Soil physical attributes induced by crop sequence under no-tillage system in tropical region with warm and dry winter

Jose Cora[A], Getulio Seben Jr[B], Carolina Fernandes[C] Adolfo Marcelo[B] and Marcio Martins[B]

[A]Faculty of Soil Science, Sao Paulo State University, Jaboticabal, SP, Brazil, Email cora@fcav.unesp.br
[B] Sao Paulo State University, Jaboticabal, SP, Brazil Email getulioseben@yahoo.com.br, adolfovalente@yahoo.com.br, reismartins@yahoo.com.br,
[C]Sao Paulo State University, Jaboticabal, SP, Brazil, Email carol@fcav.unesp.br

Abstract
The no-tillage system is utilized in approximately 100 million hectares in the world. However, this system still needs to be better adapted to tropical regions, with warm and dry winters. The adaptation of no-tillage system in tropical regions depends on the suitable choice of summer and winter crops which should contribute to improvement of soil properties and soil productive capacity. The aim of the present study was to determine the effect of crop sequences on soil physical attributes of a Rhodic Eutrudox under no-tillage system. The treatments consisted of the combination of tree summer crop sequences and seven winter crop sequences. The summer crop sequences were: maize monocrop (Zea mays L.), soybean monocrop (Glycine max (L.) Merrill), and soybean/maize rotation. The winter crops were: maize, sunflower (Helianthus annuus L.), radish (Raphanus sativus L.), pearl millet (Pennisetum americanum (L.) Leeke), pigeon pea (Cajanus cajan (L.) Millsp), grain sorghum (Sorghum bicolor (L.) Moench) and sunn hemp (Crotalaria juncea L.). The experiment began in September 2002. Lower bulk density and high soil tensile strength were found in the soybean/maize rotation after sorghum and sunn hemp. Sorghum and sunn hemp provided the highest water-stability of soil aggregates. Millet, sorghum, maize and sunn hemp provided the highest mean aggregate diameter. The water-stability of soil aggregates and mean aggregate diameter showed positive correlation with soil tensile strength. There were no differences among effects of the summer and winter crops on the soil organic matter. In general, better soil physical conditions were found in the soybean/maize crop rotation and after sunn hemp, sorghum and millet.

Key Words
Soil aggregation, soil structure, winter crops, cover crops, tropical agriculture.

Introduction
In the no-tillage system, the physical management of the soil is in practice limited to the sowing operation and to the effect of the crops on soil structure. The rotation of crops with species that increase plant residues on soil surface is fundamental to avoid soil erosion and to improve soil physical quality. Plants affect soil structure at different scales and through various direct and indirect mechanisms. The adaptation of no-tillage system in tropical regions depends on the suitable choice of summer and winter crops which should contribute to improvement of soil properties and soil productive capacity. To achieve this, the choice of adapted crops to establish the system is of fundamental importance. The aim of the present study was to determine the effect of crop sequences on soil physical attributes of a Rhodic Eutrudox under no-tillage.

Methods
Characterization of the experimental área
The field experiment was established in 2002 at Jaboticabal, SP, Brazil (218140S, 488170W and altitude of 550 m). Climatologically the area belongs to tropical/megathermal zone or Koöppen's Aw (a tropical climate with dry winter and the temperature average of the coldest month higher than 18 8C). The mean annual rainfall (1971–2006) is 1417 mm, with an annual distribution peaking in the period of October–March and a relatively dry season in the period of April–September. The soil of the experimental area is an Oxisol (Rhodic Eutrudox), based on USDA Soil Taxonomy (Soil Survey Staff 2003). In the 0– 20 cm layer, the mean contents of clay, silt and sand were 555, 63 and 381 g/kg, respectively, determined by the pipette method (Gee and Bauder 1986).

Experimental design
The experiment was conducted using a split-block design. Two sets of treatments (tree summer crop sequences and seven winter crops, totaling 21 plots per experimental block) are randomized across each other in strips in an otherwise randomized complete block design, as described by Little and Hills (1975). There were three replications (blocks). Each plot was 40 m long by 15 m wide. The summer crop sequences,

with sowing in October/November, were: maize monocrop (Zea mays L.); soybean monocrop (Glycine max (L.) Merrill); soybean/maize rotation. The winter crops, with sowed in February–March and repeated every year in the same plots, were: maize, sunflower (Helianthus annuus L.), oilseed radish (Raphanus sativus L.), pearl millet (Pennisetum americanum (L.) Leeke), pigeon pea (Cajanus cajan (L.) Millsp), grain sorghum (Sorghum bicolor (L.) Moench) and sunn hemp (Crotalaria juncea L.).

Soil sampling and analysis

Soil sampling took place after finishing the six year of the experiment, on October 2008, before sowing the summer crops of the next growing year (2008/2009). Four soil blocks measuring 10x20x15 cm of high, length and width, respectively, were taken from each plot. Then, aggregate (12.5 to 19.0 mm diameter) were taken from the blocks. Forty of these aggregates were used to evaluate soil tensile strength (Dexter and Kroesbergen 2000), 10 more remained to determine bulk density. Other aggregates (4.0 to 6.3 mm diameter) were separated to evaluated mean pondered aggregate diameter (Yoder, 1936), and other ones (1.0 to 2.0 mm diameter) were used to determine water-stability of soil aggregates (Kemper & Rosenau 1986). After evaluating the soil tensile strength, soil samples from aggregates were separated to evaluate soil total organic matter. The results were submitted to variance analysis (F test) and means were compared by the Tukey test ($p< 0.10$). Pearson linear correlation test was applied to evaluate soil attributes that showed significant differences among treatments.

Results

Lower bulk densities were found in the soil after oilseed radish, sorghum and sunn hemp in the soybean/maize rotation and after sunn hemp in the maize monocrop (Table 1). High soil tensile strength was found after sunn hemp in the soybean/maize rotation (Table 2). Sorghum and sunn hemp provided the highest water-stability of soil aggregates, independently of the summer crop sequence (Table 3). Highest mean pondered aggregate diameters were found in the soybean/maize rotation and in maize monocrop, independently of the winter crops (Table 3). Pearl millet and sorghum provided the highest mean pondered aggregate diameter, independently of the summer crop sequence (Table 3). The water-stability of soil aggregates and mean pondered aggregate diameter showed positive correlation with soil tensile strength (Table 4). There were no differences among effects of the summer and winter crops on the soil organic matter (Table 3).

Table 1. Soil bulk density after winter crops in the summer crop sequences.

Winter crops	Summer crop sequences						F test
	Soybean/maize rotation		Maize monocrop		Soybean monocrop		
Maize	1,51	A[a]	1,47	AB	1,45		1,71[ns]
Sunflower	1,45	ABb	1,53	Aa	1,48	ab	2,90*
Oilseed radish	1,41	B	1,45	AB	1,45		1,84[ns]
Pearl millet	1,46	AB	1,48	AB	1,46		1,48[ns]
Pigeon pea	1,43	AB	1,44	AB	1,41		0,35[ns]
Grain sorghum	1,41	B	1,43	AB	1,44		0,86[ns]
Sunn hemp	1,40	B	1,40	B	1,44		0,37[ns]
F test	1,99*		2,75*		0,75[ns]		

Data followed by same low case letter in line or same high case letter in the column are not considered different by Tukey test at 10% of probability.

Table 2. **Soil tensile strength (kPa) after winter crops in the summer crop sequences.**

Winter crops	Summer crop sequences						F
	soybean/maize rotation		maize monocrop		soybean monocrop		
Maize	47,64	AB[a]	42,58		38,86		1,42 [ns]
Sunflower	48,92	ABa	39,59	ab	32,92	b	4,72*
Oilseed radish	39,53	B	42,41		35,53		0,87 [ns]
Pearl millet	48,99	AB	44,65		44,93		0,43 [ns]
Pigeon pea	38,19	B	35,27		41,40		0,69 [ns]
Grain sorghum	46,89	AB	48,18		41,49		0,92 [ns]
Sunn hemp	56,84	Aa	37,83	b	34,77	b	10,43*
F test	2,71*		1,28[ns]		1,28[ns]		

Data followed by same low case letter in line or same high case letter in the column are not considered different by Tukey test at 10% of probability.

Table 3. Soil Organic matter (OM), water-stability of soil aggregates (WSA), mean pondered aggregate diameter (MPAD) and soil bulk density (BD), determined from soil submitted to the crop sequences.

Summer crops (S)	OM (g/dm^3)	WSA (%)		MPAD (mm)		BD (g/cm^3)
soybean/maize rotation	11,9	74		3,22	a	1,45
maize monocrop	12,2	72		3,17	a	1,46
soybean monocrop	12,2	73		2,76	b	1,45
F test	$0,49^{ns}$	$2,24^{ns}$		$6,34^{*}$		$0,28^{ns}$
CV(%)	10,7	3,3		15,0		4,1
Winter crops (W)						
Maize	11,7	69	bc[a]	3,21	ab	1,48
Sunflower	11,8	68	c	2,95	abc	1,49
Oilseed radish	11,9	70	bc	2,65	c	1,45
Pearl millet	12,2	75	ab	3,31	a	1,44
Pigeon pea	12,0	73	abc	2,83	bc	1,42
Grain sorghum	12,3	77	a	3,27	a	1,43
Sunn hemp	12,4	78	a	3,12	ab	1,44
F test	$0,46^{ns}$	$8,40^{*}$		$7,87^{*}$		$1,16^{ns}$
CV (%)	9,0	5,5		8,6		4,4
Interaction SxW						
F test	$0,87^{ns}$	$0,88^{ns}$		$1,31^{ns}$		$1,81^{*}$
CV (%)	7,2	3,1		8,0		2,8

Data followed by same low case letter in line not considered different by Tukey test at 10% of probability

Table 4. Coefficient of correlation between bulk density (BD), water-stability of soil aggregates (WSA), and mean pondered aggregate diameter (MPAD) and soil tensile strength.

Independent variables	Dependent variables
	Soil tensile strength
BD	ns
WSA	0,56**
MPAD	0,37**

Pearson correlation coefficient. ** P < 0,01; ns: not significant.

Conclusion
In general, better soil physical conditions were found for the soybean/maize summer crop rotation and after sunn hemp, sorghum and millet winter crops.

References

Dexter AR, Kroesbergen B (1985) Methodology for determination of tensile strength of soil aggregates. *Journal Agriculture Engineering Research* **31**,139-147.

Gee GW, Bauder JW (1986) Particle-size analysis. In 'Methods of soil analysis, Part 1. Physical and Mineralogical Methods'. (Ed A Klute) pp. 383–411. (ASA-SSSA, Madison, WI)

Kemper WD, Rosenau RC (1986) Aggregate stability and size distribution. In 'Methods of soil analysis, Part 1. Physical and Mineralogical Methods' (Ed A Klute) pp. 425–440. (ASA-SSSA, Madison, WI).

Little TM, Hills FJ (1975) Statistical Methods in Agricultural Research, 2nd ed. University of California, Davis, CA.