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Nutrients dynamics in soil solution at the outset of no-till implementation with the use of plant cocktails in Brazilian semi-arid

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Tillage systems strongly impact nutrient transformations and plant availability. Therefore, the objective of this study was to assess the impacts of conversion of conventional tillage (CT) to no-till (NT) with a mixture of cover crops and green manure as nutrient uptake in a fertilized melon (*Cucumis melon*) in a semi-arid region of Brazil. Two fields experimental involved randomized blocks design, in a split-plot scheme, with four replication treatments included three types of cover crops and two tillage systems (conventional and no-till). Subsamples of plant cocktails were used to assess the biomass production. Soil samples were analyzed during the melon growth for determination of soil moisture by the frequency domain reflectometry (FDR) probe. Soil solution samples were extracted with ceramic cups from each treatment, and analyzed for determination of TP, Na^+, Ca^{2+}, Mg^{2+}, S and NO_3-N. Mobility of these elements was assessed in relation to management and different cover crops. The data showed slight or no strong effect of plant cocktails composition on nutrients dynamics in soil under melon. However, without incorporation of biomass and slower decomposition of residue mulch retained on the surface, risks of leaching losses were lower under NT than CT system. A higher concentration of cations in CT (for example, Ca^{+2} ~ 42.07 mg L^{-1}) may be attributed to high soil moisture content and faster rate of mineralization of the biomass incorporated. Concentration of P was higher in top soil layers depth in NT system (~ 6.65 mg L^{-1} at 15 cm) because of the deposition of plant cocktail biomass in soil surface with low SOM contents placement of fertilizer, and possible formation of calcium phosphate with low solubility. Relatively, high concentration of NO_3-N (~ 60.16 mg L^{-1}) in CT was attributed to increase in decomposition of soil organic matter (SOM) and crop residues incorporated into the soil.

Key words: Macronutrient, soil fertility, cover crop, soil management, *Cocumis melo, Caatinga*.

INTRODUCTION

Soils of the semi-arid regions have been prone to degradation because of change in land cover associated with different land uses, mismanagement, and harsh climate (Lal, 2004). In the semi-arid regions of Brazil, conversion of the natural thorn forest (caatinga) into arable land is causing loss of soil organic matter (SOM), depletion of nutrients, and accelerated erosion (Wick et al., 2000). Thus, sustainability of land use systems depends on adoption of conservation agriculture (CA) methods which use cover crops to generate enough dry biomass to provide a continuous soil cover throughout the year. Thus, a mixture of cover crops, known as plant cocktail, has been evaluated for uses as cover crops and green manure in semi-arid regions of Brazil (Giongo et al., 2011).

The use of plant cocktails as cover crops can recycle nutrients from the sub-soil the surface (Carvalho et al., 2011). In addition, residues of plants cover conserves soil water by reducing runoff and evaporation, increasing water storage in the effective rooting depth, increasing plant-available water capacity, and increasing net primary production by reducing risks of drought and decreasing losses of plant nutrients by runoff, leaching and erosion (Lal, 2013).

Bohnen and Da Silva (2006) observed that no-till (NT) system changed the dynamics of nutrients in the soil in relation to conventional tillage, especially over a long-term period, although alterations in the system were observed soon after the conversion, with important effects on nutrient availability to plants. Information about composition of the soil solution may be useful in relation to environmental management, soil fertility dynamics, and plant growth (Zambrosi et al., 2008). Bohnen and Da Silva (2006) observed that higher concentrations of Ca^{2+}, Mg^{2+} PO_4^-, and K^+ were observed in surface soil layers even during the first year of conversion to NT. Ionic concentrations are affected by soil type and tillage system, and formulation of nitrogen fertilizers influence the water flux and the concentration of NO_3-N in soil solution (Sangoi et al., 2003). The reduction of water evaporation under cover crop residues in no-till systems also accentuates the downward movement of nitrate via macropores (Muzilli, 1983). Yet, high NO_3-N leaching is also observed in conventional till system, but it is attributed to the greater decomposition of SOM and of the crop residues incorporated in the soil than that in the NT system (Bayer and Mielniczuck, 1997). High concentrations of NO_3-N were also observed in the fertigated treatments, and indicated large potential for N loss by leaching (Souza et al., 2012).

Among several factors affecting nutrient movement in soil are: concentration in soil solution, adsorption capacity of the soil (Qafoku et al., 2000), loads of the complex ion exchange (Qafoku and Sumner, 2001), pH (Qafoku et al., 2000), solubility of fertilizer (Shuman, 2001), soil water content (Padilla et al., 1999) and the soil macroporosity (Shipitalo et al., 2000).

The objective of this research was to evaluate the beginning of conversion to NT with reference to the conventional tillage, and determine the effect of plant cocktails used as cover crops and green manure, in a fertilized melon (*Cucumis melo* L.) growth under semi-arid conditions of Brazil.

METHODOLOGY

The field experiment on melon was conducted at the Bebedouro Experimental Farm (latitude 09009'S, longitude 40022'W and altitude 365.5 m), Embrapa Semi-Arid (Brazilian Agricultural Research Corporation) from October to December, 2012. Before this experiment, the site was used for research on date palm crop (*Phoenix dactylifera*). There was no application of liming. The soil is classified as Ultisol dystrophic red-yellow plinthic (EMBRAPA, 2011). It has a high sand concentration of 74.87% of 0.0 to 0.2 m depth, with a gentle trend of decrease in sand content to 0.8 m depth. Thus, different soil layers are classified as sandy loam for 0.4 to 0.6 and sandy clay loam for 0.8 to 1.0 m depth (Silva et al., 2001). Analysis of composite soil samples were obtained from the experimental site for 0.0 to 0.2 m depth, according to the standard methods recommended by EMBRAPA (2011), before initiating the experiment and showed the following physical and chemical mean: CEC 0.57 ± 0.17 cmolc dm^{-3}; pH (H_2O) of 6.1 ± 0.2; P (Mehlich 1) of 46.12 ± 2.11 mg dm^{-3}; H+Al 2.14 cmolc dm^{-3}; the exchangeable value of K^+, Na^+, Ca^{2+} and Mg^{2+} of 0.36 ± 0.01, 0.03 ± 0.01, 2.33 ± 0.15, 0.43 ± 0.16 cmolc dm^{-3}, respectively; the sum of bases (S) of 3.16 ± 0.16 cmolc dm^{-3}, and base saturation (V) of 59.6 ± 1.53% (Table 1).

The climate is classified as Bswh according to the Köppen classification system, with an average annual temperature of 26.8°C, an average annual rainfall of 360 mm, and the climax vegetation called Caatinga (xeric shrubland and thorn forest). Data of air temperature (maximum and minimum), evapotranspiration and precipitation were measured at the agrometeorological weather station located at Bebedouro Experimental Farm. Plant cocktails were established in the beginning of July before the growing of melon. Melons were planted at row spacing of 0.5 m. By the end of September plant cocktails effective as a cover crop were maintained and the other parts were incorporated by a disc harrow to 40 cm depth. The treatments were arranged in four blocks in a split-plot design. Two tillage treatments as main plots had dimensions of 30 × 20 m. Conventional tillage (CT) comprised of plowing and disking compared with no soil disturbance in NT plots. Sub-plots treatments, 10 × 10 m, comprised three cropping systems (two different compositions of Plant cocktail and one natural vegetation cover): NTC1 - 75% legumes + 25% non-legumes and NT; NTC2 - 25% of legumes + 75% non-legumes and NT; NTNV - natural vegetation and NT; TC1 - 75% legumes + 25% non-legumes and CT; TC2 - 25% legumes + 75% non-legumes and CT; TNV - natural vegetation and CT. Plant species already used as green manure and cover crops adapted to semi-arid were used in this experiment. Fourteen species included in the composition of Plant cocktails, comprised legumes, oilseeds and grasses, including the

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Table 1. Results of soil analysis of composite samplings from the Bebedouro Experimental Field. Standard deviation values in brackets.

	E.C.	Ph (H_2O)	P	K	Na	Ca	Mg	Al	H+Al	S (Base)	CEC	V
Depth (m)	**dS.m^{-1}**		**mg.dm^{-3}**				**cmolc/dm^3**					%
0-20	0.57	6.10	46.12	0.36	0.03	2.33	0.43	0.50	2.14	3.16	5.30	59.67
	(0.17)	(0.20)	(2.11)	(0.01)	(0.01)	(0.15)	(0.06)	(0.0)	(0.0)	(0.16)	(0.16)	(1.53)

following species: A) Legumes - calopo (*Calopogonium mucunoide*), velvet bean (*Stizolobium aterrimum* L.), grey-seeded mucuna (*Stizolobium cinereum* Piper e Tracy), crotalaria (*Crotalaria juncea*), rattlebox (*Crotalaria spectabilis*), jack beans (*Canavalia ensiformes*), pigeon pea (*Cajanus cajan* L.), lab-lab bean (*Dolichos lablab* L.); B) no legumes: sesame (*Sesamum indicum* L.), corn (*Zea mays*), pearl millet (*Penissetum americanum* L.) and milo (*Sorghum vulgare* Pers.) sunflower (*Helianthus annuus*), castor oil plant (*Ricinus communis* L.). The natural vegetation was composed by the predominant species: benghal dayflower (*Commelina benghalensis* L.), purple bush-bean (Macroptilium atropurpureum), florida beggarweed (*Desmodium tortuosum*) and goat's head (*Acanthorpermun hispidum* DC).

Subsamples of plant cocktails from each treatment were weighted and sent to the Laboratory of Soil (Embrapa semiarid), stored in a greenhouse at 65 to 70°C for 72 h, and weight again (g kg^{-1}) was recorded to estimate the dry matter yield (Mg ha^{-1}).

Melon seeds were planted in a substrate under greenhouse and seedlings were transplanted in the field about 10 to 12 days after emergence of the first permanent leaves. One seedling per hole was transplanted at spacing of 0.3 × 2.0 m. Drip irrigation was used for both plant cocktail and melon crop. In plant cocktail, plastic pipes were distributed between the rows with drip emitters spaced at 0.5 m which provided a low flow rate of 4.0 L h^{-1}. In melon, the same plastic pipes and drip emitters were distributed between the rows with 2.0 m width. Thus, the amount of water applied was the same for all treatments and was determined on the basis of the evapotranspiration (ETo) as determined by the Class A pan evaporation (ECA). During the 70 days growth period of melon, all treatments were equally fertilized according to the specific recommendations at the rate of 38.0 kg CO(NH2)2 ha-1 (Urea - 45% N) applied 16 times, 16.0 kg KCl ha-1(60% K) applied 15 times, 67.0 kg Ca(NO3)2 ha-1 (15%N and 19%Ca) applied 5 times, 100.0 kg P2O5 ha-1 applied 8 times and 20.0 kg (NH4)H2PO4 ha-1(MAP) applied 15 times.

Dynamics of macronutrients in soil solution was studied by obtaining samples of soil solution in middle and at the end of the melon growth cycle. A PVC (1.27 cm) extractor with ceramic caps at the upper end and a fixed silicone tube for suction of soil solution were used as lysimeter. The soil solution was extracted 24 h after irrigation. This lysimetric installation consisted of 24 batteries of 3 extraction units of the soil solution. These units were installed one for each treatment in the experimental field blocks in the row at 0.15, 0.30, and 0.50 m depth. Ceramic cups were washed and immersed in deionized water until the time of installation in the field. Soil solution samples were collected in plastic bottles, properly labeled and stored at 4°C pending analyses. Soil solution samples were analyzed for total phosphorus (TP), Na^+, Ca^{2+}, Mg^{2+} and S by inductively coupled plasma optical emission spectrometry technique (ICP-OES, Perkin Elmer, USA) and NO_3-N by flow injection analysis method (FIA).

While soil solution sample were obtained at 3 times during the growing season of melon, nutrients concentration in the bulk samples were measured only for a composite sample because of the short growing cycle of only 65 to 70 days. Soil moisture content was measured to 40 cm depth at three times during the melon season: beginning of October, middle of November and middle of December, 2012. A segmented FDR probe (PR2 model - Delta T Devices) with a Dataloger HH2 moisture meter was used by installing 24 sets of 2 access tubes (1.0 m long) on the crop rows for each treatment. Soil moisture measurements were made to 0.4 m depth, which is the effective rooting depth of melon. In seasonal melons, growth in the northeast of Brazil have an effective rooting depth of 30 cm (Mota et al., 2008).

All the results were statistically analyzed for variance (ANOVA), using the ASSISTAT – free statistical program (version 7.7 beta - Federal University of Campinas Grande-Brazil). The difference between treatment means was assessed by the Tukey test, at 5 % probability.

RESULTS AND DISCUSSION

Meteorological data

The amount of precipitation received during the experimental period was small, and occurred only at the beginning of November. A high precipitation of 6.86 mm was received on November 2nd. The mean temperature during the growth period of sampling was about 28°C with the maximum of 31.06°C recorded on December 4th and minimum of 25.32°C recorded on October 1st. The pan evapotranspiration ranged from 3.71 to 8.15 mm during the growing period (Figure 1). Because of low precipitation, high temperature, and evapo-transpiration, the melon crop was irrigated every 2 days. Thus, precipitation had no influence on nutrients dynamics in soil for any treatments. Therefore, only irrigation and fertigation processes were considered as the main factors, followed by temperature and cover crop. Photodegradation is an important determinant of above-ground litter decomposition in this semi-arid ecosystem (Austin and Vivanco, 2006). The high temperature increases evatranspiration, soil metabolism process and organic matter mineralization. Thus, the principal concern is the leaching of nitrogen (Stuart et al., 2011).

Biomass yield

Figure 2 shows the dry matter (DM) for the 2 types of cocktail plant and natural vegetation. The average DM yield was 9.71 (±1.97), 10.24 (±2.85) and 5.71 (±2.51) Mg ha^{-1} for plant cocktail 1, plant cocktail 2 and natural

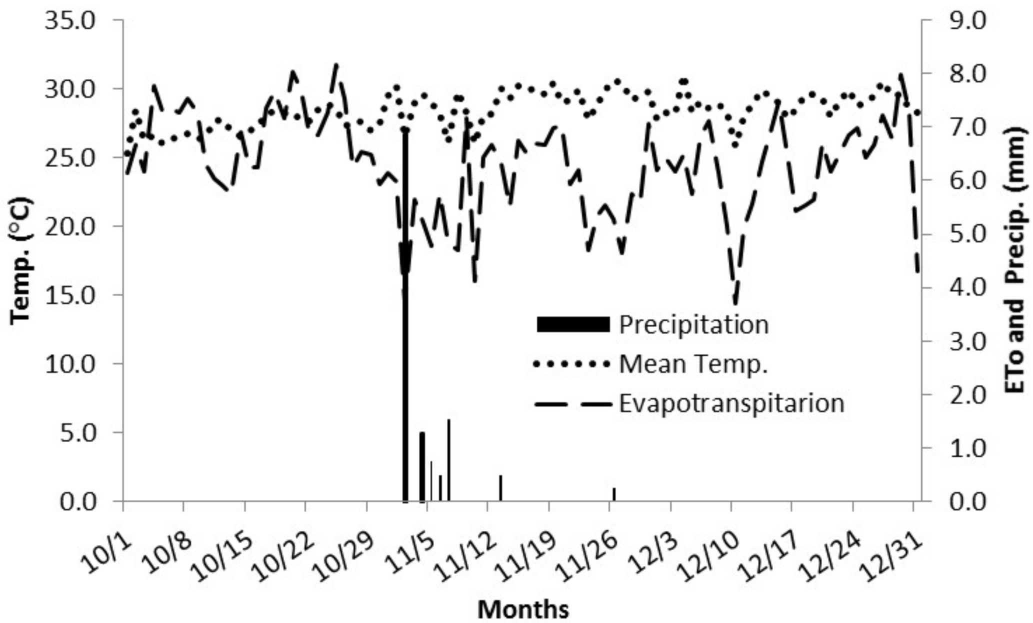

Figure 1. Mean temperature, reference evapotranspiration and precipitation in Bebedouro Experimental Field – Embrapa Semi-arid, during the period of October to December, 2012.

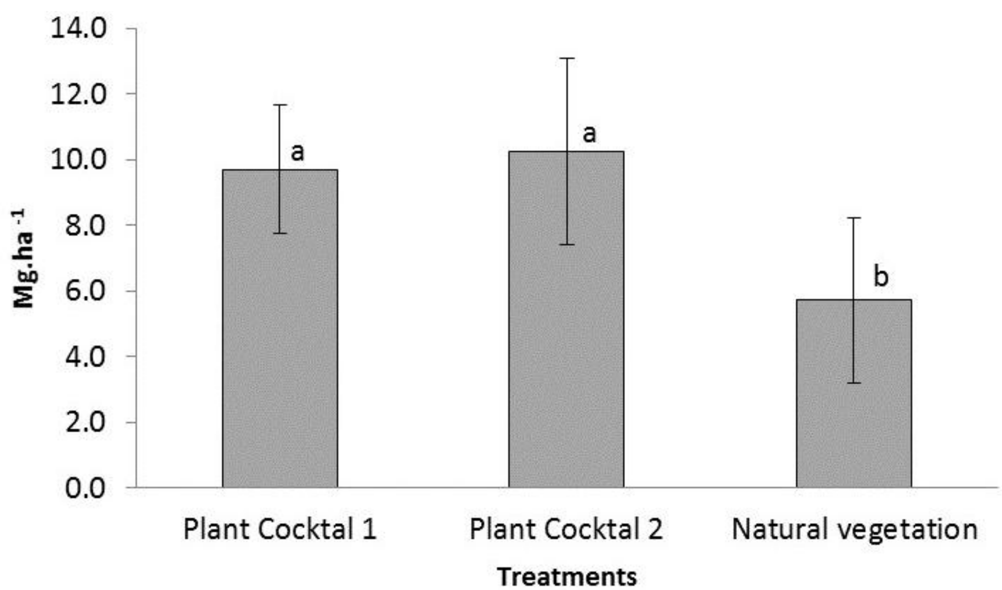

Figure 2. Dry matter yield from plant cocktails 1 and 2 compared with natural vegetation. Error bars show the standard deviation of the means. Means followed by the same letter are not significantly different by Tukey test at $P < 0.01$. LSD = 3.11 and CV% = 28.8.

vegetation, respectively. These results show the efficacy of these species as cover crops for semi-arid conditions. About 6.0 Mg ha^{-1} of plant residues is needed to provide an effective soil cover under a NT system (Alvarenga et al., 2001). However, the optimum amount may differ among plant species and edaphoclimatic conditions. The biomass produced by plants cocktails influences soil conditions, reduces nutrient losses by leaching and

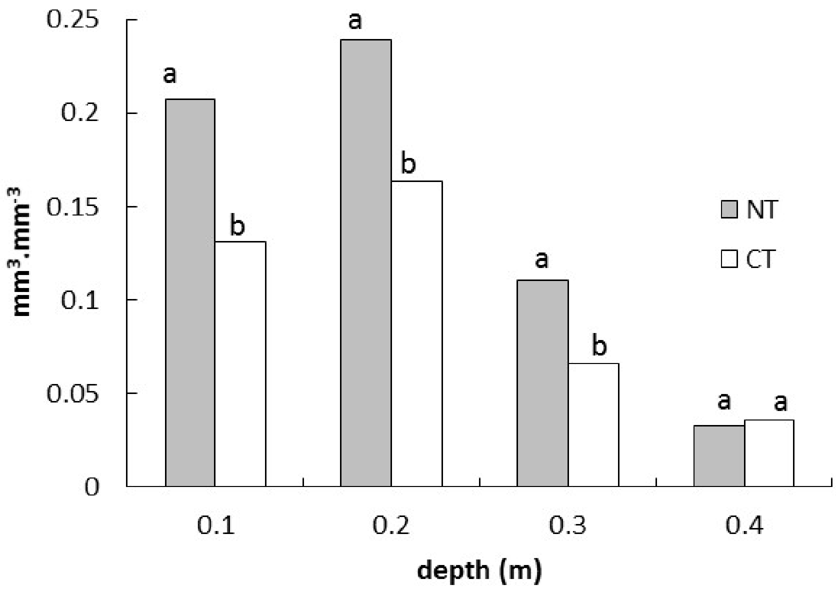

Figure 3. Variation of moisture in soil profile considering the mean of treatments under no-till (NT) and conventional tillage (CT) with the use of cocktail plants in Brazilian semi-arid. Means followed by the same letter are not significantly different by Tukey test at $P < 0.05$. LSD = 0.043

erosion, maintaining soil moisture, increases water infiltration, and reduces weed growth, recycles nutrients, especially when legume species are used, and improves soil structure especially when grasses are used (Carvalho et al., 2010). The time required to decompose half of the dry biomass of plant cocktails ranged from 116 to 173 days, depending on soil management. Relatively higher decomposition rate was observed in all plant cocktails managed with the CT (data not presented).

Soil moisture content

The soil moisture content in 0.2 m depth was higher in all treatments under NT than that CT conventional tillage, principally to depth of 0.20 m of the profile. Overall to 30 cm depth, soil moisture contents under NT treatments were significantly different than those under CT (Figure 3). In general, soils under NT store more water in the surface layer (Panachuki et al., 2015). The higher water retention in NT is attributed to the maintenance of cover crop on soil surface, which acts as a barrier, reducing water loss by evaporation (Ward et al., 2013). Despite obtaining three soil solution samples during the melon crop, only an average nutrients concentration of different layers were considered because of the short life cycle of around 65 to 70 days. Therefore, nutrients mobility and accumulation in the soil layers were verified with relation to soil management changes with different types of cover crops under drip fertigation.

Soil solution concentration

Despite of no liming, the treatments with CT (mainly TC1 and TC2) had higher concentration of Ca^{+2} in 15 cm depth (47.50 to 48.71 mg L^{-1}) than that in NTC1, NTC2 and NTNV, because of low pH, adoption of NT and low mineralization under NT than CT. Taking average concentration for two management systems (M-NT and M-CT), Ca^{+2} concentrations was 42.21 ± 34.51 mg L^{-1} under CT (Figure 4 and Table 2), and there were no significant differences among treatments for 30 cm soil depth, but trends of values were observed in the soil profile (52.97 to 65.07 mg L^{-1}).

Use of $Ca(NO_3)_2$ as fertilizer can produce a stable NO_3-N anion upon solubilization, increasing leaching of Ca^{+2} as an accompanying ion, and maintains chemical neutrality of the salt front through mass flow in soil (Ziglio and Miyazawa, 1999). Mass flow is the primary mechanism of supplying Ca^{+2}, thus soil soil solution concentration is a major factor governing this process (Silva et al., 2006). Higher soil-water content within the 30 cm layer can leach out Ca^{+2} increase in its concentration in sub-soil layers. However, mixing under of plant biomass in CT accentuates the rate of mineralization under NT system and affects the release of water-soluble organic anions, altering pH and

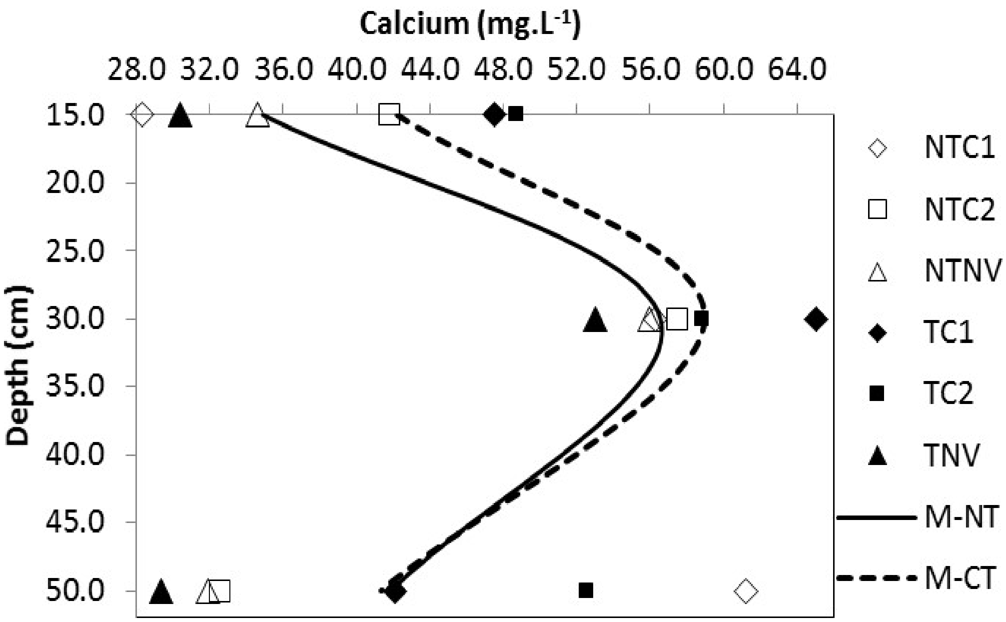

Figure 4. Concentration of calcium in the soil solution at depths of 15.0. 30.0 and 50.0 cm from two cropping systems and three different cover crop. NTC1. no-till and plant Cocktail 1; NTC2. no-till and plant Cocktail 2; NTNV. no-till and Natural vegetation; TC1. Conventional tillage and cocktail 1; TC2. Conventional tillage and cocktail 2; TNV. Conventional tillage and Natural vegetation; M-NT. means of no-tillage treatments; M-CT. means of conventional tillage treatments.

Table 2. Calcium concentration in soil solution at depths of 15.0. 30.0 and 50.0 cm for all the treatments.

Calcium (mg L^{-1})	Depth (cm)		
	15.0	30.0	50.0
NTC1	28.29^{bB}	56.24^{aA}	61.24^{aA}
NTC2	41.75^{abB}	57.49^{aA}	32.56^{cB}
NTNV	34.64^{abB}	55.92^{aA}	31.88^{cB}
TC1	47.50^{aB}	65.07^{aA}	42.07^{bcB}
TC2	48.71^{aA}	58.81^{aA}	52.54^{abA}
TNV	30.40^{bB}	52.97^{aA}	29.33^{cB}
M-NT	34.90 (29.38)	56.55 (34.59)	41.90 (18.85)
M-CT	42.21 (34.51)	58.95 (35.66)	41.32 (18.22)

Values followed by the same letter do not differ by Tukey test at 5% probability. Columns - lower case (LSD = 15.80); Lines - capital letters (LSD = 12.96). CV% = 23.01.

enhancing the mobilization of Ca^{+2} within the soil (Silva et al., 2006). The highest concentrations of Ca^{+2} observed at 50 cm soil depth (42.07 mg L^{-1}) was under NRC1, but these mean concentrations of Ca^{+2} at this depth were similar among all treatments. There were significant differences in Ca^{+2} concentrations at 15 and 50 cm depths of TC1 and TC2 than that of TNV, probably because of the mineralization of plant cocktails biomass incorporated into the soil, which is higher than that under the native vegetation regrowth.

Both Ca^{+2} and Mg^{+2} cations have a similar behavior in soil (Stinner et al., 1984). Thus, a proportional concentration of those cations was computed. The data show that moderate amounts of Mg^{+2} were leached from the top soil to 50 cm depth (Figure 5). However, no significant differences were observed among treatments and depth. Similar to Ca^{+2}, concentrations of Mg^{+2} was also the lowest at 15 cm depth, and mean concentration ranged from 3.77 mg L^{-1} in TNV to 6.67 mg L^{-1} in NTNV. Concentrations of Mg^{+2} were high at 30 cm depth in all

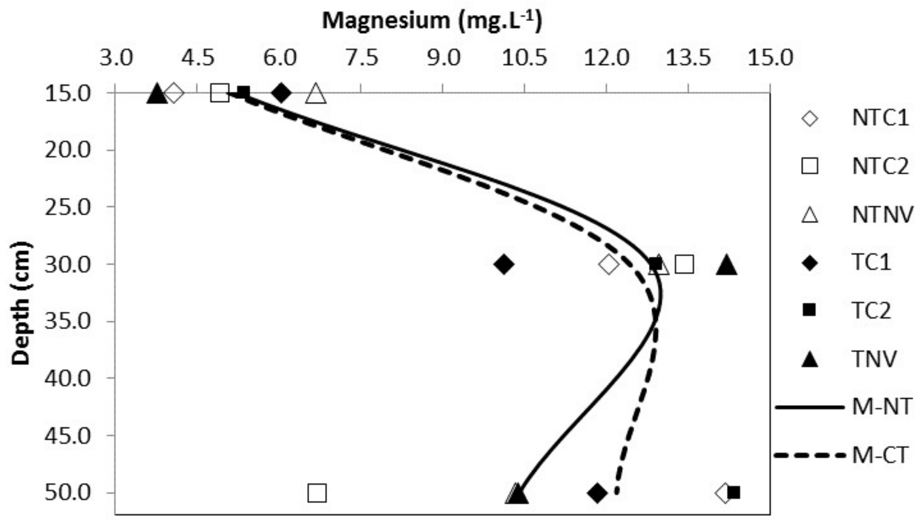

Figure 5. Concentration of magnesium in the soil solution at depths of 15.0. 30.0 and 50.0 cm from two cropping systems and three different cover crop. NTC1. no-till and plant Cocktail 1; NTC2. no-till and plant Cocktail 2; NTNV. no-till and Natural vegetation; TC1. Conventional tillage and cocktail 1; TC2. Conventional tillage and cocktail 2; TNV. Conventional tillage and Natural vegetation; M-NT. means of no-tillage treatments; M-CT. means of conventional tillage treatments

Table 3. Magnesium concentration in soil solution at depths of 15.0. 30.0 and 50.0 cm for all the treatments.

Magnesium (mg L^{-1})	Depth (cm)		
	15.0	30.0	50.0
NTC1	4.07^{aB}	12.03^{aA}	14.17^{aA}
NTC2	4.91^{aB}	13.43^{aA}	6.69^{bB}
NTNV	6.67^{aB}	12.95^{aA}	10.33^{abAB}
TC1	6.03^{aB}	10.12^{aA}	11.82^{aA}
TC2	5.35^{aB}	12.91^{aA}	14.33^{aA}
TNV	3.77^{aC}	14.19^{aA}	10.38^{abB}
M-NT	5.22 (5.69)	12.81 (9.15)	10.40 (5.16)
M-CT	5.06 (7.20)	12.41 (8.21)	12.18 (5.91)

Values followed by the same letter do not differ by Tukey test at 5% probability. Columns - lower case (LSD = 4.63); Lines - capital letters (LSD = 3.81). CV% = 40.68.

treatments, and the highest concentration of 14.19 mg L^{-1} in TNV. These trends indicate high mobility of Mg^{+2} in the soil followed by that of Ca^{+2} (Table 3).

The mean concentration of Na^{+} in soil solution reached from 3.81 to 8.16 mg L^{-1}, and there were no significant differences among treatments for 15 and 30 cm depths. Mean concentration of Na^{+} for treatments in the same management system (M-NT; M-CT) indicated similar values for different soil depths. However, concentration of Na^{+} in soil solution was slightly higher for TC1 and TC2 than that for NT treatments (NTC1 and NTC2), and the mean concentration ranged from 3.95 to 5.61 mg L^{-1} (Figure 6, Table 4). Tillage and crop residue management can strongly affect water relations and leaching of soluble salt (Dalal, 1989). Similar concentrations of Na+ were observed in all treatments probably because of a soil moisture content in all depths. The highest of concentration of > 8.0 mg L^{-1} was recorded at 50 cm depth. Salt accumulation in the profile is primarily controlled by the amount of salts released and leached from the soil and the amount of salts leaving the soil by percolation (Gupta and Abrol, 1990).

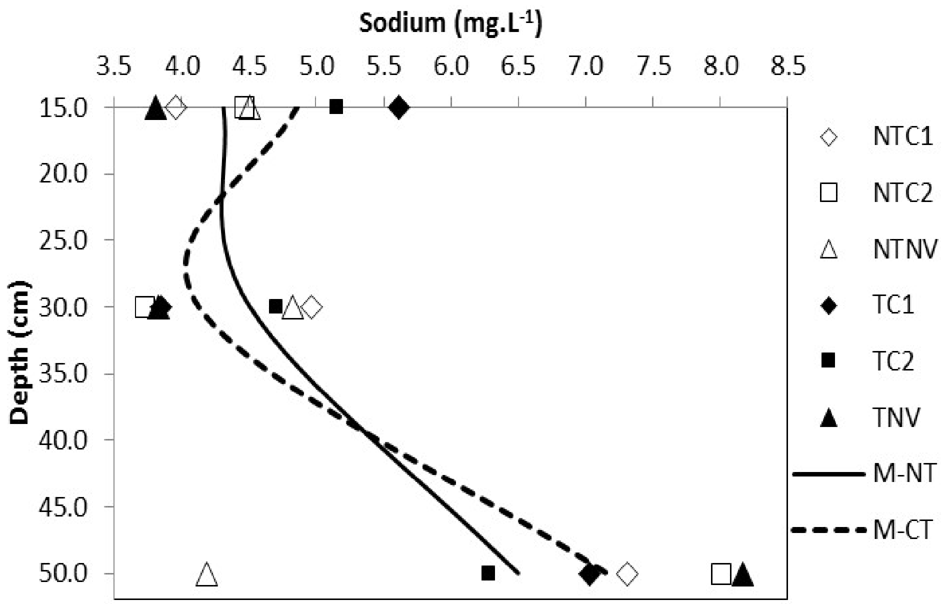

Figure 6. Concentration of sodium in the soil solution at depths of 15.0. 30.0 and 50.0 cm from two cropping systems and three different cover crop. NTC1. no-till and plant Cocktail 1; NTC2. no-till and plant Cocktail 2; NTNV. no-till and Natural vegetation; TC1. Conventional tillage and cocktail 1; TC2. Conventional tillage and cocktail 2; TNV. Conventional tillage and Natural vegetation; M-NT. means of no-tillage treatments; M-CT. means of conventional tillage treatments.

Table 4. Sodium concentration in soil solution at depths of 15.0. 30.0 and 50.0 cm for all the treatments.

Sodium (mg L^{-1})	Depth (cm)		
	15.0	30.0	50.0
NTC1	3.95^{abB}	4.96^{aB}	7.30^{abA}
NTC2	4.46^{abB}	3.72^{aB}	8.00^{abA}
NTNV	4.51^{abA}	4.82^{aA}	4.18^{cA}
TC1	5.61^{aA}	3.85^{aB}	7.02^{abA}
TC2	5.15^{abAB}	4.70^{aB}	6.27^{bA}
TNV	3.81^{bB}	3.83^{aB}	8.16^{aA}
M-NT	4.31 (2.21)	4.51 (2.34)	6.50 (2.88)
M-CT	4.86 (2.56)	4.13 (1.99)	7.16 (3.81)

Values followed by the same letter do not differ by Tukey test at 5% probability. Columns - lower case (LSD = 1.75); Lines - capital letters (LSD = 1.44); CV% = 28.35.

There were no significant differences among treatments in SO_4^{-2} concentration for 15 and 50 cm depth, and the mean concentration ranged from 10.34 ± 4.52 (M-CT) to 10.99 ± 4.34 (M-NT). In general, in SO_4^{-2} on agrosystem is rapidly cycled and easily leached (Silva et al., 1999). Despite the highest SO_4^{-2} concentration observed at 50 cm depth in the present study, high concentration of 14.27 mg L^{-1} (TEV), at 15 cm depth indicates its low mobility (Figure 7 and Table 5). Because at low mobility of SO_4^{-2} compared with Cl, N etc, it moves in soil by mass flow in the water (Vitti et al., 1994). When sulfur is not added in the soil, any slight increase in soil solution is attributed to mineralization of biomass and SOM (Miranda et al., 2006) and its leaching along with water. Despite lack of any significant differences among treatments, the CT treatments trended to have higher SO_4^{-2} concentration below 30 cm depth, because of decomposition of incorporated biomass and high soil moisture content. Stratification in SO_4^{-2} may also occur during early stages than in long-term condition of NT (Crozier et al., 1999).

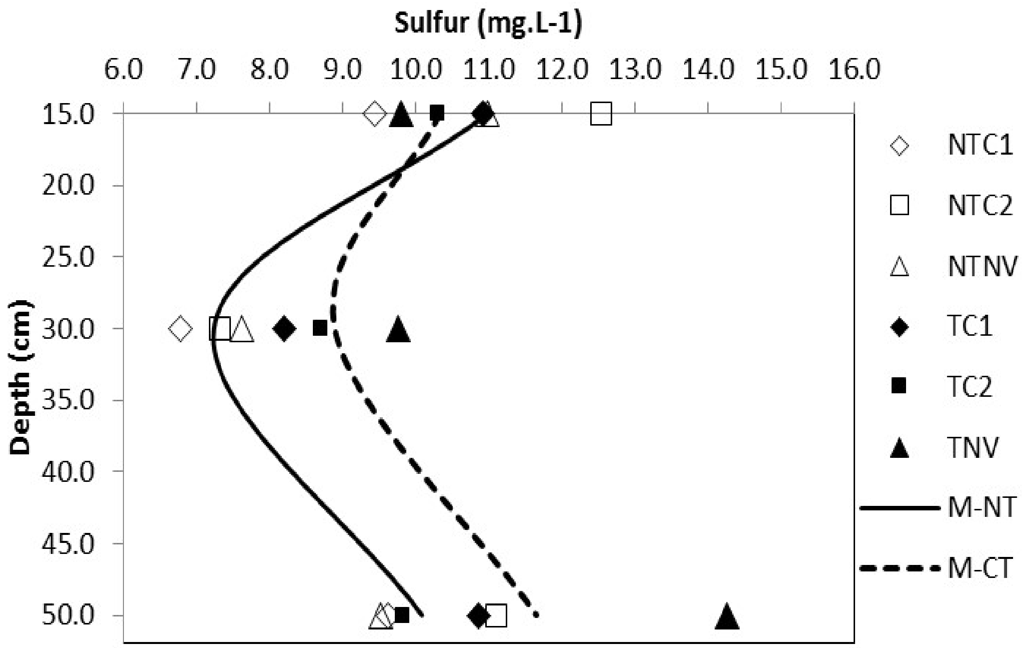

Figure 7. Concentration of sulfur in the soil solution at depths of 15.0. 30.0 and 50.0 cm from two cropping systems and three different cover crop. NTC1. no-till and plant Cocktail 1; NTC2. no-till and plant Cocktail 2; NTNV. no-till and Natural vegetation; TC1. Conventional tillage and cocktail 1; TC2. Conventional tillage and cocktail 2; TNV. Conventional tillage and Natural vegetation; M-NT. means of no-tillage treatments; M-CT. means of conventional tillage treatments.

Table 5. Sulfur concentration in soil solution at depths of 15.0. 30.0 and 50.0 cm for all the treatments.

Sulfur (mg L^{-1})	Depth (cm)		
	15.0	30.0	50.0
NTC1	9.43^{bA}	6.78^{bB}	9.61^{bA}
NTC2	12.54^{aA}	7.31^{abB}	11.11^{bA}
NTNV	10.98^{abA}	7.61^{abB}	9.53^{bAB}
TC1	10.91^{abA}	8.20^{abB}	10.86^{bA}
TC2	10.29^{abA}	8.69^{abA}	9.82^{bA}
TNV	9.79^{bB}	9.75^{aB}	14.27^{aA}
M-NT	10.99 (4.34)	7.24 (3.12)	10.09 (5.07)
M-CT	10.34 (4.52)	8.89 (2.29)	11.65 (3.75)

Values followed by the same letter do not differ by Tukey test at 5% probability. Columns - lower case (LSD = 2.67); Lines - capital letters (LSD = 2.19); CV% = 23.01.

Expectedly, the P concentrations varied strongly with soil depth from 6.65 mg L^{-1} at 15 cm to 0.13 mg L^{-1} (NTC2) at 50 cm soil depth (Figure 8). The highest P concentrations recorded in topsoil indicated its low mobility in soil profile. There were significant differences in P concentrations among NT treatments (NTC1, NTC2 and NTEV) and CT treatments (TC1, TC2 and TEV) (Table 6). Despite high value of P concentration in the surface layer, there were no significant differences between NT and CT at 30 cm depth. Because of minimal soil erosion in NT and the location of fertilizer, high accumulation of P in the surface layer can be 10 times compared to that in the surface layers (Muzilli, 1983; Rheinheimer et al., 1998).

Soil of the experimental site is slightly acidic, and thus has a low potential of formation of SOM in treatments other than NT. Under these conditions of soil pH approaching to neutral value, soluble phosphorus is

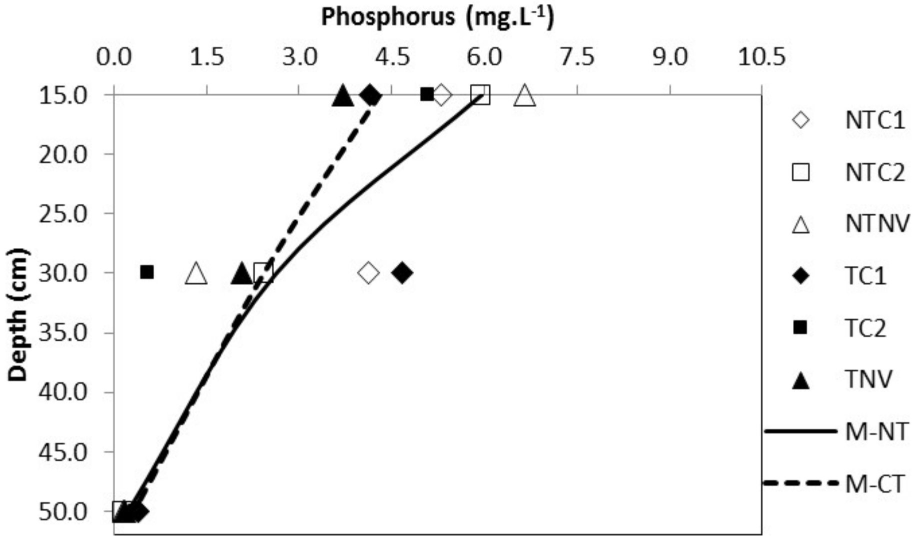

Figure 8. Concentration of phosphorus in the soil solution at depths of 15.0. 30.0 and 50.0 cm from two cropping systems and three different cover crop. NTC1. no-till and plant Cocktail 1; NTC2. no-till and plant Cocktail 2; NTNV. no-till and Natural vegetation; TC1. Conventional tillage and cocktail 1; TC2. Conventional tillage and cocktail 2; TNV. Conventional tillage and Natural vegetation; M-NT. means of no-tillage treatments; M-CT. means of conventional tillage treatments.

Table 6. Phosphorus concentration in soil solution at depths of 15.0. 30.0 and 50.0 cm for all the treatments.

Phosphorus (mg L^{-1})	Depth (cm)		
	15.0	30.0	50.0
NTC1	5.31^{bcA}	4.12^{aB}	0.40^{aC}
NTC2	5.93^{abA}	2.43^{bB}	0.13^{aC}
NTNV	6.65^{aA}	1.33^{bcB}	0.16^{aC}
TC1	4.16^{cdA}	4.67^{aA}	0.4^{aB}
TC2	5.08^{bcA}	0.56^{cB}	0.35^{aB}
TNV	3.72^{dA}	2.07^{bB}	0.19^{aC}
M-NT	5.96 (4.34)	2.63 (2.10)	0.23 (0.23)
M-CT	4.32 (2.13)	2.43 (2.14)	0.31 (0.25)

Values followed by the same letter do not differ by Tukey test at 5% probability. Columns - lower case (LSD = 1.29); Lines - capital letters (LSD = 1.06); CV% = 41.50.

transformed into low solubility form of calcium phosphate in the soil surface (Souza et al., 2012). Nonetheless, drip fertilization can increase PO_4^{-3} movement into the sub-soil compared to that with the conventional application because of concentration of the soil in a narrow range, which quickly saturates soil in vicinity of the zone of application (Villas Boas et al., 1999). However, that process depends of soil attributes and the specific formulation used (Souza et al., 2012).

Mean concentration of NO_3-N ranged from 19.45 mg L^{-1} at 15 cm to 60.16 mg L^{-1} at 50 cm soil depth, indicating high leachability (Figure 9). However, no significant differences were observed between NT and CT treatments for 15 cm depth, albeit a high value of 42.14 mg L^{-1} was recorded for TC2. The high soil moisture content at ~ 30 cm depth concentrated high NO_3-N in this layer in all treatments, with average value of 54.27 (43.10) mg L^{-1} to NT and 54.62 (43.97) mg L^{-1} to CT. At 50 cm depth, however, higher NO_3-N concentration is observed in TC1 (60.16 mg L^{-1}) and TC2 (59.19 mg L^{-1}) treatments (Table 7). Bayer and Mielniczuck (1997) observed more leaching of NO_3-N in CT system because

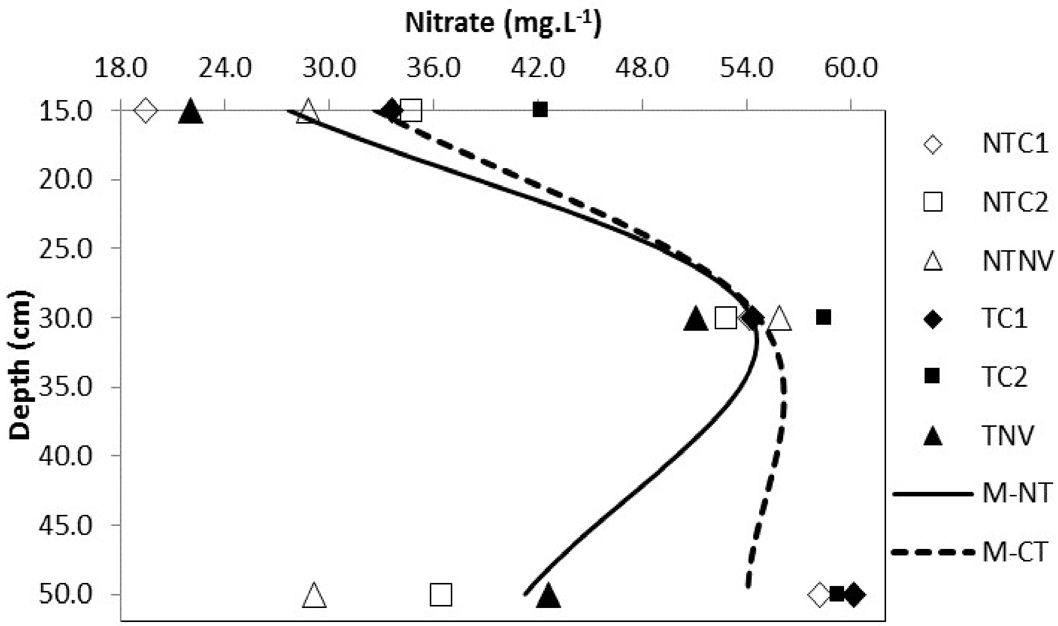

Figure 9. Concentration of nitrate in the soil solution at depths of 15.0. 30.0 and 50.0 cm from two cropping systems and three different cover crop. NTC1. no-till and plant Cocktail 1; NTC2. no-till and plant Cocktail 2; NTNV. no-till and Natural vegetation; TC1. Conventional tillage and cocktail 1; TC2. Conventional tillage and cocktail 2; TNV. Conventional tillage and Natural vegetation; M-NT. means of no-tillage treatments; M-CT. means of conventional tillage treatments.

Table 7. Nitrate concentration in soil solution at depths of 15.0. 30.0 and 50.0 cm for all the treatments.

Nitrate ($mg.L^{-1}$)	Depth (cm)		
	15.0	30.0	50.0
NTC1	19.45^{bB}	54.16^{aA}	58.21^{abA}
NTC2	34.66^{abB}	52.82^{aA}	36.37^{cB}
NTEV	28.76^{abB}	55.83^{aA}	29.13^{cB}
TC1	33.57^{abB}	54.29^{aA}	60.16^{aA}
TC2	42.14^{aB}	58.48^{aA}	59.19^{aA}
TEV	22.03^{bB}	51.10^{aA}	42.61^{bcA}
M-NT	27.62 (28.49)	54.27 (43.10)	41.24 (22.06)
M-CT	32.58 (32.58)	54.62 (43.97)	53.99 (26.69)

Values followed by the same letter do not differ by Tukey test at 5% probability. Columns - lower case (LSD = 16.08); Lines - capital letters (LSD = 13.19). CV% = 30.99.

of increased decomposition of SOM and crop residues incorporated in the soil compared to the NT system. Leaching of NO_3-N below the rooting depth of melon is a major concern. Therefore, a split application of fertilizer can reduce leaching losses in sand soils.

Stinner et al. (1984) observed that concentrations of NO_3-N were the highest in CT those in NT soils. Indeed, nitrification is reduced in NT compared with that CT soil because NH_4-N is the predominant form of N in NT soil (Souza et al., 2012). In addition, use of $Ca(NO_3)_2$ with drip fertigation leads to a uniform distribution of NO_3-N in the soil profile (Haynes, 1990). Leaching of NO_3-N requires presence of accompanying cations, while the protons produced by ammonium nitrification or organic by nitrogen are remain in the surface layer as a source of potential acidity (Franchini et al., 2000). The data from this study indicate between the cations ($Ca^{+2}$and Mg^{+2}) and the anion (NO_3-N) for all the treatments and soil

Table 8. Correlation between the concentrations of cations (calcium and magnesium) and nitrate for all the treatments.

Treatment	Equation[a]	r^2
NTC1	Cations = 0.9611 N-NO_3^-+ 13.621	0.77*
NTC2	Cations= 0.9568 N-NO_3^-+ 13.854	0.79*
NTNV	Cations = 0.9554 N-NO_3^-+ 13.98	0.81*
TC1	Cations = 0.9528 N-NO_3^-+ 14.117	0.82*
TC2	Cations = 0.9611 N-NO_3^-+ 13.308	0.84*
TNV	Cations = 0.9539 N-NO_3^-+ 13.825	0.82*
Total[b] Cations = 0.9611 N-NO_3^- + 13.308 0.84*		

[a]Considering the three depths. [b]Considering the 6 treatments in three depths. *Significant t test P < 0.001.

depths studied (r^2 = 0.84; p < 0.001) (Table 8), suggesting that Ca^{+2} and Mg^{+2} are the accompanying cations. The use of $Ca(NO_3)_2$ as fertilizer produces $Ca^{+2}$and Mg^{+2} which accentuates the mobility of Ca^{+2} and Mg^{+2} and maintains chemical neutrality of the salt front by mass flow (Ziglio and Miyazawa, 1999).

Conclusions

The data presented support the following conclusions:

(i) There was either slight or no strong effect of plant cocktails composition on nutrients dynamics in soil under melon. Perhaps, the short time of melon growing cycle crop was not long enough to cause a substantial mineralization of the cocktail biomass. Nonetheless, some changes were observed with the adoption of NT system.
(ii) Without incorporation of biomass and slower decomposition of residue mulch retained on the surface, risks of leaching losses were lower under NT then CT system.
(iii) The higher concentrations of cations (that is, Ca^{+2}) in CT may be attributed to a high soil moisture content and faster rate of mineralization of the biomass incorporated.
(iv) In general, S had a low mobility. Concentration of S was high in CT from 30 cm depth because of the high rate of decomposition of plants biomass incorporated and high soil moisture content.
(v) Concentration of P was higher in top soil layers depth in NT system, because of the deposition of plant cocktail biomass in soil surface with low SOM contents placement of fertilizer, and possible formation of calcium phosphate with low solubility.
(vi) Concentration of NO_3-N was high and large amount were leached into the sub-soil. However, high concentration of NO_3-N in CT may be attributed to increase in decomposition of SOM and crop residues incorporated into the soil.

Conflict of Interests

The authors have not declared any conflict of interest

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