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Sustainable weed management in a lettuce growing conservationist system

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Abstract

Soil disturbance, irrigation, and nitrogen fertilization excesses in lettuce crops have reduced the sustainability of the sector and favoured competition against weeds. This study aimed to evaluate the effect of cover crops and nitrogen fertilization management on weed control, weed-species dynamics, and soil seed bank in successive lettuce cultivation under no-tillage. The experiment was carried out in a tropical region during summer and arranged in a (3×4) +1 factorial scheme. Treatments consisted of three soil cover managements (*Crotalaria juncea*, *Urochloa ruziziensis*, and fallow) and four nitrogen (N) topdressing rates (0, 60, 120, and 180 kg ha^{-1}) in a lettuce crop under fertigation. A conventional tillage system under more intense soil disturbance was also evaluated at the highest N rate. The results showed that lettuce cultivation on *U. ruziziensis* stood out regarding weed control. Higher soil disturbance in the conventional tillage increased weed emergence (288.9 and 245.8 plants m^{-2}) compared to the fallow area (13.9 and 38.9 plants m^{-2}), *U. ruziziensis* (4.2 and 9.7 plants m^{-2}), and *C. juncea* (56.9 and 20.8 plants m^{-2}) in successive cultivations, respectively. Soil cover management changed the dynamics of weed species emergence, especially in the first cultivation. Nitrogen topdressings did not affect weed dry matter and density at the time of weeding. The average number of non-dormant weed seeds within the 0.0-0.10 m soil seed bank layer reached 7,077 seeds m^{-2}, with no difference among treatments. Therefore, sustainable management of lettuce cultivation using cover crops in rotation, associated with no-tillage, effectively controls weed communities, with emphasis on *U. ruziziensis*, regardless of the nitrogen fertilization management.

Keywords: *Crotalaria juncea*, fallow, *Lactuca sativa*, no-tillage, *Urochloa ruziziensis*, weed seed bank.

Introduction

Conservation agriculture has been promoted as a method to increase sustainability and mitigate climate change, and globally used and implemented (Lundy et al., 2015; Pittelkow et al., 2015). In this conservationist context, cover crops produce biomass that can contribute to soil and water conservation, as well as increase soil nitrogen and organic matter, and suppress weed infestation (Creamer and Baldwin, 2000; Isık et al., 2009; Mennan et al., 2020).
Currently, weed management is based on herbicide application and soil tillage. However, both measures have promoted growing negative environmental impacts and weed resistance (MacLaren et al., 2020).
Production system changes may alter weed population dynamics and management (Ngouajio et al., 2003, Buhler, 1997). Given the scarcity of herbicides for “minor crops”, high labour cost and limitations, viable cultural practices are needed to control weeds in leafy vegetables such as lettuce (Shem-Tov et al., 2006). In this sense, studies on lettuce have shown that cover crop effects on weeds are species-specific (Isık et al., 2009, Hirata et al., 2014).
Nitrogen supply is another key factor in integrated weed management, and its levels can affect weed interference with crops (Jørnsgård et al., 1996, Abouziena et al., 2007, Wang et al., 2019). Therefore, nitrogen fertilization level can enhance crop competitiveness against weeds (Evans et al., 2003; Wang et al., 2019), but so can the opposite (Andreasen et al., 2006). This is because some weed species respond better than crops to nitrogen inputs and may therefore be more competitive at higher rates. According to Jørnsgård et al. (1996), increases in nitrogen rates tend to decrease total weed biomass and have a differential effect on individual species biomass. Therefore, the effects of nitrogen levels on crops and weeds must be well understood (Barker et al., 2006).
Tillage practices can also change physical and chemical soil properties, leading to changes in seed banks (Nicolik et al., 2020, Murphy et al., 2006). Added to this, larval foraging of weed-seed predators is known to be up to 10 times more intense in no-tillage than in conventional tillage areas (Blubaugh and Kaplan, 2015).
Mennan et al. (2020) emphasized that cover crops are rarely used in growing vegetables in several regions. This scenario is due to technological gaps and a lack of experimentation at a local scale. To this end, Kruse and Nair (2016) suggested that cover crops can be integrated into vegetable cultivation, but species selection is a critical factor for success.
Given the above, this study aimed to evaluate the effect of cover crops and nitrogen fertilization on weed control, weed-species dynamics, and soil seed bank in successive lettuce cultivation under no-tillage.

Results and discussion

Soil cover and nitrogen fertilization showed independent effects on weeds, with no interaction between them for weed density and dry matter.

Soil cover

In the first cultivation, weed density was markedly reduced under *Urochloa ruziziensis* cover (Figure 1). Fallow and *Crotalaria juncea* cover areas did not differ from each other. *U. ruziziensis* cover was about 10 times more efficient in controlling weed emergence than was *C. juncea*. The initial amounts of *C. juncea* and *U. ruziziensis* straw were 5.3 and 4.4 t ha^{-1}, reaching 3.0 and 2.2 t ha^{-1} at the end of the experiment, respectively. Therefore, there was little difference between the initial amounts of straw of both cover crops. *U. ruziziensis* cover controlled weeds successfully due to a dense straw layer formation and homogeneous soil cover. By contrast, *C. juncea* did not fully cover the soil owning to a greater stem volume and rapid leaf decomposition. This is because legumes generally have high nitrogen content in plant matter and produce low C: N ratio straw, hence relatively fast decomposition (Silva et al. 2009). Grasses, in turn, have large amounts of biomass high C/N, increasing soil cover persistence. Finally, the fallow area was kept free of weeds during cover crop growth, explaining its similar weed control efficiency as *C. juncea* cover.

Weed biomass was expressively reduced under *Urochloa ruziziensis* cover as did weed density. Similarly, Kruse and Nair (2016) found lower weed biomass in lettuce cultivation under cover of *Avena strigosa*, *Sorghum bicolor*, and *Fagopyrum esculentum* straw compared to conventional tillage. Isik et al. (2009) found that *Vicia villosa*, *Sorghum bicolor*, and *S. vulgare* covers reduced total dry weed biomass in lettuce crops by 90.3, 87.4, and 86.9%, respectively.

Soil cover managements did not differ from each other in the second consecutive lettuce crop. This is because the absence of soil disturbance prevented the emergence of new plants. According to Jensen (1995), weed emergence increases after soil tillage are due to seed exposure to light. In this sense, Buhler (1997) pointed out that seeds of many plant species require brief exposure to light to induce germination. Therefore, changes in the light availability during soil tillage may alter weed emergence.

Regarding species, in the first cultivation, *C. juncea* and fallow managements showed a higher proportion of *Cyperaceae* and lower of grasses, while *U. ruziziensis* cover had a higher proportion of broadleaf species. However, considering dry mass, broadleaf weeds showed higher accumulations. Thus, cover crop species can affect weed community dynamics. Yet, in the second cultivation, the proportion of grass species increased in the fallow area. Conservation and conventional tillage methods are known to distinctly influence weed populations (Chauhan et al., 2012).

Topdressing nitrogen fertilization

Nitrogen topdressing rates did not differ for weed density and dry matter accumulation in both crops (Figure 2). Evaluations took place before rows were closed, that is, during weeding, as in commercial crops. By this time, 40% topdressing fertilization had been already applied. Thus, nitrogen fertilization did not favour weed growth. However, Sweeney et al. (2008) stated that nitrogen fertilization influence on weed emergence varies with species, seed source, and environmental conditions.

As weeds were at an early growth stage, environmental resources were enough to maintain their growth despite applied nitrogen. Since weed dry mass did not differ among applied N rates, weeds were not benefited by topdressing. Moreover, topdressing rates did not affect weed density.

Treatments versus conventional tillage

During both cultivations, no-tillage and fallow treatments showed expressive reductions in weed community when compared to conventional tillage (Table 1), regardless of nitrogen application. At the highest N rate, weed emergence rates in the first and second cultivations were 288.9 and 245.8 plants m^{-2} in conventional tillage, 4.2 and 9.7 plants m^{-2} under *U. ruziziensis* cover, 13.9 and 38.9 plants m^{-2} in fallow area, and 56.9 and 20.8 plants m^{-2} under *C. juncea*, respectively. When comparing conventional tillage with *U. ruziziensis* cover management, weed emergence reduced 68.8 and 25.3 times and weed mass accumulation 115.9 and 131.6 times in the first and second crops, respectively, at the highest nitrogen rate. Such soil cover management may be more sustainable since it uses less labour force for weeding and soil tillage, as well as less fossil fuel use.

Our results corroborate those in the literature. Indeed, the combination of no-tillage, crop rotation, and surface residue may enhance weed control (Nichols et al., 2015). A prior summer cover crops can improve both conventional and organic vegetable production systems (Ngouajio et al., 2003).

Importance value index of weed species in lettuce cultivation

Table 2 shows the importance value indexes (IVI) of the weed species in both lettuce cultivations. Nitrogen topdressing rates had no significant effect on the dynamics of weed species. Andersson and Milberg (1998) also found that nitrogen application rate has a weak influence on the weed flora.

Conversely, the IVI of weed species was affected by soil cover management. In the first cultivation, *Commelina benghalensis* and *Richardia brasiliensis* were the only species to emerge under *U. ruziziensis* cover. This treatment was desiccated with glyphosate before lettuce planting, and both weed species are glyphosate-tolerant, even at the highest concentrations (Monquero et al., 2005). However, the other weed species were effectively controlled by *U. ruziziensis* straw layer. In *C. juncea* and fallow treatments, besides *C. benghalensis* and *R. brasiliensis*, other weed species emerged, such as *Cyperus difformis*, *Digitaria horizontalis*, *Eleusine indica*, *Portulaca grandifolia*, and *P. oleracea*. This greater species richness can be attributed to uneven soil cover in *C. juncea* treatment and lack thereof in the fallow area. Surface straw quantity and distribution uniformity play a major role in weed control in conservationist cultivation (Chauham et al., 2012).

In this study, the area under conventional tillage showed greater weed species richness compared to the other management evaluated. Therefore, the presence of straw and absence of disturbance in the soil help to control weeds. In this context, Plaza et al. (2015) claimed that soil tillage increases available niche opportunities for weeds.

Furthermore, *Amaranthus* sp. was mostly found in uncovered soils, i.e., conventional tillage and fallow areas. Since the species of this genus have very small seeds, the presence of straw can control them. Campiglia et al. (2010) found that *Amaranthus retroflexus* and *Chenopodium album* are weed species typical of conventional tillage systems. Moreover, Nichols et al. (2015) pointed out that germination and growth

Table 1. Dry matter (DM) and density (DS) of weeds in successive summer lettuce cultivations on *Urochloa ruziziensis* (RU), *Crotalaria juncea* (CRO), and fallow (FLW) under different topdressing nitrogen rates evaluated before weeding, and soil seed bank (SB) after two lettuce cultivations compared to conventional tillage (CT).

		Cultivation 1				Cultivation 2				
		DM ($g\ m^{-2}$)		DS ($pls\ m^{-2}$)		DM ($g\ m^{-2}$)		DS ($pls\ m^{-2}$)		SB
Management	N ($kg\ ha^{-1}$)	Data	$\sqrt{X+1}$	Data	$\sqrt{X+1}$	Data	$\sqrt{X+1}$	Data	$\sqrt{X+1}$	seeds m^{-2}
RU	0	0.08	1.04*	5.5	2.4*	0.21	1.09*	13.9	3.7*	6.539
	60	0.10	1.05*	8.3	2.8*	0.32	1.15*	30.5	5.4*	10.706
	120	0.14	1.07*	4.2	2.2*	0.15	1.07*	12.5	3.6*	11.238
	180	0.14	1.06*	4.2	2.0*	0.19	1.08*	9.7	3.0*	9.010
FLW	0	0.70	1.28*	52.8	6.8*	0.87	1.34*	37.5	5.9*	5.522
	60	0.69	1.29*	33.3	5.3*	0.44	1.19*	16.7	4.1*	7.847
	120	1.23	1.47*	63.9	7.6*	0.90	1.36*	33.3	5.4*	8.090
	180	0.24	1.11*	13.9	3.7*	0.57	1.24*	38.9	5.8*	7.460
CRO	0	0.84	1.33*	44.4	6.2*	0.42	1.19*	22.2	4.7*	6.685
	60	0.94	1.36*	37.5	5.5*	0.21	1.10*	15.3	3.9*	7.121
	120	0.90	1.35*	63.9	7.2*	0.29	1.14*	18.0	4.3*	6.588
	180	0.99	1.40*	56.9	7.2*	0.31	1.14*	20.8	4.5*	7.024
CT	180	16.23	4.10	288.9	16.3	25.0	4.87	245.8	15.5	7.169
LSD		0.52		5.39		1.01		3.3		6.521

RU = *Urochloa ruziziensis*, FLW = fallow, CRO = *Crotalaria juncea*, SB = seed bank, N = nitrogen, Data = original data, √(X+1) = transformed data, DM = dry matter, DS = density.
Means followed by * differ from conventional tillage by the Dunnett's test at a 5% probability.

Table 2. Importance value index of weed species found in successive summer lettuce cultivations on *Urochloa ruziziensis*, *Crotalaria juncea*, and fallow, under different topdressing nitrogen rates, evaluated before weeding, and compared to conventional tillage (CT).

	Cultivation 1 summer							Cultivation 2 summer						
Importance value index	*U. ruziziensis*		*C. juncea*		Fallow		CT	*U. ruziziensis*		*C. juncea*		Fallow		CT
	N0	N180	N0	N180	N0	N180	N180	N0	N180	N0	N180	P0	P180	N180
	Importance value index													
Alternanthera tenella	0.0	0.0	0.0	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4
Amaranthus sp.	0.0	0.0	0.0	0.0	17.2	32.5	18.4	0.0	0.0	20.8	0.0	15.1	21.4	28.9
Blainvillea latifolia	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cenchrus echinatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.1	14.3	5.5
Chenopodium album	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0	15.1	14.3	4.4
Commelina benghalensis	225.0	200.0	48.1	32.0	23.9	32.5	21.9	0.0	48.6	20.8	0.0	0.0	0.0	21.9
Conyza sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.0	0.0	33.3	0.0	0.0	14.3	0.0
Cyperus difformis	0.0	0.0	123.1	98.2	109.5	105.0	58.0	0.0	77.1	54.2	91.7	52.4	107.1	30.0
Cyperus rotundus	0.0	0.0	0.0	0.0	0.0	0.0	13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Digitaria horizontalis	0.0	0.0	27.9	32.0	17.2	32.5	29.2	72.5	125.7	33.3	65.0	97.1	42.9	68.3
Digitaria insularis	0.0	0.0	13.9	16.0	0.0	0.0	8.8	0.0	0.0	20.8	0.0	0.0	14.3	5.5
Eleusine indica	0.0	0.0	32.7	51.5	41.1	0.0	81.1	32.5	0.0	41.7	51.7	74.9	42.9	52.4
Euphorbia heterophylla	0.0	0.0	0.0	0.0	0.0	0.0	13.6	0.0	0.0	0.0	0.0	0.0	0.0	5.5
Gnaphalium spicatum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.0	48.6	54.2	0.0	15.1	0.0	0.0
Indigofera hirsuta	0.0	0.0	0.0	0.0	11.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Portulaca grandifolia	0.0	0.0	13.9	0.0	0.0	0.0	0.0	32.5	0.0	0.0	0.0	0.0	14.3	47.9
Portulaca oleracea	0.0	0.0	13.9	11.1	0.0	0.0	36.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Richardia brasiliensis	75.0	100.0	26.4	48.0	67.4	65.0	6.3	32.5	0.0	20.8	91.7	15.1	14.3	21.0
Sida cordifolia	0.0	0.0	0.0	0.0	11.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sida glaziovii	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	4.4
Synedrellopsis grisebachii	0.00	0.0	0.0	0.0	0.0	32.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	300.00	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.00	300.0	300.0	300.0	300.0	300.0

U. ruziziensis = *Urochloa ruziziensis*, *C. juncea* = *Crotalaria juncea*, CT = conventional tillage. N0 = 0 kg N ha^{-1}; N180 = 180 kg N ha^{-1}. At the sampling time, 40% of the N rate had been applied to the lettuce crop

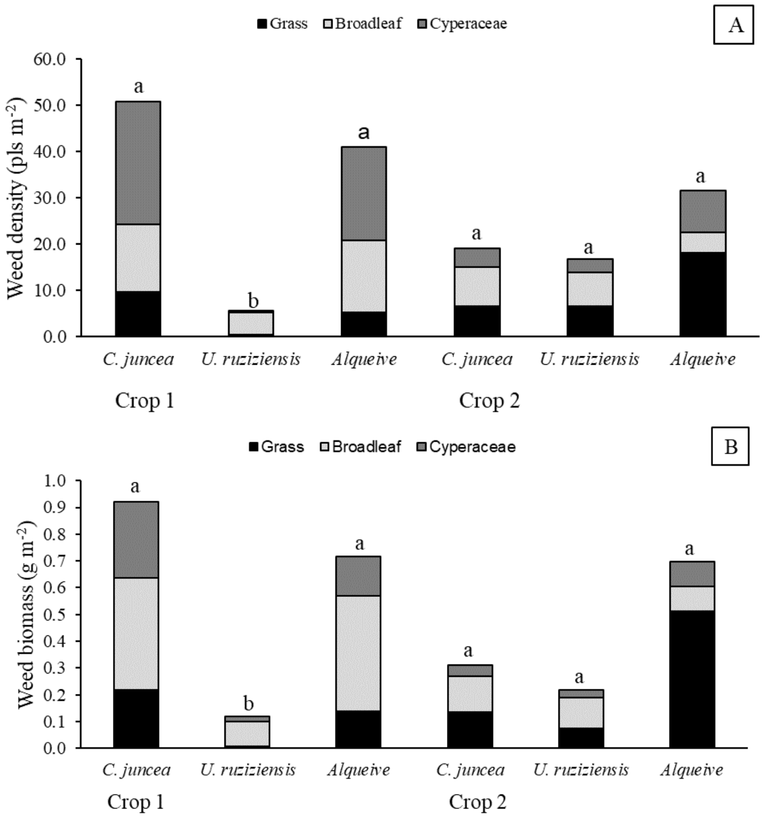

Fig 1. Density (A) and dry matter (B) of weeds in successive summer lettuce cultivations under no-tillage on *Urochloa ruziziensis*, *Crotalaria juncea*, and fallow, evaluated before weeding. The data were transformed into $\sqrt{x+1.0}$ for statistical analysis – original data presented. Comparison by the Tukey's test at a 5% probability within each cultivation.

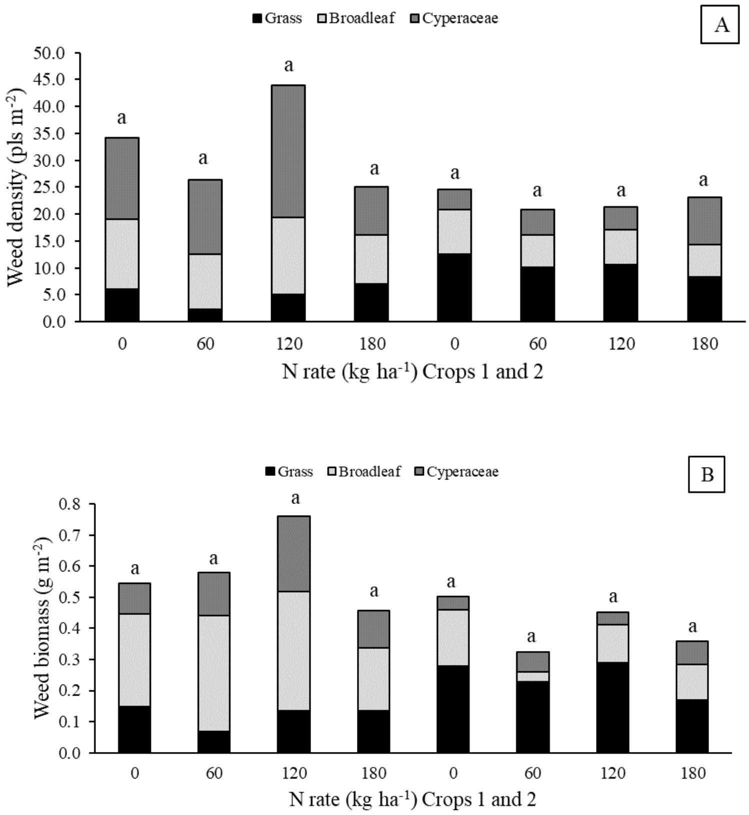

Fig 2. Density (A) and dry matter (B) of weeds in successive summer lettuce cultivations before weeding as a function of topdressing nitrogen rates in two summer lettuce cultivations. At the time of evaluation, 40% N was applied in treatments in both cultivations (1 and 2). The data were transformed into $\sqrt{x+1.0}$ for statistical analysis – original data presented. Comparison by the Tukey's test at a 5% probability within each cultivation.

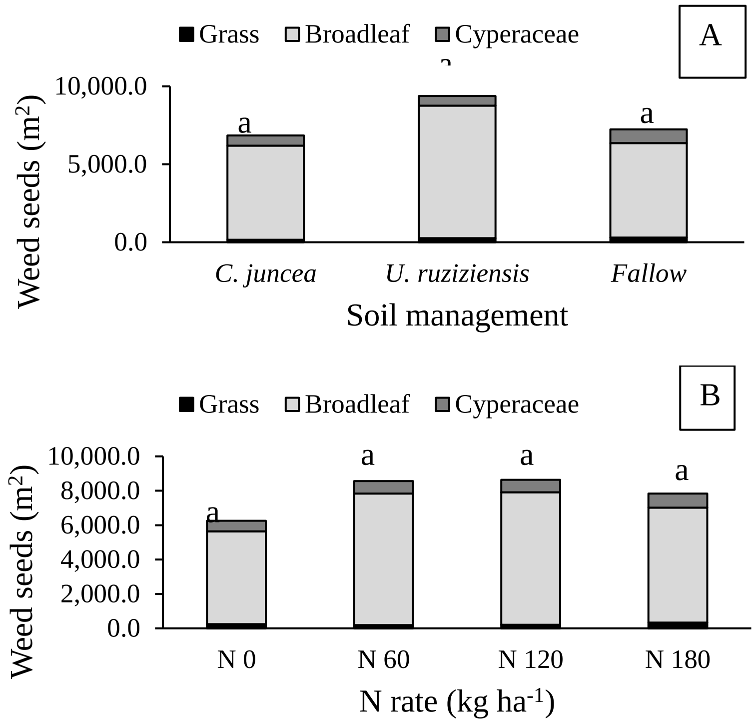

Fig 3. Soil weed seed banks in the 0–10 cm depth layer after two successive summer lettuce cultivations under no-tillage on *Urochloa ruziziensis*, *Crotalaria juncea*, and fallow (A), and different topdressing nitrogen rates (B). Means compared by the Tukey's test at a 5% probability.

Table 3. Importance value index of non-dormant weeds in seed banks of lettuce crops on *Urochloa ruziziensis*, *Crotalaria juncea*, and fallow under different topdressing nitrogen rates after two summer cultivations compared to cultivation conventional (CT).

	Soil management						
	U. ruziziensis		*C. juncea*		Fallow		CT
Species	N0	N180	N0	N180	N0	N180	N180
	Importance value index						
Alternanthera tenella	0.0	0.0	0.0	5.9	8.4	0.0	0.0
Amaranthus sp.	11.1	8.3	7.0	5.9	10.2	25.0	38.5
Brachiaria decumbens	0.0	0.0	0.0	0.0	0.0	9.3	0.0
Cenchrus echinatus	0.0	0.0	0.0	7.3	0.0	0.0	0.0
Chamaesyce hirsuta	0.0	0.0	0.0	5.9	0.0	0.0	0.0
Chenopodium album	0.0	0.0	0.0	5.9	0.0	0.0	0.0
Commelina benghalensis	8.1	15.2	14.0	0.0	0.0	0.0	17.7
Conyza sp.	0.0	5.1	0.0	0.0	8.4	0.0	0.0
Cyperus difformis	22.2	32.1	30.0	43.0	51.6	35.4	0.0
Desmodium tortuosum	0.0	0.0	7.0	0.0	0.0	0.0	0.0
Digitaria horizontalis	20.7	10.2	7.0	24.7	34.0	13.2	25.8
Eleusine indica	0.0	5.1	7.0	5.9	0.0	0.0	11.3
Galinsoga parviflora	8.1	0.0	0.0	0.0	0.0	0.0	0.0
Galinsoga quadriradiata	0.0	0.0	0.0	0.0	0.0	15.9	0.0
Gnaphalium spicatum	189.6	170.8	177.3	145.1	163.5	173.4	135.7
Indigofera hirsuta	0.0	0.0	0.0	5.9	0.0	0.0	0.0
Nicandra physaloides	0.0	0.0	0.0	7.3	0.0	0.0	0.0
Portulaca grandifolia	0.0	10.2	0.0	0.0	0.0	0.0	13.1
Portulaca oleracea	0.0	11.2	7.0	5.9	5.3	0.0	46.1
Richardia brasiliensis	31.9	26.8	36.7	25.2	18.6	19.8	11.8
Sida sp.	0.0	5.1	0.0	5.9	0.0	0.0	0.0
Solanum americanum	0.0	0.0	0.0	0.0	0.0	8.0	0.0
Triumfetta bartramia	8.1	0.0	7.0	0.0	0.0	0.0	0.0
TOTAL	300.0	300.0	300.0	300.0	300.0	300.0	300.0

N0 = 0 kg N ha^{-1}; N180 = 180 kg N ha^{-1} applied to each lettuce cultivation.

of annual plants with small seeds are negatively affected by low light availability, physical growth barriers, and straw allelopathic potential.

Non-dormant weed seed bank in the soil

After both successive lettuce cultivations, the weed seed bank in the 0.0-0.10 m soil layer of the soil managements with cover crops did not differ from the conventional tillage, regardless of nitrogen topdressing rates (Table 1).

The average number of seeds within this soil layer was 7,077 seeds m^{-2}. Since the amounts of seeds that emerged over the two cultivations were high in conventional tillage and low in conservationist managements, one hypothesis for such correspondence between seed banks would be the straw effect on seed decomposition and mainly the absence of soil disturbance over two cultivations. Unlike conventional tillage, conservationist cultivations have plant beds renewed using a rotating hoe, bringing these seeds up to the soil surface.

The seed banks were not different among *U. ruziziensis*, *C. juncea*, and fallow areas and neither among nitrogen topdressing rates (Figure 3). Murphy et al. (2006) verified a reduction in seed bank under no-tillage from 41,000 to 8,000 seeds m^{-2} within 6 years. Unlike, Santín-Montanyá et al. (2016) found cumulative effects of soil conservation practices on seed banks, with increases in seed density and species diversity, which might have been due to specific conditions created in the soil. A little soil disturbance may have allowed maintenance of inactive seeds in the seed bank. Among other reasons, better aggregate stability and organic matter content may have helped such a situation. Despite the intensive activity in this study, the evaluation time may have been short for changes in the seed bank.

Finally, as regards the proportion of each species, the majority of non-dormant seeds that emerged were broadleaf plants, with very small proportions of grasses and cyperaceous.

Importance value index (IVI) of weed species in the soil seed bank

Table 3 shows the identified species and their importance value index (IVI) in the seed banks of all soil managements and at the extreme nitrogen rates (0 and 180 kg ha^{-1}). In this regard, few species stood out, with *Gnaphalium spicatum* being the most important in all treatments, showing indexes between 135.7 to 189.6. Hirata et al. (2018) found that this species has high abundance and density in the autumn-winter, thus germinating in the same season in the next year. The species *Amaranthus* sp. (IVI = 38.5) and *Portulaca oleracea* (IVI = 46.1) stood out in the conventional treatment. The species *R. brasiliensis* and *C. difformis* were also important in *U. ruziziensis* and *C. juncea* treatments, while the species *C. difformis* stood out in the fallow. According to Derakhshan and Gherekhloo (2013), seeds of *C. difformis* sown on the soil surface reached the highest seedling emergence percentage, and no seedlings emerged from seeds buried to a depth of 0.01 m. This species is usually adapted to high moisture soils, and no seeds were found in the seed bank of the conventional tillage treatment. Soil disturbance in conventional tillage may have affected negatively the weed seeds compared to no-tillage areas, where moisture is well preserved.

The dynamics of weed species in the seed bank was not affected by nitrogen fertilization. For Davis (2007), soil nitrogen effect on weed seed mortality is species-specific, wherein some species are affected by nitrogen in soil microbiota, which, in turn, act as seed predators, whereas other species are affected during germination.

Other factors such as soil temperature, pH, electrical conductivity, structure, and organic matter content, as well as liming, preceding crops, herbicide use, cropping time, and manure amounts, can be the main responsible for week community changes and formation of different associations, as stated by Iqbal et al. (2018).

Materials and methods

Experimental site

The experiment was installed at the Agency for Agribusiness Technology of São Paulo (APTA), in the city of Presidente Prudente, São Paulo State, Brazil (22°07’21” S, 51°23’17S” W, and 460-m altitude). According to Köppen’s classification, the local climate is classified as *Aw*, which stands for a rainy tropical climate with dry winters (CEPAGRI, 2015).

Physical and chemical description of the soil

The experiment was carried out on loamy sandy soil, which is classified as arenic dystrophic Red Yellow Argissolo by the Brazilian Soil Classification System. The soil is composed of 4.7% clay, 12.1% silt, and 82.3% total sand, with a predominance of fine sand. Soil chemical characteristics are as follows: 5.4 pH in $CaCl_2$, 17 g dm^{-3} organic matter, 73% base saturation, 63.0 mg dm^{-3} P, 1.8 mg dm^{-3} Zn, 22.0 mg dm^{-3} Fe, 26.3 mg dm^{-3} Mn, 1.3 mg dm^{-3} Cu, 0.21 mg dm^{-3} B, 5.2 $mmol_c$ dm^{-3} K, 21.0 $mmol_c$ dm^{-3} Ca, 7.0 $mmol_c$ dm^{-3} Mg, and 12.0 $mmol_c$ dm^{-3} H+Al. The chemical analysis was performed according to the method proposed by Raij et al. (2001), with soil correction using dolomitic limestone to increase base saturation to 80%.

Experimental design

The experimental design was carried out in random blocks with four replicates. Treatments were arranged in a (4×3) +1 factorial scheme, with the additional control. The first factor consisted of four topdressing nitrogen rates (0, 60, 120, and 180 kg ha^{-1}) applied to lettuce through drip system fertigation, using urea as nitrogen source. The second factor comprised three soil cover management systems: fallow (soil tilled and hoed for 50 days), and two no-tillage systems, one using *Crotalaria juncea* cover and the other *Urochloa ruziziensis* cover.

The additional control consisted of conventional tillage, representing the traditionally used system. Therein, organic fertilization was performed by applying poultry manure superficially in both lettuce cultivations (N = 18 g kg^{-1}, P = 16.6 g kg^{-1}, K = 23.9 g kg^{-1}, Ca = 92.2 g kg^{-1}, Mg = 6.3 g kg^{-1}, and S = 4.0 g kg^{-1}) at a rate of 200 g m^{-2} (9.6% moisture) to replace cover crops. A micro-sprinkler irrigation system was used in this treatment, and a nitrogen topdressing rate of 180 kg ha^{-1} was applied manually. In this treatment, the planting bed was first built when lettuce seedlings were planted, and then rebuilt in the second cultivation, incorporating thermophosphate fertilizer (total P_2O_5 = 16%, total Ca = 16%, Mg = 6.5%, B = 0.1%, Cu = 0.05%, Mn = 0.3%, Zn = 0.55%, S = 6.0%, and Si = 9.0%) in both cultivations at 100 g m^{-2}.

All treatments were fertilized at planting with 50 kg K_2O ha^{-1} and 20 kg N ha^{-1}, according to Trani et al. (2018).

Cover crop implantation

Planting beds were built using a bed mulcher, and plots were 4.2 m long and 1.2 m wide. Thermophosphate (100g m^{-2}) was incorporated into the planting beds before sowing *C. juncea* and *U. ruziziensis*. Sowing was performed along four rows spaced 0.30 m apart and longitudinally to the beds, using 40 kg ha^{-1} *C. juncea* seeds (60% germination) and 12 kg ha^{-1} *U. ruziziensis* seeds (65% germination). Cover crops were desiccated using glyphosate at 2.5 L commercial product ha^{-1} (480 g a.i. L^{-1}) on December 28, 2019 (50 days after emergence).

Lettuce planting

Crispy-leaf lettuce plants of the cultivar Vanda were used. The first cultivation was started 14 days after desiccation and harvested 37 days after planting. After harvesting, the area was newly desiccated with ammonium glufosinate at 2.0 L commercial product ha^{-1} (200 g a.i. L^{-1}). The second planting was then carried out 7 days after the previous crop harvest and harvested 38 days after its planting.

Measured traits

Cover crop

Cover crop straws were sampled at lettuce planting time and after both lettuce cultivations. Sampling was carried out using two 0.30 × 0.30 m frames placed on each plot. Straw amounts within frames were washed to remove adhered soil and dried in a forced-air circulation oven at 65 °C.

Weed community

Weed community was evaluated 15 and 17 days after the first and second cultivations, respectively, before weeding and crop row full covering. Weed sampling was done by randomly casting two 0.30 × 0.30 m frames along crop interrow. The weeds within the frames were identified, separated into broadleaf species, grasses, and nutgrasses (Cyperus), and measured for dry matter after drying a forced-air circulation oven at 65 °C.

Weed seed banks

Soil weed seed banks were evaluated at the end of the second cultivation. Three soil samples were collected per plot within the 0.0–0.10 m depth layer using a cylinder. Cylinder dimensions allowed to calculate the volume of soil collected from each plot, and the number of weeds per square meter of soil collected in the treatment.

Soil samples were placed onto plastic trays and kept wet in a greenhouse for weed emergence evaluation. After each weed emergence flow, the plants were removed and the soil disturbed to stimulate further flows. This procedure was performed for about 7 months. Afterwards, the water supply was suppressed to stimulate new emergence flows.

Phytosociological parameters

Phytosociological parameters assessed were frequency, density, and abundance of weed species, using data from evaluations. The results allowed calculating relative frequency, relative density, and relative abundance to then determine the importance value index of each species. These parameters were calculated using the formulas proposed by Mueller-Dombois and Ellenberg (1974).

Statistical analysis

The results were subjected to analysis of variance, and means compared by the Tukey's test at 5% probability. The Dunnett's test at 5% probability was used to compare treatments and additional control.

Conclusions

Lettuce cultivation on *Urochloa ruziziensis* cover improves weed control efficiency. Due to high soil disturbance, conventional tillage is more favourable to weed infestation than cultivations in fallow, *U. ruziziensis*-covered, and *C. juncea*-covered areas. Nitrogen topdressing does not interfere with weed management in lettuce crops. Tillage systems and nitrogen fertilization do not affect weed seed banks. The tillage system alters weed species dynamics in lettuce crops.

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