

PHYTOSOCIOLOGICAL STUDY ON THE WEED COMMUNITIES IN GREEN SUGARCANE FIELD REFORM USING CONSERVATION TILLAGE AND OILSEED CROPS IN SUCCESSION

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Abstract. The objective of this study was to evaluate the weed community in green sugarcane field reform with three tillage managements and oilseed crops in succession. The experiment was conducted during the 2007/08 season on a sugarcane area harvested without prior burning in the last five cuts. Treatments were arranged in a split-plot design with four replications. Whole plots were conventional-till, minimum-till and no-till cropping systems and the subplots were fallow or crop rotation with peanut, soybean or sunflower. After 180 days of sugarcane harvest, weeds have been identified, the number of weeds.m⁻² was counted and biomass of weeds above ground were taken. All data were subjected to analysis of variance using a split-plot model and the means were compared by Tukey's test at 5% probability. The phytosociological indices were calculated. No-till system in the reform of green sugarcane significantly reduces the number and biomass of weeds. The use of soybean and peanuts in rotation with sugarcane in field reform was beneficial to controlling the weed population and suppressing weed species difficult to control as *Cyperus rotundus* and *Commelina bengalensis*.

Keywords: *Arachis hypogaea*; *Glycine max*; *Helianthus annuus*; minimum tillage; no-till

Introduction

Brazil is currently the largest producer of sugarcane (*Saccharum spp.* L.), being responsible for one third of that harvested in the world (FAO- STAT, 2009). A large part (85%) of the sugarcane cropped in the country is concentrated in the south-central region, where São Paulo state is the main producer, with close to two-thirds of the Brazilian cropped area.

In Brazil, the traditional process of sugarcane harvesting is manually performed using the practice of pre-harvest burning. However more recently manual harvesting has been replaced by combiners that do not require the burning practice, in a system called green cane management. In São Paulo state 73% of sugarcane harvested refers to green cane harvesting (Canasat Project, 2015).

In various regions where sugarcane is grown, research on the agronomic implications of green-cane harvest with trash-blanket systems has been carried out. Leal et al. (2013) mentioning that in mechanized harvesting without burning, the straw blanket is left on the ground and there are several possible agronomic benefits such as increase of soil

organic carbon content, inhibition of weed growth, nutrient recycling and reduction of soil water losses. Kingston et al. (2005) reported that are reduced preemergent herbicide use, tillage and soil erosion, as well as soil moisture conservation.

However, some of the benefits are countered by the suppressive effect of trash on ratoons, the harbouring of some diseases and insect pests and the difficulty of undertaking remedial tillage under a trash blanket (Meyer et al., 2005)

Due to not burning of sugar cane and mechanized harvesting make certain the presence of straw sugar cane for years in the area and bring the discussion on the use of the conservation tillage on renewal of plantations (Soares et al. 2012).

Traditional tillage systems can destroy soil structure and organic matter, and increase erosion potential. The adoption of minimum or no tillage planting and crop rotation systems as part of an improved sustainable cropping system, is seen as a major advance (Meyer et al., 2005).

Crop rotation is also seen as a desirable increase in productivity stands out among the benefits of crop rotation, in addition to aid in the control of pests, diseases and weeds; improvement in fertility and in the physical characteristics of the soil; improvement in efficiency in the use of water and nutrients; optimization of the use of machinery on the property; promotes diversification and consequent reduction of the economic risks (Christoffoleti et al., 2007). Nevertheless, in the most of the area of sugarcane renewal still is practiced the fallow land, i.e. the maintenance of uncultivated soil.

Weed community changes cannot be accounted for by a single variable because communities are influenced by multiple abiotic and biotic factors (Lègère and Samson, 1999). The knowledge of the weed community composition and also the combined weed management practices, will contribute to the required weed control efficacy, as well as to reduce the excessive herbicide application environmental risks (Fleck et al., 2008). The presence of straw blanket on the soil surface may modify the conditions of seeds germination and emergence of seedlings, due to the physical effect of cover and the release of allelopathic substances.

The benefits of most crops in succession in reducing weed infestation in the sugar cane renewal areas have been proven using the conventional till, in which the waste is incorporated into the soil. The studies concerning the comparison of tillage systems on weed population dont contemplate the succession of cultures and dont compare effects of different levels of soil disturbance in sugarcane monoculture (Mascarenhas et al., 2012).

Our objective was to determinate the phytosociological index values of a weed community in a sugarcane renewal area harvested without prior-burning at the last five cuts with three tillage managements and oilseed crops in succession.

Materials and methods

This study was conducted at Brazilian municipality of Novais, SP (20° 59' 32" south latitude, 48° 55' 07" west longitude and average altitude 555 m) on an eutroferric red-yellow acrisol soil. The last sugarcane harvest was done in the first fortnight of July. After harvesting, the amount of sugarcane straw was calculated at 14 t.ha⁻¹ using random samples of 1 m². After defining the plots for renovation the areas were desiccated with glyphosate at a dose of 2,160 g.ha⁻¹.

The survey consisted in the evaluation of three cropping systems associated with fallow or an oilseed crop. Treatments were arranged in a split-plot design with four replications. Whole plots were conventional-till (CT), minimum-till (MT) and no-till (NT) cropping systems and the subplots were fallow or crop rotation with peanuts, soy or sunflower. Each plot was 8 m wide by 20 m long, and the whole plot was considered as floor area for randomly throwing the leaked sample frame (1 m^2).

Conventional-till (CT) was established by the use of harrow + moldboard plow + graders; minimum-till (MT) was established by the use of vegetation chemical desiccation with glyphosate + plow levee with clod breaker (ASTMATIC 450); and no-till (NT) was established by the use of glyphosate desiccation followed by planting without soil disturbance. The subplots were fallow and the oilseed crops: soybean cv. Monsoy 7908 RR, peanut cv. IAC-886 and sunflower cv. IAC-Iarama.

The subplots in fallow were kept with spontaneous vegetation without mowing or herbicide use. The peanuts crop of cultivar Runner IAC 886 (creeping cultivar of high-yield potential; 125 day cycle) was sown in a 0.90 m spacing between rows in eight crop rows with planting density of 18 seeds per linear meter, the crops of soybean cv. Monsoy 7908 RR (cultivar resistant to glyphosate; 135-day cycle) and sunflower cv. Iarama (small and early maturity cultivar; 95-day cycle) were sown in the 0.45 m spacing, planting density of 16 seeds per linear meter for the soy and 3.6 seeds per linear meter for the sunflower, with a seeder with eight rows and a double mismatched disk system in the fertilizer distribution.

The fertilization was performed according to the analyses results and the technical recommendations. While conducting the test, chemical weed control was used for peanuts and soybeans. For peanut crop, imazapic was applied at the recommended dose of 98 g a.i./ha by the manufacturer (140 g of commercial product per hectare) in preemergence of the peanut culture, i.e., 135 days before evaluation of the weeds. The procedure was a single application of glyphosate on soybeans at a dose of 2.16 kg-eq acid. ha^{-1} , 50 days after sowing, i.e. 116 days before evaluation of weeds. Ten days after the last crop (peanut) harvest, two points of 1.0 m^2 per plot were sampled at random for weed evaluation. In each sample, the plants were identified; then their aboveground parts were cut, placed in paper bags and sent to the laboratory where they were dried in a forced air circulation oven and kept at 60°C for 72 hours for later weighing on a precision scale (0.01 g). Data were tabulated and statistically interpreted using analysis of variance, the means were compared by the Tukey's test ($p < 0.05$). Number of plants, dry matter and specific frequency data were used for determination of the phytosociological indices: relative density – RDe; relative dominance – RDo; relative frequency – RFr; importance value index – IVI; and relative importance value index – RIVI (Braun-Blanquet, 1979).

Results

Twenty-four weed species were found in the area, divided into 12 botanical families (Table 1). The families with the highest number of species found were Asteraceae, Amaranthaceae and Poaceae. No-till showed higher species richness (19), followed by conventional tillage (17) and minimum tillage (16). The plots planted with soybeans presented a higher number of species (17), followed by the fallow plots (16), the plots cultivated with peanuts (15) and sunflower plots (8).

Table 1. List of species found in the area, botanical families, their respective experimental EPPO codes, soil management systems and succession crops. Novais, SP, 2008

Family	Scientific name	EPPO code ¹	Soil Management ²	Crop ³
Amaranthaceae	<i>Amaranthus deflexus</i> L.	AMADE	CT, MT, NT	Pe, Fa, So
	<i>Chenopodium ambrosioides</i> L.	CHEAP	NT	Pe, Fa
	<i>Gomphrena globosa</i> L.	GOMGL	CT, MT, NT	Pe, Su, So
Asteraceae	<i>Acanthospermum hispidum</i> D.C.	ACNHI	NT	Fa
	<i>Ageratum conyzoides</i> L.	AGECO	CT, MT	Su, Fa
	<i>Bidens pilosa</i> L.	BIDPI	CT, NT	Pe, Su, So
	<i>Conyza canadensis</i> (L.) Cronquist	ERICA	CT, MT, NT	Pe, Su, So
	<i>Emilia fosbergii</i> Nicolson	EMISO	CT, MT, NT	Pe, Fa, So
	<i>Galinsoga parviflora</i> Cav.	GASPA	CT	Fa
	<i>Parthenium hysterophorus</i> L.	PYNHY	NT	Fa, So
	<i>Tridax procumbens</i> L.	TRQPR	CT, MT, NT	Fa, So
Commelinaceae	<i>Commelina benghalensis</i> L.	COMBE	CT, MT, NT	Pe, Su, Fa, So
Convolvulaceae	<i>Ipomoea nil</i> (L.) Roth	IPONI	NT	Pe
Cyperaceae	<i>Cyperus rotundus</i> L.	CYPRO	CT, MT, NT	Pe, Su, Fa, S
Fabaceae	<i>Aeschynomene rudis</i> Benth.	AESSH	MT	Fa
Malvaceae	<i>Sida rhombifolia</i> L.	SIDRH	CT, MT, NT	Pe, Su, Fa, So
Phyllanthaceae	<i>Phyllanthus tenellus</i> Roxb.	PYLTE	MT, NT	Pe, Su, Fa, So
Poaceae	<i>Digitaria insularis</i> (L.) Fedde.	DIGIN	CT, MT	Pe, So
	<i>Digitaria sanguinalis</i> (L.) Scop.	DIGNU	CT, MT, NT	Su, Fa, So
	<i>Eleusine indica</i> (L.) Gaertn.	ELEIN	CT	Su
	<i>Urochloa plantaginea</i> (Link) Hitchc.	BRAPL	CT, MT, NT	Su, Fa, So
Portulacaceae	<i>Portulaca oleracea</i> L.	POROL	CT, MT, NT	Pe, Su, So
Rubiaceae	<i>Richardia brasiliensis</i> Gomes	RCHBR	CT, MT, NT	Pe, Su, Fa, So
Solanaceae	<i>Solanum americanum</i> Mill.	SOLAM	MT, NT	Pe, So

¹EPPO code: also known as Bayer code, is an encoding system used by the European and Mediterranean Plant Protection Organization (EPPO) to designate plants, pests and pathogens that are important for agriculture, 2014.

²Soil management systems: CT= Conventional tillage, MT = Minimum tillage, NT = No-till;

³Crops in succession: Fa = Fallow, So = Soybean, Pe= Peanut, Su = Sunflower

When evaluating the number of weeds in the area (Table 2), there was a significant interaction between the whole plots (soil management) and subplots (succession crops). The subplots kept in fallow land or with peanut planting (Table 2) suffered a significant

reduction in the number of weeds only when they were grown in no-till (40.2% and 40.7%, respectively), compared to conventional tillage.

Table 2. Average number of weeds in the three soil management systems for fallow and oilseed crops sowing in succession. Novais-SP, 2008

	Number of plants ¹				F-Test
	Fallow	Peanut	Sunflower	Soybean	
Conventional tillage	82,00 aB	81,00 aB	139,00 aA	101,50 aB	79, 6297**
Minimum tillage	98,00 aA	72,00 aB	99,00 bA	71,00 bB	
No-till	49,00 bB	48,00 bB	73,00 bA	48,00 cB	
F-Test	20,0957**				
Interaction	6,7329**				
CV plot (%)	13,2				
CV subplot (%)	14,19				

¹Means followed by the same letters, lowercase in the columns and uppercase in row, do not differ significantly by Tukey's test ($p < 0.05$); ** Significant at 1% probability by the F-test; ns Nonsignificant

The effect of biomass of culture as mitigating circumstance of exposure of the soil is not noticed for sunflower and soybean crops. For the sunflower, the adoption of soil conservation tillage practices, either the minimum till or no-till, decreases significantly the number of weeds in up 47.5%. The number of weeds in soybean culture differed significantly among themselves for the three systems of soil management. The number of weeds in no-till for soybean crop was about 46% less compared to conventional tillage and 34% less in relation to the minimum tillage, which in turn was 30% less than in conventional tillage (Table 2).

The average values of the dry mass of weeds in the three soil management systems for fallow land and planting of oilseed crops in succession are observed in Table 3.

Table 3. Weeds dry matter in the three soil management systems for fallow and oilseed crops sowing in succession. Novais-SP, 2008

	Dry matter ¹ (g.m ⁻²)				F-Test
	Fallow	Peanut	Sunflower	Soybean	
Conventional tillage	810,00aB	455,00aC	1035,00aA	500,00aC	201, 6448**
Minimum tillage	685,00aA	495,00aB	440,00 bB	585,00aAB	
No-till	305,00bAB	240,0 bB	410,00 bA	230,00bB	
F-Test	22, 5525**				
Interaction	15,0216**				
CV plot (%)	11,15				
CV subplot (%)	16,31				

¹Means followed by the same letters, lowercase in the columns and uppercase in row, do not differ significantly by Tukey's test ($p < 0.05$); ** Significant at 1% probability by the F-test; ns Nonsignificant

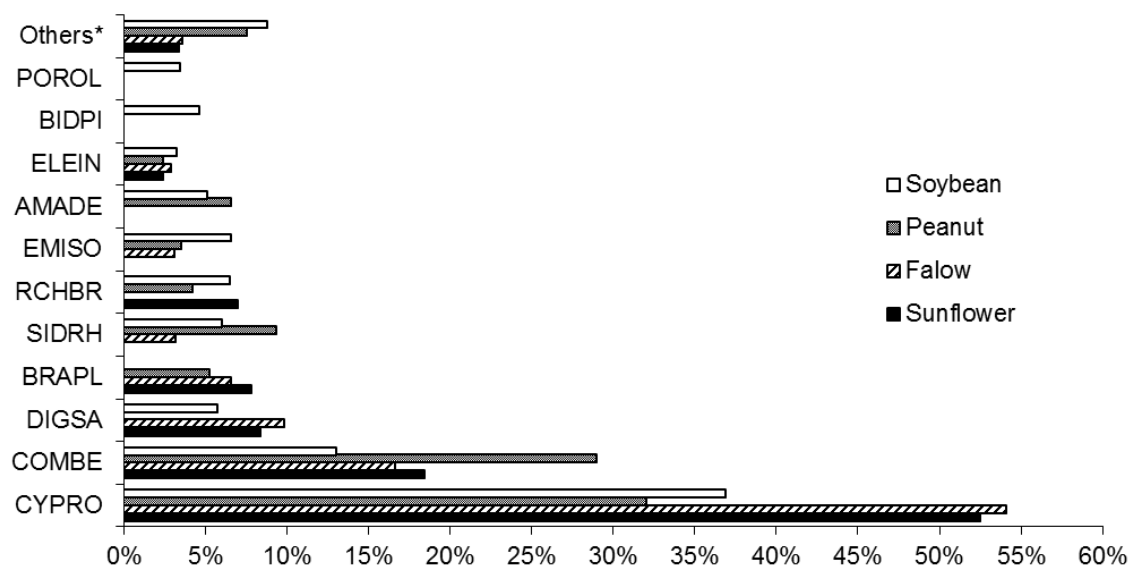
For weed dry matter, as well as the number of weeds, there was a significant interaction between the whole plots and subplots. Thus, in the areas of conventional

tillage, when they are left in fallow, the weed dry matter was higher than in the other treatments. No-till provided a dry mass of weed lesser than conventional tillage (57.7%) and minimum tillage (46.2%), which in turn proved to be intermediate, differing themselves also from conventional tillage (21.2%). The sunflower subplots stand out from the other cultures, not differing of fallow plots.

In sunflower grown subplots, the use of any of the conservation tillage was efficient in the control of weeds in relation to conventional planting, reducing by up to 60.4% dry mass. For the other succession crops, only the no-till system promoted a significant decrease of weed dry mass .

Figures 1, 2 and 3 show the relative importance value index (RIVI) of the species found in the soil management systems for the area in fallow and oilseed crops cultivation in succession.

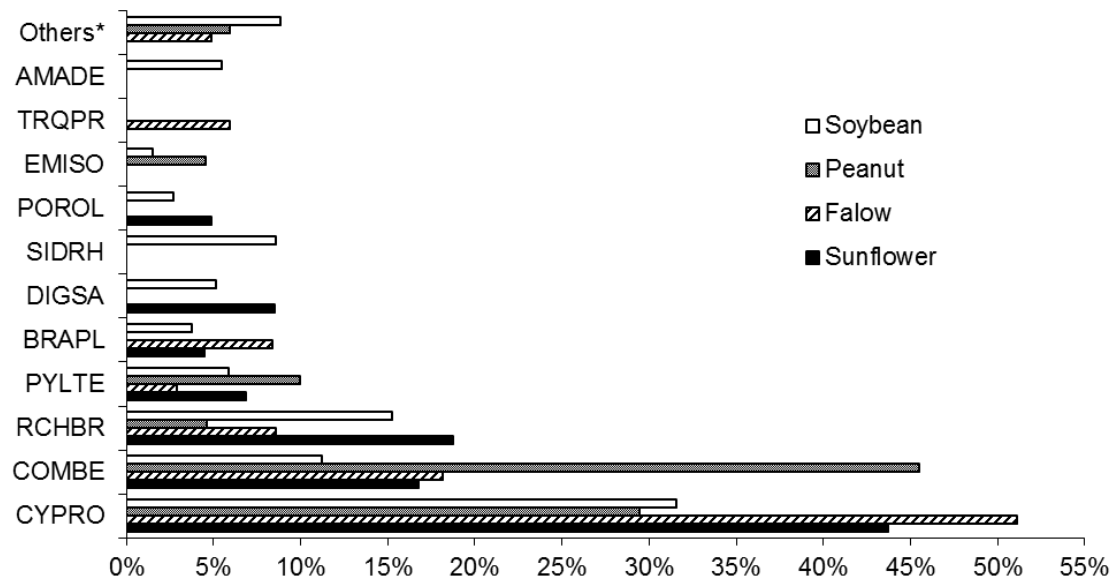
Cyperus rotundus and *Commelina benghalensis* presented the highest relative importance value index (RIVI%) in the areas cultivated with conventional soil management. The species *Eleusine indica*, *Galinsoga parviflora* and *Digitaria insularis* were exclusive of this soil management. *C. rotundus* presented relative importance value index greater than 50% for fallow and sunflower subplots, subplots of growing soybeans and peanuts present 36.91% and 32.01% relative importance value index, respectively (Fig. 1).



*Other species found in area, however, with low Relative Importance Value Index – RIVI: *Ageratum conyzoides*, *Galinsoga parviflora*, *Conyza canadensis*, *Digitaria insularis*, *Tridax procumbens* and *Gomphrena globosa*.

Figure 1. Relative Importance value index (RIVI%) for the weed species in areas with conventional tillage in fallow plot or oilseed crop in succession. Novais, 2008.

The species with greater relative importance value index (RIVI) in minimum tillage areas were *C. rotundus*, *C. benghalensis*, *Richardia brasiliensis* and *Phyllanthus tenellus*, the specie *Aeschynomene rudis* appeared exclusively in this soil management (Fig. 2).



*Other species found in area, however, with low Relative Importance Value Index – RIVI: *Conyza canadensis*, *Aeschynomene rudis*, *Ageratum conyzoides*, *Solanum americanum* e *Gomphrena globosa*

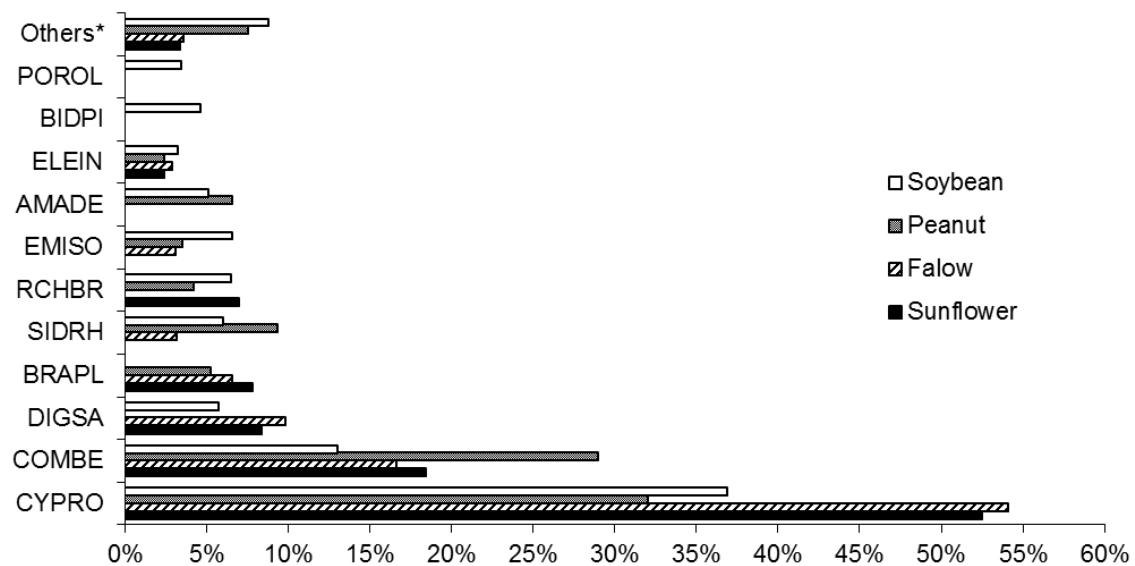
Figure 2. Relative Importance value index (RIVI%) for the weed species in areas with minimum-till in fallow or oilseed crops in succession. Novais, 2008.

In the areas of minimum tillage, as compared to conventional tillage, *C. rotundus* lost importance in the cultivation of peanuts. It maintained the value index of relative importance in the fallow land and had its importance increased in the sunflower and soybean crops. The species *C. benghalensis* presented greater relative importance in the culture of peanuts to this soil management system (45.52%) and, because of its dominance, inhibited the development of other weeds. The species *R. brasiliensis* had its relative importance value increased in the minimum tillage, reaching relative importance value index of 18.73% and 15.22% in the areas of sunflower and soybean planting, respectively.

In the no-till area there has been greater variety of species and decreased value of RIVI of species considered difficult to control compared to conventional tillage.

For the areas kept in fallow land in no-till (Fig. 3), only *C. rotundus* reached relative importance value index above 30% (RIVI = 37.19%), presenting greater homogeneity and lesser dominance of problematic species in relation to other studied soil management.

The value of relative importance index (RIVI%) of *C. rotundus* in fallow areas in conventional soil management system is 54.13% decreasing to 13.82% when it is made the crop rotation with soybeans and no-till as soil management. *Commelina benghalensis* had greater importance in minimum tillage when the culture in succession was the peanut, however either use of no-till or crop rotation with soybeans show up as alternatives to the suppression of this weed, especially when used together (RIVI = 2.70%).



*Other species found in area, however, with low Relative Importance Value Index – RIVI: *Parthenium hysterophorus*, *Solanum americanum*, *Chenopodium ambrosioides*, *Acanthospermum hispidum*, *Gomphrena globosa*, *Tridax procumbens*, *Ipomoea nil* e *Conyza canadensis*.

Figure 3. Relative Importance value index (RIVI%) to the weed species in areas with no-till in fallow or oilseed crops in succession. Novais, SP, 2008.

Discussion

There are difficulties for a proper management of weeds in sugarcane, however, the use of conservation tillage provides greater control of weed in relation to conventional management (Dantas et al., 2015).

Weed biomass, density, composition and temporal variation are closely associated with management practices, especially tillage (Nichols et al., 2015). Minimal or reduced tillage can shift weed composition from broadleaf to grass species (Swanton et al., 1999) or perennial weeds (Vogel, 1995), or increase weed species diversity when specific habitats for certain weeds are created (Murphy et al., 2006)

No-till resulted 45.9% reduction in the number of weeds if compared to conventional tillage and 33.9% reduction in relation to the minimum tillage. Pereira and Velini (2003) highlight the greater efficiency of no-till system in cultural weed control, reducing the total number of individuals and the diversity of weed community

No-till soil management is more efficient, especially when there is no crop rotation (fallow) or the succession to the sugar cane provides less vegetal cover. No-till also provided a greater variability of weed species, and a smaller representation of species considered to be difficult to control in the culture of sugar cane, as the species of the families Poaceae and Cyperaceae. This soil management requires attention for development of morning-glory species (Convolvulaceae), also considered difficult to control.

The minimum tillage presented an intermediate behavior, especially dependent on crop grown in succession. In some cases, the minimum tillage is as efficient as no-till on weed suppression.

In most cases, greater exploitation of cover crop and crop residue mulches are discussed as a key strategy for suppressing weeds, particularly in warm climates where

sufficient biomass may be generated to provide season-long weed suppression (Brainard et al., 2013).

Largest biomass of living mulch, use of a high residual effect herbicide in the peanut crop and the dominance of some weeds in fallow can have suppressed the effect of absence of mulch in the conventional tillage system making this system not significantly different from minimum tillage system. The exposure of the seed bank in conventional tillage and minimum tillage was an important factor to differentiate them from the no-till. The practice of not burn the waste of high C/N ratio may favor the improvement of soil chemical properties over the other productive cycles of sugarcane (Carvalho et al., 2013).

It is possible to maintain problematic weeds under control in no-till, provided they are employees efficient rotation programs combined with appropriate soil management and chemical control. The use of no-till doesn't prevent the emergence of some species difficult to control, especially if the area is close to the focus of infestation, because the seeds in some cases are easily transported by wind.

The use of the sunflower crop resulted in greater numbers of weeds for all soil management systems used and the peanut crop resulted in lower incidence of weeds, this can be explained by plants architecture and by the use of early maturity cultivar of sunflower (95-day cycle), exposing the soil after its harvest for a longer period. The sunflower despite to present great biomass due to the high content of lignin and cellulose in their tissues not necessarily results in improved soil cover, by virtue of their waste consisting predominantly of stems or stalks (Sodré Filho et al., 2004). Cover crops or mulching only can suppress weeds effectively when the cover is adequate, and should cover at least 30% of the soil surface (CTIC, 1999).

According to Zimdahl (2013), the predecessor culture can interfere in the composition of the plant community, since some weed species are associated with greater intensity to certain cultures than others. Cardina et al. (2002) observed, in continuous system of 35 years, the crop rotation influenced more the seed bank of weeds than the soil preparation.

The mulch or crop cover may reduce or inhibit weed germination through the release of allelopathic compounds (Christoffoleti et al., 2007) or smothering of weeds (Thierfelder and Wall, 2010). Furthermore, weeds can be influenced by location, time, nitrogen management (Swanton et al., 1999), timing of cultivation, rainfall (Teasdale et al., 1991), crop residue management, crop rotations, harvest procedures and other aspects of the production system.

The greater the effect of crop biomass of succession in physical and chemical suppression of weed community, the smaller is the effect of soil tillage. Thus, in rotation with crops with great weed suppression capacity, the importance of soil management is not very significant. In sugarcane renewal areas kept fallow, choosing a conservation tillage is critical for weed control.

In agreement with the data obtained by Swanepoel et al. (2015), species composition also is changed. While few weed species made up the bulk of the importance in conventional tillage, these species represented only a fraction of the importance of weeds in the conservation tillage.

According to Kuva et al. (2007), *C. rotundus* has been the most important specie in green sugarcane harvested on the mechanized system. Monocots considered difficult to control as *C. rotundus*, *C. benghalensis*, *Digitaria sanguinalis* and *Urochloa plantaginea* are of great importance in the fallow areas. *C. benghalensis* also proved

important in the areas of conventional tillage with peanut crop sown in succession, considering that the use of the herbicide imazapic is not recommended to control *C. benghalensis*. Soybean areas planted in conventional tillage have greater variety of weed species, thus reducing the importance of *C. rotundus* and promoting the appearance of other species such as *Portulaca oleracea*, *Bidens pilosa*, *D. insularis* and *Tridax procumbens*.

The specie *C. rotundus* was affected by the management of the chosen soil, gradually decreasing its importance as the soil management becomes more conservative, this weed is also affected by the culture of succession and the combination of these two factors.

C. benghalensis presented higher index of relative importance in the conservation tillage, however, the choice of combination of soil management and proper appear as viable alternatives to the removal of this weed.

Grasses were less important in areas where conservation tillage was adopted, particularly when the rotation with the peanut and soybean crops was made. The large biomass of cane straw and cultural practices used for these crops inhibited the development of the species of this family

Adaptable weed management (where continued monitoring of a system should influence the decision-making process and can be changed as needed, depending on available resources) or integrated weed management (combination of biological, chemical and mechanical weed management) should be practiced for allow effective weed control (Swanepoel et al., 2015).

Conclusions

Conservation tillage acts positively in the suppression of weeds, in green sugarcane reform areas.

Leguminous crops such as soybeans and peanuts in rotation with green sugarcane in reform areas were beneficial from the standpoint of control of weed population.

Crop rotation with the sunflower, from the point of view of weed population management, cannot be considered to be favorable in the studied conditions. It does not adequately control the populations of the same weeds compared to areas kept fallow.

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