Universidade Federal Rural do Semi-Árido
Pró-Reitoria de Pesquisa e Pós-Graduação
http://periodicos.ufersa.edu.br/index.php/sistema

ISSN 0100-316X (impresso)
ISSN 1983-2125 (online)

SOIL MANAGEMENT SYSTEMS FOR SUSTAINABLE MELON CROPPING IN THE SUBMEDIAN OF THE SÃO FRANCISCO VALLEY[1]

VANDERLISE GIONGO[2]*, ALESSANDRA MONTEIRO SALVIANO[2], MÔNICA DA SILVA SANTANA[3], NIVALDO DUARTE COSTA[2], JONY EISHI YURI[2]

ABSTRACT – Changes in soils management systems, including the application of green manure, are able to increase crop productivity. The aim of this study was to propose a soil management system with the use of green manure to improve the nutritional status and melon productivity in the submedian of the São Francisco Valley. The experiment was installed in Typic Plinthustalf and conducted in split plot. There were two soil tillage systems, tillage (T) and no tillage (NT), and three types of green manure (two vegetal cocktails: VC1- 75% legumes (L) + 25% non-legumes (NL); VC2- 25% L+ 75% NL and spontaneous vegetation (SV)). The experimental design was a randomised block with four replications. Fourteen species of legumes, grasses and oilseeds were used for the composition of the plant cocktails. We evaluated production of the dry shoot and root biomass and carbon and nutrient accumulation by green manures and melon plant. Data were subjected to analysis of variance and the treatment means were compared by Tukey´s test ($P<0.05$). Shoot biomass production and carbon and nutrient accumulation were higher in plant mixtures compared to spontaneous vegetation. The root system of the plant cocktails added larger quantities of biomass and nutrients to the soil to a depth of 0.60 m when compared to the spontaneous vegetation. The cultivation of plant cocktails with soil tillage, regardless of their composition, is a viable alternative for adding biomass and nutrients to the soil in melon crops in semi-arid conditions, providing productivity increases.

Keywords: *Cucumis melo* L. Green manure. No-tillage. Soil cover.

SISTEMAS DE MANEJO DO SOLO PARA CULTIVO SUSTENTÁVEL DO MELÃO NO VALE DO SUBMÉDIO SÃO FRANCISCO

RESUMO - Mudanças nos sistemas de manejo de solos, incluindo adubação verde, podem aumentar a produtividade das culturas. O objetivo deste trabalho foi propor um sistema de manejo do solo com uso de adubação verde para melhorar o estado nutricional e a produtividade do melão no Vale do Submédio São Francisco. O experimento foi instalado em Argissolo Amarelo, em parcelas subdivididas, sendo as parcelas dois sistemas de preparo do solo, convencional (C) e plantio direto (PD), e as subparcelas três tipos de adubação verde (dois coquetéis vegetais: CV1- 75% leguminosas (L) + 25 % não-leguminosas (NL); CV2- 25% L + 75% NL e vegetação espontânea (VE)). Após 70 dias da semeadura os adubos verdes foram manejados. Foram avaliados a produção de fitomassa aérea e radicular, acúmulo de nutrientes e C dos adubos verdes e a produtividade meloeiro. Os dados foram submetidos à análise de variância ao nível de 5% de probabilidade e as médias dos tratamentos foram comparados pelo teste de Tukey, ao nível de 5% de probabilidade. A produção de fitomassa da parte aérea e o acúmulo de carbono e nutrientes foram maiores nos coquetéis vegetais. O sistema radicular dos coquetéis vegetais adicionou maior quantidade de fitomassa e nutrientes no solo até 0,60 m, quando comparado com a vegetação espontânea. O cultivo de coquetéis vegetais, com incorporação da fitomassa, independentemente da sua composição, é uma alternativa viável para a adição de biomassa e nutrientes ao solo em condições semiáridas, proporcionando aumento de produtividade do meloeiro.

Palavras-chave: Cucumis melo L. Adubação verde. Plantio direto. Cobertura do solo.

*Corresponding author
[1]Received for publication in 05/14/2014; accepted in.04/26/2016.
[2]Empresa Brasileira de Pesquisa Agropecuária, Petrolina, PE, Brazil; vanderlise.giongo@embrapa.br, alessandra.salviano@embrapa.br, nivaldo.duarte@embrapa.br, jony.yuri@embrapa.br.
[3]Department of Nuclear Energy, Universidade Federal de Pernambuco, Recife, PE, Brazil; monica_ssantana@hotmail.com.

INTRODUCTION

Melon (Cucumis melo L.) is the eighth most produced and third most exported fruit in Brazil (AGRIANUAL, 2013), with 94% of the national production in the north eastern part of Brazil.

In the 1980s, with the beginning of the settlement of irrigated perimeters executed by the Development Company of the Valleys São Francisco and Parnaíba (CODEVASF) (HEINZE, 2002; SOBEL; ORTEGA, 2010), producers in the submedian of the São Francisco Valley implemented melon cultivation, which was the first plant crop to be exported in the region. Today, the São Francisco Valley is a region producing quality fruit, exporting melon, mangoes and (ARAÚJO; SILVA, 2013). Increased production costs due to pest management and irrigation resulted in a drastic reduction of the area planted with melon and was aggravated by the introduction and expansion of melon cultivation in new regions, such as Rio Grande do Norte and Ceará.

However, after years of exploitation, a fragility of the agricultural system that was adopted in the region, has been observed soil degradation due to improper management of soil and water. Changes in soil use and management contribute to solve problems related to sustainability. The implementation of no-tillage systems, integrated cropping systems, the use of species with high biomass production and disposal of burned biomass are examples of change management strategies (CARVALHO et al., 2010).

The plant mixture or cocktail is composed of a group of species that belong to different botanic families, sowed and conducted at the same time for cutting during the flowering period of most species. Those species are grown before the main crop or intercropped, and in some cases, they are incorporated into the soil. The use of the plant cocktail, due to the different depths explored by the radicular system of the different species, improves the biological diversity of the soil (WILDNER, 2014).

Singogo et al. (1996) studied the productivity of melon with green manure treatments in a sandy loam soil and obtained similar results compared to treatments that received mineral nitrogen doses of 70 or 100 kg ha^{-1} and crops treated with green manure associated with manure. In the semiarid region of Brazil, adding organic waste to the soil increases negative charges and therefore provides plant nutrients (SALCEDO, 2004). Furthermore, according to RAMOS et al. (2010), the addition of straw can prevent quality losses by protecting the melon fruit from direct contact with the soil.

However, one of the major limitations is the search for species that adapt well to local climatic and soil conditions. The use of intercropped legumes and grass species can make important contributions to the challenges of developing productive and environmentally friendly agricultural systems (NYFELER et al., 2011). It is therefore assumed that the use of plant cocktails, associated with untilled soil, can be a viable strategy for melon cultivation. Therefore, the objective of this study is to propose a soil management system with the use of green manure to improve the nutritional status and melon productivity in the submedian of the São Francisco Valley region.

MATERIAL AND METHODS

The experiment was conducted in May 2011 at the Bebedouro Experimental Station, which belongs to the semi-arid region of Embrapa. The soil was classified as Typic Plinthustalf with a sandy loam texture and has the following physical and chemical characteristics at a depth of 0.0-0.20 m (Table 1):

Table 1. Physical and chemical characteristics of the Typic Plinthustalf at a depth of 0-0.2 m.

Prof.	pH	MO	P	K	Ca	Mg	Na
m	H_2O	g kg^{-1}	mg dm^{-3}	...............................cmol$_c$ dm^{-3}...................................			
0-0.2	6.3	6.62	23.01	0.25	1.8	0.5	0.02
	S	**H+Al**	**CTC**	**V**	**Sand**	**Silt**	**Clay**
	..............cmol$_c$ dm^{-3}................			%	………… g kg^{-1}……..…		
0-0.2	2.57	0.64	3.21	80	831.26	119.78	48.96

The climate is Bswh' according to the Köppen classification system. In 2011, the average annual temperature was 26.8°C and the average rainfall 360 mm. The native vegetation is dominated by *Caatinga hyperxerophila*. The experiment was carried out from May to October 2011, and monthly averages of climatic parameters are described in Figure 1.

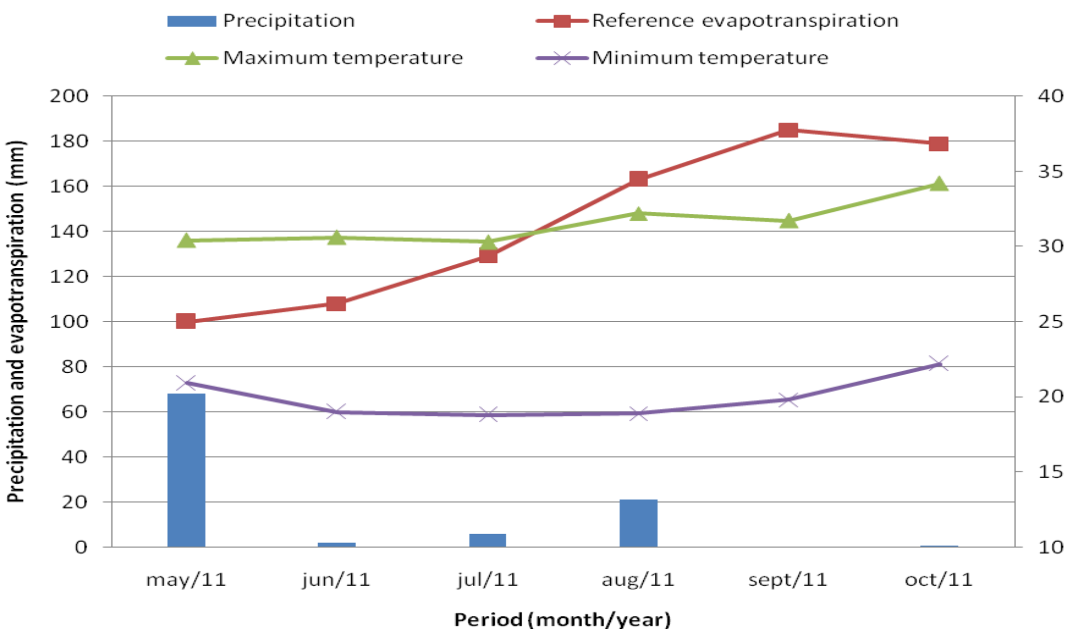

Figure 1. Monthly average of climatic parameters: Precipitation (P), Reference evapotranspiration (ETo) and Temperature (T) during the experiment.

The experiment was conducted in split plot design with two soil tillage systems as plots, tillage (T) and no tillage (NT), and three types of green manure (two vegetal cocktails: VC1- 75% legumes (L) + 25% non-legumes (NL); VC2- 25% L+ 75% NL and spontaneous vegetation (SV)) as subplots. The experimental design was a randomised block design with four replications. The plot area was 1,080 m^2 (45 x 24 m), each subplot was comprised of 360 m^2 (15 x 24 m), with 320 m^2 as used area. Soil tillage consisted of ploughing and harrowing at planting, then ploughing and harrowing to incorporate the green manure. In the NT treatments, green manure biomass was cut using a portable mower and deposited on the soil surface.

Fourteen species of legumes, oil seeds and grasses were used in the composition of the vegetal cocktails: Legumes - Calopogonio (*Calopogonium mucunoide*), black velvet bean (*Mucuna aterrina*), gray velvet bean (*Mucuna conchinchinensis*), sunn hemp (*Crotalaria juncea*), rattlebox (*Crotalaria spectabilis*), jack bean (*Canavalia ensiformes*), pigeonpea (*Cajanus cajan* L.), lab-lab bean (*Dolichos lablab* L.); non legumes: castor oil plant (*Ricinus communis* L.), sunflower (*Helianthus annuus* L.), sesame (*Sesamum indicum* L.), corn (*Zea mays*), pearl millet (*Penissetum americanum* L.) and sorghum (*Sorghum vulgare* Pers.). The spontaneous vegetation was composed of the following predominant species: *Commelina benghalensis* L., *Macroptilium atropurpureum Desmodium tortuosum* and *Ancanthorpermun hispidun* DC. The green manure species were chosen because they are well adapted to the soil and climatic conditions of the region and present good biomass production (FARIA et al., 2007; CAVALCANTE et al., 2012; MASSAD et al., 2013; MAGALHÃES et al., 2013; SANTOS et al., 2013). Table 2 shows the seed quantities per species in each vegetal cocktail.

In May 2011, the vegetal cocktails were sown with a spacing of 0.50 m. After seventy days, the plants were cut to assess species contribution to the vegetal cocktails and spontaneous vegetation to the total biomass production. Subsamples were removed and sent to the laboratory where they were dried at 65-70°C for 72 h to determine dry biomass, carbon and nutrient contents.

In each treatment, trenches were opened (1.0 m x 0.2 m x 1.0 m) for sampling the radicular biomass of the vegetal cocktails and spontaneous vegetation. Root samples were removed in soil blocks with a volume of 20 cm^3 at depths of 0-0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8 and 0.8-1.0 m. The soil samples were sieved and washed in 2 mm sieves to separate the root samples from the soil.

In the laboratory, the roots were washed in distilled water and dried at 65-70°C for 48 h. The dry biomass samples were then ground, sieved though a1 mm mesh and analysed for carbon and nutrients.

After sampling, we analysed biomass values according to each specific treatment.

Table 2. Seed quantity of green manure species used in vegetal cocktails.

Species	VC1	VC2
	--------- g. subplot^{-1} ---------	
Sunflower	183.39	550.19
Castor oil plant	2020.59	6061.77
Sesame	58.50	175.50
Corn	877.50	2632.50
Pearl millet	58.50	175.50
Sorghum	146.25	438.75
Rattlebox	300.10	100.03
Sunn hemp	789.75	263.25
Pigeonpea	13127.40	4375.80
Calopogonio	224.64	74.88
Black velvet bean	5928.39	1976.13
Jack bean	745.875	248.62
Lab-lab bean	3510.00	1170.00
Gray velvet bean	5928.39	1976.13

VC1-75% legumes (L) and 25% non-legumes (NL); VC2- 25% legumes (L) and 75% non-legumes (NL).

Melons (cultivar 10/00) were planted on August 16, 2011, ten days after cutting of the vegetation cover. Initially, the melon seeds were sown in polystyrene trays (200 cells) and after 12 days, seedlings were transplanted to the field with a spacing of 0.40 m by 2.0 m. A drip irrigation system was used with a spacing of 0.5 m and the average flow rate was measured in the field. Irrigation was performed three times a week and the depth was calculated based on class (A) pan evaporation and crop coefficient (Kc) with 92% irrigation system efficiency.

Crop were fertilised in accordance with the results of the soil analysis. We applied 20 t ha^{-1} of manure and 600 kg ha^{-1} of 06-24-12 as foundation. Topdressing fertilisation was performed through fertigation (three times a week) using 90 kg ha^{-1} N (in the form of urea), 90 kg ha^{-1} of K_2O (in the form of potassium chloride) and 30 kg ha^{-1} P_2O_5 (using purified MAP). The fertilisers were applied 40 days after transplanting. The culture was kept clean by manual weeding and phytosanitary treatments which are commonly used in melon crops.

Plants were harvested 65 days after transplanting, on October 21. To evaluate productivity, we counted, harvested and weighed all fruits of each plant per plot and expressed the results in Mg ha^{-1}. Soluble solids were determined using a digital refractometer PAL-1 model (Atago, Tokyo, Japan) with automatic temperature compensation and an operating range of 0 to 53° Brix. Measurements were performed using 1 mL of juice of each fruit. Ten fruits were analysed per treatment and replicate, totalling 240 fruits. The results were expressed as ° Brix.

After harvesting, total dry biomass weight of the melon plants was determined and samples were sent to the laboratory for chemical analysis and determination of organic carbon and nutrient levels. The chemical analyses to determine the levels of calcium, magnesium, phosphorus, potassium and sulphur in root and shoot tissues of the vegetal cocktails and the spontaneous vegetation as well as in the melon shoots were performed according to the methodology described by Silva (2009). Total carbon and nitrogen contents were quantified by dry oxidation in an Elemental Analyzer model TruSpec Leco CN.

Considering that data for dry matter production of the shoot and root systems as well as nutrient content and accumulation are calculated for the first crop cycle, they were analysed without taking into account the factor soil tillage systems. Thus, they considered three treatments (three types of green manure) with eight repetitions. For the melon crop related data, we considered two factors: soil tillage system and green manure type. In both cases, data were subject to analysis of variance and the average treatments were compared by Tukey´s test at 5% probability, using Assistat software (SILVA; AZEVEDO, 2002).

RESULTS AND DISCUSSION

The production of dry biomass by aerial parts of the vegetal cocktails (VC1 e VC2) was significantly higher than biomass production by spontaneous vegetation (Table 3). Comparing the composition of the two vegetal cocktails, using a higher proportion of grasses and oilseeds (25% L + 75% NL) did not alter the production of dry shoot biomass. Menezes et al. (2009) found that the grass species used in single roofing with the highest biomass production were grain sorghum (10.23 Mg ha^{-1}) followed by goose grass (9.20 Mg ha^{-1}) and Brachiaria (8.60 Mg ha^{-1}), not differing from the legume Crotalaria (8.69 Mg ha^{-1}) and intercrops millet + Crotalaria (9.18 Mg ha^{-1}) and millet + pigeon peas (6.69 Mg ha^{-1}). However, PERIN et al. (2004) observed in isolated and intercropped crops of grasses and legumes that the legume biomass production (Crotalaria) was 108% (9.34 Mg ha^{-1}) greater than that of the spontaneous vegetation (4.49

Mg ha^{-1}) and 31% higher than grass (millet) (7.12 Mg ha^{-1}); and legume intercropped with grass contributed 65% of the produced biomass (8.04 Mg ha^{-1}) and increased productivity by 13% compared to the isolated grass crop. It is important to consider the variability of different vegetal species in green manures in relation to edaphoclimatic factors, resulting in significant fluctuations in biomass production.

Table 3. Dry biomass, carbon and nutrient levels of plant mixture shoots and spontaneous vegetation in Typic Plinthustalf after 70 days of cultivation.

Green manure	Dry biomass	C	N	C/N	P	K	Ca	Mg	S
	Mg ha^{-1}	----g kg^{-1}-----			---------------------g kg^{-1}---------------				
VC1	8.3 a	422.8a	21.0a	20.6a	2.6a	29.5b	11.3b	3.61b	1.3ab
VC2	9.20 a	421.4a	18.0a	24.4a	1.9b	30.3b	6.1c	3.4b	1.0b
Spontaneous	4.5 b	392.0b	20.1a	19.9a	2.8a	36.7a	19.1a	5.3a	1.7a
DMS	1.9	8.5	4.3	5.1	0.6	5.3	2.8	0.8	0.5
CV (%)	21.0	1.6	17.2	18.5	19.6	13.1	18.4	15.3	29.8

VC1-75% legumes (L) and 25% non-legumes (NL); VC2-75% non-legumes (NL) and 25% legumes (L).
Means followed by the same letter in the same column are not significantly different at 5% by Tukey´s test.

Regarding the nutrient contents (Table 3), we found significant differences between nutrients except for nitrogen. Although there was a predominance of leguminous species in the CV1, there were no differences in N contents of the aerial biomass between green manures. N contents may differ more between species of the same than between species from other botanical families. Thus, the use of leguminous species in green manure does not necessarily provide increased N cycling capacity compared to the use of a grass or oleginosa species. In this sense, RODRIGUES et al. (2012), when comparing different compositions of green manure, found that nitrogen content varied more than 55% between legume species, but for some species, there was no significant difference when compared to grass (millet). They found N levels of 35.1, 31.0, 21.9, 16.4 and 13.3 g kg^{-1}, respectively, for velvet bean, jack bean, pigeon pea, sunn hemp and millet. Nitrogen contents ranged from 15.4 to 20.3 g kg^{-1} for each cultivated legume intercropped with millet.

ZHOU et al. (2012) evaluated biomass production in an experiment with leguminous and non-leguminous species in an arid environment to investigate the impact of green manure in carbon and nitrogen cycling. They observed variability in biomass production, N contents and C/N ratio between different families, with grasses and members of the family Brassicacea as the cultivated species with the highest nitrogen contents, and a legume species which presented the second highest C/N ratio. In the present study, the different proportions of legumes and non-legumes in the vegetal cocktail did not guarantee different C/N ratios, and soil and climatic factors must also be considered in the development of management strategies. Spontaneous vegetation showed the highest average levels of phosphorus, potassium, calcium, magnesium and sulphur, but phosphorus and sulphur levels did not differ statistically from levels of the plant cocktail with a predominance of legumes (75% L + 25% NL). The plant cocktail with a predominance of grasses and oilseeds showed significantly lower levels of all nutrients, except nitrogen (Table 3).

The predominantly non-leguminous CV2 (25% L + 75% NL) added the largest quantity of carbon to the soil, followed by the predominantly leguminous vegetal cocktail and spontaneous vegetation. Regarding nitrogen accumulation in the shoots (Table 4), we found no difference between the two vegetal cocktails, but N accumulation was significantly higher than in the spontaneous vegetation. The plant cocktails added 82.7 to 74.0 kg ha^{-1} N more to the soil system than the spontaneous vegetation. The values observed in this study were similar to those observed in studies conducted in other regions of the country (TEODORO et al., 2011; LIMA et al., 2012).

Table 4. Accumulation of nutrients and carbon in the aerial part of plant mixtures and in spontaneous vegetation in Typic Plinthustalf after 70 days of cultivation.

Green manure	C	N	P	K	Ca	Mg	S
	---kg ha^{-1}---						
VC1	3505.3b	174.2a	21.7a	244.6a	93.7a	29.9a	10.7a
VC2	3876.9a	165.5a	17.3ab	278.5a	55.9b	30.9a	9.3a
Spontaneous	1783.8c	91.5b	12.9b	167.1b	87.1a	24.3b	7.5a
DMS	63.1	34.0	4.5	46.5	19.6	4.9	3.3
CV (%)	1.6	18.7	20.4	16.0	19.7	13.6	28.6

VC1-75% legumes (L) and 25% non-legumes (NL); VC2- 25% legumes (L) and 75% non-legumes (NL). Means followed by the same letter in the same column are not significantly different at 5% by Tukey´s test.

Regarding nutrient accumulation by aerial biomass (Table 4) in relation to dry matter production, spontaneous vegetation showed the lowest accumulation levels for nitrogen, phosphorus, potassium and magnesium, which did not differ from the amounts of calcium and sulphur in the predominantly leguminous plant cocktail (75% NL + 25% L) nor from the amount of sulphur in the vegetal cocktail with a predominance of grasses and oilseeds (25% L + 75% NL). The sequence of the quantity of accumulated nutrients maintained in the three types of green manure was K>N>Ca>Mg>P>S.

We found the highest level and quantity of accumulated calcium in the shoot biomass of the predominantly leguminous plant cocktail (Tables 3 and 4). This is in agreement with a study by Rodrigues et al. (2012) who found the highest levels of calcium in legumes compared with a grass species. Duarte Junior and Rabbit (2008) observed higher Ca accumulation in bean-to-pig who had the equivalent to 197 kg ha-1 of Ca, while levels in crotalaria (123 kg ha^{-1}) and mucuna (95 kg ha^{-1}) did not differ significantly. However, the latter two accumulated on average nine times more Ca than the spontaneous vegetation. Ca concentration in plants depends on growth conditions, the species and the evaluated organ, ranging from 1 to 50 g kg^{-1}; however, the required amount of Ca for the growth of monocotyledons is lower than for dicotyledonous (HAWKESFORD et al., 2012). In the present study, to interpret the effects of soil management and green manure types, it was important analyse Ca amounts accumulated by each species.

Besides the contribution of aerial biomass by green manure, it is important to quantify the production of radicular biomass and of nutrients accumulated by the roots along the soil profile. However, due to the difficulty of studying the root system, few studies about this component have been carried out.

Radicular biomass of plant cocktails and spontaneous vegetation in a full flowering stage was significantly different between the depths. The predominantly leguminous plant cocktail (75% L + 25% NL) showed a higher radicular biomass production in the 0-0.2 and 0.8-1.0 m layer. In the 0.2-0.4 and 0.4-0.6 layers, the highest biomass production occurred in the plant cocktail composed predominantly of grass species and oilseeds. Spontaneous vegetation showed the lowest values of radicular biomass at all depths (Table 5).

Table 5. Dry biomass production and carbon and nutrient levels of the root system of plant cocktails and spontaneous vegetation in Typic Plinthustalf at different depths after 70 days of cultivation.

Green manure	**Dry biomass**	**C**	**N**	**C/N**
	Mg ha^{-1}	---------------g kg^{-1}------------		
		0.0-0.2 m		
VC1	3.9a	382.8a	14.6b	26.6a
VC2	2.7b	393.8a	14.2b	27.8a
Spontaneous	1.4c	427.8a	18.4a	23.3a
DMS	0.7	45.8	2.4	4.6
CV (%)	16.1	6.8	8.9	10.6
		0.2-0.4m		
VC1	0.8b	427.6a	16.4a	26.0b
VC2	1.5a	410.5a	15.0a	27.5b
Spontaneous	0.4c	443.5a	12.1b	32.8a
DMS	0.3	40.5	2.2	4.9
CV (%)	17.6	5.6	9.1	10.2
		0,4-0,6 m		
VC1	0.4b	421.2b	10.8b	41.7a
VC2	0.5a	435.1ab	13.9a	32.0b
Spontaneous	0.2c	465.0a	14.7a	31.7b
DMS	0.1	32.3	3.0	8.7
CV (%)	21.2	4.4	13,6	14,7
		0.6-0.8 m		
VC1	0.2a	424.5	12.8	33.2
VC2	0.2a	427.0	13.5	31.5
Spontaneous	0.2a	502.1	14.4	34.8
DMS	0.7			
CV (%)	21.3			
		0.8-1.0 m		
VC1	0.3a	426.9	12.0	35.5
VC2	0.1b	436.6	14.9	29.3
Spontaneous	0.1b	450.5	14.6	30.9
DMS	0.3			
CV (%)	13.1			

VC1-75% legumes (L) and 25% non-legumes (NL); VC2- 25% legumes (L) and 75% non-legumes (NL). Means followed by the same letter in the same column are not significantly different at 5% by Tukey´s test.

The total production of radicular biomass (0-1.0 m) was 5.6, 5.1 and 2.3 Mg ha^{-1} for the plant cocktail with predominance of legumes (75% L + 25% NL), for the plant cocktail with a predominance of grasses and oilseeds (25% L + 75% NL) and for spontaneous vegetation, respectively. Of this total, following the same treatment sequence, 69.96, 53.53 and 62.23% of the root biomass was found up to a depth of 0.2 m. The 0-0.4 m layer concentrated 85.25, 83.72 and 81.12% of the roots of the three green manures. The distribution percentages of the radicular biomass at different depths were similar to those found by KÄTTERER et al. (2011) in corn, where 71% of the roots were concentrated in the 0-0.2 m layer, 85% in the 0-0.4 layer and only 15% in the layers below 0.4 m. In a four-year experiment with the cultivation of a perennial grass species, *Panicum virgatum*, GARTEN et al. (2010) found that the total root biomass, including rhizomes, live and dead roots, was 12.29 Mg ha^{-1} up to a depth of 0.9 m at the end of a growing season. The authors observed the highest amount of subterranean biomass, 76%, on the surface up to a depth of 0.3 m. Although the total biomass was higher than the results obtained in our study, the proportions in each depth were similar. These results show the first and second layers have the highest amounts of biomass, thereby increasing nutrient and carbon amounts near the soil surface. However, a smaller proportion of roots was located at depths greater than 40 cm, responsible for nutrient cycling outside the root absorption zone of crops.

Regarding the carbon and nitrogen contents and C/N ratios (Table 5) in the root biomass, we found that the carbon content did not differ among the green manures at most depths. Only in the 0.4-0.6 m layer, the spontaneous vegetation showed a higher carbon content compared to the plant cocktail with a predominance of legumes (75% L + 25% NL). Nitrogen content showed significant differences just to a depth of 0.6 m. The spontaneous vegetation showed higher N levels in the 0-0.2 m layer, Nitrogen content showed significant differences just to a depth of 0.6 m. The spontaneous vegetation showed higher levels of N in the 0-0.2 m layer; however, we did not observe statistically significant differences in the C/N ratio when compared to plant cocktails. The roots of the plant cocktails showed a higher content of N in relation to spontaneous vegetation in the 0.2-0.4 m layer. The CV 1 (75% L + 25% NL) showed the lowest nitrogen content at a depth of 0.4 to 0.6 m; there was no significant difference in the C/N ratio in the surface layer and below 0.4 m. The spontaneous vegetation and CV1 (75% L + 25% NL) presented the largest C/N ratio in the 0.2-0.4 m and 0.4-0.6 m layers, respectively. In the upper layers of the soil, different fixation and nutrient absorption mechanisms were involved simultaneously, regardless of the composition of the plant cocktail. However, from 0.4 m onwards, the lowest N content in the VC1 may be associated with decreased biological activity and lower levels of N absorbing root biomass (Table 5). According to NYFELER et al. (2011), grass-legume interactions stimulate the acquisition of symbiotic and non-symbiotic nitrogen, which in turn stimulates a conversion of nitrogen into a more efficient biomass in comparison to monocultures. Apparently, mixtures of species comprising 40-60% legumes, can, due to functional diversity, contribute substantially to the productivity and efficiency of resources in agricultural systems, including grasslands.

We found significant differences in carbon and nutrient accumulation by the root system between the green manures at all evaluated depths (Table 6).

Table 6. Carbon and nutrient accumulation of carbon and nutrients by the root system of the plant cocktail and spontaneous vegetation in Typic Plinthustalf at different depths after 70 days of cultivation.

Green manure	C	N	P	K	Ca	Mg	S
	---------------------------------------kg ha^{-1}---------------------------------						
				0.0-0.2 m			
VC1	1486.3a	56.8a	3.7a	30.4a	36.2a	4.9a	4.4a
VC2	1064.6b	38.3b	2.3b	22.7b	20.0b	3.5b	3.6a
Spontaneous	619.8c	26.7b	1.5c	6.9c	12.1c	3.2b	2.3b
DMS	275.8	11.9	0.6	6.0	5.7	0.9	0.9
CV (%)	15.5	17.3	15.2	17.7	14.8	14.5	16.1
				0.2-0.4 m			
VC1	364.6b	14.1b	0.8b	6.2b	7.6b	1.0b	1.1b
VC2	635.0a	23.2a	1.4a	12.8a	15.4a	1.9a	2.2a
Spontaneous	193.1c	5.3c	0.3c	2.5c	3.3c	0.4c	0.5c
DMS	127.1	5.3	0.2	2.2	2.7	0.3	0.4
CV (%)	19.0	22.2	17.7	18.5	18.3	18.0	18.2

VC1-75% legumes (L) and 25% non-legumes (NL); VC2- 25% legumes (L) and 75% non-legumes (NL). Means followed by the same letter in the same column are not significantly different at 5% by Tukey´s test.

Table 6. Continuation.

Green manure	C	N	P	K	Ca	Mg	S
	---------------------------------------kg ha^{-1}---------------------------------						
				0.4-0.6 m			
VC1	154.9b	4.0b	0.4a	2.1b	1.9b	0.2b	0.4b
VC2	220.9a	7.1a	0.3a	4.2a	2.9a	0.3a	0.6a
Spontaneous	86.2c	2.7b	0.1b	0.6c	1.1c	0.04c	0.2c
DMS	59.7	2.3	0.1	0.7	0.7	0.05	0.1
CV (%)	23.0	29.7	22.9	18.2	21.4	19.6	20.7
				0.6-0.8 m			
VC1	79.7a	2.4a	0.2a	0.9a	0.9ab	0.1a	0.2ab
VC2	104.3a	3.3a	0.2a	0.9a	1.2a	0.1ab	0.3a
Spontaneous	89.3a	2.6a	0.1b	0.6a	0.8b	0.1b	0.2b
DMS	31.3	0.9	0.1	0.3	0.3	0.05	0.1
CV (%)	20.4	20.5	25.9	24.0	21.5	26.7	21.7
				0.8-1.0 m			
VC1	109.1a	3.1a	0.2a	0.33ab	1.1a	1.1a	0.2a
VC2	35.3b	1.2b	0.04b	0.27b	0.3b	0.03b	0.1b
Spontaneous	40.4b	1.3b	0.04b	0.34a	0.48b	0.05b	0.1b
DMS	13.6	0.4	0.02	0.07	0.14	0.11	0.03
CV (%)	13.1	13.0	13.5	13.8	13.0	16.6	13.1
				0.0-1.0 m			
VC1	2194.6	80.4	5.3	39.9	47.7	7.3	6.3
VC2	2060.1	7.1	4.2	40.9	39.8	5.8	6.8
Spontaneous	1028.8	38.6	2.0	10.9	17.8	3.8	3.3

VC1-75% legumes (L) and 25% non-legumes (NL); VC2- 25% legumes (L) and 75% non-legumes (NL). Means followed by the same letter in the same column are not significantly different at 5% by Tukey´s test.

The CV1 (75% L + 25% NL) added larger quantities of carbon and nutrients to the soil surface at the 0.2 m layer. VC2, with a predominance of non -leguminous species (25% L + 75% NL), added larger amounts of carbon and nutrients to the 0.2-0.6 m layer, coinciding with the depths with the largest biomass production. This result indicates the importance of using a "cocktail" of green manure, with diverse plant species, rather than a single legume, which is more common. There was no difference in the accumulation of carbon and nutrients between the plant cocktails in the 0.6-0.8 m layer. In the deepest layer (0.8-1.0 m), although the values were very low, the CV1 added higher amounts of carbon and nutrients to the soil, except for potassium. Spontaneous vegetation not differing from CV2, at a depth of 0.8-1.0 m and added the smallest quantities of carbon and nutrients at all depths,. The quantities accumulated along the profile (0-1 m) were higher in the CV1, except for sulphur (Table 6).

In the first year of melon cultivation, after cultivation of the plant cocktails, there was no significant interaction between the factors of green manure composition and soil management as well as the effect of isolated factors for commercial productivity, total productivity and soluble solids (Table 7). Commercial melon productivity ranged from 36.14 to 49.87 Mg ha^{-1} and a total productivity of 40.17 to 55.91 Mg ha^{-1}, values that are above the national and north eastern averages, which are 25.37 and 28.00 Mg ha^{-1} (AGRIANUAL, 2013), respectively. However, these values are lower than those found by Braga et al. (2010) when testing the use of different soil covers in yellow-type melons (commercial hybrid, not specified by the authors) in edaphoclimatic conditions similar to those in our study. The researchers obtained a total yield ranging from 59.28 to 74.63 Mg ha^{-1} and a commercial productivity from 57.50 to 73.22 Mg ha^{-1}. ARAÚJO et al. (2003), when testing different ground covers (carnauba straw, black polyethylene film, double-sided polyethylene film (silver and black) and uncovered soil) and planting methods (direct seeding and direct transplanting) also observed no significant differences in commercial productivity, with mean values ranging from 32.6 to 41.3 Mg ha^{-1}.

The soluble solids content is the characteristic that is traditionally used to determine the quality of the fruits. According to BRAGA et al. (2010), fruits with values of soluble solids above 9.0^{o} Brix are considered quality fruits with a good acceptance in the consumer market, while SALES JUNIOR et al. (2004) report that in the case of the yellow melon, fruits with 9 to 11° Brix are fully accepted. Taking these averages into consideration, we found that all treatments showed values of soluble solids within the commercial range as they were greater than 10°Brix (Table 7).

Table 7. Commercial and total yield (Mg ha^{-1}) and total soluble solids of *Cucumis melo* L. cv. 10/00, in Typic Plinthustalf cultivated after management of plant mixtures and spontaneous vegetation.

Green manure	Commercial productivity	Total productivity	Soluble solids
	---------------------------Mg ha^{-1}------------------------------------		Brix°
VC1	49.87a	55.91a	10.25a
VC2	40.71ab	43.43ab	10.24a
Spontaneous	36.14b	40.17b	10.39a
DMS	13.09	14.31	1.23
Soil management			
No tTillage	37.03b	43.36a	10.06a
Tillage	47.45a	49.64a	10.53a
DMS	8.79	9.61	0.82
CV (%)	24.29	24.10	9.21

VC1-75% legumes (L) and 25% non-legumes (NL); VC2- 25% legumes (L) and 75% non-legumes (NL). Means followed by the same letter in the same column are not significantly different at 5% by Tukey´s test.

After harvesting the fruits, it is important to quantify the residue in the soil system and to either incorporate it into the soil or leave in on the surface as covering. We observed no interaction between the composition of green manure and soil preparation systems, nor was there any significant difference between the different green manures in terms of dry biomass values and stock levels of carbon and nutrients in the melon shoots. However, significant differences were noted for the soil management factor. There was a higher dry biomass production and consequently a higher nutrient accumulation in the melon plants grown in treatments where plant cocktails and spontaneous vegetation were not rotated (Tables 8 and 9).

Table 8. Dry biomass (Mg ha^{-1}), C/N ratio, carbon and nutrients tenors (g kg^{-1}) from *Cucumis melo* L. cv. 10/00 plant residue in Typic Plinthustalf after harvesting.

Green manure	DB	C/N	C	N	P	K	Ca	Mg	S
	Mg ha^{-1}		-------------------------------g kg^{-1}------------------------						
VC1	2.87a	13.8a	350.2a	25.6a	2.4a	26.1a	53.6a	8.7a	2.3a
VC2	2.88a	12.7a	350.0a	27.9a	2.3a	24.1a	53.5a	8.8a	2.0a
Spontaneous	2.66a	13.0a	349.0a	27.1a	2.6a	24.4a	52.1a	8.6a	2.0a
DMS	0.72	1.7	16.1	0.4	0.9	3.9	8.2	1.5	0.4
Soil management									
No Tillage	3.1a	13.1a	348.9a	2.7a	2.4a	26.2a	52.7a	8.9a	1.9b
Tillage	2.5b	13.2a	350.5a	2.7a	2.5a	23.5b	53.4a	8.5a	2.4a
DMS	0.5	1.2	10.8	0.3	0.61	2.6	5.5	1.0	0.2
CV (%)	20.2	10.4	3.6	11.1	29.0	12.3	12.2	13.4	13.4

VC1-75% legumes (L) and 25% non-legumes (NL); VC2- 25% legumes (L) and 75% non-legumes (NL). Means followed by same letter in the same column do not differ from one another at 5% by Tukey test.

Table 9. Amount of carbon and nutrients accumulated (kg ha^{-1}) in the residue plants of *Cucumis melo* L. cv. 10/00 in a Typic Plinthustalf after harvest.

Green Manure	C	N	P	K	Ca	Mg	S
	----------------------------------kg ha^{-1}-----------------------------------						
VC1	1009.6a	73.6a	6.9a	75.9a	155.3a	24.9a	6.6a
VC2	1012.7a	81.0a	6.6a	69.1a	153.4a	25.3a	5.8a
Spontaneous	922.1a	72.3a	6.7a	67.1a	140.5a	23.7a	5.3a
DMS	268.7	24.6	1.7	25.4	47.2	7.4	2.0
Soil management							
No tillage	1092.2a	85.3a	7.4a	82.6a	165.6a	27.8a	5.9a
Tillage	870.8b	65.9b	6.1b	58.8b	133.9a	21.5b	5.9a
DMS	180.5	16.5	1.1	17.0	31.7	5.0	1.3
CV (%)	21.4	25.5	19.4	28.1	24.7	23.5	26.2

VC1-75% legumes (L) and 25% non-legumes (NL); VC2- 25% legumes (L) and 75% non-legumes (NL). Means followed by the same letter in the same column are not significantly different at 5% by Tukey´s test.

The low biomass quantity of the melon shoots (Table 6), average of 2.80 Mg ha^{-1}, and low C/N ratio shows that the residue, due to the presence of water and high temperatures, quickly decomposes, releasing significant quantities of nutrients into the soil system which can be absorbed by plants in the subsequent cultivation. Silva Junior et al. (2006) observed an accumulation of 0.96 Mg ha^{-1} dry biomass and 21.3, 4.8, 81.3, 74.1 and 5.5 kg ha^{-1} nitrogen, phosphorus, potassium, calcium and magnesium, respectively, in "toad skin" melon plants (10,000 plants ha^{-1}) in semi-arid conditions. The quantities of aerial biomass and nutrients were lower than those added to the soil system by the yellow melon 10/00, due to higher population density. Terceiro Neto et al. (2012) observed values lower than those in the present study, only taking the low salinity treatments into consideration for comparison purposes.

CONCLUSIONS

The cultivation of plant cocktails combined with soil tillage, regardless of their composition, is a viable alternative for adding biomass and nutrients to the soil in melon crops in semi-arid conditions, providing productivity increases.

REFERENCES

AGRIANUAL 2013: **Anuário da agricultura brasileira**. 18. ed. São Paulo, SP: Informa Economics FNP, 2013. 480 p.

ARAÚJO, A. P. et al. Rendimento de melão amarelo cultivado em diferentes tipos de cobertura do solo e métodos de plantio. **Horticultura Brasileira**, Brasília, v. 21, n. 1, p. 123-126, 2003.

ARAÚJO, G. J. F. de; da SILVA, M. M. Crescimento econômico no semiárido brasileiro: o caso do polo frutícola Petrolina/Juazeiro. **Caminhos de Geografia,** Uberlândia, v. 14, n. 46, p. 246-264, 2013.

BRAGA, M. B. et al. Produtividade e qualidade do melão submetido a diferentes tipos de cobertura de solo. **Irriga**, Botucatu, v. 15, n. 4, p. 422-430, 2010.

CARVALHO, J. L. N. et al. Potencial de sequestro de carbono em diferentes biomas do Brasil. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 34, n. 2, p. 277-289, 2010.

CAVALCANTE, V. S. et al. Biomassa e extração de nutrientes por plantas de cobertura **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 16, n. 5, p. 521–528, 2012.

DUARTE JÚNIOR, J. B.; COELHO, F. C. Adubos verdes e seus efeitos no rendimento da cana-de-açúcar em sistema de plantio direto. **Bragantia**, Campinas, v. 67, n. 3, p. 723-732, 2008.

FARIA, C. M. B. et al. Atributos químicos de um argissolo e rendimento de melão mediante o uso de adubos verdes, calagem e adubação. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 31, n. 2, p. 299-307, 2007.

GARTEN JR. C. T. et al. Intra-annual changes in biomass, carbon, and nitrogen dynamics at 4-year old switchgrass field trials in west Tennessee, USA. **Agriculture Ecosystems & Environment**, Amterdam, v. 136, n. 1-2, p. 177–184, 2010.

HAWKESFORD, M. et al. Functions of Macronutrients. In*:* MARSCHNER, P. (Ed.). **Marschner's Mineral Nutrition of Higher Plants**. Third Edition. Chapter 6, p. 135-189, 2012.

HEINZE, B. C. L. B. A. **Importância da agricultura irrigada para o desenvolvimento da Região Nordeste do Brasil**. Brasília, DF: ECOBUSINESS SCHOOL/FGV, 2002.70 p.

KÄTTERER T. et al. Roots contribute more to refractory soil organic matter than above-ground crop residues, as revealed by a long-term field experiment. **Agriculture Ecosystems & Environment**, Amterdam, v. 141, n. 1, p. 184–192, 2011.

LIMA, J. D. et al. Produção de biomassa e composição química de adubos verdes cultivados no Vale do Ribeira. **Bioscience Journal**, Uberlândia, v. 28, n. 5, p. 709-717, 2012.

MAGALHÃES, I. D. et al. Viabilidade do consórcio mamona- gergelim para a agricultura familiar no semiárido paraibano: Influência de diferentes épocas de plantio. **Revista Brasileira de Agroecologia**, Pelotas, v. 8, n. 1, p. 57-65, 2013.

MASSAD, M. D. et al. Comportamento de leguminosas anuais utilizadas como adubos verdes na região semiárida mineira. Rev. Acad., **Ciência Agrária e Ambiental**, Curitiba, v. 11, Supl. 2, p. S121-S127, 2013.

MENEZES, L. A. S. et al. Produção de fitomassa de diferentes espécies, isoladas e consorciadas, com potencial de utilização para cobertura do solo. **Bioscience Journal**, Uberlândia, v. 25, n. 1, p. 7-12, 2009.

NYFELER, D. et al. Grass legume mixtures can yield more nitrogen than legume pure stands due to mutual stimulation of nitrogen uptake from symbiotic and non-symbiotic sources. **Agriculture Ecosystms & Environment**, Amterdam, v. 140, n.1, p. 155–163, 2011.

PERIN, A. et al. Produção de fitomassa, acúmulo de nutrientes e fixação biológica de nitrogênio por adubos verdes em cultivo isolado e consorciado. **Pesquisa Agropecuária Brasileira**, Brasilia, v. 39, n. 1, p. 35-40, 2004.

RAMOS, R. F. et al. Fitossociologia de plantas daninhas na cultura do melão em dois sistemas de plantio. In: CONGRESSO BRASILEIRO DA CIÊNCIA DAS PLANTAS DANINHAS, 27, 2010, Ribeirão Preto. **Anais...** Ribeirão Preto: SBCPD, 2010. p. 1068-1072.

RODRIGUES, G. B. et al. Matéria e nutrientes da parte aérea de adubos verdes em cultivos exclusivo e consorciado. **Revista Ceres**, Viçosa, v. 59, n. 3, p. 380-385, 2012.

SALCEDO, I. H. Fertilidade do solo e agricultura de subsistência: Desafios para o Semi-arido Nordestino. In: REUNIÃO BRASILEIRA DE FERTILIDADE DO SOLO E NUTRIÇÃO DE PLANTAS, 26., 2004, Lages. **Anais...** Lages: SBCS, 2004. CDRom.

SALES JÚNIOR, R. et al. Qualidade do melão exportado pelo porto de Natal. **Horticultura Brasileira**, Brasília, v. 22, n. 1, p. 98-100, 2004.

SANTOS, J. F. dos et al. Comportamento produtivo do girassol em função de doses de nitrogênio. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, Pombal, v. 8, n. 2, p. 291 - 296, 2013.

SILVA JÚNIOR, M. J. et al. Acúmulo de matéria seca e absorção de nutrientes pelo meloeiro “Pele-de -Sapo”. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande v. 10, n. 2, p. 364-368, 2006.

De SILVA, F. A. S. E.; de AZEVEDO, C. A. V. Versão do programa computacional Assistat para o sistema operacional Windows. **Revista Brasileira de Produtos Agroindustriais**, Campina Grande, v. 4, n. 1, p. 71-78, 2002.

SILVA, F. C. da. (Ed.). **Manual de análises químicas de solos, plantas e fertilizantes**. 2. ed. Brasília, DF: Embrapa Informação Tecnológica; Rio de Janeiro: Embrapa Solos, 2009. 627 p.

SINGOGO, W. et al. Fall-planted cover crops support good yields of musck melons. **HortScience**, Alexandria, v. 31, n. 7, p. 62-64, 1996.

SOBEL, T. F.; ORTEGA, A. C. Desenvolvimento Territorial e Perímetros Irrigados: avaliação das políticas governamentais implantadas nos Perímetros Irrigados Bebedouro e Nilo Coelho em Petrolina (PE). **Planejamento e Politicas Publicas**, Brasília, v. 35, n. 2, p. 87-118, 2010.

TEODORO, R. B. et al. Aspectos agronômicos de leguminosas para adubação verde no Cerrado do Alto Vale do Jequitinhonha. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 35, n. 2, p. 635-643, 2011.

TERCEIRO NETO, C. P. C. et al. Acúmulo de matéria seca e nutrientes no meloeiro irrigado sob estratégias de manejo da salinidade. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 16, n. 10, p. 1069-1077, 2012.

ZHOU, X. Q. et al. Soil labile carbon and nitrogen pools and microbial metabolic diversity under winter crops in an arid environment. **Applied Soil Ecology**, Belfield, v. 53, n. 2, p. 49-55, 2012.

WILDNER, L. do P. Adubação verde: conceitos e modalidades de cultivo. In: LIMA FILHO, O. F.; AMBROSANO, E. J.; ROSSI, F.; CARLOS, J. A. D. (Eds.). **Adubação verde e plantas de cobertura: Fundamentos e Práticas**. Brasília: Embrapa Informação Técnológica, 2014. 2. ed., cap. 14, p. 19-44.