WEED SPECIES DIVERSITY IN LONG-TERM SOYBEAN-RAPESEED SUCCESSION

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ABSTRACT

We aimed with this study to evaluate weed species diversity and similarity in areas grown with rapeseed following soybean, under Brazilian Savannah cropping systems. The long-term experiment was installed in 2010 at Dourados-MS, Brazil, in completely randomized blocks design with five replications with 12 x 24m plot size. For three consecutive cropping seasons (2010/11, 2011/12 and 2012/13), soybeans were planted in all the area by October/November being harvested in February/March, when half of the area was planted in April with rapeseed (*Brassica napus*) and the other half left under winter fallow – no plantation after soybeans. In all years the same crop was repeated at the same plots, with no crop rotation. Phytosociological characterization of weed species was carried out in winter (after oilseeds harvest), pre-planting and post-emergence of soybean for the three years. Areas were intra-characterized by the coefficients of Simpson, Shannon-Weiner and Shannon-Weiner's Evenness Proportion, and areas were compared for species dissimilarity with Jaccard's presence-only coefficient, by multivariate cluster analysis. There is evidence that areas grown with rapeseed post-soybean may be less stressed than areas left under fallow in terms of species selection, but this needs to be confirmed by further studies.

Keywords: phytosociology; diversity; similarity; sustainability.

INTRODUCTION

Soybean is one of the leading economical crops grown in Brazil, with about 27.7 million hectares planted in the 2013/2014 cropping season. Soybean yields in Brazil had significantly increased in the last decades, and current Brazilian average yield is 3,035 kg ha^{-1} (CONAB, 2014). Among the factors which limit crop yield, the occurrence of weed species can be highlighted as one of the most relevant.

Recent GMO technologies have aimed to employ herbicide resistance to soybean varieties, and the weed infestation have drastically reduced in most fields with such technologies. Lack of Government regulation and Farmer's mismanagement of such technologies, however, led to the selection of weed species tolerant or resistant to the herbicides applied with these technologies.

As described, the repetitive use of the same management practice tends to eliminate part of the flora present in agricultural areas; those species most tolerant or resistant to the management applied to the field will mostly prevail. As consequence, unbalancing in occurrence of species occur and diversity is likely to be reduced (BARBOUR et al., 1998). According to CORREIA & DURIGAN (2004), diversity is not directly related to higher infestation levels, but this does not mean the opposite is true. Most data hypothesize that areas with adequate balancing among plant species, due to a well planned weed management scheme, tend to present higher diversity than high-stressed areas (BARBOUR et al., 1998).

We aimed with this study to evaluate weed species diversity and similarity in areas grown with rapeseed following soybean, under Brazilian Savannah cropping systems.

MATERIAL AND METHODS

A field long-term experiment was installed in 2010 at Embrapa Western Agriculture, Dourados city, state of Mato Grosso do Sul, Brazil, at coordinates 22º 16' S and 54º 49' W at 408 m above sea level. The trial was installed in completely randomized blocks design with five replications and plot size of 12 x 24m.

For three consecutive years (2010/11, 2011/12 and 2012/13), soybeans were planted in all the area of the experiment by October/November, being harvested in February/March of the following year. After each soybean crop, half of the experiment was planted in April with rapeseed (*Brassica napus*) while the other half was left under winter fallow (i.e. no plantation after soybeans). In all years the rapeseed was repeated at the same plots, with no crop rotation.

Soybean was planted, fertilized and managed according to the official Brazilian Recommendations for Soybean Crop in Cerrado (Savannah). Rapeseed was planted in rows spaced in 0.4 m, at plant densities 25 plants m^{-1} in the row. Fertilization was accomplished by applying 347 kg ha^{-1} of NPK 08-20-20 in the seeding furrow at planting every year. No further management (fertilization or pest control) was accomplished.

Phytosociological characterization of weed species was carried out every year for all areas, at three periods. “Winter” evaluations were accomplished right after rapeseed harvest, by July/August; “Pre-Planting” evaluations were accomplished about 30 days after chemical burndown (no residual herbicides were used) prior to planting soybean, usually by end of September or beginning of October; “Post-Emergence” evaluations occurred about 25 days after soybean emergence, in November. For that, the Random Quadrats method (BARBOUR et al., 1998) was used and five areas of 0.50 x 0.50 m were sampled in each plot (25 quadrats per treatment in each evaluation). All the emerged seedlings inside each quadrat were identified by species, collected and stored in paper bags, being dried in oven with continuous air circulation for posterior dry mass determination. Sampling precision was estimated as follows:

$$Pr=\frac{1}{s^2}$$

where s^2 = variance of sample means.

Areas were intra-characterized by the diversity coefficients of Simpson (D) and modified Shannon-Weiner (H') (BARBOUR et al., 1998), as well as by the Shannon-Weiner's Evenness Proportion (SEP) coefficients (MacMANUS & PAULY, 1990), as follows:

$$D=1-\frac{\sum ni*(ni-1)}{N*(N-1)} \qquad H'=\sum(pi*\ln(pi)) \qquad SEP=\frac{H'dominance}{H'density}$$

where *D* = diversity coefficient of Simpson; *H'* = diversity coefficient of Shannon-Weiner (based on density); *ni* = number of individuals from species “*i*”; *N* = total number of individuals in the sample; *pi* = proportion of individuals in the sample from species “*i*”; *SEP* = Shannon-Weiner's Evenness Proportion; *H' dominance* = Shannon-Weiner's diversity based on biomass; *H' density* = Shannon-Weiner's diversity based on number of individuals.

After these analyses, areas were compared by Jaccard's presence-only similarity coefficient (BARBOUR et al., 1998) in a way to estimate the current degree of weeds similarity between areas. Based on Jaccard's binary coefficient, areas were grouped by cluster analysis considering the qualitative trait only (presence or absence of the species), according to the dissimilarities obtained from the inverse of Jaccard's similarity matrix, as follows:

$$J=\frac{c}{a+b-c} \qquad Di=1-J$$

where J = Jaccard's similarity coefficient; a = number of plant species in area “a”; b = number of plant species in area “b”; c = number of plant species common to areas “a” and “b”; and Di = dissimilarity.

Hierarchical grouping was determined from the distance matrix (dissimilarities) by using the Unweighted Pair Group Method with Arithmethic Mean (UPGMA) method. Grouping validation was accomplished by the cophenetic correlation coefficient, using the Pearson linear correlation between the cophenetic matrix and the original matrix of distances.

All analyses were ran under the R Statistical Environment, using functions made available by the following additional packages: vegan, Hmisc, cluster and ExpDes. All formulas and procedures, both at sampling and description of the areas, as well as at species clustering, followed the requirements suggested by BARBOUR et al. (1998) for synecological analyses.

Results and Discussion

Sampling precision proved most areas were precisely sampled (Table 1), as according to the demanded by BORDEAU (1953) and GOLDSMITH & HARRISON (1976), who stated the variance of sample means increases as number of sampled quadrats per area decreases. BARBOUR et al. (1998) finally proposed the inverse of the variance as indicator of precision. Only dominance of rapeseed in Winter was considered not reliable (Table 1), being considered with restrictions in the further analysis.

Table 1. Sampling precision as a function of season, crop and parameter evaluated. Embrapa Western Agriculture, Dourados-MS, Brazil, 2014.

	Winter		**Pre-Planting**	
Area	**Pr.De.**	**Pr.Do.**	**Pr.De.**	**Pr.Do.**
Rapeseed	1134	0.8	19	493
Fallow	148	152	37	62
	Post-Emergence		**Pooled**	
Area	**Pr.De.**	**Pr.Do.**	**Pr.De.**	**Pr.Do.**
Rapeseed	51	1054	32	523
Fallow	36	54	152	61

Precision was obtained as 1/(variance of sample means), according to Barbour et al. (1998), based on 25 sampled quadrats per area.

The diversity coefficient of Simpson (D) quantifies, in simple terms, the probability of two individuals randomly collected in the same area to be from the same species (BARBOUR et al., 1998). In Winter, D showed a most homogeneous group of areas in terms of diversity, while H' put rapeseed and fallow apart (Table 2). The diversity coefficient of Shannon-Weiner (H'), on the other hand, derives from the Theory of the Information and sometimes confuses diversity with richness of species (BARBOUR et al., 1998). This difference, although not highly remarkable, shows that the overall group of important weeds was mostly composed by dense species, as H' is most influenced by this group. At Pre-Planting, both D and H' reported rapeseed area as the one with the lowest diversity in terms of plant species (Table 2).

Table 2. Diversity and stress coefficients of areas as a function of crop and evaluation season (average of 2011/2012/2013). Embrapa Western Agriculture, Dourados-MS, Brazil, 2014.

	Winter			**Pre-Planting**		
Area	**D**	**H'**	**SEP**	**D**	**H'**	**SEP**
Rapeseed	0.84	2.18	0.97	0.64	1.47	1.25
Fallow	0.77	1.89	1.29	0.7	1.65	1.33
	Post-Emergence			**Pooled**		
Area	**D**	**H'**	**SEP**	**D**	**H'**	**SEP**
Rapeseed	0.61	1.38	1.16	0.78	1.97	1.19
Fallow	0.84	2.08	0.96	0.79	2.03	1.24

At Post-Emergence of soybean, both coefficients agreed while forming two groups: rapeseed and fallow were again put apart (Table 2). We hypothesize that the allelopathic effect attributed to rapeseed may be one of the responsible for such results. This demonstrates that the beneficial effects of growing rapeseed last longer into summer helping to reduce weeds occurrence. As both diversity coefficients (D and H') are weighted not only by the number of species but also by the balancing in the number of individuals from each species (BARBOUR et al., 1998), one can infer the allelopathic potential often attributed to rapeseed will be even more positive to the cropping system if they are able to inhibit the germination or emergence of the main weed species in the production system, which should be verified in further studies.

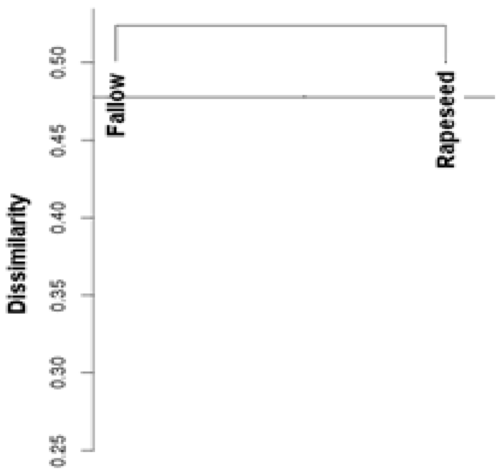
The season-pooled analysis reported a single group of diversity according to both D and H' (Table 2). This may mean that weed suppression caused by rapeseed in the cropping system throughout the year is most probably effective on all weed species at similar levels, which would mostly result in lower overall infestation in real production systems.

The Shannon-Weiner's Evenness Proportion (SEP) is able to evaluate trends of stress in a given environment over time, and as its relation with the Difference in Area by Percent (DAP) is log-linear (McMANUS & PAULY, 1990), the cropping system is likely to be as stressed as the SEP grows. In Winter, there was a trend for areas often planted with rapeseed to be less stressed than the area under fallow, contributing for selection of less adapted weed species (Table 2). This trend was moderately observed in the Pre-Planting assessment being almost diluted at Post-Emergence being also not observed in the pooled analysis. Further studies will be necessary to infer if rapeseed planted in winter, following soybean, contribute to lower the level of species selection stress in commercial fields.

The cluster analysis showed the nesting pattern for areas, according to their levels of similarity (Figure 1). The clustering tree obtained by the UPGMA method was validated for Winter and Pooled Analysis, with respective cophenetic correlation coefficients equal to 99% and 98%. Both at Pre-Planting and Post-Emergence, the cophenetic coefficient was equal respectively 0.75% and 0.78%, which was considered not sufficient for reliability thus being discarded (data not shown).

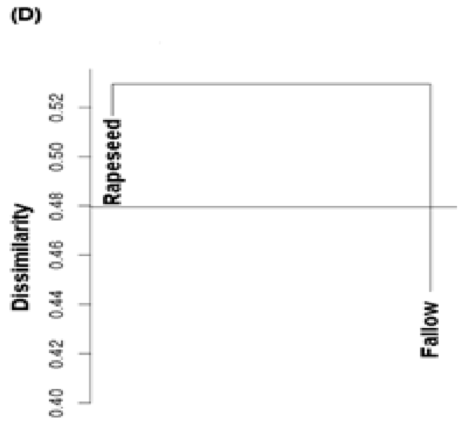
Both valid nesting patterns did not group rapeseed and fallow areas, respectively for Winter and year-round (Pooled) analysis (Figure 1). In summary, the area planted with rapeseed greatly differs for the area under fallow in terms of composition of weed species present. Overall, rapeseed may constitute an economically viable alternative for rotation with the intercrop corn+Brachiaria, which is planted after soybean in most areas of Brazilian Savannah (Cerrado), and definitely they contribute for a more sustainable weed management as a cultural tool.

A)



C.C. = 0.99 *

D)



C.C. = 0.98 *

Figure 3. Cluster analysis by dissimilarity of weed species in areas submitted to distinct winter managements for three years. (A) = Winter (evaluation right after harvest of rapeseed, by July/August); (B and C) = evaluations at pre-planting and post-emergence of soybean; data not shown and not considered due to a low coffenetic coefficient; (D) = pooled analysis (Winter + Pre-planting + Post-emergence). Distances were found by using the inverse of Jaccard's coefficient, and grouping was accomplished by the UPGMA method. Embrapa Western Agriculture, Dourados-MS, Brazil, 2014.

CONCLUSIONS

After three years of repetitive crop successions, some weeds started to be selected, and rapeseed was able to inhibit the overall infestation in the cropping system. There is evidence that areas grown with rapeseed post-soybean may be less stressed than areas left under fallow in terms of species selection, but this needs to be confirmed by further studies.

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