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NITRATE IN SOIL SOLUTION WITH USE OF PLANT COCKTAILS AS GREEN MANURE IN DIFERENT TILLAGE SYSTEMS IN THE BRAZILIAN SEMI-ARID

NITRATO EN LA SOLUCIÓN DEL SUELO CON EL USO DE CÓCTELES DE PLANTAS COMO ABONO VERDE EN DIFERENTES SISTEMAS DE LABRANZA EN EL SEMIÁRIDO BRASILEÑO

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ABSTRACT

Tillage systems strongly affect nutrient transformations and plant availability. The objective of this study was to assess the nitrate dynamic in soil solution in different tillage systems with use of plant cocktail as green manure in fertilized melon (*Cucumis melon*) in Brazilian semi-arid. The treatments were arranged in four blocks in a split-plot design and included three types of cover crops and two tillage systems, conventional tillage (CT) and no-till (NT). The data showed no strong effect of plant cocktails composition on NO_3-N dynamic in the soil. 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. No significant differences were observed between NT and CT treatments for 15 cm depth. The high soil moisture content at ~ 30 cm depth concentrated high NO_3-N in all treatments, mean of 54.27 mg L-1 to NT and 54.62 mg L-1 to CT. The highest NO3-N concentration was observed at 50 cm depth in TC (60.16 mg L-1). High concentration of NO_3-N in CT may be attributed to increase in decomposition of soil organic matter and crop residues incorporated into the soil.

KEY WORDS: Macronutrient; soil fertility, cover crop; soil management.

RESUMEN

Los sistemas de labranza afectan fuertemente a las transformaciones de nutrientes y la disponibilidad de la planta. El objetivo de este estudio fue evaluar la dinámica de nitrato en la solución del suelo en diferentes sistemas de labranza con uso de cóctel de plantas como abono verde en el melón fertilizado (*Cucumis melon*) en el semiárido brasileño. Los tratamientos se dispusieron en cuatro bloques con parcelas divididas que incluyeron tres tipos de cultivos de cobertura y dos sistemas de labranza, labranza convencional (LC) y siembra directa (SD). Los datos mostraron ningún fuerte efecto de la composición de cócteles de plantas en el dinámico de NO_3-N en el suelo. La media de concentración de NO_3-N varió de 19.45 mg L^{-1} a 15 cm a 60,16 mg L^{-1} a 50 cm de profundidad del suelo, que indicó una alta capacidad de lixiviación. No se observaron diferencias significativas entre los tratamientos LC y SD en 15 cm de profundidad. El alto contenido de humedad del suelo a ~ 30 cm de profundidad concentró alta NO_3-N en todos los tratamientos, con una media de 54,27 mg L^{-1} a SD y 54.62 mg L^{-1} a la LC. Se observó que la mayor concentración de NO_3-N a 50 cm de profundidad fue en LC (60,16 mg L^{-1}). La alta concentración de NO_3-N en la LC puede ser atribuido al aumento de la descomposición de la materia orgánica y de los desechos vegetales incorporados en el suelo.

PALABRAS CLAVE: Micronutriente; fertilidad del suelo; cultivo de cobertura; manejo del suelo.

INTRODUCTION

The use of plant cocktails as cover crops can recycle nutrients from the sub-soil to 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, 2008). Ionic concentrations are affected by soil type and tillage system, and formulation of nitrogen fertilizers influence the water flux and the concentration of NO3-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 macrospores (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).

The objective of this study was to evaluate the nitrate dynamic in soil solution in different tillage systems with use of plant cocktail as green manure in fertilized melon (*Cucumis melon*) in Brazilian semi-arid.

MATERIAL AND METHODS

The field experiment was conducted at the Bebedouro Experimental Farm, Embrapa Semi-Arid (Brazilian Agricultural Research Corporation) from October to December 2012. The soil is classified as Ultisol dystrophic red-yellow plinth with the following physical and chemical mean for 0.0 to 0.2 m depth: 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, 0.0 3±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% (EMBRAPA, 2011). 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. Meteorological data 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. 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): NTC -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.

Fourteen species included in the composition of Plant cocktails, comprised legumes, oilseeds and grasses: 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, stored in a greenhouse at 65 to 70°C for 72 h, and weight again (g kg^{-1}) and 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 which provided a low flow rate of 4.0 L h^{-1}. 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 growth period of melon, all treatments were equally fertilized with 38.0 kg $CO(NH_2)_2$ ha^{-1} (Urea - 45% N), 67.0 kg $Ca(NO_3)_2$ ha^{-1} (15%N and 19%Ca).

Nitrate dynamic was studied by obtaining samples of soil solution in the beginning, 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. 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 NO_3-N by flow injection analysis method (FIA) and the cations $Ca^{2+}$and Mg^{2+} by inductively coupled plasma optical emission spectrometry technique (ICP-OES, Perkin Elmer, USA). Soil moisture content was measured to 40 cm depth at three times during the melon season, by 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.

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

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 (Figure 1).

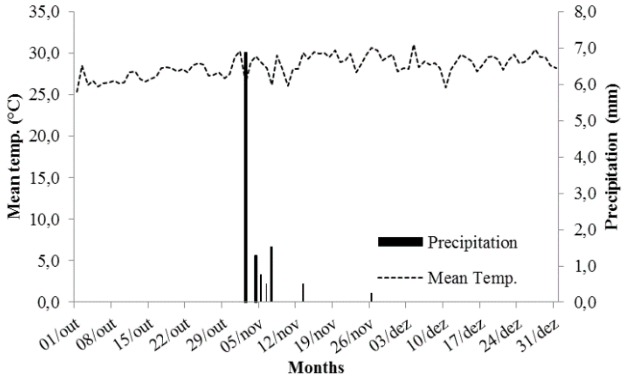


Figure 1. Mean temperature, and precipitation in Bebedouro Experimental Field – Embrapa Semi-arid, during the period of October to December, 2012.

Because of low precipitation and high temperature, 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. 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).

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 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 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).

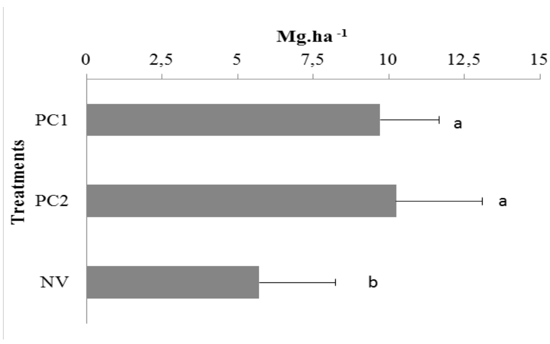


Figure 2. Dry matter yield from plant cocktails 1 and 2 compared with natural vegetation. Error bars show the standard deviation of the means. Means followed by the same letter are not significantly different by Tukey test at P < 0.01. LSD = 3.11 and CV% = 28.8

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). Despite obtaining three soil solution samples during the melon crop, only an average nitrate concentration of different layers were considered because of the short life cycle, around 65 to 70 days. Therefore, nitrate mobility and accumulation in the soil layers were verified with relation to soil management changes with different types of cover crops under drip fertigation.

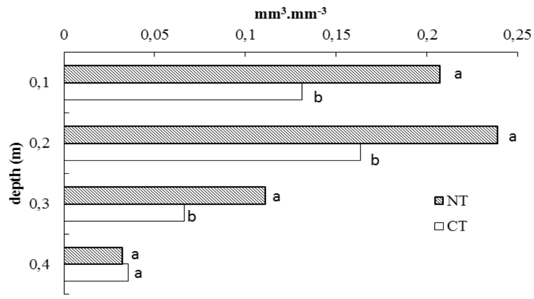
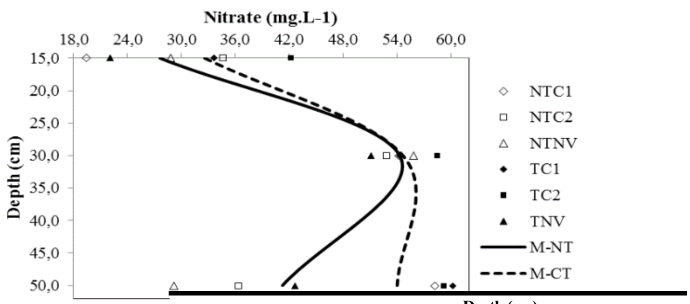


Figure 3. Variation of moisture in soil profile considering the mean of treatments under no-till (NT) and conventional tillage (CT) with the use of cocktail plants in Brazilian semi-arid. Means followed by the same letter are not significantly different by Tukey test at $P < 0.05$. LSD = 0.043

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 4). 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 1). Bayer and Mielniczuck (1997) observed more leaching of NO_3-N in CT system because 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).

Table 1. Nitate concentration in soil solution at depths of 15.0. 30.0 and 50.0 cm for all the treatments

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.



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)

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 depths studied (r^2 = 0.84; $p < 0.001$) (Table 2), 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).

Table 2. Correlation between the concentrations of cations (Ca^{+2} and Mg^{+2}) and nitrate for all the treatments.

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

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

CONCLUSIONS

The data presented support the following conclusions:

- There was slight or no strong effect of plant cocktails composition on nitrate dynamic in soil. 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;

- Because of the biomass retention on the soil surface, which promotes a lower residue decomposition process, the risk of loss of nitrate through leaching become lower in no-till than in conventional tillage;

- Concentration of NO_3-N was high and large amount were leached into the sub-soil. However, high con-centration of NO_3-N in CT may be attributed to increase in decomposition of SOM and crop residues incorporated into the soil;

- The high soil moisture content at ~ 30 cm depth promoted high NO_3-N concentration in all treatments;

- The strong correlation between cations and nitrate indicates that its leaching requires the presence of accompanying cations.

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