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Full Length Research Paper

Soil properties and tomato agronomic attributes in no-tillage in rotation with cover crops

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Cover crops associated with no-tillage improves soil fertility by the production of mulch on the soil surface. This experiment was conducted in 2008 and 2009 to evaluate the potential of different cover crops grown in rotation with tomato in no-tillage in the soil and agronomic attributes of tomato. The treatments were velvetbeans (*Mucuna deeringiana* [Bort] Merr.), sunn hemp (*Crotalaria junceae* L.), pearl millet (*Pennisetum americanum* Leeke), fallow with free growth of weed, and maize crop in conventional tillage as control. Shoot dry biomass of the cover crop, weed establishment, concentration of the nutrient in tomato leaves, fertility and microbiology of soil and tomato yield were evaluated. Maize had the greatest shoot dry mass yield, but it was incorporated into the soil by tillage, being the control treatment. Regarding the crops for which the residue remained on the soil surface, millet and sunn hemp were the most productive. Millet and sunn hemp, as well as corn in tillage, were the most efficient in the suppression of the weed establishment in the tomato crop. Sunn hemp increased potassium content and nitrification activity of the soil nitrate. Tomato yield was higher when grown on straw of sunn hemp.

Key words: *Lycopersicon esculentum* Mill., weeds, soil microbiology, soil fertility, leaf nutrient.

INTRODUCTION

Modern agriculture aims at high yields along with the use of conservationist practices that reduce the environmental impact on natural resources, including soil, water, and organic matter content of soil. Vegetables are crops which require sophisticated technology to obtain economic profitability, and the intensive cultivation in a single area without proper soil management often decreases soil fertility (Bonanomi et al., 2011). Staked tomato cultivation in Brazil is predominantly carried out in areas of steep slopes subject to erosion by excessive storm water runoff on the soil surface. Cover crops are excellent tools for soil protection and for the maintenance of the chemical, physical and biological balance of the soil, supporting the sustainability of environment production (Abdul-Baki et al., 1997a; Castro et al., 1993). Grass and legumes are frequently used as cover crops, because they satisfy the essential requirements of cover crops, such as ruggedness, vigorous vegetative growth, and high shoot dry matter yield (Wutke et al., 2009). Another advantage of cover crops in no-till is the improvement of soil microbial activity by the increase of organic matter (Duda et al., 2003; Castro et al., 1993), reduction of weeds (Carrera et al., 2004; Campiglia et al., 2010), improvement of the soil fertility (Perin et al., 2004; Wang et al., 2009), and consequently, an increase in crop yield (Kieling et al., 2009; Sainju et al., 2002). No-till also contributes to reduce erosion by avoiding the soil

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exposure through harrowing and ploughing. For successful no-tillage, it is necessary to keep a certain amount of mulch on the soil surface which contributes to reduce erosion and improve soil fertility (Argenton et al., 2005; Colla et al., 2000). For this reason, the interaction between no-tillage and cover crops is very important for the quality of the technology. Therefore, this experiment aimed at evaluating the performance of no-tillage tomato and cover crops towards the suppression of weeds, improvement of soil fertility, soil microbial activity, nutrient content of tomato leaves and tomato yield.

MATERIALS AND METHODS

The experiment was conducted over two consecutive years, from 2007 to 2009 in Ribeirão Preto, São Paulo, located in the tropics at 21° 12' 26" S and 47° 51' 48" N, mean altitude of 646 m. The annual mean rainfall is 1427 mm, concentrated from November to March, and annual mean maximum and minimum temperatures are 25 and 19.3°C. The soil is classified as Oxisol udic eutrophic, which consists 10.2% sand, 32.1% silt, and 57.7% clay, presenting the following chemical fertility: pH = 5.5, organic matter (OM) = 23 g dm^{-3}, P = 43 mg dm^{-3}, K = 3.8 $mmol_c$ dm^{-3}, Ca = 26 $mmol_c$ dm^{-3}, Mg = 11 $mmol_c$ dm^{-3}, cation exchange capacity (CEC) = 70 $mmol_c$ dm^{-3}, V% = 58%, sum of the bases (SB) = 41 $mmol_c$ dm^{-3}, H + Al = 29 $mmol_c$ dm^{-3}, B = 0.27 mg dm^{-3}, Cu = 6.7 mg dm^{-3}, Mn = 34.8 mg dm^{-3} and Zn = 1.0 mg dm^{-3}. Limestone was applied to the soil at the beginning of the experiment to raise the base saturation to 80%, followed by harrow plowing. In the following two years, no more limestone or tillage were used during the experiment, characterizing it as a no-tillage soil.

The experimental design was complete randomized block with five treatments and five replications, with plots of 7 × 10 m. The treatments consisted of velvetbeans (*Mucuna deeringiana* [Bort] Merr.), sunn hemp (*Crotalaria junceae* L.), millet (*Pennisetum americanum* Leeke) and fallow with unrestricted growth of weed, followed by no-tillage tomato crop. Treatments were compared to a maize crop as a control, with conventional tillage for tomato. Cover crops were sowed in December 2007, with 0.50 m row spacing for velvetbeans and sunn hemp at seeding rates of eight and 27 seeds per linear meter, respectively. Millet was seeded at 0.30 m row spacing and 35 seeds per linear meter. The natural soil fertility was considered sufficient for cover crops growth; no weed control was applied. In the fallow experimental plots, weeds grew freely. Maize was sown at 0.90 m row spacing and seeding rate of five plants per linear meter in the conventional tillage plots. Cover crops were mowed at 80 days after sowing, remaining the whole biomass on the soil surface. To control the remnant weeds, 2.0 L ha^{-1} of glyphosate was applied before transplanting of tomato. In the plots of conventional tillage the soil was prepared with the rotary hoe to 0.20 m of depth. At mowing, the shoot dry biomass of cover crop was evaluated by sampling 1.0 m^{-2} sites of each experimental plot. The samples were oven-dried at 65°C until constant weight before evaluation. Seedlings of the tomato hybrid Débora Victori were transplanted in April at 1.20 × 0.40 m spacing. The crop was drip irrigated and fertilized with 300 kg ha^{-1} N, 500 kg ha^{-1} P_2O_5, and 300 kg ha^{-1} K_2O in irrigation water in the tomato crop cycle. Tomato was grown with a single stem up and with six bunch fruit.

The establishment of weeds was evaluated by counting the number of individuals per species at two randomized sites of 0.250 m^2 of each experimental plot 30 days after tomato transplanting. The nutritional conditions of tomato plants were determined by analysis of leaf nutrient concentration from mature leaves collected between the third and fourth fruit bunches. After collection, the leaves were washed with distilled water and neutral detergent, dried in a forced air circulation oven at 65°C to constant weight. Later, the samples were milled and sent for laboratory analysis of nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur (Malavolta et al., 1989). Tomato yield was assessed including fruits of the sixth bunch by harvesting ripe fruit and fruit changing color from green to red, indicating the beginning of ripening. After each harvest, the number and fresh fruit mass of market-quality and non-market-quality fruit and mean fruit mass of market-quality fruit were determined. To study the soil fertility, samples were taken at four times during the experiment, in the beginning and at the final stage of tomato growth in the two years, 2008 and 2009, in the soil profile from 0 to 0.20 m depth at three points of each experimental unit, which formed a representative sample. The pH, OM, CEC, phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) of soil was analyzed according to Raij et al. (1997).

For the microbiological analysis, the samples were taken just once, in the final stage of tomato growth in 2009. They were then sent to the microbiology laboratory for analysis of soil microorganisms. For counting bacteria and fungi in the soil samples (10 g, dry weight), 95 ml of sodium pyrophosphate 0.1% were added and stirred for 30 min in an orbital shaker. After serial dilution, some volumes of this suspension were added to the culture medium and distributed in Petri dishes. A Bunt and Rovira (1955) medium containing per liter: 5.0 g glucose, 0.4 g K_2HPO_4, 0.5 g $(NH_4)_2HPO_4$, 0.05 g $MgSO_4$, 0.1 g $MgCl_2$, 0.01 g $FeCl_3$, 0.1 g $CaCl_2$, 1.0 g peptone, 1.0 g yeast extract, 250 ml soil extract (1 kg soil L^{-1} H_2O, sterilized for 15 min), 15 g agar and pH 7.4 was used throughout this study for bacteria counting and Martin (1950) medium containing per liter: 10.0 g glucose, 0.5 g K_2HPO_4, 0.5 g KH_2PO_4, 0.5 g $MgSO_4.7H_2O$, 5.0 g peptone, 0.5 g yeast extract, 0.03 g rose bengal, 15 g agar, pH 5.5 and streptomycin (0.03 g L^{-1}) was added in the melted and cooled medium to pour onto the plates for fungi counting. The incubation time was 72 h for bacteria and 96 h for fungi at a temperature of 30°C, and counts made according to Vieira and Nahas (2005). Nitrification activity was determined after incubation of soil for 30 days, with moisture content adjusted to 60% of water retention capacity (WRC) and with or without the addition of 160 mg of $(NH_4)_2SO_4$ g dry $soil^{-1}$. The nitrate produced was extracted and determined by the Keeney and Nelson (1982) method. The respiratory activity in the amount of 100 g of dry soil in accordance with Rezende et al. (2004) was determined with humidity corrected to 60% of WRC. The urease activity of soil was determined using 2.0 g of soil and, as substrate, 1.0 ml of 10% urea (McGarity and Myers, 1967).

The average maximum temperatures during the growth of the cover crops in 2008 and 2009 were 29.9 and 30.1°C, respectively, and the average minimum temperature in both years was 19.1°C. The accumulated rainfall during the cover crop grown in 2008 and 2009 were 813 and 810.5 mm, respectively. During the growth of tomato in the two years, the average maximum temperatures were 27.4 and 27.1°C, and the average minimum temperatures were 13.0 and 14.0°C, respectively. Rainfall during the period was 138.4 and 301.9 mm, respectively. The second tomato crop had greater and better distributed rainfall. The weather was favorable for the development, growth and production of tomato according to Nuez (1995).

The effects of the different cover crops, time, and their interactions with weed, fruit yield and tomato plant nutrition were tested using the software PROC MIXED of SAS (Littel et al., 2006) with data from a randomized block experimental design with repeated measures in time. Soil microbiology activity was measured only once during the experiment, so time and time × treatment interaction were not included in its model. The degrees of freedom were calculated using the Kenward-Roger correction. The most appropriate co-variance structure for each variable was chosen based on the Akaike and Schwarz criterion. Treatments, time and treatments × time interactions were considered significant when $P \leq 0.05$. Differences among means were tested for statistical

Table 1. Shoot dry biomass of cover crops.

Cover rop	Shoot dry biomass (Mg ha^{-1})
Velvetbean	7.02^{b}
Sunn hemp	10.05^{bc}
Millet	14.40^{ab}
Fallow	6.40^{c}
Maize (Conventional)	18.26^{a}
Year	
2008	7.59^{b}
2009	14.87^{a}
ANOVA (P value)	
Treatment	0.0018
Year	0.0004
Treatment versus Year	0.5626

Values followed by the same letter in the column are not significantly different (Tukey test, $P < 0.05$).

Table 2. Weed suppression represented by the number of individuals per 0.25 m^2 in no-tillage cover crop treatment.

Cover crop (CC)	2008	2009
Velvetbean	24^{b†}	119^{a}*
Sunn hemp	27^{ab}	66^{b}
Millet	18^{b}	42^{b}
Fallow	62^{a}	156^{a}*
Maize (Conventional)	40^{ab}	49^{b}
ANOVA (P values)		
Treatment	<0.0001	
Year	<0.0001	
Treatment versus Year	0.0185	

[†]Values followed by the same letter in columns are not significantly different (Tukey test, $P \leq 0.05$).*In lines are significantly different (Tukey test, $P \leq 0.05$).

significance using Tukey's test.

RESULTS AND DISCUSSION

The treatments had different shoot dry biomass yields, ranging from 6.4 to 14.4 mg ha^{-1}. Maize presented the highest production compared to that of velvetbeans, sunn hemp and weed (fallow), but it was not different from millet (Table 1). Although the highest dry biomass was of maize, the benefits of mulching were not realized due to the incorporation of their straw into the soil by tillage. The analysis of shoot biomass of cover crops by years showed a greater shoot dry biomass yield in the second year, 2009, but no significant interaction between cover crop and year. The greater yield of 2009 must be related to the nutrients remaining from the 2008 tomato crop, and the better rainfall distribution over the period of cover crops growth in 2009. Perin et al. (2004) also reported similar shoot dry biomass yields for millet and sunn hemp. Millet and maize were more efficient in the production of shoot dry biomass because of their C4 status which have a greater capacity to incorporate CO_2 and produce dry mass (Taiz and Zeiger, 2002). The greater yield of shoot dry biomass of millet, in relation to legumes such as sunn hemp and velvetbeans, has also been reported (Torres et al., 2008; Suzuki and Alves, 2006).

The establishment of weeds, 30 days after tomato transplanting, was impacted by an interaction between cover crop treatment and year (Table 2). In 2008, millet and velvetbeans had fewer weeds than fallow, but did not differ in relation to the other treatments. In 2009, millet, sunn hemp, and corn showed better results than velvetbeans and fallow in the suppression of the weed. The suppression of weeds varied between years for velvetbeans and fallow, as these treatments were less efficient in 2009. The weeds with the greatest occurrence in all treatments were *Alternanthera ficoidea* (L.) R. Br. and *Lepidium virginicum* L. This demonstrated the benefit of millet as a cover crop; its fast initial growth and greater biomass yield suppressed weeds in tomato crops. However, legumes such as sunn hemp, hairy vetch, and soybeans also suppress the weeds when they are used as cover crops (Campiglia et al., 2010; Carrera et al., 2004; Silva et al., 2009). No-till also contributes to the suppression of weeds by minimizing the dissemination of seeds (Sutton et al., 2006), which is not the case of the present work. Soil microbiological activity was more intense in sunn hemp and millet cultivation in comparison with conventional tillage for the nitrification activity of nitate. For all other microbiological characteristics analyzed, nitrification activity of ammonia, urease, total bacteria and fungi, and soil respiration rates did not differ among treatments (Table 3). The stimulus of nitrification activity of nitrate provided by sunn hemp and millet compared to conventional tillage indicates improvement in the process of transformation of nitrogen compounds and even the mineralization of organic nitrogen, provided for the maintenance of plant residue on the soil surface by no-tillage (Babujia et al., 2010). On the other hand, the other microbiological activities did not differ among treatments, contradicting the results of increased microbial activity in the no-till situation. We believe that the natural microbial activity of this soil was responsible for supressing the increase in these properties by cover crops. Hamido and Kpomblekou-A (2009) and Buyer et al. (2010) reported that the discrepancy in results of soil microbiology is related to several factors such as species of cover crop, climate and time and depth of soil sampling. According to Bonanomi et al. (2011), intense agricultural activity with excessive use of agricultural input deteriorates the microbiological quality of soil, which

Table 3. Nitrification activity of ammonia, nitrification activity of nitrate, urease activity, quantity of total bacteria, quantity of total fungi and soil activity respiration of experimental treatments of cover crops.

Cover crop	Nitrification activity NH_4 (mg NH_4-N g^{-1} ds*)	Nitrification activity NO_3 (mg NO_3^--N g^{-1} ds)	Urease (mg NH_4-N 3 $h^{-1}g^{-1}$ ds)	Bacteria (UFC g^{-1} ds)	Fungi (UFC g^{-1} ds)	Respiratory Activity (mg CO_2 100 g ds)
Velvetbean	53.4^{a}	50.7^{ab}	26.2^{a}	$8.7E+06^{a}$	$8.6E+04^{a}$	5.72^{a}
Sunn hemp	49.5^{a}	53.7^{a}	22.6^{a}	$1.0E+07^{a}$	$7.0E+04^{a}$	6.18^{a}
Millet	51.2^{a}	53.9^{a}	30.5^{a}	$9.1E+06^{a}$	$7.1E+04^{a}$	3.52^{a}
Fallow	52.2^{a}	39.8^{ab}	26.5^{a}	$1.1E+07^{a}$	$1.1E+05^{a}$	6.16^{a}
Maize (Conventional)	58.2^{a}	37.4^{b}	28.8^{a}	$1.1E+07^{a}$	$7.3E+04^{a}$	9.68^{a}
ANOVA (P values)	0.3062	0.0491	0.4742	0.6267	0.2475	0.2111

[†]Values followed by the different small letter in columns are significantly different (Tukey test, $P \leq 0.05$). *ds, Dry soil.

was not the case for this work.

No difference was detected among treatments for pH, organic matter and cation exchange capacity, probably due to high natural fertility of the soil regarding these characteristics. Potassium soilconcentration increased with the cultivation of sunn hemp in relation to velvetbean, fallow and maize (conven-tional tillage), but on the other hand, nutrients phosphorus, calcium and magnesium did not differ among the treatments. Millet had the same performance as sunn hemp to the potassium content in the soil (Table 4). Potassium is the nutrient extracted in greater quantity by tomato plants (Fontes et al., 2004), which may have favored the performance of tomato grown after the sunn hemp. Silva et al. (2002) and Wang et al. (2009) reported significant amounts of potassium recycled for use of sunn hemp as cover crops. However, in this experiment, it was not detected that there was any increase in the levels of potassium in tomato plant leaves when grown after the sunn hemp (Table 5). Nutrient content of tomato leaves did not show any significant interaction between cover crops and years for nitrogen, phosphorus and potassium (Table 5). The leaf concentrations of nitrogen and potassium in tomato plants did not differ among cover crop treatments, but in 2009 the concentrations of these nutrients were greater than 2008, including phosphorus. The concentration of phosphorus in tomato leaves was higher when it was grown on the straw of fallow than velvetbean, sunn hemp and millet, but not significantly different from maize straw (conventional tillage). Calcium, magnesium and sulphur showed interactions (Table 6). The calcium concentration did not differ significantly between treatments during the experiment, but it was observed that in 2009, velvetbeans and fallow had greater concentrations than in 2008. Magnesium concentration in tomato leaves was higher in velvetbean, sunn hemp and millet treatments in the first year, and in the second year, fallow had a higher concentration than maize and sunn hemp. In 2009, magnesium concentrations were higher than in 2008 for all treatments. In relation to sulphur, velvetbean had a lower concentration in leaves of tomato in 2008, and millet, in 2009. The comparison of the two years shows that millet and fallow had greater sulphur concentrations in the leaves of tomato in 2008, and velvetbeans, in 2009.

Due to the crop rotation and green manure with velvetbean and sunn hemp, we had expected an increase in the leaf nitrogen concentration, which was not observed in this experiment. According to Thönnissen et al. (2000), the recovery of nitrogen from green manure by tomato crop is in the order of 9 to 15%, being more expressive in low fertility soils, which was not the case in this experiment and explains why the nitrogen concentrations in leaves did not increase in the legume crop treatment. In this experiment, the tomato crop had great nutrient leaf content in comparison with other reports of tomato status leaf nutrient (Fontes et al., 2004; Abdul-Baki et al., 1997b). Total fruit yield and marketable fruit yield of tomato was higher when grown on the straw of sunn hemp compared to other treatments; but it was not different from that of millet. The fallow treatment had the lowest total fruit yield and marketable fruit yield of tomato. The number of total marketable fruit was similar among treatments; only the fallow had the lower numbers of fruit than the other treatments. The highest fresh mass of marketable fruit of tomato was with sunn hemp, but not differing from millet (Table 7). All measured parameters were higher in 2009 than in 2008, possibly due to the greater leaf nutrient concentration in the tomato. Tomato yield results demonstrated the efficiency of no-tillage, mainly in

Table 4. Phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) content in the soil in the tretaments of cover crops, Ribeirão Preto.

Cover crop	P ($g\ dm^{-3}$)	K ($mmol_c\ dm^{-3}$)	Ca ($mmol_c\ dm^{-3}$)	Mg ($mmol_c\ dm^{-3}$)
Velvetbean	71.7[a]	3.4[b]	26.8[a]	14.4[a]
Sunn hemp	64.2[a]	4.2[a]	27.4[a]	15.0[a]
Millet	60.3[a]	3.8[ab]	27.9[a]	14.7[a]
Fallow	60.5[a]	3.2[b]	27.8[a]	15.0[a]
Maize (Conventional)	59.2[a]	3.3[b]	28.3[a]	14.3[a]
ANOVA (P value)	0.167	0.054	0.863	0.931

Values followed by the different letter in columns are significantly different (Tukey test, P ≤ 0.05).

Table 5. Concentration of macronutrients (N, P and K) in the leaves of tomato in the treatments of cover crops.

Cover crop (CC)	N	P	K
		($g\ kg^{-1}$ dry mass)	
Velvetbean	31.7[a]	2.5[b]	45.7[a]
Sunn hemp	33.2[a]	2.4[b]	44.8[a]
Millet	33.9[a]	2.5[b]	45.5[a]
Fallow	34.8[a]	2.9[a]	45.3[a]
Maize (Conventional)	34.3[a]	2.7[ab]	47.7[a]
Year			
2008	31.9[b]	1.7[b]	40.2[b]
2009	35.3[a]	3.4[a]	51.5[a]
ANOVA (P ≤ 0.05)			
CC	0.1074	0.0282	0.6927
Year	<0.0010	<0.0010	<0.0010
PC versus Year	0.7084	0.1443	0.4846

Values followed by the same letter in columns are not significantly different (Tukey test, P ≤ 0.05). Samples of leaves were collected between 3rd and 4th fruit bunches.

Table 6. Concentration of macronutrients (Ca, Mg and S) in the leaves of tomato in the treatments of cover crops.

Cover crop (CC)	Ca ($g\ kg^{-1}$ dry mass)		Mg ($g\ kg^{-1}$ dry mass)		S ($g\ kg^{-1}$ dry mass)	
	2008	2009	2008	2009	2008	2009
Velvetbeans	37.3[a†]	42.3[a]*	9.5[a]	11.3[ab]*	5.1[b]	5.8[a]*
Sunn hemp	40.2[a]	40.9[a]	8.6[a]	10.6[bc]*	5.9[a]	5.8[a]
Millet	37.2[a]	39.6[a]	8.6[a]	11.1[abc]*	6.0[a]*	5.3[b]
Fallow	36.0[a]	44.2[a]*	7.1[b]	11.9[a]*	6.3[a]*	5.9[a]
Maize (Conventional)	38.9[a]	38.3[a]	8.0[b]	10.1[c]*	6.2[a]	5.9[a]
ANOVA (P ≤ 0.05)						
PC	0.4076		0.0043		0.0022	
Year	0.0047		<0.0010		0.0798	
PC vs. Year	0.0153		0.0028		0.0009	

Samples of leaves were collected between 3rd and 4th fruit bunches. Values followed by the same letter in columns are not significantly different (Tukey test, P≤0.05). *In lines are significantly differ rent (Tukey test, P ≤ 0.05).

Table 7. Total fruit yield (TFY), marketable fruit yield (MFY), total fruit number (TFN), marketable fruit number (MFN) and average fresh mass of marketable fruit (AFMMF) of tomato in the treatments of cover crop.

Cover crop (CC)	TFY (Mg ha^{-1})	MFY (Mg ha^{-1})	TFN (1.000 ha^{-1})	MFN (1.000 ha^{-1})	AFMMF (g)
Velvetbean	73.5^{b†}	67.4^{b}	631^{a}	575^{a}	117.1^{b}
Sunn hemp	79.2^{a}	73.4^{a}	645^{a}	598^{a}	122.0^{a}
Millet	74.5^{ab}	67.5^{b}	611^{a}	558^{ab}	120.3^{ab}
Fallow	62.9^{c}	58.7^{c}	569^{b}	520^{b}	111.7^{c}
Maize (Conventional)	72.8^{b}	66.3^{b}	626^{a}	569^{a}	115.7^{bc}
Year					
2008	65.4^{b}	58.6^{b}	507^{b}	507^{b}	114.7^{b}
2009	79.8^{a}	74.6^{a}	726^{a}	620^{a}	120.0^{a}
ANOVA (P value)					
CC	0.0004	0.0017	0.0211	0.0316	0.0034
Year	<0.0001	<0.0001	<0.0001	<0.0001	0.0076
PC versus Year	0.4542	0.5390	0.6383	0.6976	0.5657

[†]Values followed by the same letter in columns are not significantly different (Tukey test, P ≤ 0.05).

rotation with cover crops like sunn hemp and millet, thus eliminating the need of tillage for growth. Wang et al. (2009) also reported better yields for tomato when grown after sunn hemp, with an average yield of marketable fruits similar to that produced in this experiment. The results of the tomato yield in this experiment in no-till were similar to those of Campiglia et al. (2010), Abdul-Baki et al. (1996) and Lenzi et al. (2009). However, Sainju et al. (2002) reported that the no-tillage tomato yield was lower than the minimum and conventional tillage, which was attributed to soil com-paction, but in the following year, the tomato yield was similar to those of tillage treatments due to the better physical conditions of the soil provided by the no-tillage treatment.

Conclusion

This field study demonstrated that tomato no-tillage in rotation with cover crops is technologically viable over two years. Millet was the best cover crop to produce dry biomass together with sunn hemp; it was also the best to suppress the establishment of weeds. Sunn hemp increased tomato yield and ensured a high quality of fruits. In the soil, potassium content and nitrification activity were enhanced by sunn hemp. The cycling of nutrients by cover crops did not impact on the nutritional satus of tomato except in fallow soil, which contributed to increase phosphorus leaf content in tomato. However, the growth of tomato in no-till in rotation with cover crops provides good practices for the growers who want to contribute to the development of sustainable agriculture around the world.

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