6 m spacing between the lines. In this off-season cropping system, the same cover plants were sown, aiming at the formation of straw for the 2013/2014 season. Afterwards, in November of 2013, desiccation management practices were carried out using the herbicides previously described. Seven days after desiccation management, soybeans of TMG 2183 IPRO RR® cultivar were sown (season 2013/2104), with 0.5 m spacing between the lines, depth of 2-3 cm and planting fertilization with 500 kg ha^{-1} of NPK 00-20-18 fertilizer, was conducted.

At 7, 14 and 28 days after soybean emergence (DAE) or equivalent to 21, 35 and 49 days after herbicide application (DAA), the dry matter of cover crops, dry matter, height and phytotoxicity to soybean crop, and volunteer RR® corn control at the time of desiccation were determined. Dry matter of cover crops was determined according to the methodology proposed by Crusciol et al. (2005), using an iron square sized 50 x 50 cm (0.25 m²), in which the aerial part and residues

Table 1 - Chemical composition (0-20 cm) of the soil in the experimental area before the experimental installation. Sinop-MT, harvest 2013/2014

pH	P (Mehlich)	K	Ca	Mg	Al	H+Al	O.M.[1/]
($CaCl_2$)	(mg dm^{-3})		(cmol$_c$ dm^{-3})				(g dm^{-3})
4.9	7.6	48.0	1.7	1.1	0.06	5.7	34.0
V[2/]	CTC[3/]	Fe	B	Mn	Zn	Cu	S
(%)	(cmol$_c$ dm^{-3})	(mg dm^{-3})					
41	8.6	96	0.3	11	3.0	0.4	17.0

[1/] M.O.: organic matter; [2/]V%: basis saturation; [3/]CTC: cation exchange capacity.

of cover crops are collected through three sampling points per subplot. Soybean dry matter was determined through collecting five plants per plot which, as the cover crops matter, were taken to a forced ventilation oven at 65 ^{o}C for 72 hours. Plant height was evaluated by measuring from the lap to the summit of the apical meristem. For the control of volunteer RR® corn in soybean crops, notes were assigned according to a percentage scale that ranges from zero to 100, where zero means no plants and 100 means total presence of the plants; a witness that received only glyphosate was the main parameter. In order to evaluate the occurrence of phytotoxicity symptoms, a visual assessment was carried out using a percentage scale of notes, where zero (0) represents the absence of symptoms and one hundred (100.0) represents death of all plants of that plot.

At 28 DAE soybean, the ground coverage rate provided by cover crops was determined with the use of a square iron sized 0.5 x 0.5 m (0.25 m^2) and a string network spaced 5 cm forming ten points, in which one observes the presence or absence of coverage provided by plant residues in each of the sampling points (Sodré Filho et al., 2004). At 50 DAE soybean, we observed (as previously described) a volunteer RR® corn control derived of emergence fluxes following desiccation, therefore, the residual effect of the herbicide. At the time of soybean harvest, we determined the grain yield in useful area of each plot, on the basis of 13% moisture content.

After collection and tabulation of data, we performed the analysis of variance, and the means of the significant variables were grouped by Scott-Knott test at 5% of significance with the statistics program Sisvar. As for analysis on phytotoxicity and control, data were subjected to arcsine transformation $(x+1)^{0.5}$; however, the values presented are the original means.

RESULTS AND DISCUSSION

Regardless of evaluation period, herbicides used in desiccation management did not affect the dry matter of cover crops (Table 2). Differences in dry matter were observed only among cover crops species at 28 DAE soybean, especially *P. glaucum* and *U. ruziziensis,* that displayed 104% and 187%, respectively, higher values for dry matter when compared to *C. spectabilis*. These data corroborate those of Carneiro et al. (2008) and Pacheco et al. (2013a), who found that dry matter production of *P. glaucum* and *U. ruziziensis* is higher than that of *C. spectabilis*.

We can note that, after desiccation management, the dry matter of *C. spectabilis* markedly decreased, with 2,722 kg ha^{-1} at 49 DAD, equivalent of only 42% of the initial dry matter measured at 21 DAD (Table 2). This drastic loss of *C. spectabilis* dry matter is due to the decomposition of plant residues, which have low C/N ratio. Additionally, this aspect gains importance as, in this region, the soil organic matter (SOM) mineralization rate reaches high levels in residues decomposition due to the high temperature and microbial activity, reducing the amount of these compounds in the soil (Pacheco et al., 2011). It is important to highlight that this dry matter loss coincides with the onset of the total period to prevent weed interference (Nepomuceno et al., 2007), at which the maximum dry matter accumulation on the soil would be desirable, thereby targeting a possible supressing effect on weeds and volunteer corn.

The ground coverage rate at 49 DAD followed the same trends as dry matter, with the highest values for *P. glaucum* and *U. ruziziensis*, which displayed 78% and 99% ground coverage rates, respectively (Table 3). Similar results were observed by Pacheco et al. (2008), who found that, under normal cerrado conditions, the ground coverage rate was 84% and 100% for *P. glaucum* and *U. ruziziensis*, respectively, at 60 DAD.

Despite the lack of significant difference in dry matter production of *P. glaucum* and *U. ruziziensis* at 49 DAD, the same was not true for the ground coverage rate, where the highest values were observed for *U. ruziziensis*, with a ground coverage rate 27% higher than *P. glaucum*. This fact is related to the morphological and physiological characteristics of the two species. While *P. glaucum* accumulates most of its dry matter in the stem, *U. ruziziensis* directs the accumulation of dry matter to the leaves (Petter et al., 2013). Thus, those results attest to the

Table 2 - Dry matter of cover crops in desiccation management

Herbicide (g ha^{-1})	Cover crops		
	P. glaucum	*U. ruziziensis*	*C. spectabilis*
	Dry matter (kg ha^{-1}) - 7 DAE soybean (21 DAD)		
Glyphosate (1.080)	5.322^{ns}	5.645^{ns}	6.209^{ns}
Glyphosate (1.080) + Haloxyfop-R (260)	6.370	5.967	7.830
Glyphosate (1.080) + Fluazifop-p-butil (187)	5.403	8.548	5.161
Glyphosate (1.080) + Imazethapyr (106)	6.935	6.129	6.693
Glyphosate (1.080) + Imazaquin (160)	7.903	7.938	6.338
Means	6.370	6.854	6.451^{ns}
	Dry matter (kg ha^{-1}) - 14 DAE soybean (35 DAD)		
Glyphosate (1.080)	5.645^{ns}	5.080^{ns}	4.596^{ns}
Glyphosate (1.080) + Haloxyfop-R (260)	6.862	5.064	5.667
Glyphosate (1.080) + Fluazifop-p-butil (187)	5.056	6.536	5.491
Glyphosate (1.080) + Imazethapyr (106)	5.387	7.185	4.508
Glyphosate (1.080) + Imazaquin (160)	6.354	4.919	5.016
Means	5.860	5.758	5.002^{ns}
	Dry matter (kg ha^{-1}) - 28 DAE soybean (49 DAD)		
Glyphosate (1.080)	5.241^{ns}	6.612^{ns}	2.354^{ns}
Glyphosate (1.080) + Haloxyfop-R (260)	6.129	6.177	3.387
Glyphosate (1.080) + Fluazifop-p-butil (187)	5.629	6.693	2.903
Glyphosate (1.080) + Imazethapyr (106)	5.564	5.080	2.661
Glyphosate (1.080) + Imazaquin (160)	7.161	5.209	3.306
Means	5.556 A	5.954 A	2.722 B

Means followed by the same letter, lower case letter in the column and capital letter in the line, are not significantly different by Scott-Knott test at 5% probability. ^{ns} non-significant. DAE – days after soybean emergence. DAD – days after desiccation management.

Table 3 - Ground coverage regarding herbicide application on cover crops in desiccation management. Sinop-MT, 2013/2014

Herbicide (g ha^{-1})	Cover crops		
	P. glaucum	*U. ruziziensis*	*C. spectabilis*
	Ground coverage rate (%) - 28 DAE soybean (49 DAD)		
Glyphosate (1.080)	73^{ns}	100^{ns}	48^{ns}
Glyphosate (1.080) + Haloxyfop-R (260)	91	100	43
Glyphosate (1.080) + Fluazifop-p-butil (187)	63	98	58
Glyphosate (1.080) + Imazethapyr (106)	79	99	55
Glyphosate (1.080) + Imazaquin (160)	84	98	47
Means	78 B	99 A	50 C

Means followed by the same letter, lower case letter in the column and capital letter in the line, are not significantly different by Scott-Knott test at 5% probability. ^{ns} non-significant. DAE – days after soybean emergence. DAD – days after desiccation management.

greater efficiency of *Urochloa* in ground coverage, as it was verified by Timossi et al. (2007), whereas *P. glaucum* may be more efficient in maintaining residues on the soil surface.

According Petter et al. (2013), the distinct patterns of dry matter partitioning to aerial parts of *Urochloa* sp. and *P. glaucum* species enables a different management, since *U. ruziziensis* species accumulate, on average, 70% of the dry matter in the leaves and so it may be more efficient at ground coverage, while *P. glaucum* species accumulate 60% in the stem, which can contribute for a better plant residue retention on the soil. Accordingly, the highest ground coverage rate allows a better weed control (Goulart et al., 2009; Pacheco et al., 2013b).

There was no significant effect of herbicides in desiccation management of cover crops on dry matter, height and phytotoxicity of soybean plants at 7, 14 and 28 DAE (Tables 4, 5 and 6). These results corroborate those obtained by Brighenti et al. (2002) and Barros et al. (2005), who found no effect of imazaquin herbicide on soybean genotypes when the recommended dose (160 g ha^{-1}) was used. A significant effect on plant height was observed, but only on cover plants, especially *C. spectabilis*, which displayed the highest values, regardless of evaluation period. This result can be assigned to the ability of nitrogen fixation of this species, that in some way may have contributed to reduce nitrogen immobilization in the soil, since predecessors cultivation remains had come from plants with a mechanism of C4 carbon fixation and, therefore, with a high C/N ratio. Thus, the increased availability of N in the soil to plants may have contributed to this greater initial growth.

Although imazaquin herbicide is recommended for post-emergence soybean cultivation, there was a concern about possible toxic effects on soybean plantations. However, in the specialized literature such effects have been observed with greater intensity when applied in a higher dose than that recommended. These results are important because they open up new options for the use of herbicides combined with glyphosate in desiccation management, aiming at controlling volunteer RR® corn in soybean crops.

Except a single application of glyphosate in desiccation management, other herbicides provide significant volunteer RR® corn control derived from desiccation (Table 7). We have observed that, in general, a better control at 35 and 49 DAA was found in glyphosate + haloxyfop-R treatment and it could be a good alternative for volunteer RR® corn control upon desiccation. In this case, as the cover crops were planted after the RR® corn harvest from the previous season, no effects on volunteer RR® corn germination and early development were observed.

Table 4 - Soybean dry matter under cover crops and herbicides in desiccation management. Sinop-MT, 2013/2014

Herbicide (g ha^{-1})	Cover crops		
	P. glaucum	*U. ruziziensis*	*C. spectabilis*
	Soybean dry matter (g per plant) - 7 DAE soybean		
Glyphosate (1.080)	0,35^{ns}	0,45^{ns}	0,42^{ns}
Glyphosate (1.080) + Haloxyfop-R (260)	0,37	0,47	0,45
Glyphosate (1.080) + Fluazifop-p-butil (187)	0,45	0,45	0,40
Glyphosate (1.080) + Imazethapyr (106)	0,30	0,40	0,35
Glyphosate (1.080) + Imazaquin (160)	0,35	0,47	0,32
Means	0,36	0,45	0,39^{ns}
	Soybean dry matter (g per plant) - 14 DAE soybean		
Glyphosate (1.080)	7,1^{ns}	6,2^{ns}	6,7^{ns}
Glyphosate (1.080) + Haloxyfop-R (260)	7,5	7,3	7,6
Glyphosate (1.080) + Fluazifop-p-butil (187)	6,5	7,2	7,5
Glyphosate (1.080) + Imazethapyr (106)	6,9	7,7	7,5
Glyphosate (1.080) + Imazaquin (160)	7,8	6,6	7,7
Means	7,1	7,0	7,4^{ns}
	Soybean dry matter (g per plant) - 28 DAE soybean		
Glyphosate (1.080)	8,9^{ns}	7,2^{ns}	8,0^{ns}
Glyphosate (1.080) + Haloxyfop-R (260)	8,9	8,8	9,3
Glyphosate (1.080) + Fluazifop-p-butil (187)	7,4	7,8	9,3
Glyphosate (1.080) + Imazethapyr (106)	8,4	8,6	7,8
Glyphosate (1.080) + Imazaquin (160)	9,0	8,1	8,3
Means	8,6	8,1	8,6^{ns}

^{ns} non-significant. DAE – days after soybean emergence.

Table 5 - Height of soybean plants under cover crops and herbicides in desiccation management. Sinop-MT, 2013/2014. Sinop-MT, 2013/2014

Herbicide (g ha^{-1})	Cover crops		
	P. glaucum	*U. ruziziensis*	*C. spectabilis*
	Height of soybean plants (cm) - 7 DAE soybean		
Glyphosate (1.080)	7,6^{ns}	9,7^{ns}	9,6^{ns}
Glyphosate (1.080) + Haloxyfop-R (260)	9,0	8,9	9,0
Glyphosate (1.080) + Fluazifop-p-butil (187)	8,4	9,1	9,9
Glyphosate (1.080) + Imazethapyr (106)	8,4	9,3	9,5
Glyphosate (1.080) + Imazaquin (160)	8,5	9,0	9,8
Means	8,4 B	9,2 A	9,5 A
	Height of soybean plants (cm) - 14 DAE soja		
Glyphosate (1.080)	11,7^{ns}	11,3^{ns}	12,6^{ns}
Glyphosate (1.080) + Haloxyfop-R (260)	11,7	11,8	13,0
Glyphosate (1.080) + Fluazifop-p-butil (187)	11,1	12,5	13,0
Glyphosate (1.080) + Imazethapyr (106)	11,9	11,2	12,8
Glyphosate (1.080) + Imazaquin (160)	12,1	11,4	12,7
Means	11,7 B	11,6 B	12,8 A
	Height of soybean plants (cm) - 28 DAE soja		
Glyphosate (1.080)	20,9^{ns}	22,5^{ns}	24,7^{ns}
Glyphosate (1.080) + Haloxyfop-R (260)	21,3	21,7	25,3
Glyphosate (1.080) + Fluazifop-p-butil (187)	20,2	21,1	24,9
Glyphosate (1.080) + Imazethapyr (106)	21,2	22,6	23,1
Glyphosate (1.080) + Imazaquin (160)	20,9	22,4	23,7
Means	20,9 B	22,1 B	24,4 A

Means followed by the same capital letter in the line are not significantly different by Scott-Knott test at 5% probability. ^{ns} non-significant. DAE – days after soybean emergence.

Table 6 - Phytotoxicity in soybean plants under cover crops and herbicides in desiccation management. Sinop-MT, 2013/2014

Herbicide (g ha^{-1})	Soybean phytotoxicity (%) – DAE soybean		
	7	14	28
Glyphosate (1.080)	0	0	0^{ns}
Glyphosate (1.080) + Haloxyfop-R (260)	0	0	0
Glyphosate (1.080) + Fluazifop-p-butil (187)	0	0	0
Glyphosate (1.080) + Imazethapyr (106)	0	0	0
Glyphosate (1.080) + Imazaquin (160)	0	0	0

^{ns} non-significant. DAE – days after soybean emergence.

It is important to mention that, besides the expected effects of graminicidal haloxyfop-R and fluazifop-p-butyl mixed with glyphosate for RR® corn control, glyphosate + imazethapyr mixture also provided satisfactory control (> 80%) when used in desiccation management. A satisfactory control together with the use of glyphosate + imazethapyr becomes an important tool for volunteer RR® corn management, since it is a mixture well-known by producers and technicians, however it is necessary to use an imazethapyr full dose (0.1 kg ha^{-1}).

Another important aspect is that imazethapyr herbicide at a dose of 0.1 kg ha^{-1} shows a residual effect, aiming at the control of volunteer RR® corn derived from emergence fluxes subsequent to desiccation management (Table 8). Imazaquin herbicide (0.16 kg ha^{-1}) also displayed a residual effect that provides satisfactory control of volunteer RR® corn derived from emergence fluxes subsequent to desiccation management; nonetheless, it presents a lower maize plants control at the time of drying when compared to imazethapyr (Table 6). Residual effects of imazethapyr and

Table 7 - Control of maize in desiccation under cover crops and herbicides in desiccation management. Sinop-MT, 2013/2014

Herbicide (g ha^{-1})	Cover crops			Means
	P. glaucum	*U. ruziziensis*	*C. spectabilis*	
	Maize control (%) - 21 DAA			
Glyphosate (1.080)	0^{ns}	0^{ns}	0^{ns}	0^{ns}
Glyphosate (1.080) + Haloxyfop-R (260)	30	32	35	32
Glyphosate (1.080) + Fluazifop-p-butil (187)	35	30	33	33
Glyphosate (1.080) + Imazethapyr (106)	34	30	30	31
Glyphosate (1.080) + Imazaquin (160)	33	25	28	29
Means	26	23	25^{ns}	25
Glyphosate (1.080)	Maize control (%) - 35 DAA			
Glyphosate (1.080) + Haloxyfop-R (260)	0 d	0 c	0 c	0 c
Glyphosate (1.080) + Fluazifop-p-butil (187)	85 a	90 a	85 a	87 a
Glyphosate (1.080) + Imazethapyr (106)	65 c	70 b	75 a	70 b
Glyphosate (1.080) + Imazaquin (160)	75 a	65 b	75 a	72 b
Glyphosate (1.080) + Imazaquin (160)	50 b	60 b	55 b	53 b
Means	55	57	58^{ns}	57
	Maize control (%) - 49 DAA			
Glyphosate (1.080)	0 c	0 c	0 c	0 c
Glyphosate (1.080) + Haloxyfop-R (260)	90 a	100 a	95 a	95 a
Glyphosate (1.080) + Fluazifop-p-butil (187)	75 b	85 a	90 a	83 b
Glyphosate (1.080) + Imazethapyr (106)	85 a	80 a	85 a	83 b
Glyphosate (1.080) + Imazaquin (160)	65 b	70 b	75 b	70 c
Means	63	67	69^{ns}	66

Means followed by the same lower case letter in the column are not significantly different by Scott-Knott test at 5% probability. ^{ns} non-significant. DAA – days after application in desiccation management.

Table 8 - Control of volunteer corn derived from emergence fluxes subsequent to desiccation management under cover crops and herbicides at the onset of soybean flowering. Sinop-MT, 2013/2014

Herbicide (g ha^{-1})	Cover crops		
	P. glaucum	*U. ruziziensis*	*C. spectabilis*
	Control volunteer fluxes (%) - 50 DAE soybean		
Glyphosate (1.080)	18 b	25 b	10 b
Glyphosate (1.080) + Haloxyfop-R (260)	17 b	23 b	11 b
Glyphosate (1.080) + Fluazifop-p-butil (187)	21 b	27 b	10 b
Glyphosate (1.080) + Imazethapyr (106)	77 a	82 a	70 a
Glyphosate (1.080) + Imazaquin (160)	75 a	78 a	67 a
Means	40 B	47 A	33 C

Means followed by the same letter, lower case letter in the column and capital letter in the line, are not significantly different by Scott-Knott test at 5% probability. ^{ns} non-significant. DAE – days after soybean emergence. DAD – days after desiccation management.

imazaquin up to 60 days after application on maize plants were also verified by Artuzi & Contiero (2006). However, these researchers did not find any effect on corn when it was planted after 60 DAA. Dan et al. (2012) have found little residual effect of imazethapyr in maize plants at 97 DAA.

Divergent responses regarding sensitivity of maize to imazethapyr are due to genetic variability present in different cultivars (Abit et al., 2009), the physico-chemical characteristics of the herbicide and the soil (microbiological) and the ecological conditions of region (Oliveira Jr. et al., 1999). In general, researches (Artuzi & Contiero, 2006; Dan et al., 2012; Souto et al., 2013) show an absence of imazethapyr residual effects from 90 DAA. Based on these results, maize cultivation in the off-season after application of glyphosate + imazethapyr for soybean desiccation management is completely viable, because one would have a period of not less than 100 DAA, even with precociuos soybean cultivars. However, it would be important to quantify the persistence of this herbicide in the soil and climate conditions of that region, considering that the half-life of herbicides in soils depends on the chemical and physical characteristics, as well as the soil microbial activity. In this sense, Souto et al. (2013) found 93% imazethapyr degradation in soybean rhizosphere soil at 63 DAA. According to those authors, imazethapyr degradation is greater in soils cultivated with plant species as they provide a more favorable environment for microbial activity. Thus, the use of cover crops with herbicide management, besides helping control volunteer RR® corn, can reduce possible residual and phytotoxic effects of herbicides on corn crops in the subsequent off-season.

U. ruziziensis cultivation assisted in controlling volunteer RR® corn in approximately 25%, which can be verified in treatments without the use of herbicides that display residual effects (Table 8). When we applied herbicides glyphosate and imazethapyr under *U. ruziziensis*, the control of volunteer RR® corn derived from fluxes subsequent to desiccation management was above 80%, keeping the crop free from RR® corn throughout the critical period of interference prevention. Morphological and physiological characteristics of *U. ruziziensis* allow a greater ground coverage and, consequently, a higher suppressive effect on volunteer RR® corn derived from fluxes subsequent to desiccation. *U. ruziziensis* dry matter effect and ground coverage rate on weeds was also reported by Pacheco et al. (2013b), becoming more evident when the residual disposal rate was above 4.0 t ha^{-1}. In the present experiment, *U. ruziziensis* dry matter rate was approximately 6.0 t ha^{-1}, explaining its effect on RR® corn early development.

We did not find any effects (p>0.05) of herbicide managements and cover crops on soybean yield (Table 9). These data are similar to those obtained by Artuzi & Contiero (2006), who also found no effect of imazethapyr and imazaquin in soybeans. The absence of graminicidal effects was expected, since they are totally selective herbicides for soybean crops.

However, it is possible to notice a reduced productivity in glyphosate treatments, glyphosate + haloxyfop-R and glyphosate + fluazifop-p-butyl, when compared to glyphosate treatments glyphosate + imazethapyr and glyphosate + imazaquin, and this can be due to interspecific competition between volunteer RR® corn and soybean. Another aspect to consider is that, even with no significant reduction (p>0.05) in productivity, the presence of volunteer RR® corn amid soybean crops at the time of mechanical harvesting can adversely affect the grain moisture and increase the amount of impurities.

The results demonstrate that the combined application of glyphosate and imazethapyr in desiccation management associated with cover crops, such as *U. ruziziensis* allows a satisfactory control of volunteer RR® corn present at the desiccation and derived from emergence fluxes subsequent to that period, without adversely affecting soybean yields. The advantage of using this

Tabela 9 - Soybean yield under cover crops and herbicides in desiccation management. Sinop-MT, 2013/2014

Herbicide (g ha^{-1})	Cover crops		
	P. glaucum	*U. ruziziensis*	*C. spectabilis*
	Soybean yield (kg ha^{-1})		
Glyphosate (1.080)	2.650^{ns}	2.680^{ns}	2.690^{ns}
Glyphosate (1.080) + Haloxyfop-R (260)	2.720	2.740	2.720
Glyphosate (1.080) + Fluazifop-p-butil (187)	2.750	2.670	2.640
Glyphosate (1.080) + Imazethapyr (106)	2.980	3.050	2.930
Glyphosate (1.080) + Imazaquin (160)	2.830	2.910	2.790
Means	2.786	2.810	2.754^{ns}

^{ns} non-significant by Scott-Knott test at 5% probability.

management is that imazethapyr herbicide (ALS inhibitor) not only provide an effective control of volunteer corn, but also of broadleaf weeds. Another option for volunteer corn management in soybean crops is desiccation management with glyphosate + haloxyfop-R and, in case of fluxes subsequent to desiccation management, a post-emergence application of haloxyfop-R.

LITERATURE CITED

ABIT, M. J. M. et al. Differential response of grain sorghum hybrids to foliar applied mesotrione. **Weed Technol.**, v. 23, n. 1, p. 28-33, 2009.

ARTUZI, J. P.; CONTIERO, R. L. Herbicidas aplicados na soja e produtividade do milho em sucessão. **Pesq. Agropec. Bras.**, v. 41, n. 7, p. 1119-1123, 2006

BARROS, A. C. et al. Tolerância de cultivares de soja aos herbicidas imazaquin, diclosulam e sulfentrazone, aplicados em solo de textura Arenosa. **R. Bras. Herbic.**, v. 4, n. 1, p. 8-14, 2005.

BRIGHENTI, A. M. et al. Persistência e fitotoxicidade de herbicidas aplicados na soja sobre o girassol em sucessão. **Pesq. Agropec. Bras.**, v. 37, n. 4, p. 559-565, 2002.

CARNEIRO, M. A. C. et al. Produção de fitomassa de diferentes espécies de cobertura e suas alterações na atividade microbiana de solo de cerrado. **Bragantia**, v. 67, n. 2, p. 455-462, 2008.

CHAUHAN, B. S. et al. Ecology and management of weeds under conservation agriculture: A review. **Crop Protec.**, v. 38, n. 1, p. 57-65, 2012.

COMPANHIA NACIONAL DE ABASTECIMENTO – CONAB. **10º Levantamento da Produção de Grãos – Safra 2013/14**. Brasília: CONAB, 2014. Disponível em: < http://www.conab.gov.br>. Acesso em: 23 de agosto de 2014.

CRUSCIOL, C. A. C. et al. Persistência de palhada e liberação de nutrientes do nabo forrageiro no plantio direto. **Pesq. Agropec. Bras.**, v. 40, n. 2, p. 161-168, 2005.

DAN, H. A. et al. Resíduos de herbicidas utilizados na cultura da soja sobre o milho cultivado em sucessão. **R. Caatinga**, v. 25, n. 1, p. 86-91, 2012.

GIMENES, M. J. et al. Interferência da *Urochloa decumbens* Stapf. sobre plantas daninhas em sistema de consórcio com o milho. **R. Caatinga**, v. 24, n. 3, p. 215-220, 2011.

GOULART, P. et al. Desempenho da biomassa das plantas de cobertura de verão na supressão de plantas espontâneas. **R. Bras. Agroecol.**, v. 4, n. 2, p. 3494-3498, 2009.

NEPOMUCENO, M. et al. Períodos de interferência das plantas daninhas na cultura da soja nos sistemas de semeadura direta e convencional. **Planta Daninha**, v. 25, n. 1, p. 43-50, 2007.

OLIVEIRA JR., R. S. et al. Spatial variability of imazethapyr sorption in soil. **Weed Sci.**, v. 47, n. 2, p. 243-248, 1999.

PACHECO, L. P. et al. Ciclagem de nutrientes por plantas de cobertura e produtividade de soja e arroz em plantio direto. **Pesq. Agropec. Bras.**, v. 48, n. 9, p. 1228-1236, 2013a.

PACHECO, L. P. et al. Cover crops on the development of beggar's-tick. **Pesq. Agropec. Trop.**, v. 43, n. 2, p. 170-177, 2013b.

PACHECO, L. P. et al. Desempenho de plantas de cobertura em sobressemeadura na cultura da soja. **Pesq. Agropec. Bras.**, v. 43, n. 7, p. 815-823, 2008.

PETTER, F. A. et al. Manejo de herbicidas na cultura da soja Roundup Ready®. **Planta Daninha**, v. 25, n. 3, p. 557-566, 2007.

PETTER, F. A. et al. Desempenho de plantas de cobertura submetidas à déficit hídrico. **Semina**, v. 34, n. 6, p. 3307-3320, 2013.

QUEIROZ, L. R. et al. Supressão de plantas daninhas e produção de milho-verde orgânico em sistema de plantio direto. **Planta Daninha**, v. 28, n. 2, p. 263-270, 2010.

SODRÉ FILHO, J. et al. Fitomassa e cobertura do solo de culturas de sucessão ao milho na Região do Cerrado. **Pesq. Agropec. Bras.**, v. 39, n. 4, p. 327-334, 2004.

SOUTO, K. M. et al. Biodegradação dos herbicidas imazetapir e imazapique em solo rizosférico de seis espécies vegetais. **Ci. Rural**, v. 43, n. 10, p. 1790-1796, 2013.

TIMOSSI, P. C. et al. Formação de palhada por *braquiárias* para adoção do sistema plantio direto. **Bragantia**, v. 66, n. 4, p. 617-622, 2007.

PACHECO, L. P. et al. Produção de fitomassa e acúmulo e liberação de nutrientes por plantas de cobertura na safrinha. **Pesq. Agropec. Bras.**, v. 46, n. 1 p. 17-25, 2011.

ZUFFO, A. M. et al. Microbiological attributes in a Latosol in glyphosate application under water deficit conditions. **African J. Agric. Res.**, v. 9, n. 32, p. 2495-2505, 2014.