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JANINE COLARES GADELHA

MATÉRIA ORGÂNICA E NUTRIENTES EM AGROECOSSISTEMAS SOB CULTIVO ORGÂNICO E IRRIGADO

FORTALEZA
2015

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Tese apresentada ao Curso de Doutorado em Ecologia e Recursos Naturais do Departamento de Biologia da Universidade Federal do Ceará, como parte dos requisitos para obtenção do título de Doutora em Ecologia e Recursos Naturais. Área de concentração: Conservação dos Recursos Naturais.

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RESUMO

Pela necessidade de entender o funcionamento e a dinâmica da matéria orgânica do solo em locais onde esse recurso está disponível em altas quantidades (sistemas orgânicos) e como essa dinâmica pode ser afetada pela interação entre a matéria orgânica e os fatores que estão presentes no sistema como o tipo de solo, o clima, e o manejo utilizado, esse estudo teve como objetivo geral avaliar os efeitos da matéria orgânica e nutrientes adicionados ao solo via compostos orgânicos, quantificando os mesmos com enfoque nas propriedades químicas do solo, o tempo e teores de armazenamento desse nutrientes, a forma de liberação dos mesmos pela ação da irrigação e sombreamento nos insumos aplicados em pomares de acerola orgânica. A pesquisa foi desenvolvida na fazenda Amway Nutrilite do Brasil localizada na região da Ibiapaba, estado do Ceará no período de fevereiro de 2011 a abril de 2013. Áreas com um, seis e dez anos de manejo orgânico foram investigadas. Entradas e saídas de substâncias na cultura foram medidas, os solos foram analisados quanto aos teores de nutrientes (N, P, K, Ca, Mg), matéria orgânica (MO), densidade e propriedades químicas, condutividade elétrica (CE), soma de bases trocáveis (SEB), capacidade de troca catiônica efetiva (ECEC) a pH 7 (CEC) e índice de saturação por bases (IBS). As amostras foram coletadas em quatro profundidades (0 a 20; 20 a 50; 50 a 100; 100 a 150 cm) nas linhas e entrelinhas. Uma parte experimental foi desenvolvida com auxílio de caixas de decomposição feitas de forma retangular com uma base e suas laterais menores de malha de 4 milímetros e as laterais maiores de PVC, e uma tampa da mesma malha. Foram preenchidas com o composto utilizado na fazenda e avaliadas em sete tempos (0, 2, 4, 6, 8, 10, 12 meses) após a montagem, as quantidades restantes de composto foram pesadas e sua umidade calculada, bem como a quantidade de nutrientes presentes, as taxas de decomposição e os valores de meia vida foram calculados. Solos sob as caixas de decomposição foram analisados antes e depois da remoção das caixas para os teores de nutrientes (N, P, K, Ca, Mg) e carbono orgânico, em três profundidades (0 a 5, 5 a 10, 10 a 20 cm). As propriedades químicas diminuíram com a profundidade, e o carbono orgânico e teores de nutrientes aumentaram com as crescentes quantidades de MO e nutrientes aplicados. Apenas uma pequena percentagem da MO aplicada permaneceu no solo a 150 cm de profundidade. Grande parte do K, Ca, Mg aplicados não estavam presentes no solo e o P disponível (P_{M1}) era uma proporção menor do P aplicado. A MO foi positivamente relacionada com a CE, P_{M1}, K, Ca, Mg, SEB, ECEC, CEC, IBS e N. A cultura recuperou parte significativa do K e N aplicado, mas Ca, Mg e P foram perdidos ou não permaneceram em formas disponíveis, provavelmente pela lixiviação

(Ca, Mg) e também, possivelmente, pela remoção por insetos (Ca, Mg, P). Grandes depósitos de MO (até 300 t.ha^{-1}) foram adicionados por um período de 10 anos, não promovendo aumento significativo no teor de MO de qualquer horizonte do solo, indicando que a decomposição microbiana e outras perdas da MO adicionada foram extensivas sob esse manejo (Capítulo 1). O composto foi decomposto rapidamente ao longo do tempo, sendo mais rápido sob pivô central do que micro aspersor. Sombreamento total causou maiores taxas de decomposição. O tempo de meia vida variou de 0,12 a 1,02 anos. As perdas de nutrientes foram substanciais, com P e K sendo decompostos em taxas mais rápidas do que a perda de massa. Os nutrientes perdidos do composto não estavam em sua maioria presentes no solo. Insetos podem ter removido composto das caixas tornando-se indisponível para as plantas (Capítulo 2). Diante desses resultados verificou-se que o aporte de grandes quantidades de matéria orgânica nos solos por períodos prolongados não causou o efeito esperado, mas manteve o sistema em equilíbrio. Recomenda-se outros estudos na área principalmente no que discerne a fauna presente, para um melhor entendimento dessa dinâmica, nas condições estudadas.

Palavras-chave: Composto. Decomposição. Fauna do solo. Meia vida. Palha de carnaúba. Solos arenosos.

ABSTRACT

The need to understand the workings and dynamics of soil organic matter in areas where this feature is available in high quantities (organ systems) and how this dynamic can be affected by the interaction between the organic matter and the factors that are present in the system as the type of soil, climate, and management used, this study aimed to evaluate the effects of organic matter and nutrients added to the soil via organic compounds, quantifying the same with focus on chemical properties of soil, time and levels of storage of this nutrient, the form of release thereof by the action of irrigation and shade on inputs applied in organic caribean cherry orchards. The research was developed in Amway Nutrilite farm located in Brazil, Ibiapaba region, state of Ceará, from February 2011 to April 2013. Areas with one, six and ten years of organic management were investigated. Inputs and outputs of substances in the culture were measured, the soils were analyzed for nutrient content (N, P, K, Ca, Mg), organic matter (OM), density and chemical properties, electrical conductivity (EC), sum bases exchangeable (SEB), capacity of effective cation exchange (ECEC) at pH 7 (CEC) and base saturation index (IBS). The samples were collected at four depths (0-20; 20-50; 50-100; 100-150 cm) lines and between lines. An experimental part was carried out with the aid of litter boxes made of rectangular form with a base and their lower side mesh 4 mm and the largest side of PVC, and the same mesh cover. Were filled with the compound used in farm and evaluated in seven times (0, 2, 4, 6, 8, 10, 12 months) after assembly, the remaining amounts of the compound were weighed and calculated moisture as well as the amount of nutrients present, decomposition rates and half-life values were calculated. Soil under litter boxes were analyzed before and after the removal of boxes to analyzed nutrients content (N, P, K, Ca, Mg) and organic carbon, at three depths (0 to 5, 5 to 10, 10 to 20 cm). The chemical properties decreased with depth, and the organic carbon and nutrient contents increased with increasing amounts of organic matter and nutrients applied. Only a small percentage of OM applied remained in the soil to 150 cm deep. Much of K, Ca and Mg were not present in the soil and available P (P1) was a minor proportion of P applied. The OM was positively related to the EC, P_{M1}, K, Ca, Mg, SEB, ECEC, CEC, IBS and N. Culture recovered significant part of the K and N applied, but Ca, Mg and P were lost or did not remain in available forms, probably due to leaching (Ca, Mg) and also possibly by removal by insects (Ca, Mg, P). Large deposits OM (up to 300 t ha^{-1}) were added over a period of 10 years, not promoting significant increase in the OM content of any soil horizon, indicating that the microbial decomposition and other losses of OM were added under extensive this management (Chapter

1). The compound decomposed rapidly over time, and faster in central pivot than micro-sprinkler. Total shading caused higher rates of decomposition. The half-life ranged from 0.12 to 1.02 years. The nutrient losses were substantial, P and K being decomposed at faster rates than weight loss. Lost compound nutrients were not mostly in the soil. Insects can be removed compound from the boxes becoming unavailable to plants (Chapter 2). From these results it was found that the intake of large amounts of organic matter to the soil for long periods did not cause the expected effect, but kept the system in balance. It is recommended further studies in the area especially in discerns this fauna, to a better understanding of this dynamic, in the studied conditions.

Keywords: Carnauba straw. Compost. Decomposition. Half-life. Sandy soils. Soil fauna.

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LISTA DE ABREVIATURAS E SIGLAS

A1	Área com acerola plantada há 1 ano
A10a	Área com acerola plantada há 10 anos a
A10b	Área com acerola plantada há 10 anos b
A6	Área com acerola plantada há 6 anos
Ac	Área controle
CEC	Capacidade de Troca de Cátions
EC	Condutividade Elétrica
ECEC	Capacidade de Troca de Cátions Efetiva
FAO	*Food and Agriculture Organization of the United States*
IAS	Índice de Saturação de Alumínio
IBS	Índice de Saturação de Bases
IR	Entre as Linhas
LTDA	Limitada
PA	Acidez Potencial
R	Linhas
SEB	Soma de Bases Trocáveis
TOM	Matéria Orgânica Total
WRB	*World Reference Base*

LISTA DE SÍMBOLOS

%	Percentagem
°C	Grau Celsius
BSh	Clima de estepes áridas quentes
C:N	Relação carbono nitrogênio
CEC:C	Relação capacidade de troca de cátions carbono
cm	Centímetros
$cmol_c.kg^{-1}$	Centimol de carga por quilograma
Ds	Densidade do solo
$dS.m^{-1}$	DeciSiemens por metro
$g.kg^{-1}$	Grama por quilograma
ha	Hectare
$HClO_4$	Ácido perclórico
HNO_3	Ácido nítrico
$Kg.ha^{-1}.year^{-1}$	Quilograma por hectare por ano
$L.ha^{-1}.year^{-1}$	Litro por hectare por ano
log	Logarítimo
m	Metro
M	Molar
m^3	Metro cúbico
$m^3.ha^{-1}.year^{-1}$	Metro cúbico por hectare por ano
$mg.L^{-1}$	Miligrama por litro
mm	Milímetro
$mm.year^{-1}$	Milímetros por ano
$mS.m^{-1}$	MiliSiemens por metro
P_{CaCl2}	Fósforo extraído por cloreto de cálcio
pH	Potencial hidrogeniônico
P_{M1}	Fósforo extraído por Melich 1
S	Sul
$t.ha^{-1}$	Tonelada por hectare
$t.m^3$	Tonelada por metro cúbico
Vs	Volume do solo
W	Oeste

SUMÁRIO

1 INTRODUÇÃO GERAL

A agricultura orgânica no Brasil vem crescendo nos últimos anos. Dados mostram um aumento de 50% ao ano, destacando o país no mercado orgânico internacional. Tal crescimento supera países como os Estados Unidos e a União Européia, onde os mercados crescem em média 20 a 30 % ao ano, respectivamente (FBIL/IFOAM, 2010; FONTENELE; DAVID, 2003). As regiões centro sul do país são as que participam dessa fatia de mercado com maior intensidade, portanto os trabalhos e pesquisas relacionados a agricultura orgânica, estão em sua maior parte, direcionados a essas regiões.

A agricultura orgânica tem muitas definições. De acordo com Henning *et al.* (1991) "é um processo que conserva os recursos naturais, incentiva a auto regulação através da diversidade, para minimizar impactos ambientais, preservando a rentabilidade da exploração". Em termos práticos, a agricultura orgânica se baseia em um equilíbrio ecológico abrindo mão de insumos sintéticos e utilizando práticas agrícolas como espaçamento adequado entre plantas, rotação de culturas, incorporação de matéria orgânica ao solo e compostagem (KUO *et al.*, 2004). Segundo Lampkin (1994, 1997), o objetivo da agricultura orgânica é "criar sistemas de produção que tenham a parte humana, ambiental e econômica integradas de forma sustentável, as quais maximizem a obtenção de recursos renováveis provenientes da produção e a gestão dos processos ecológicos e biológicos e suas interações, de forma a promover níveis aceitáveis de produção da cultura, nutrição animal e humana, proteção contra pragas e doenças e um retorno econômico viável".

A produção de alimentos orgânicos no nordeste do Brasil também vem aumentando nos últimos anos (LIMA; PINHEIRO, 2004). Essa região apresenta baixos índices de precipitação, elevadas temperaturas, estações do ano pouco, ou não, definidas, elevada umidade relativa, o que caracteriza o clima semiárido (SILVA; RAO, 2002). Essas características peculiares ao semiárido tornam os estudos realizados nessa região muito importantes para conhecer o comportamento das espécies e do meio em condições tão adversas, bem como indicar o manejo adequado dessas áreas.

Apesar de todos os fatores que dificultam a produção orgânica na região nordeste, um deles é limitante, a falta de água. A necessidade, quase que obrigatória, do uso da irrigação é evidente. Essa prática tem uma influência fundamental na movimentação e assimilação dos nutrientes que são disponibilizados para as plantas (ASADI *et al.*, 2002).

Os solos dessa região também exercem uma influência importante nesse contexto de dificuldade na produção orgânica, pois, em alguns casos, tem-se solos de pouca fertilidade, com reduzida disponibilidade de nitrogênio (N) e fósforo (P), além dos teores mínimos de matéria orgânica (MENEZES; SILVA, 2008). Tais características estão associadas, dentre outros fatores, à textura dos solos. Em muitos casos, áreas agrícolas estão sendo desenvolvidas em solos de textura arenosa que, dentre outras características, apresentam baixa capacidade retenção de água e nutrientes. Essas características estão associadas à menores proporções de cargas negativas da fração areia (baixa superfície específica), que resulta na reduzida capacidade de retenção de nutrientes. Nesse sentido, quando a água penetra no solo, poderá ocasionar a lixiviação de nutrientes no perfil, ocasionando problemas ambientais, como eutrofização de águas subterrâneas e de lagos (BRADY; WEIL, 2008).

Avaliando a movimentação de C e N em solos do México, Noguez *et al.* (2008) reportaram que solos com textura arenosa facilitam a lixiviação de nutrientes no perfil, o que foi também observado por Xavier *et al.* (2009), nesse caso o movimento descendente de P em solos arenosos sob cultivo orgânico no Ceará, nordeste do Brasil. A movimentação descendente de nutrientes em solos arenosos, se torna mais acentuada a partir da adoção da irrigação.

No manejo orgânico, onde as aplicações de fertilizantes químicos e sintéticos não são utilizadas, as plantas retiram os nutrientes necessários ao seu crescimento e desenvolvimento através da Matéria Orgânica do Solo (MOS), (ALTIERI, 2002). Nestas áreas, adubos orgânicos são recursos vitais de fornecimento de nutrientes para as plantas e reposição de matéria orgânica (XAVIER *et al.*, 2009).

A matéria orgânica do solo (MOS) é um recurso renovável, considerada como fonte de nutrientes para o solo. Também funciona como um local de troca de íons, promove a formação de agregados, influenciando as propriedades físicas e a umidade do solo, e é uma fonte de energia para a macro e microfauna do solo (FERNANDES *et al.*, 1997).

Os níveis de MOS em qualquer agroecossistema é dependente da interação entre os fatores que determinam a sua formação e aqueles que promovem a sua decomposição (NYE; GREENLAND, 1964). A redução da MOS é influenciada por fatores tais como: aumento da erosão do solo e da taxa de mineralização/oxidação dos resíduos orgânicos. Em sistemas agrícolas,a facilidade do acesso à MOS pelos microrganismos, como resultado das práticas de manejo, ocasiona maior mineralização e Oxidação do C Orgânico do Solo (COS) em comparação a ecossistemas naturais. Em alguns sistemas onde a MOS é manejada, como nos sistemas orgânicos, o aumento da produtividade das culturas está diretamente relacionada com os níveis de MOS (LUGO; BROWN, 1993; SANCHEZ *et al.*, 1982). Os níveis de MOS são considerados por Gregorich *et al.* (1996) como uma função dos resíduos orgânicos inseridos e assimilados pelo sistema de cultivo utilizado.

A manutenção ou recuperação dos teores de MOS pode ser alcançada pela utilização de métodos de preparo com baixo ou nenhum revolvimento e de sistemas de culturas que priorizem a adição de resíduos vegetais (BAYER; MIELNICZUK, 1999). Bayer *et al*. (2000a, 2000b, 2000c), verificaram efeito direto no aumento da MOS em sistemas que diminuíram as práticas de preparo do solo e utilizaram culturas que aportam maior quantidade de resíduos no solo. Outra forma de aumentar os teores de MOS é a utilização de composto. Sédogo (1981) recomendou a utilização de compostagem em solos do Sahel, na África, para aumentar a disponibilidade de nutrientes e decrescer a relação C: N em decorrência das baixas taxas de decomposição do material orgânico, fertilidade dos solos e principalmente quantidades de P. Nessa mesma região, considerada semiárida, a matéria orgânica é utilizada como amenizador da degradação do solo. Quédraogo *et al.* (2001) mostraram um resultado positivo no incremento das propriedades físicas e químicas do solo e na produtividade da cultura.

A adubação em sistemas orgânicos tem sido foco de vários estudos (JIAO; WHALEN; HENDERSHOT; 2006; KANCHIKERIMATH; SINGH, 2001). É necessário entender o funcionamento e a dinâmica da MOS em locais onde esse recurso está disponível em altas quantidades (sistemas orgânicos) e como essa dinâmica pode ser afetada pela interação entre a matéria orgânica e os fatores que estão presentes no sistema como o tipo de solo, o clima, e o manejo utilizado. Clark *et al.* (1998) encontraram que os teores de C, P, K, Ca e Mg no solo foram maiores em sistemas orgânicos submetidos a aplicação de composto e a incorporação de culturas de cobertura ao solo do que em sistemas convencionais.

Em estudo realizado com o objetivo de encontrar o efeito das práticas de manejo, tipos de culturas e fontes de fertilizantes na distribuição dos agregados do solo estáveis em água e a concentração de nutrientes nos agregados, Jiao *et al.* (2006) encontraram que a quantidade de nutrientes presentes nos agregados é suficiente para poluir as fontes d’água em ecossistemas sensíveis a lixiviação de nutrientes.

A movimentação de nutrientes e a lixiviação estão diretamente relacionadas com a textura e estrutura dos solos. Diepeningen *et al.* (2006) verificaram que a textura do solo, argilosa ou arenosa, proporcionou maior efeito na maioria das características do solo do que o tipo de manejo adotado. Segundo os autores, com o uso de certas análises, as diferenças químicas, biológicas e de práticas de manejo podem ser conectadas ao tipo de solo (textura), mas também ao tipo de cultura, ao uso de culturas de cobertura e ao histórico de manejo da área estudada.

Alguns nutrientes, como C, N e K, em formas mais solúveis, podem ser facilmente lixiviados em solos arenosos. Processos de transformação de nutrientes no solo, como mineralização ou imobilização são fortemente influenciados pelas variações sazonais de temperatura, umidade, crescimento das plantas e atividade da raiz, pela matéria orgânica e acúmulo de serrapilheira (ZHAO *et al.*, 2009).

As perdas de P por lixiviação ocorrem principalmente em áreas onde as concentrações são muito elevadas e a capacidade de adsorção do solo são baixas, como ocorre nas condições de solos arenosos em sistemas orgânicos (ELRASHIDI *et al.*, 2001; EGHBALL; BINFORD; BALTENSPERGER, 1996; SHARPLEY; WITHERS, 1994; SIMS; SIMARD; JOERN, 1998).

A agricultura orgânica disponibiliza formas solúveis de nutrientes a partir da mineralização da MOS. A movimentação vertical desses nutrientes é intensificada quando os cultivos estão presentes em solos arenosos e irrigados.A lixiviação de nutrientes é um dos causadores de contaminação dos aquíferos e do meio ambiente. Portanto, é importante quantificar a perda de nutrientes em sistemas orgânicos verificando o manejo utilizado no mesmo (ZHAO *et al.*, 2009). Poucos estudos foram realizados considerando tais aspectos na região nordeste do Brasil.

Esse estudo está dividido em dois capítulos, onde o primeiro visa quantificar aportes de MO e nutrientes adicionados ao solo via compostos e resíduos orgânicos, avaliar os teores destes nutrientes armazenados no solo ao longo de vários anos de cultivo e verificar a influência da MO nos teores de nutrientes armazenados no solo. Já o segundo capítulo procura estudar a influência da irrigação e do sombreamento sobre as taxas de decomposição da biomassa e a liberação de nutrientes do composto orgânico em pomares de acerola.

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ARTIGO 1: LONG-TERM ORGANIC HORTICULTURE IMPACTS ON CHEMICAL PROPERTIES OF SANDY SOILS IN NORTHEAST BRAZIL

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ABSTRACT

Organic agriculture is increasing around the world and the long-term impacts on soil and environment are understudied. Soils after one, six and ten years of management for organic agriculture were investigated. Inputs and crop outputs were measured, soils were analyzed for nutrients (N, P, K, Ca and Mg), organic matter (OM), bulk density and the chemical properties, electrical conductivity (EC), sum of exchangeable bases (SEB), effective cation exchange capacity (ECEC) at pH7 (CEC) and index of base saturation (IBS). Samples were collected at four depths to 150 cm in crop rows and interrows. Chemical properties decreased with depth, and the organic carbon and nutrient concentrations increased with the increasing amounts of OM and nutrients applied. Only a small proportion of the applied OM remained in the soil to 150 cm depth. Much of the applied K, Ca and Mg was not present in the soil and available P (P_{M1}) was a minor proportion of P applied. OM was positively related to EC, P_{M1}, K, Ca, Mg, SEB, ECEC, CEC, IBS and N. The crop recovered much of the applied K and N but little of the applied Ca, Mg and P and little of these elements remained in available forms due to leaching (Ca and Mg) and possibly to removal by insects (Ca,Mg and P). Large inputs of OM (up to 300 t ha^{-1}) over 10 years had not systematically increased the OM content of any soil horizon indicating that microbial decomposition and other losses of added OM have been extensive under this management regime.

Keywords: Carnauba straw. Compost. Irrigated. Long-term. Sandy soils. Soil quality.

1 INTRODUCTION

Organic agriculture is increasing around the world, due to consumers of primary products seeking a healthier lifestyle, free of chemically contaminated food. In organic agriculture management where synthetic chemical fertilizers are not used, plants must obtain most of the nutrients essential for growth and development from applied organic matter (Altieri, 2002) or approved mineral sources (CFR, 2015). Organic fertilizers and amendments are vital features of the system, supplying nutrients to plants and enhancing soil organic matter (Xavier et al., 2009b).

Organic matter (OM) is involved in many processes in the soil and has been identified as a sensitive indicator for assessing soil quality, particularly for agricultural land uses (Maia et al., 2007, Leifeld, 2012). Among many benefits, OM can improve soil physical conditions, stimulate microbial growth, enhance nutrient cycling and increase soil cation exchange capacity (Gentile et al., 2013, Kanchikerimath and Singh, 2001; Oorts et al., 2003).

Fertilization in organic systems has been the focus of several studies (Jiao et al., 2006; Kanchikerimath and Singh, 2001; Drinkwater et al., 1998). It is necessary to understand the functioning and dynamics of organic materials applied in high quantities in organic systems and clarify complex interactions involving organic matter and soil, climate, and management. Clark et al. (1998) who studied organic agriculture under a temperate climate found that the levels of organic carbon, phosphorus, potassium, calcium and magnesium in the soil were higher for organic systems subjected to large-scale applications of compost and incorporation of cover crops than in soil under conventional management systems.

Semi-arid regions, with high temperatures, sandy soils, low soil fertility, low availability of nitrogen (N) and phosphorus (P), and minimum levels of OM are common around the world as in Northeast Brazil. Organic farming management in these systems requires high levels of fertilization and irrigation, which increases the movement of nutrients in the soil profile (Sitthaphani et al, 2009). The long-term impacts on soil and environment of organic production in this zone are still understudied.

The aim of this study was to evaluate the impact of 10 years of organic management of horticultural production on the chemical properties of a Ferrasol under a steppe hot seasonally arid climate.

2 MATERIALS AND METHODS

2.1 Site description

The study area is managed by Amway Nutrilite LTDA of Brazil and is located in the Ibiapaba region, Ubajara county, Ceará, in the Northeast of Brazil ($3^o51'12''S/41^o5'10''W$) at 850 m above sea level. The climate is steppe hot arid (BSh), following Köeppen's classification with annual average temperature and rainfall of 28^oC and 670 mm $year^{-1}$ respectively (Chen and Chen, 2013). The rainy season is between January and May. The Nutrilite Farm (www.fazendanutrilite.com.br) has operated since 1997 growing Caribbean cherry (*Malpighia punicifoilia* L.) for vitamin C production under organic management certified under biodynamic standards (Diver, 2007).

Based on an understanding of the topography (quite flat) and soil distribution at the site with 240 ha planted, three locations in the plantation were chosen to develop a better understanding of soils in the area. Soil pits were opened and soils were examined at each of these locations representing 10 (two areas, (A10a) and (A10b)), 6 (A6) and 1 (A1) years of organic farming. The two areas of 10 years management are separated by 300 meters as are A6 and A1 locations, however 3000 meters separate A10a/A10b from A6/A1. The soils were classified as Ferrasols (Table 1.1) according to the Brazilian System of Soil Classification (Embrapa, 1999b), which resembles the FAO/WRB system (Eswaran et al., 2002). The soils are sandy with about 120 g kg^{-1} clay in the topsoil (Table 1.1). See appendix.

Table 1.1 – Chemical and physical properties of topsoil and subsoil of Ferrasols in interrows after 1 (A1), 6 (A6) and 10 (A10) years, under organic Caribbean cherry farming at Ubajara, Ceará, Northeast Brazil

Chemical and physical properties	Area and soil horizons								
	A1			A6			A10		
	Ap	AB	BW	Ap	AB	BA	Ap_1	Ap_2	Ap_3
Depth (cm)	0-10	10-23	23-53	0-9	9-21	21-41	0-7	7-13	13-22
Organic carbon (%)[a]	1.07	0.61	0.53	3.29	0.53	0.53	3.06	1.69	0.69
N (%) [b]	0.08	0.06	0.06	0.20	0.06	0.05	0.22	0.16	0.1
EC (dS m^{-1}) [c]	0.13	0.05	0.05	0.21	0.15	0.17	0.14	0.09	0.08
pH (soil:water 1:2.5)[c]	7.26	6.12	4.94	6.06	5.14	4.77	7.32	7.45	7.44
P_{M1} (mg kg^{-1}) [c]	91.1	4.97	3.02	60.8	13.2	7.5	243	158	149
K^+ (mg kg^{-1}) [a]	72.8	34.9	20.1	226	61.8	57.2	122	21.5	9.03
Ca^{2+} ($cmol_c$ kg^{-1}) [a]	2.16	0.6	0.13	3.08	0.65	0.42	6	4.67	3.67
Mg^{2+} ($cmol_c$ kg^{-1}) [a]	0.40	0.19	0.09	1.54	0.35	0.36	2.06	1.31	0.92
Al^{3+} ($cmol_c$ kg^{-1}) [a]	0	0	0	0	0.06	0.13	0	0	0
PA ($cmol_c$ kg^{-1}) [a]	0.47	1.54	2.68	2.47	1.71	2.01	0.76	0.9	0.9
SEB ($cmol_c$ kg^{-1}) [a]	2.74	0.88	0.28	5.19	1.15	0.92	5.08	5.17	5.17
ECEC ($cmol_c$ kg^{-1}) [a]	2.74	0.88	0.67	5.19	1.21	1.04	8.37	6.03	4.61
CEC ($cmol_c$ kg^{-1}) [a]	3.21	2.42	2.96	7.66	2.86	2.93	9.13	6.93	5.51
P_{CaCl2} (mg L^{-1}) [c]	54.3	50.5	40.2	55.5	54.1	51.1	49.3	58.8	56.8
IBS (%) [a]	85.3	36.4	9.3	67.8	40.3	31.3	91.6	87	83.6
IAS (%)[a]	0	0	59	0	4.9	12.0	0	0	0
Sand (g kg^{-1}) [d]	800	770	700	830	790	740	820	820	840
Silt (g kg^{-1}) [d]	90	40	100	50	50	80	70	50	40
Clay (g kg^{-1}) [d]	110	190	200	120	170	190	120	130	120
Waterdispersible clay (g kg^{-1}) [d]	100	130	120	50	100	140	30	40	60
Degree of flocculation (g kg^{-1}) [d]	40	300	380	590	380	220	770	710	520
Texture [e]	LS	SL	SL	SCL	SCL	SL	LS	LS	LS
Grade or structure development/structure size/type [e]	mo/vf/ blsa	mo/vf/ blsa	mo/fi& me/blsa	ms/fi/ gr	mo/fi/ blsa	mo/fi& me/blsa	we/fi/ gr	mo/fi/ blsa	mo/fi/ blsa
Consistency: moist/stickiness/ Plasticity [e]	vfr/ nst/pl	vfr/nst/ pl	vfr/nst/ pl	vfr/sst/ pl	fr/sst/ pl	fr/st/pl	vfr/nst/ spl	fr/nst/ spl	fr/nst/ spl
Soil colour (wet) [e]	10YR 5/2	10YR 5/2	7.5YR 5/2	10YR 3/2	10YR 5/4	10YR 5/4	7.5YR 3/2	10YR 3/2	10YR 4/2

[a] Analysis made following techniques of Defelipo and Ribeiro (1997); electrical conductivity (EC), pH in water, available phosphorus mehlich (P_{M1}), Calcium chloride extractable P content (P_{CaCl2}), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), aluminum (Al^{3+}), potential acidity (PA), sum of exchangeable bases (SEB), effective cation exchange capacity (ECEC), cation exchange capacity at pH 7 (CEC) index of base saturation (IBS), index of aluminum saturation (IAS), total nitrogen (N); [b]Analysis made following techniques of Tedesco *et al.* (1985); [c] Analyses made following techniques of Braga and Defelipo (1974); [d] Analysis made using the pipette method of Embrapa (1999); [e] Analysis made following techniques of Santos et al. (2005); Texture: LS = loamy sand, SL = sandy loam, SCL = Sandy clay loam. Grade or structure development: we = weak, mo = moderate, st = strong, ms = moderate to strong. Structure size: ec = extremely coarse, vc = very coarse/thick, co = coarse/thick, me = medium, fi = fine/thin, vf = very fine/thin. Structure type: gr = granular, bl = block, blab = angular block, blsa = subangular block, pr = prismatic. Consistency: moist: vfr = very friable, fr = friable. Stickiness: nst = non-sticky, sst = slightly sticky, st = sticky, vst = very sticky. Plasticity: spl = slightly plastic, pl = plastic, vpl = very plastic (FAO, 2006).

The study area was under agriculture and fallow at the time of establishment of the Caribbean cherry orchard (Table 1.2). In preparing the site, vegetation cover was incorporated using a disc harrow and pH was corrected by liming. Gafsa rock phosphate and dolomitic limestone were applied frequently based on soil analyses made twice a year. For area A6, cultivation of mixed legumes and grasses preceded the establishment of the orchard. Forty days after planting, the biomass produced (approximately 45 t ha^{-1} of fresh residue) was incorporated into the soil surface as green manure (Xavier et al., 2009b). The species used were calopo (*Calopogonium mucunoides* Desv.), castor bean (*Ricinus communis* L.), crotalaria (*Crotalaria juncea* L. and *Crotalaria spectabilis* Roth), corn (*Zea mays* L.), cowpea (*Vigna unguiculata* L. Walp.), jackbean [*Canavalia ensiformes* (L.) DC], lab-lab (*Dolichos lablab* L.), millet (*Pennisetum americanum* L. K. Schum.), pigeon pea (*Cajanus cajan* L. Millsp.), sorghum (*Sorghum bicolor* L. Moench), sunflower (*Helianthus annuus* L.) and velvet beans (*Stizolobium aterrimum* Piper & Tracy). For areas A1 and A10 additional green manure {buffel grass (*Cenchrus ciliaris* L.), calopo (*Calopogonium mucunoides* Desv.) and soybeans [*Glycine wightii* (Wight & Arn.) Verdc.]} was applied to interrows (IR) after the Caribbean cherry was established.

Organic compost and castor bean residue were applied before planting seedlings in rows (R). After establishment of the seedlings, these same organic inputs were again applied to rows plus potassium sulfate. This topdressing (R) with organic matter was repeated every two months during the first year and subsequently compost was applied twice a year and castor bean residue four times a year, together with biofertilizer and liquid factory waste, three times a year (R). Carnauba (*Corpenicia cerifera* Mart.) straw was also applied to the rows as mulch twice a year. In total, an amount of up to 300 t ha^{-1} of organic residues was applied to the soil. The composition and chemical characterization of compost, biofertilizer, carnauba straw and some others inputs are presented in Table 1.3. Areas A1 and A6 were irrigated by using a central pivot system with 400-900 mm $year^{-1}$, whereas A10a and A10b utilized micro sprinklers with 400 mm $year^{-1}$. Details of management procedures developed in each area are present in Table 1.2.

Table 1.2 – Management procedures adopted on areas farmed for 1, 6 and 10 years, under organic Caribbean cherry farming at Ubajara, Ceará, Northeast Brazil

Procedures	Areas			
	A1	A6	A10a	A10b
Year of planting	End of 2009	Beginning of 2005	Beginning of 2001	Beginning of 2001
Size of area (ha)	14	17	10	10
Past agricultural use	Traditional mango cultivation until 1998 after that fallow	Traditional mango cultivation until 1998 after that fallow	Native vegetation	Native vegetation
Number of plants ha^{-1}	667	531	592	599
Number of plants area $^{-1}$	9,349	9,035	5,921	5,999
Spacing (inter plant x inter row in m)	3 x 4.85	2.85 x 6.6	3.5 x 4.82	3.5 x 4.77
Irrigation type and amount (m^3 ha^{-1} year)	Central pivot 9600	Central pivot 7906	Micro sprinklers 4028	Micro sprinklers 4680
Average productivity (kg of fruit plant^{-1})	0	24	25	22
Compost (kg ha^{-1} year^{-1})	21,750	15,508	19,425	20,137
Carnauba straw mulch (kg ha^{-1} year^{-1})	41,786	11,471	12,295	12,365
Limestone (kg ha^{-1} year^{-1})	439	60	266	374
Gafsa rock phosphate (kg ha^{-1} year^{-1})	475	60	3	33
Castor bean residue (kg ha^{-1} year^{-1})	354	66	20	19
Liquid fruit waste (L ha^{-1} year^{-1})	6429	882	2175	563
Biofertilizer (L ha^{-1} year^{-1})	857	353	50	545
Others inputs [a] (kg ha^{-1} year^{-1})	13	0	311	62

[a] Others minor inputs are: biofertilizer type 2; cow urine; Crop set (leaf fertilizer); Hufmax B; Hufmax Cu; Hufmax Mg; Hufmax Zn; oyster shell meal; Irece phosphate (phosphorite); potassium sulfate; Rocksil; seawater and Sulpomag.

The applied amounts of organic carbon (OC), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg), and their forms are shown in Tables 1.2 and 1.4. The nutrient compounds conform to the requirements for organic certification.

2.2 Soil sampling and analysis

Analysis of inputs involved total acid digestion with perchloric acid ($HClO_4$) after pre-treatment with nitric acid (HNO_3) for samples with a high content of organic matter. OC, N, P, K, Ca and Mg were determined by titration or spectrophotometry (Embrapa, 1999a).

Soil samples were collected in February 2011 with hand auger at 0-20, 20-50, 50-100 and 100-150 cm depth in the planted lines (row/R) of the selected areas in a zigzag transect design (Fig. 1.1), with 10 replicates in each study area. Samples were also collected at between lines (interrow/IR) at the same depths randomly throughout the areas and with the same number of replicates, on the middle of the IR away from the shadow of trees and presumably from the influence of roots and leaves. These samples were considered the control (A_C) treatments, providing baseline data for comparisons in order to determine the effects of organic inputs to soil in the rows. Undisturbed samples were also collected with rings of 2.5 cm high and 7.4 cm diameter in a Uhland sampler to determine soil bulk density (Blake and Hartge, 1986).

Figure 1.1 – Diagram showing the soil sample collection procedure with a zigzag design for the organic farm, Ubajara, Ceará, Northeast Brazil

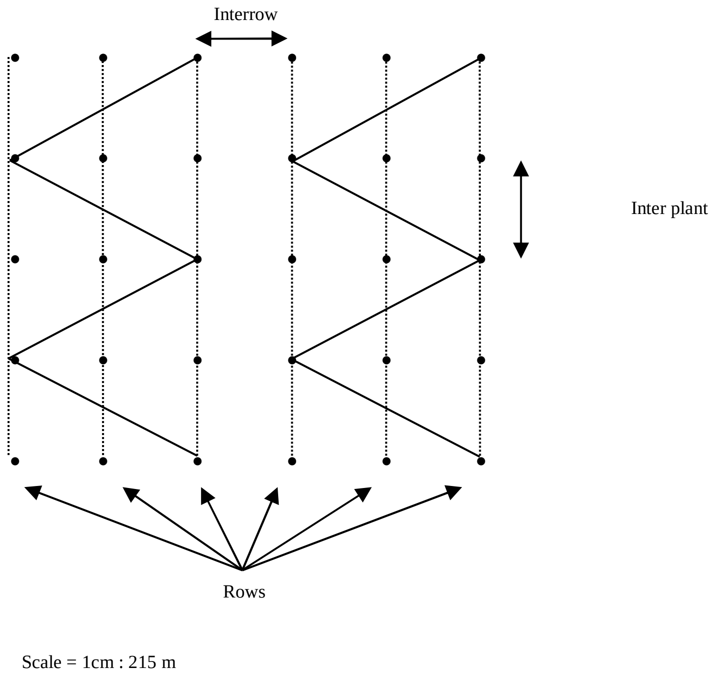


Table 1.3 – Composition of compost and biofertilizer and chemical characterization of compost, biofertilizer, carnauba straw, castor bean residue, Gafsa rock phosphate, factory liquid waste and limestone used for organic Caribbean cherry farming, at Ubajara, Ceará, Northeast Brazil

Composition		**Chemical characterization**			
Compost [a]	**(%)**	**Compost**	**(%)**	**Carnauba Straw** [a]	
		Nitrogen	1.33		
		Phosphorus	0.25	OC (%)	28.2
Biodynamic preparation[b]	0.1	Potassium	1.38	EC 1:5 ($mS.cm^{-3}$)	0.77
Caribbean cherry residue	9.7	Calcium	1.16	TOM (burning)(%)	48.50
Cattle manure	19.2	Magnesium	0.51	pH $_{CaCl2}$ 0.01M (1:5)	7.70
Sugar cane bagasse	41.0	Organic carbon	20.5	C:N ratio	2.88
Water	30.0	Moisture	63.9	CEC:C ratio	31.50
		pH*	6.50	Moisture (65°C)(%)	40.20
				Nitrogen total (%)	2.92
Biofertilizer [a]	**(%)**	**Biofertilizer**	**(%)**	Phosphorus (%)	0.37
Ash	0.1			Potassium (%)	0.72
Crushed bush	0.5	Nitrogen	0.01	Calcium total (%)	1.64
Fresh manure	2.5	Phosphorus	3.28	Magnesium total (%)	0.54
Milk	0.5	Potassium	1.07	Sulfur total (%)	0.64
Molasses	0.2	Calcium	1.29	Sodium (%)	0.25
Water	96.2	Magnesium	0.07		

Chemical characterization					
Castor bean residue	**(%)**	**Gafsa rock phosphate**	**(%)**	**Liquid factory waste**	**(%)**
Nitrogen	8.54	Nitrogen	0.09		
Phosphorus	0.86	Phosphorus	7.86	Nitrogen	0.12
Potassium	1.67	Potassium	0.43	Phosphorus	2.14
Calcium	1.19	Calcium	17.70	Potassium	0.51
Magnesium	1.03	Magnesium	0.85	Calcium	19.90
Organic carbon	38.3	Organic carbon	5.48	Magnesium	0.86
Limestone	**(%)**	Calcium	32	Magnesium	16

[a] Source: Amway Nutrilite of Brazil farm; [b] Herbal powder mixture made at farm. Organic carbon (OC), Electrical conductivity (EC), Total organic matter (TOM), Calcium chloride ($CaCl_2$), Cation exchange capacity (CEC), Carbon (C), Nitrogen (N).

After soil collection, the samples were air dried, sieved to < 2 mm prior to analysis for: electrical conductivity 1:5 (EC), pH in water, available phosphorus by the Mehlich method (P_{M1}), calcium chloride extractable P (P_{CaCl2}) according to Braga and Defellipo (1974), exchangeable potassium (K), exchangeable calcium (Ca), exchangeable magnesium (Mg), exchangeable aluminum (Al), and organic matter (OM) (Embrapa, 1997).

Table 1.4 – Quantities of nutrients and organic carbon applied in rows of Caribbean cherry over 1, 6 and 10 years under organic farming at Ubajara, Ceará, Northeast Brazil

Inputs	**Age**	**Applied (t ha^{-1})**	**Nutrients (kg ha^{-1})**					
			N	**P**	**K**	**Ca**	**Mg**	**OC**
Biofertilizer	**1**	8.59	0.011	2.82	0.920	1.11	0.062	n.m.
	6	28.00	0.036	9.19	2.995	3.62	0.201	n.m.
	10a	4.83	0.006	1.59	0.517	0.63	0.035	n.m.
	10b	53.40	0.068	17.60	5.720	6.92	0.384	n.m.
Carnauba straw	**1**	360	10498	1330	2589	5896	1941	101388
	6	781	22791	2888	5620	12801	4215	220107
	10a	1019	29759	3771	7338	16714	5503	287400
	10b	1041	30411	3854	7499	17080	5624	293699
Castor bean residue	**1**	3.37	287	28.9	56.2	40.1	34.7	1290
	6	4.98	425	42.8	83.2	59.3	51.3	1910
	10a	1.87	160	16.1	31.2	2.2	19.2	716
	10b	1.76	150	15.2	29.4	21.0	18.1	675
Compost	**1**	157	2092	393	2171	1825	802	32343
	6	444	5899	1109	6121	5145	2262	91188
	10a	677	9001	1692	9339	7850	3452	139143
	10b	713	9481	1782	9838	8269	3636	146569
Gafsa rock phosphate	**1**	4.61	4.14	362.0	19.80	814.0	39.1	252.0
	6	4.61	4.15	362.0	19.80	814.0	39.2	253.0
	10a	0.24	0.21	18.5	1.01	41.7	2.0	12.9
	10b	3.13	2.82	246.0	13.50	554.0	26.6	172.0
Limestone	**1**	4.40	n.m.	n.m.	n.m.	1408	704	n.m.
	6	4.74	n.m.	n.m.	n.m.	1516	758	n.m.
	10a	25.70	n.m.	n.m.	n.m.	8219	4109	n.m.
	10b	36.60	n.m.	n.m.	n.m.	11721	5861	n.m.
Liquid factory waste	**1**	64.4	0.75	13.8	3.31	128	5.53	n.m.
	6	69.9	0.82	15.0	3.60	139	6.00	n.m.
	10a	210.0	2.45	44.9	10.80	418	18.01	n.m.
	10b	55.2	0.64	11.8	2.84	110	4.73	n.m.
Others [a]	**1**	-	15.3	0.00	20.6	0	0.0	0.00
	6	-	0.0	0.00	0.0	0	0.0	0.00
	10a	-	147.0	469.00	218.0	1184	33.0	6.11
	10b	-	15.0	0.12	75.5	3955	0.44	4.64
Total [b] (t ha^{-1})	**1**	-	12.9	2.10	4.86	10.11	3.53	135
	6	-	29.1	4.43	11.80	20.50	7.33	313
	10a	-	39.1	6.00	16.90	34.00	13.10	427
	10b	-	40.1	5.90	17.50	41.70	15.20	441

[a] Others inputs: biofertilzer type 2; cow urine; Crop set (leaf fertilizer); Hufmax B; Hufmax Cu; Hufmax Mg; Hufmax Zn; oyster meal; phosphate Irece (phosphorite); potassium sulfate; rocksil; seawater and sulpomag. The units of quantities applied are varied, so total applied weight per ha could not be reported, only the quantities of nutrients containing in it; [b] for Totals, the units are t ha^{-1}. n.m. = not measured.

Soil total nitrogen (N) was measured according to Tedesco et al. (1985). Potential acidity (PA), sum of exchangeable bases (SEB), effective cation exchange capacity (ECEC), cation exchange capacity at pH 7 (CEC), index of base saturation (IBS) and index of aluminum saturation (IAS) were calculated following Embrapa (1997). The stocks of elements were calculated using the formula (1).

$$Stock(tha^{-1}) = \frac{Concentration(kgt^{-1}) \times V_s \times D_s}{1000} \qquad (1)$$

Where *Ds* is the soil bulk density (t m^{-3}) determined by the soil core method (Embrapa, 1997), and *Vs* is the volume of the soil layer (m^3).

To calculate *Vs* for the application area (R), it was considered that fertilizers were applied in a band of ± 0.25m on each side of the plants providing a band of application 0.5 m wide. To calculate *Vs* (IR), we used the same area values as for (R). It was considered that there was no difference in the density of soil for (R) and (IR) as this land use activity does not compact soil (Watanabe, 2013).

2.3 Statistical analysis

Statistical procedures utilized included simple Pearson correlation and simple and multiple linear regression involving soil variables and quantities of nutrients applied via the several inputs. Statistica 7.0 software was used and a confidence level of 5% was adopted. The data used for correlation and regression were log transformed, as they were not normally distributed. Results from multivariate analysis are not shown, as they provided no additional insight.

3 RESULTS AND DISCUSSION

Properties of the soils are presented in Table 1.1, with the top horizon being sandy with more clay in deeper horizons for A1 and A6. The study area is on a flat landscape, but the orchards are large (40 ha each) and it was necessary to choose orchards on the same soil type. An adjacent area with 13 years under organic management, which had Acrisols and Arenosols (Brazilian System of Soil Classification - Embrapa, 1999), could not be studied.

Commonly, organic agriculture systems are supplied with compost from cattle manure with no other additives or tillage management, in our study the approach is very different with a variety of inputs, where each has a specific function in supplying nutrients and organic matter to the soil. Drinkwater et al. (1998) found that qualitative differences in nitrogen and carbon inputs had a major influence on retention of these nutrients on soil of some agroecosystems. The three areas were not treated identically (Tables 1.2-1.4). The characterization of inputs for this research was by direct analysis (biofertilizer, carnauba straw, castor bean residue, compost, Gafsa rock phosphate and liquid factory waste) or by using information supplied by the farm and manufacturers of inputs. In this way the total quantities of nutrients and OM applied were calculated (Table 1.4).

The diversity of inputs applied in response to soil analyses can be attributed to the need to meet specific requirements of the organic farm management practices. Compost was extensively used as is common in many organic agriculture systems. It is a source of soil organic carbon and several plant nutrients and is intended to improve the chemical quality of the soil (Quedraogo et al., 2001). Carnauba straw was used as a mulch, for small plants until the closing of the canopy (Queiroga et al., 2002). It also contributed considerable amounts of nutrients and organic carbon. Biofertilizer and factory waste were sources of organic matter and nutrients, supplying the system with considerable quantities of phosphorus and calcium respectively (Table 1.3 and 1.4). Recycling of nutrients on the farm occurs when factory waste is returned to the field. Biofertilizer applied in small quantities is believed to improve both yield and soil quality. Rivera-Cruz et al. (2008) observed enhanced P uptake due to bacteria present in biofertilizer as well as positive correlations between soil quality parameters and the amount of biofertilizer applied. Pesakovic et al. (2013) concluded that biofertilizer could improve yields and both chemical properties and biological activity of soils. In this Caribbean cherry plantation castor bean residue, limestone, Gafsa rock phosphate and other materials were applied in small quantities (Table 1.4). Castor bean residue was added to improve nitrogen and organic carbon levels in the soil, in addition this input has a particular property of being toxic to microorganisms and soil animals including nematodes, which may have helped to control soil borne pests and diseases (Adegbite and Adesiyan, 2005; Adomako and Kwoseh, 2013). Limestone was applied as a source of calcium but, mainly to ameliorate low pH and increase base saturation. Dolomitic limestone also increased the amount of magnesium in the soil (Pagani and Mallarino, 2012; Wilkinson et al., 1987). The purpose of Gafsa rock phosphate was to supply phosphorus, but it also provided calcium and organic carbon (Correa et al., 2005; Faria et al., 2006). Brazilian rock phosphates have low reactivity as they are of igneous and metamorphic origins so sedimentary Gafsa rock phosphate from Tunisia was used, Arad rock phosphate from Israel and North Carolina rock phosphate from the United States, all with a sedimentary origin and high reactivity have been used (Correa et al., 2005; Yost et al., 1982). However, the P supplied by rock phosphate was less than 17 % of the total P input, being much less than the Carnauba straw input.

Araujo et al. (2008) studied organic cultivation of Caribbean cherry over several time periods, comparing organic with conventional management. Areas with 6, 12, 18 and 24 months under organic management used inputs similar to this study in their diversity, including cattle manure (50 t ha^{-1} $year^{-1}$), rock phosphate (0.5 t ha^{-1} $year^{-1}$), MB4 (lime plus micronutrients, 1.2 t ha^{-1} $year^{-1}$) and carnauba straw (100 t ha^{-1} $year^{-1}$). The average annual inputs were calculated (Table 1.4) and can be compared with data from Araujo et al. (2008). For the site A1 the average of annual input was the amount applied in the single year of operation. The values for this study were higher than those of Araujo et al. (2008), mainly in relation to amounts of carnauba straw and compost. Amounts of compost at about 70 t ha^{-1} $year^{-1}$ on A6, A10a and A10b and 157 t ha^{-1} $year^{-1}$ on A1 and carnauba straw around 110 t ha^{-1} $year^{-1}$ on A6, A10a and A10b and 360 t ha^{-1} $year^{-1}$ on A1 at Nutrilite farm were similar to the quantities used by Araujo et al. (2008). It should be considered that values for this study were calculated using the actual application area (R) against the total area of the plantation, which was used in the Araujo et al. (2008) study. Gafsa rock phosphate application rates were very different for A1 (480 kg ha^{-1} $year^{-1}$) and A10a (3 kg ha^{-1} $year^{-1}$) but were similar (330-600 kg ha^{-1} $year^{-1}$) for the other two areas. Carnauba straw was used as a mulch for weed control at both studies. Compost used at Nutrilite farm was enriched with minor amounts of others components, so was not only composted cattle manure. In summary inputs in the Araujo et al. (2008) study were similar in type to those used at this study, but materials were applied in different amounts and the soil type was different.

The variety of inputs at Nutrilite farm aims to provide the nutrients and organic matter necessary for optimum plant growth and to improve productivity without contravening the principles of an organic system.

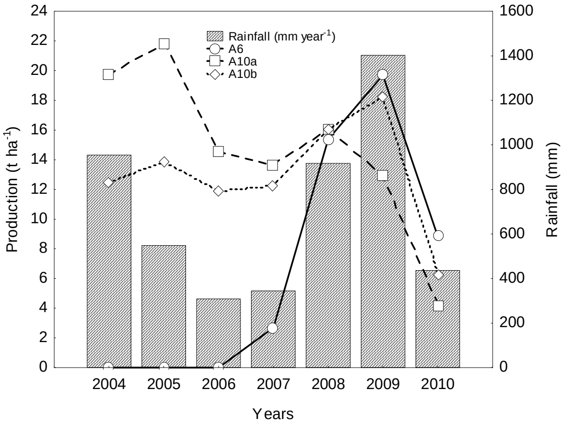
Some mineral and nonorganic fertilizers were used in small quantities in order to reduce soil nutrient deficiencies according to soil analysis done periodically a strategy permitted by the standard setting organization (United States Department of Agriculture - USDA). Details of this organic management strategy are located at CFR (2015). These mineral fertilizers are also permitted for use in organic systems by the Ministry of Agriculture, Livestock and Supply of Brazil through Normative Instruction number 46 (Brasil, 2011). Some mineral materials, such as potassium sulfate, may be used in organic systems since they are obtained by physical processes rather than by chemical treatments to increase the solubility of nutrients. For all other, mineral or nonorganic inputs, used at Nutrilite farm Normative Instruction number 46 gives permission but, with some restrictions.

The percentage of contributions of inputs differed for the nutrients and organic carbon received by the soil. Much of the calcium and magnesium were applied as limestone providing 25% of the total Ca applied and 28% of Mg. Minor amounts of P were provided in Gafsa rock phosphate. The most important source of potassium was compost (52%). The major contributor of almost all nutrients and organic carbon was carnauba straw, which provided between 70 to 80% of the total applied to the soil.

Different quantities of inputs were applied each year. However, both of the areas with 10 years of production had received the most nutrients. Quantities of amendments and the types of fertilizer changed over time as management procedures developed. Consequently, fertilizers have been applied in almost the same quantities for both 1 and 6 years of production. For areas A10a and A10b, biofertilizer, liquid factory waste and Gafsa rock phosphate were applied in different amounts because in 2010, A10a experienced a thinning of plant density as plant varieties were changed from less productive to more productive varieties and different application rates were used during re-planting. Because of this diversity of inputs we have chosen to consider only the total quantities of organic matter and nutrients (N, P, K, Ca and Mg) received by each area, prior to the time when soils were sampled and analyzed (Table 1.4).

The oldest areas (A10a, A10b) received smaller rates of irrigation than the newer ones (A1, A6) (Table 1.2), consequently leaching due to irrigation may have been greater in new areas. Despite irrigated areas receiving between 400 and 960 mm year^{-1} of water through irrigation, production of berries was closely related to rainfall levels, which varied from 300 mm (2006) to 1400 mm (2009). Clearly, production of berries is highly responsive to total available water (Fig. 1.2). The extent to which berry production is limited by inadequate soil fertility is not known.

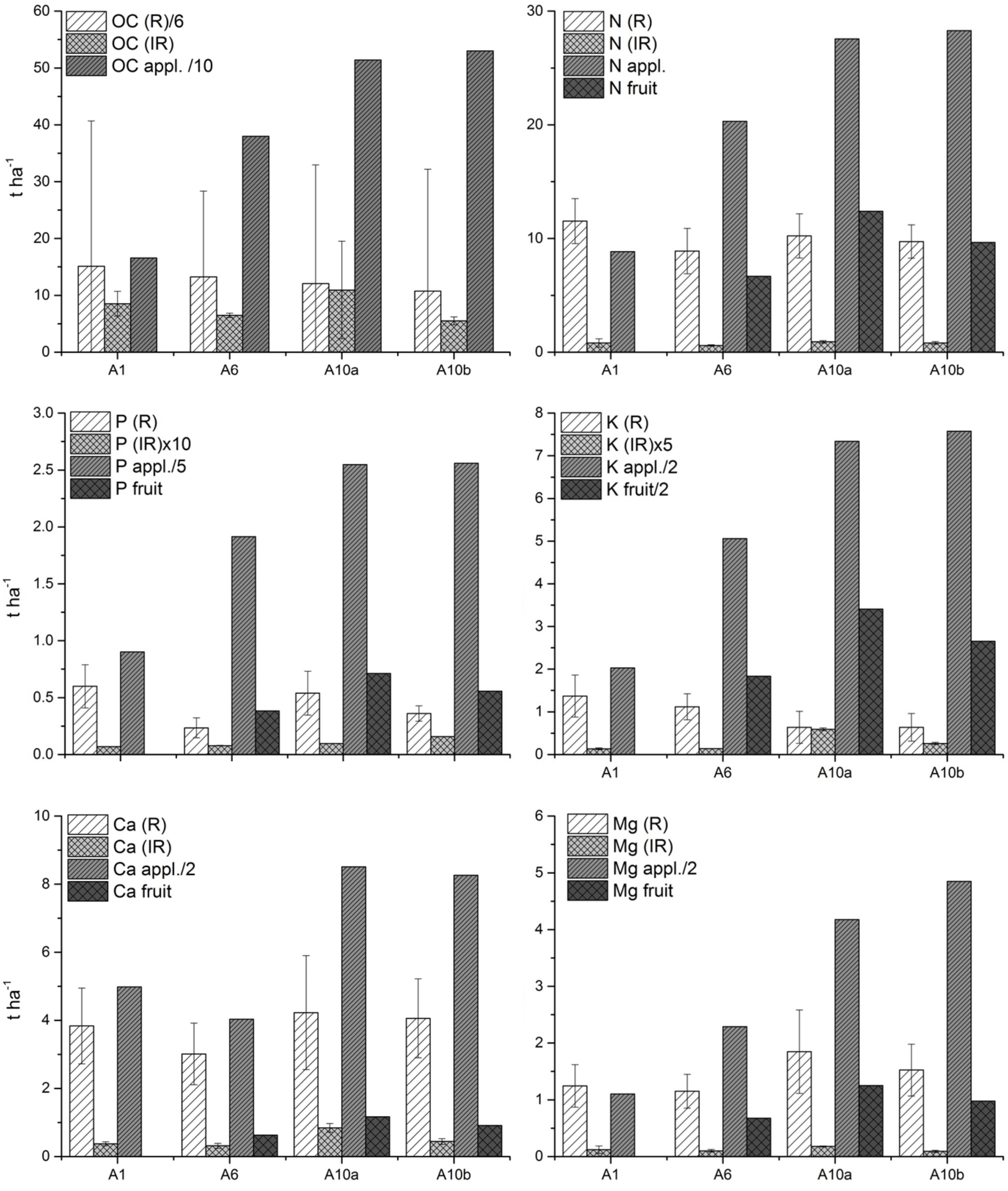
Figure 1.2 – Average annual berry production (t ha^{-1}) for the three organic production sites (A6, A10a and A10b see details in Table 3) and total annual rainfall (mm) for the organic Caribbean cherry farm at Ubajara, Ceará, Northeast Brazil. The first harvest at the A6 site occurred in 2007



The stocks in the soil to 150 cm depth for N, P, K, Ca, Mg and OC in all four areas were calculated from the soil analyses and were compared to the sum of inputs and the outputs of these elements in fruit in Figure 1.3. In each instance amounts in the soil were much lower than the amounts applied indicating that most of the nutrients (between 25 and 90 %) received through inputs over the years were not in the soil to 150 cm depth. Losses varied depending on area and variable (nutrients or OC) and elements appear to have been lost by volatilization (C and N), leaching (N, K, Ca and Mg), were removed by insects or had reverted to a non-extractable form (P). Some of the applied nutrients had been removed in the harvested fruits (3 to 10 % for P, Ca, Mg and up to 40% for N, K) but for P, Ca and Mg this mostly represents a minor proportion of total losses. It is proposed that leaching may be responsible for much of the losses of Ca, Mg and K and for some of the lost N. Torstensson et al. (2006) compared organic and conventional cropping systems for leaching and nutrient use efficiency on a similar sandy loam soil and found that in organic systems with green manure, leaching of nutrients was much higher (59%) than for conventional systems (22%) with cover crops.

The amounts of nutrients and organic carbon in soil in the interrows were much smaller compared to the amounts in the rows. These results were expected considering that all fertilizers were applied only to rows (Fig. 1.3). Interrows were not fertilized over the years, with exception of green manure application performed at the initial stage of establishment of the culture.

Figure 1.3 – Stocks present to 150 cm depth (t ha^{-1}) for row (R) and interrow (IR) of organic carbon (OC), nitrogen (N), available phosphorus (P_{M1}), exchangeable potassium (K), calcium (Ca) and magnesium (Mg); quantities applied to rows and total quantities removed in fruits (t ha^{-1}), for areas A1, A6, A10a and A10b at the organic Caribbean cherry farm at Ubajara, Ceara, Northeast Brazil. There was no harvest from A1 and some values have been divided or multiplied by a factor to fit on the figure



Area A1 presented higher stocks of OC, P and K in the rows than the three other areas, whereas the oldest crop areas (A10a, A10b) showed similar stocks of N, Ca and Mg, compared to A1 and A6.

In summary it is evident that little of the OC, N, K, Ca and Mg applied to the soil are present in the soil after 10 years of organic management. Similarly, the available P is only a very minor proportion of the large amounts of P applied to all sites. For K and N a significant proportion (36 to 46%) of amount applied was present in fruit harvested over 10 years.

Figure 1.3 does not show the amount of OC removed in fruits and as the majority of the carbon in the crop comes from carbon dioxide (CO_2) obtained from the air via photosynthesis, it is not possible to calculate a carbon budget for the soil.

This difference between amount of elements retained in the soil and those applied is largest for A10a and A10b. Although organic management is considered to increase soil quality including chemical fertility over time, this has happened, to a much smaller extent than might be expected from the very large inputs.

It is probable that the major losses of K, Ca, Mg and some N were at least partly due to leaching below the root zone, whereas losses of OC and some N are due to volatilization. There has possibly been extensive removal of organic matter by insects so that OC, N and other nutrients did not enter the soil (Sitthaphanit et al., 2009; Dendooven et al., 2010). Many species of termites are active in this region (Moura et al., 2011, Vasconcellos et al., 2010). These losses are consistent with results of a study made in the same area and under similar management to quantify losses of compost applied in the field over one year (Table 1.5).

Table 1.5 – Percentage of compost lost over 12 months under irrigation: central pivot (P) and micro sprinkler (S) and with different extents of shadowing: total shadow (TS); medium shadow (MS) and without shadow (WS), under organic Caribbean Cherry farming at Ubajara, Ceara, Northeast Brazil

Field time	Compost lost (%)				
Months	PTS	PMS	PWS	STS[a]	SWS[a]
2	25	2.5	24	23	18
4	35	31	36	25	21
6	47	32	37	32	23
8	50	56	53	49	82
10	75	72	80	54	83
12	84	86	93	59	89

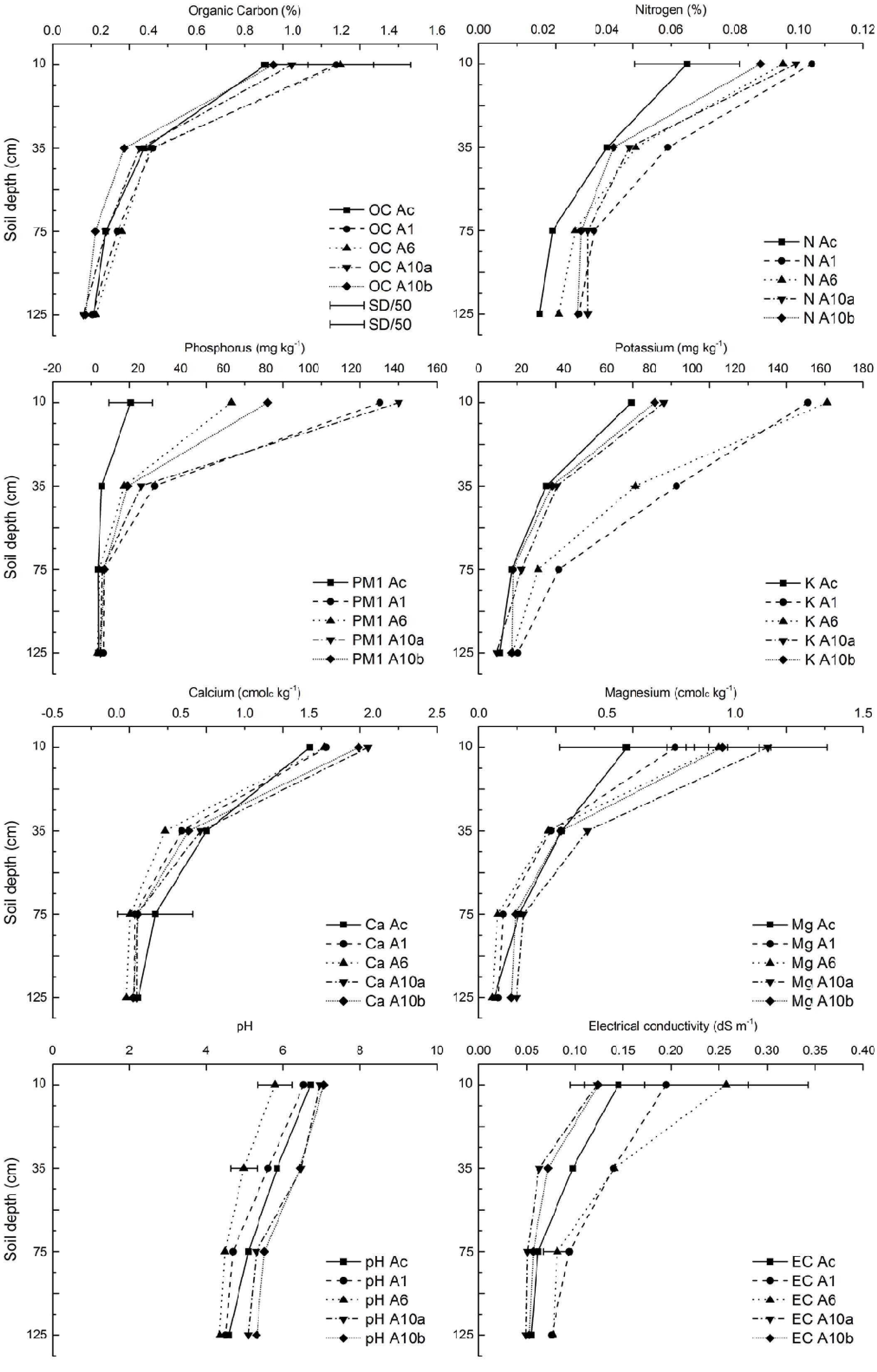
[a] Medium shadow for sprinkler irrigation was not measured.

Losses of up to 93% applied compost were due to decomposition, volatilization, consumption by insects and possibly removal by wind. Rates of decomposition of litter and compost in tropical regions are often high due to the high temperature and moisture (Isaac and Nair, 2005; Kirschbaum, 1995). However Kirschbaum (2006) analyzing his results and other studies made on this subject suspected that some results on the temperature dependence of decomposition of soil OM could be confounded with variations in soil respiration with substrate availability being important considerations. Ngo et al. (2012) found that in tropical regions, compost and vermicompost applied to soil improved the quantity and chemical composition of soil OMwhereas bioturbation from earthworms reduced OC and N concentrations in soil. In our study, the activity of soil microfauna and mesofauna probably contributed to the major losses of the OM and nutrients applied to the soil although insects rather than worms were the important fauna.

Figure 1.4 shows the average concentration of nutrients and some properties of soil at intervals to 150 cm depth, for the four sites, compared with the control site (IR). Nutrient contents (N, P, K, Ca and Mg), OC, pH and electrical conductivity decreased with depth, as is generally observed (Katterer et al., 2014).

There were no systematic differences in OC concentration at depth between the treatments and control. The topsoil OC concentration was higher for A1 and A6 sites presumably reflecting the more recent application of large amounts of OM. The N concentrations of all soil horizons were systematically higher for R sites relative to the control IR sites but there was no systematic difference in N concentrations between the four fertilized sites. For A1 and A6 sites potassium was more abundant throughout the upper three soil horizons compared to the control and A10a and A10b sites. Magnesium was more abundant in the topsoil of fertilized sites relative to the control sites but there was no systematic difference between sites for subsoil horizons. Calcium concentration showed no systematic differences between sites for any horizon. Extractable P was much more abundant in the topsoil and the second horizon of fertilized sites relative to the control sites, but there was no systematic difference in extractable P between sites for the two deepest horizons.

Figure 1.4 – Mean concentrations of nutrients (N, P_{M1}, K, Ca, Mg), OC, pH and EC at four soil depths for each area (Ac, A1, A6, A10a, A10b), where Ac is the control measured in the IR, for the organic Caribbean cherry farm at Ubajara, Ceara, Northeast Brazil. Standard deviations (SD) are presented for some points



These profile depth functions indicate that large applications of OM and nutrients have had surprisingly little effect on the concentration of nutrients below the surface horizon. The highest concentration of K at depths for the two most recently fertilized soils (A1 and A6) suggests that leaching of some K to the subsoil had occurred. After 10 years (A10) extractable K values had reverted to values similar to those for the control, presumably due to leaching of K from the top 1.5 m of soil, other losses and to plant uptake. The available N concentration.

In row has increased relative to the interrow, but concentrations remain less than would be expected in a highly fertilized soil (Tarkalson et al., 2006). Extractable P is only a small proportion of the applied P and high values for the two upper soil horizons may indicate that applied P has been lost or is strongly retained by adsorption on soil constituents near the soil surface (Pizzeghello et al., 2011).

Xavier et al. (2009a) studying P fractionation in sandy soils in the same region as this study and for Caribbean cherry orchards found increased concentrations of labile P in deeper soil layers (40-50cm) indicating vertical movement of P. However, this study was performed in very sandy soils that differ from our soils, which have more clay at depth (Table 1.1). Sites A1 and A10a had much more extractable P in topsoil than did sites A6 and A10b, even though the oldest sites had received more P than newer sites (Table 1.4). Presumably, the adsorbed P became more strongly fixed against extraction with increasing duration of soil-P contact (Mcdowell and Sharpley, 2001).

A central consideration of organic agriculture practice is that addition of OM to soils will increase soil OC and enhance those properties of soil that are related to OC. The relationships of the logarithm of soil properties with the logarithm of organic matter concentration are shown in Figure 1.5 and support this hypothesis. The values of N, P, K, Ca, Mg and CEC increase systematically with OM with statistically significant relationships for (log) data in each case and with the coefficient of correlation larger than 0.70. Thus, the central assumption of organic agriculture in which high inputs of organic matter will improve soil fertility, was confirmed, nevertheless, the extent of this improvement is much less than might be anticipated from the large applications of OM, in this study.

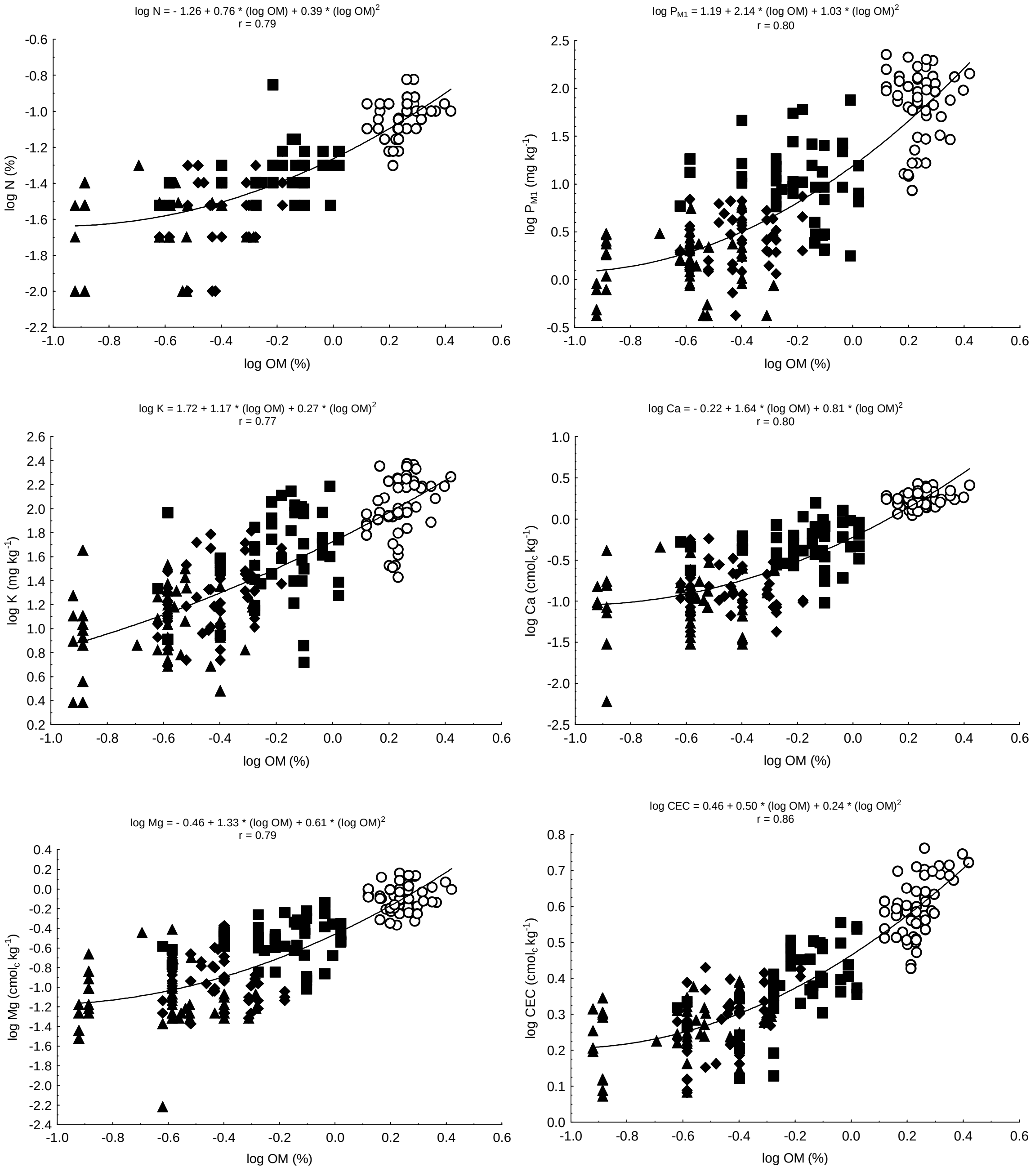
The strength of these statistical relationships (Fig.1.5) is strongly affected by the topsoil values for all variables being relatively high and therefore being located in a group in these plots of data. When relationships between OM and soil properties were examined separately for each soil horizon, the relationships were absent or weak. Values of soil pH and EC were not systematically related to soil OM concentration.

4 CONCLUSIONS

Inputs of very large amount of OM for up to 10 years only slightly increased the OM concentration of the topsoil horizon and associated chemical fertility relative to adjacent soil that don´t receive OM. The quite small increases indicate that microbial decomposition and removal by insects of added organic matter is rapid and highly efficient, leaching and loss of some plant nutrient elements has also occurred. The N concentration for all soil horizons was higher than for the control.Much of N was lost by leaching, volatilization, consumption by insects, plant uptake and in fruit. K has been lost by leaching, removal by insects and in fruit, most Ca and Mg have been leached or removed and most OM was rapidly oxidized or removed. Much P may remain in the topsoil being strongly adsorbed by soil constituents and as undissolved rock phosphate and is unlikely to be removed by insects.

It is reasonable to consider a reduction of the inputs applied at this site, since after ten years the properties of the soil have not improved substantially under this management. However, more studies should be conducted to assess the benefits and cost of nutrients applied in OM compared to other sources and to identify factors affecting uptake of nutrients by plants under this management regime. In particular, the roles of biota in removing OM and nutrients should be quantified as this loss may impinge substantially on management objectives. In local woodland termites have been shown to transport very large amounts of litter and soil OM to their nests (Vasconcellos et al., 2010).

Figure 1.5 – Relationships between the concentration of organic matter (OM) and other soil variables: nitrogen (N); available phosphorus (P_{M1}); potassium (K); calcium (Ca); magnesium (Mg) and cation exchange capacity (CEC) for soil depths 0-20cm (○), 20-50cm (■), 50-100cm (♦) and 100-150cm (▲), at the organic Caribbean cherry farm at Ubajara, Ceara, Northeast Brazil



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ARTIGO 2: COMPOST AND NUTRIENT DYNAMICS UNDER IRRIGATION AND SHADOWING FOR HORTICULTURE IN NORTHEAST BRAZIL

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ABSTRACT

Organic Caribbean cherry cultivationunder central pivot and sprinkler was investigated to determine the decomposition of compost applied under two types of shadowing (total and without) and the dynamics of nutrient release into soil. Litter boxes were made with a 4mm mesh base, and PVC sides, filled with the compost used at the farm. Boxes were recovered after 0, 2, 4, 6, 8, 10, 12 months. Amounts of remaining compost and nutrients were measured and decomposition rates and half-life values were calculated. Soil under the litter boxes was analyzed before and after removing boxes, for nutrient contents (N, P, K, Ca, and Mg) and organic carbon. Compost was lost quickly over time. Losses were faster under central pivot than sprinkler irrigation. Total shadowing caused higher rates of decomposition than without shade. Half-life values varied from 0.12 to 1.02 years. Losses of nutrients were substantial, with P and K being lost at faster rates than mass loss. The nutrients lost from compost were mostly not present in the soil. Insects may have removed compost from the boxes.

Keywords: Decomposition rate, half-life,litter box, soil fauna, soil organic matter.

1 INTRODUCTION

Fertilization in organic horticulture systems has been the focus of several studies (Jiao *et al.*, 2006; Kanchikerimath and Singh, 2001) where organic matter is applied in high quantities (organic systems). The dynamics of organic matter in these systems is dependent of many factors including soil type, climate, management practices, microbial activity, radiation, etc. The combination of all factors will determine the behavior of organic carbon and nutrients in the system.

Irrigation increases humidity and consequently microbial activity in compost and soil, accelerating the decomposition process and transfer of nutrients from compost to soil and plants (Buldeman, 1988).

The management of organic system with large applications of mulch and compost in semi-arid regions needs to be better understood (Davidson and Janssens, 2006; Magnuson *et. al*., 2002, Smith *et. al*, 2010). Is it necessary and effective to apply huge amounts of compost? Are the nutrients presents in compost and mulch retained by the soil to become available to plants and how do irrigation methods and shadowing affect these processes?

This study aimed was to provide an understanding organic matter decomposition and the dynamics of nutrient release from compost, under different types of irrigation and solar radiation intensities. in a commercial orchard in northeast Brazil.

2 MATERIALS AND METHODS

2.1 Site description

The study area is managed by Amway Nutrilite LTDA of Brazil and is located in the Ibiapaba region, Ubajara county, Ceará, in the Northeast of Brazil (3º51'12''S/41º5'10''W) at 850m above sea level. The climate is rainy tropical monsoon, following Köeppen's classification with annual average temperature and rainfall of 28ºC and 670 mm year^{-1} respectively (Chen and Chen, 2013). The rainy season is between January and May with extensive irrigation required to support plant growth. The Nutrilite Farm has operated since 1997 growing Caribbean cherry (*Malpighia punicifoilia* L.) for vitamin C production under organic management certified under biodynamic standards (Diver, 2007).

Based on type of irrigation [central pivot (P), micro sprinkler (S)] and differences in shadowing by cherry trees, areas were chosen to investigate the effect of these management conditions on the decomposition of compost. Two levels of shadowing were used: without shadow (WS), in areas with one year old plants (P and S) with sparse canopy and total shadow (TS), in areas with 6 year (P) or 13 year (S), old plants where the canopy of trees was completely closed creating a complete shadow.

The farm was divided in areas by age of plants. Two areas with 13-year-old plants (A13), two areas with 10-year-old plants (A10), and these four areas were under micro sprinkler (S) irrigation. One central pivot bay was divided into two areas with one (A1) and six (A6) year old plants, respectively. All areas were planted with Caribbean cherry, further information about management and the past use of the areas is presented in Table 2.1. For treatment SWS, 10 years old plants were removed (A10) and replaced by more productive varieties, STS used area A13 and PWS and PTS used areas A1 and A6 respectively. The soil of these areas were classified (Table 2.2) as Ferrasols (A1, A6 and A10) and Acrisols (A13) according to the Brazilian System of Soils Classification (Embrapa, 1999b), which resembles the FAO/WRB system (Eswaran *et al*., 2002).

Litter boxes were placed on the soil surface, randomly, within the areas of study. For all treatments (SWS, STS, PWS, PTS) the boxes were filled with compost made on the farm. The boxes were made of polyvinylchloride (PVC) with 4mm plastic mesh top and bottom. The dimensions of the boxes were 30 cm x 13 cm x 10 cm (length x width x height). The typical composition of the compost is shown in Table 2.3 but the composition varied over time. The compost was pre-weighed (2650 g, wet) and the same amount was placed in each box.

Table 2.1 – Management procedures adopted on areas farmed for 1, 6, 10 and 13 years, under organic Caribbean cherry farming at Ubajara, Ceará, Northeast Brazil

Procedures	Areas			
	A1	A6	A10	A13
Year of planting	End of 2009	Beginning of 2005	Beginning of 2001	Beginning of 1998
Size of area (ha)	14	17	10	10
Past agricultural use	Traditional mango cultivation until 1998 after that fallow	Traditional mango cultivation until 1998 after that fallow	Native vegetation	Traditional strawberries and watermelon cultivation
Number of plants ha^{-1}	667	531	592	565
Number of plants area $^{-1}$	9,349	9,035	5,921	5,652
Spacing (inter plant x inter row in m)	3 x 4.85	2.85 x 6.6	3.5 x 4.82	3.5 x 5.0
Irrigation type and amount (m^3 ha^{-1} year)	Central pivot 9600	Central pivot 7906	Micro sprinklers 4028	Micro sprinklers 16780
Average productivity (kg of fruit plant-1)	0	24	25	29

Table 2.2 – Chemical e physical properties of Ferrasols and Acrisols after 1 (A1), 6 (A6), 10 (A10) and 13 (A13) years, under organic Caribbean cherry farming at Ubajara, Ceará, Northeast Brazil

Chemical and physical properties	Area and soil horizons											
	A1			A6			A10			A13		
	Ap	AB	BW	Ap	AB	BA	$\mathrm{Ap_1}$	$\mathrm{Ap_2}$	$\mathrm{Ap_3}$	Ap	BA	$\mathrm{Bw_1}$
Depth (cm)	0-10	10-23	23-53	0-9	9-21	21-41	0-7	7-13	13-22	0-12	12-56	56-92
Organic carbon (%) [a]	1.07	0.61	0.53	3.29	0.53	0.53	3.06	1.69	0.69	1.99	0.23	0.23
N (%) [b]	0.08	0.06	0.06	0.2	0.06	0.05	0.22	0.16	0.1	0.2	0.03	0.03
EC ($\mathrm{dS\ m^{-1}}$) [c]	0.13	0.05	0.05	0.21	0.15	0.17	0.14	0.09	0.08	0.19	0.08	0.07
pH (soil:water 1:2.5) [c]	7.26	6.12	4.94	6.06	5.14	4.77	7.32	7.45	7.44	7.22	6.87	5.4
P_{M1} ($\mathrm{mg\ kg^{-1}}$) [c]	91.1	4.97	3.02	60.8	13.2	7.5	243	158	149	238	19	13.5
K^+ ($\mathrm{mg\ kg^{-1}}$) [a]	72.8	34.9	20.1	226	61.8	57.2	122	21.5	9.03	174	20	11
Ca^{2+} ($\mathrm{cmol_c\ kg^{-1}}$) [a]	2.16	0.6	0.13	3.08	0.65	0.42	6	4.67	3.67	4.1	0.95	0.24
Mg^{2+} ($\mathrm{cmol_c\ kg^{-1}}$) [a]	0.4	0.19	0.09	1.54	0.35	0.36	2.06	1.31	0.92	1.6	0.3	0.2
Al^{3+} ($\mathrm{cmol_c\ kg^{-1}}$) [a]	0	0	0	0	0.06	0.13	0	0	0	0	0	0.17
PA ($\mathrm{cmol_c\ kg^{-1}}$) [a]	0.47	1.54	2.68	2.47	1.71	2.01	0.76	0.9	0.9	0.7	0.8	1.27
SEB ($\mathrm{cmol_c\ kg^{-1}}$) [a]	2.74	0.88	0.28	5.19	1.15	0.92	5.08	5.17	5.17	6.2	1.3	0.5
ECEC ($\mathrm{cmol_c\ kg^{-1}}$) [a]	2.74	0.88	0.67	5.19	1.21	1.04	8.37	6.03	4.61	6.2	1.3	0.66
CEC ($\mathrm{cmol_c\ kg^{-1}}$) [a]	3.21	2.42	2.96	7.66	2.86	2.93	9.13	6.93	5.51	6.9	2.1	1.75
P_{CaCl2} ($\mathrm{mg\ L^{-1}}$) [c]	54.3	50.5	40.2	55.5	54.1	51.1	49.3	58.8	56.8	47.8	45.9	45.1
IBS (%) [a]	85.3	36.4	9.3	67.8	40.3	31.3	91.6	87	83.6	89.7	62.5	27.6
IAS (%)[a]	0	0	59	0	4.9	12	0	0	0	0	0	26.6
Sand ($\mathrm{g\ kg^{-1}}$) [d]	800	770	700	830	790	740	820	820	840	890	870	840
Silt ($\mathrm{g\ kg^{-1}}$)[d]	90	40	100	50	50	80	70	50	40	60	30	20
Clay ($\mathrm{g\ kg^{-1}}$) [d]	110	190	200	120	170	190	120	130	120	50	100	140
Water dispersible clay ($\mathrm{g\ kg^{-1}}$) [d]	100	130	120	50	100	140	30	40	60	20	90	100
Degree of flocculation ($\mathrm{g\ kg^{-1}}$) [d]	40	300	380	590	380	220	770	710	520	620	90	250
Texture [e]	LS	SL	SL	SCL	SCL	SL	LS	LS	LS	S	LS	LS
Grade or structure development/structure size/type [e]	mo/vf/blsa	mo/vf/blsa	mo/fi&me/blsa	ms/fi/gr	mo/fi/blsa	mo/fi&me/blsa	we/fi/gr	mo/fi/blsa	mo/fi/blsa	we/fi/gr	we/fi/blsa	mo/fi/blsa
Consistency: moist/stickiness/	vfr/nst/	vfr/nst/	vfr/nst/	vfr/sst/	fr/sst/	fr/st/	vfr/nst/	fr/nst/	fr/nst/	vfr/nst/	fr/nst/	fr/nst/
Plasticity [e]	pl	pl	pl	pl	pl	pl	spl	spl	spl	spl	spl	spl
Soil colour (wet) [e]	10YR 5/2	10YR 5/2	7.5YR 5/2	10YR 3/2	10YR 5/4	10YR 5/4	7.5YR 3/2	10YR 3/2	10YR 4/2	10YR 3/2	10YR 5/3	10 YR 6/2

[a] Analysis made following techniques of Defelipo and Ribeiro (1997); electrical conductivity (EC), pH in water, available phosphorus mehlich (P_{M1}), Calcium chloride extractable P content (P_{CaCl2}), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), aluminum (Al^{3+}), potential acidity (PA), sum of exchangeable bases (SEB), effective cation exchange capacity (ECEC), cation exchange capacity at pH 7 (CEC) index of base saturation (IBS), index of aluminum saturation (IAS), total nitrogen (N); [b]Analysis made following techniques of Tedesco *et al.* (1985); [c] Analyses made following techniques of Braga and Defellipo (1974); [d] Analysis made using the pipette method of Embrapa (1999); [e] Analysis made following techniques of Santos et al. (2005); Texture: LS = loamy sand, SL = sandy loam, SCL = Sandy clay loam. Grade or structure development: we = weak, mo = moderate, st = strong, ms = moderate to strong. Structure size: ec = extremely coarse, vc = very coarse/thick, co = coarse/thick, me = medium, fi = fine/thin, vf = very fine/thin. Structure type: gr = granular, bl = block, blab = angular block, blsa = subangular block, pr = prismatic. Consistency: moist: vfr = very friable, fr = friable. Stickiness: nst = non-sticky, sst = slightly sticky, st = sticky, vst = very sticky. Plasticity: spl = slightly plastic, pl = plastic, vpl = very plastic (FAO, 2006).

The amounts of nutrients applied to each box are shown in Table 2.4 and were different for pivot and sprinkler systems because the compost had a different composition at each time. The treatments (PTS, PWS, STS and SWS) were distributed randomly with four replicates and seven times of sampling (0, 2, 4, 6, 8, 10 and 12 months) after installation. Time zero was used as a control. There were 25 boxes per treatment.

Every sampling time, four litter boxes were collected for each treatment, a total of 16 boxes. The compost remaining in the box was weighed and a subsample was taken immediately after sampling for moisture determination, by a gravimetric method (Embrapa 1999a). The samples were dried at 105°C and analyzed for total N, P, K, Ca, Mg and C. These analyses involved total digestion with perchloric acid ($HClO_4$) pre-treated with nitric acid (HNO_3).

Plots of the mass of remaining compost, carbon and nutrients versus time were fitted to linear or exponential functions and rate of loss constants (k) and half-life values were calculated for exponential functions using the following formulas, respectively (Janssen, 1984): $y(t) = y(0) \times e^{-kt}$ $and\ Half - life = -\frac{Ln(2)}{k}$. Where $y(0)$ is the original amount of material applied, $y(t)$ the amount left after a period of time (t), e is the natural logarithm ($e = 2.718$) and k is the loss constant. Half-life is the time taken to lose half of the material or nutrient from the mulch (Buldeman, 1988). Ln is the natural logarithm. For the linear relationship, the half-life was derived directly from the fitted line.

Table 2.3 – Composition and typical chemical composition of compost used for organic Caribbean cherry farming, at Ubajara, Ceará, Northeast Brazil

Composition		**Chemical characterization**	
Compost [a]	**(%)**	**Compost**	**(%)**
		Nitrogen	1.33
		Phosphorus	0.25
Biodynamic preparation[b]	0.1	Potassium	1.38
Caribbean cherry residue	9.7	Calcium	1.16
Cattle manure	19.2	Magnesium	0.51
Sugar cane bagasse	41	Organic carbon	20.5
Water	30	Moisture	63.9
		pH[*]	6.50

[a] Source: Amway Nutrilite of Brazil farm; [b] Herbal powder mixture made at farm.

2.2 Soil sampling and analysis

Before distribution of boxes in the field, soil samples were collected at 0-5, 5-10, and 10 to 20 cm depths from the soil surface at each point that a box would be installed. These samples will be referred to as the control samples. Boxes were periodically removed for the remaining compost to be weighed and analyzed. After removal of litter boxes, soil samples were taken at the same three depths from below the location of the removed boxes. The soil samples were air dried, sieved to < 2 mm prior to evaluation of: available phosphorus by the Mehlich method (P) according Braga and Defelipo (1974), exchangeable potassium (K), exchangeable calcium (Ca), exchangeable magnesium (Mg) and organic matter (OM) as described by Embrapa (1997), and total nitrogen (N) according to Tedesco *et al*. (1985).

Table 2.4 – Amount of nutrients applied to the soil by compost in an organic Caribbean cherry farming at Ubajara, Ceará, Northeast Brazil

Elements (g)	PTS	PWS	STS	SWS
C	256	256	323	323
N	19	19	24	24
P	4.4	4.4	3.4	3.4
K	1.1	1.1	1.6	1.6
Ca	12	12	7.4	7.4
Mg	11	11	8.3	8.3

PTS – pivot total shadow; PWS – pivot without shadow; STS – sprinkler total shadow; SWS – sprinkler without shadow.

2.3 Statistical analysis

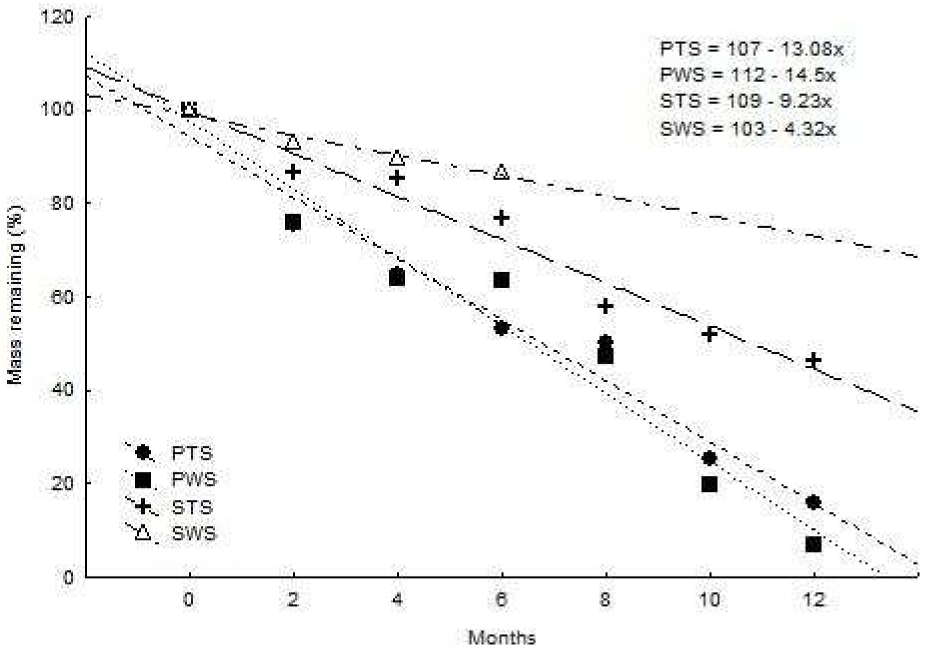
Statistical analysis included simple linear and exponential regression. Statistica 7.0 software was used. Mean data from the replicates was adopted in this analysis.

3 RESULTS AND DISCUSSION

The percentage of compost remaining over time is shown in Fig.2.1, which indicates a rapid and nearly linear loss of compost over time. The rate of loss varies greatly between the treatments with losses under pivot irrigation being much faster than losses under sprinkler irrigation. For sprinkler irrigation, loss of compost was much larger under total shade compared to without shade. Other authors (Ayres *et al.* 2009; Cong *et al.*, 2015) studying decomposition of compost have also reported major effects of humidity and radiation.

The loss of nutrient elements over time was also rapid and curves describing these losses were variously linear or exponential in form (Figure 2.2). These data are best evaluated by comparing half-life values (Table 2.5) obtained from fitted curves. When we consider all elements and treatments there is considerable variation in half-life with values ranging from 0.12 to 1.02 years. For C, N, Ca and Mg half-lives were shorter under pivot irrigation compared to sprinkler irrigation. The reverse situation occurred for P and K. There was no systematic effect of plus/minus shadow on half-life of the elements although compost without shadow

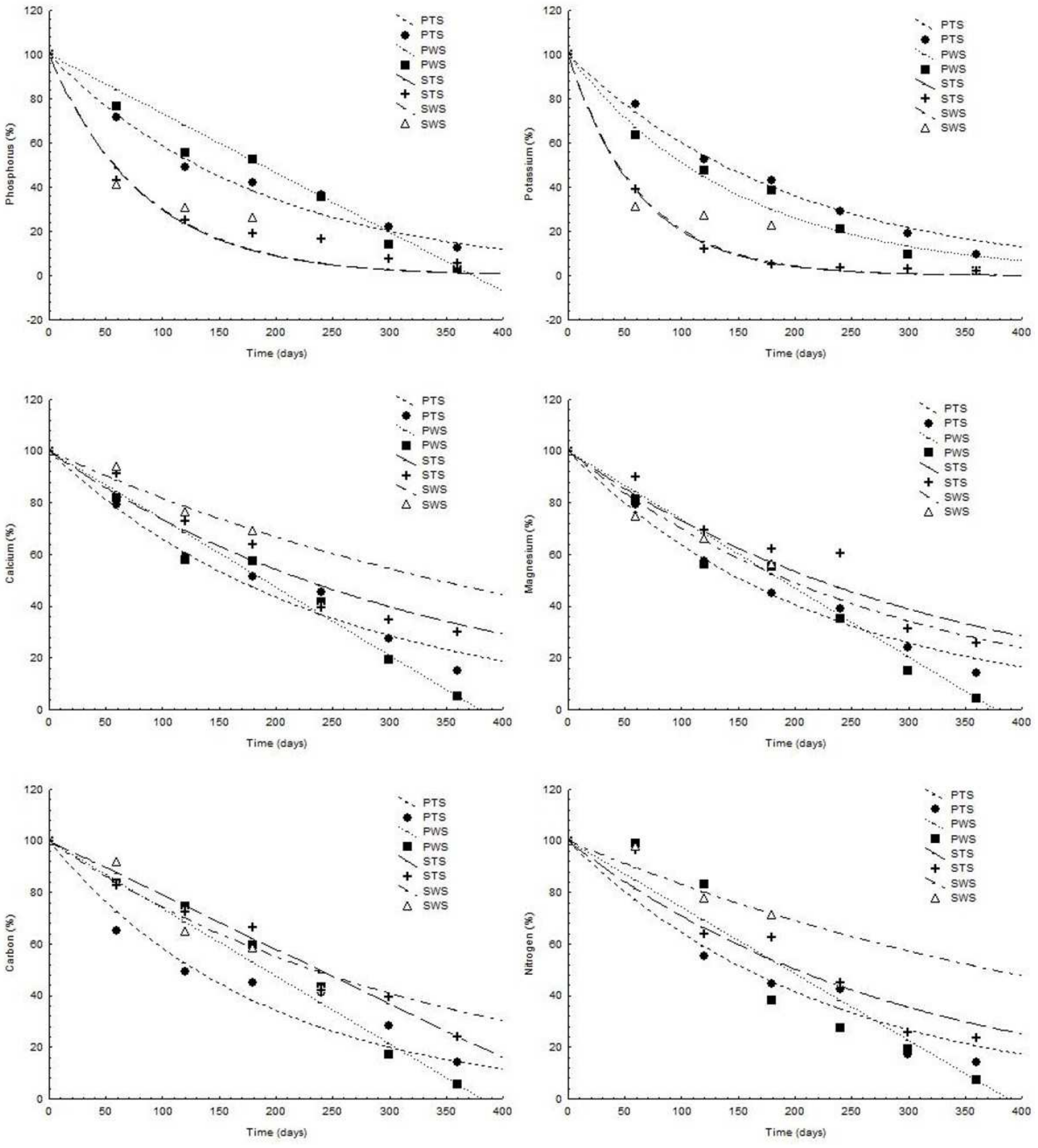
Figure 2.1 – Percentage of compost remaining over 12 months for organic Caribbean cherry farming at Ubajara, Ceará, Northeast Brazil. (PTS – pivot total shadow; PWS – pivot without shadow; STS – sprinkler total shadow; SWS – sprinkler without shadow)



More commonly had a longer half-life than compost under shadow. This was particularly marked for N under sprinkler irrigation where the half-lives with and without shadow were 0.55 and 1.02 years, respectively. For P and K under sprinkler irrigation half-lives were particularly short (0.16 and 0.12 years respectively). These diverse half-lives for different elements and management conditions reflect the changing composition of the residual compost over time. These trends are best illustrated by plotting the ratio of element content/carbon content as shown in Figure 2.3. It should be noted that the initial (time zero) ratios for Ca, P and Mg differ for pivot and sprinkler treatments. This is because different batches of compost were used for the two treatments, the composition of compost listed in Table 2.3 is simply indicative although the two batches used in this experiment were analyzed. The faster loss of P and K relative to C is evident in this diagram and is consistent with the shorter half-lives for these elements.

The half-life values obtained in this experiment are compared in Table 2.6 with some published half-life values for diverse plant materials obtained using procedures similar to those employed in this research. In particular, the plant material was contained within a mesh and the environment was tropical. It is apparent that the half-lives obtained in this research are

Figure 2.2 – Percentages of nutrients and carbon in compost over time and fitted curves for organic Caribbean cherry farming at Ubajara, Ceará, Northeast Brazil. (PTS – pivot total shadow; PWS – pivot without shadow; STS – sprinkler total shadow; SWS – sprinkler without shadow)



Mostly longer and often much longer than the literature values. However, the half-life values for chopped secondary forest materials (Reichert *et al.*, 2015) are quite similar to our values but the more rapid loss of K and P did not occur. Bolan *et al.* (2012) found half-life values for poultry manure compost were similar to our values, ranging from 139 to187 days.

Table 2.5 – Rate constants for linear and exponential models and half-lives for carbon (C), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) for compost applied to Caribbean cherry plants at Ubajara, Ceará, Northeast Brazil

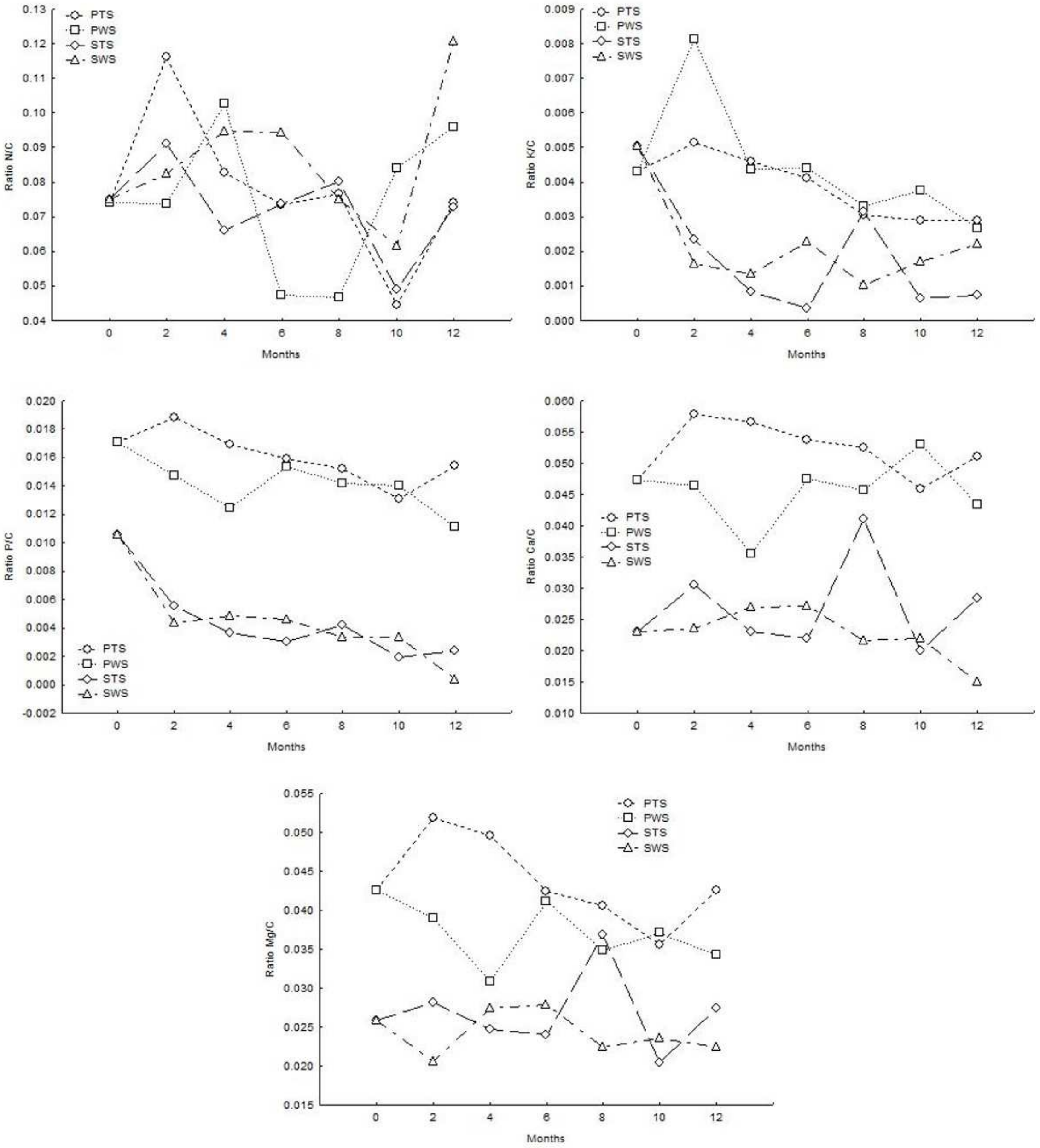
		Half-life value (years)	Rate constant K	Correlation coefficient r	Statistical significance P
C	PTS	0.35	0.0054 b	0.91	0.005
	PWS	0.52	0.26 a	0.98	0.001
	STS	0.65	0.21 a	0.93	0.012
	SWS	0.64	0.0030 b	0.81	0.164
N	PTS	0.43	0.0044 b	0.87	0.083
	PWS	0.53	0.26 a	0.91	0.058
	STS	0.55	0.0035 b	0.90	0.058
	SWS	1.02	0.0019 b	0.75	0.225
Ca	PTS	0.46	0.0042 b	0.97	0.003
	PWS	0.52	0.26 a	0.95	0.006
	STS	0.62	0.0031 b	0.95	0.016
	SWS	0.94	0.0020 b	0.87	0.113
Mg	PTS	0.42	0.0045 b	0.98	0.001
	PWS	0.52	0.27 a	0.95	0.007
	STS	0.60	0.0031 b	0.91	0.043
	SWS	0.53	0.0036 b	0.73	0.061
P	PTS	0.36	0.0053 b	0.97	0.001
	PWS	0.51	0.27 a	0.96	0.004
	STS	0.16	0.012 b	0.92	0.001
	SWS	0.16	0.012 b	0.81	0.084
K	PTS	0.37	0.0051 b	0.99	0.000
	PWS	0.28	0.0067 b	0.97	0.001
	STS	0.12	0.016 b	0.99	0.000
	SWS	0.12	0.016 b	0.69	0.112

a - K linear; b - K exponential; PTS – pivot total shadow; PWS – pivot without shadow; STS – sprinkler total shadow; SWS – sprinkler without shadow.

3.1 Changes in soil composition under compost

The substantial amounts of elements lost from the compost (Fig. 2.2) might be expected to have been leached into the underlying soil where they could be detected by soil analysis. Table 2.7 shows the amounts in grams of extractable P, K, Ca and Mg together with total C and N in the 0-20cm layer of soil from beneath the compost box for the six sampling times and four treatments. The table shows the contents of elements in this soil layer before installation of litter boxes (control), the amounts of nutrients lost from the compost (applied),

Figure 2.3 – Ratios between nutrient and carbon concentrations in compost over time for organic Caribbean cherry farming at Ubajara, Ceará, Northeast Brazil. (PTS – pivot total shadow; PWS – pivot without shadow; STS – sprinkler total shadow; SWS – sprinkler without shadow)



The sum of these two amounts, which is the amount of each element that would be present if all of the element lost from the compost was retained in the 0-20cm soil layer (expected), and the amounts of element measured as being present in this soil layer after removed litter boxes (found). For P the amounts found are substantially less than the expected amount in most instances, which might be interpreted as indicating that the P was removed from the litter by fauna and so was not leached in to the soil. Alternatively, the amount of P in the soil was estimated by extraction with Mehlich solution that might only dissolve a minor proportion of the P leached into the soil and retained by adsorption on soil colloids.

The results for K do not show a single systematic trend. For central pivot irrigation, the amounts of K found in the soil were greater than the expected amount as was the case for two and four month samples from sprinkler irrigated compost. However, for 6-12 month soil samples watered by sprinkler the observed amounts of K were much less, than the expected amounts. This may have been due to plant roots removing K from the soil. For Ca, Mg, OC and N the amounts found in the soil were substantially less than the amounts expected to be in the soil if all of the elements lost from the compost had been leached into the 0-20 cm soil layer. One explanation for this discrepancy is that these elements were removed from the compost by insects and so were not leached into the soil. Some C and N may have been volatilized during microbial decomposition. Several authors (Schroth et al., 1992; Luizão and Shubart, 1987; Buldeman, 1988) have made similar observations and ascribed major losses of OC and nutrients from litter to removal by termites and other insects, which are smaller than the mesh size of litterbags.

Gadelha *et al.* (2015) explained the major losses of organic material from compost and mulch used by managers at this site to removal of plant material by insects. Portela (2012) working at the same region, made a fauna study and found insects of many classes and in elevated quantities were present in plantation soils.

Table 2.6 – Half-life values for nutrient loss from compost and litter for this work and published studies

Authors	Observations	Materials used	Climate conditions	Treatments	Half life (days)					
					C	N	P	K	Ca	Mg
This study	Range for 4 treatments PTS, PWS, STS, SWS	Compost	Steppe hot arid	PTS	129	157	129	135	166	153
				PWS	190	193	186	103	189	188
				STS	237	200	57	43	225	220
				SWS	232	373	57	44	343	194
Buldeman, 1998	Three species *Gliricidia sepium/ Leucaena leucocephala/ Flemingia macrophylla,*	Leaves	Humid tropical	Gs	22	22	20	11	29	16
				Ll	30	38	26	12	46	24
				Fm	53	53	34	22	69	38
Reichard *et al.*, 2015	Secondary forest chopped to 4 sizes (Fs1<Fs<2,<Fs3<Fs4), litter bags	Secondary forest	Tropical	Fs1		86	78	42	49	73
				Fs2		128	82	119	49	78
				Fs3		136	140	201	76	77
				Fs4		96	124	77	125	64
Nygren *et al.*, 2000	Nodules of *Erythrina variegata* 2 soils (O,V), mesofauna+microbes/ microbes(Mm/M) in humid and dry seasons,litter bags	Woody legume nodules	Humid and subhumid tropical	OMm		3.71				
				OM		3.39				
				VMm		4.37				
				VM		2.54				
Schroth *et al.*, 1992	Leaves and branches(L,B) of *Cajanus cajan* litter bags	Leaves and branches	Subhumid tropical	L1	16	10	10	9	27	19
				B1	20	16	10	7	32	13
Luizão and Schubart, 1987	Leaves of *Clitoria racemosa* litter bags	Leaves, dry and wet seasons	Humid tropical	Pd			30	50		115
				Pw		30	15	15	75	15

PTS – pivot total shadow; PWS – pivot without shadow; STS – sprinkler total shadow; SWS – sprinkler without shadow; Gs - *Gliricidia sepium*; Ll - *Leucaena leucocephala*; Fm - *Flemingia macrophylla*;; Fs1 – 1 to 7mm residue size; Fs2 – 7 to 25mm residue size; Fs3 – 25 to 35mm residue size; Fs4 - >35mm residue size; –; d – dry season; w – wet season.

Table 2.7 – Amounts of nutrients and carbon (both in grams) in 0-20 cm depth soil under litter boxes for 6 times (two, four, six, eight, ten and twelve months) for soils receiving compost with quantities of nutrient lost from compost (Appl.), amounts expected in the soil (Exp.) and amounts found for each management regime for organic Caribbean cherry farming, at Ubajara, Ceará, Northeast Brazil

Phosphorus

	PTS				PWS				STS				SWS			
Time	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.
2	0.82	0.96	1.78	0.62	1.73	0.94	2.68	0.22	0.95	0.40	1.35	0.20	0.67	0.20	0.87	1.02
4	0.66	1.37	2.04	0.60	1.19	1.41	2.59	0.59	0.86	0.44	1.30	0.81	0.79	0.31	1.11	1.19
6	0.72	1.81	2.53	0.35	1.33	1.42	2.75	0.56	0.42	0.70	1.12	0.42	0.91	0.40	1.31	1.12
8	0.77	1.94	2.71	0.57	1.59	2.06	3.65	1.28	0.71	1.28	1.99	0.41	0.84			
10	0.65	2.90	3.54	0.61	0.84	3.12	3.96	0.64	0.87	1.46	2.33	0.43	0.72			
12	0.85	3.26	4.11	0.34	1.11	3.62	4.74	1.08	0.51	1.62	2.14	0.35	0.32			

Potassium

	PTS				PWS				STS				SWS			
Time	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.
2	1.42	0.24	1.66	4.36	1.06	0.24	1.29	2.37	0.47	0.19	0.66	2.37	1.86	0.10	1.96	2.14
4	1.52	0.35	1.87	3.14	1.06	0.35	1.42	2.49	0.51	0.21	0.72	1.61	1.01	0.15	1.16	2.36
6	1.35	0.46	1.80	1.83	2.47	0.36	2.83	4.28	1.58	0.33	1.92	0.40	1.91	0.19	2.10	0.70
8	1.95	0.49	2.44	2.84	0.82	0.52	1.34	2.15	1.94	0.61	2.55	0.26	1.68			
10	1.94	0.73	2.67	2.82	1.23	0.79	2.02	2.79	1.82	0.70	2.51	0.38	1.24			
12	2.42	0.82	3.24	2.26	1.50	0.91	2.41	2.56	1.99	0.78	2.77	0.24	1.18			

Calcium

	PTS				PWS				STS				SWS			
Time	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.
2	7.54	2.64	10.18	9.31	6.60	2.61	9.21	5.90	6.89	0.87	7.76	7.39	8.38	0.44	8.82	7.69
4	8.15	3.79	11.94	6.66	7.30	3.89	11.19	8.30	8.63	0.96	9.59	7.61	8.58	0.68	9.27	7.72
6	7.84	5.01	12.85	6.65	6.21	3.93	10.13	6.18	5.54	1.52	7.05	5.26	9.79	0.87	10.66	9.11
8	6.94	5.37	12.30	5.45	6.36	5.68	12.05	7.74	7.94	2.77	10.71	9.40	9.75			
10	8.62	8.01	16.63	7.52	6.48	8.63	15.11	7.57	7.80	3.17	10.97	7.94	8.62			
12	8.00	9.01	17.02	7.70	7.15	10.02	17.17	10.24	6.27	3.53	9.80	7.29	6.73			

Magnesium

	PTS				PWS				STS				SWS			
Time	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.
2	2.38	2.38	4.75	3.02	1.80	2.35	4.15	1.54	2.43	0.98	3.41	1.79	2.33	0.50	2.83	1.95
4	2.45	3.41	5.86	2.50	1.97	3.50	5.47	2.22	2.38	1.08	3.46	2.28	1.76	0.77	2.53	2.15
6	2.27	4.51	6.78	2.68	1.63	3.53	5.16	1.36	1.71	1.70	3.42	1.49	2.50	0.97	3.47	1.80
8	2.12	4.83	6.95	1.69	1.58	5.11	6.69	1.82	2.36	3.11	5.47	2.47	2.21			
10	2.49	7.20	9.69	2.41	1.64	7.76	9.41	1.55	3.08	3.55	6.63	2.13	2.12			
12	2.50	8.11	10.61	2.57	1.84	9.01	10.86	3.05	2.16	3.96	6.12	2.41	1.47			

Organic carbon

	PTS				PWS				STS				SWS			
Time	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.
2	168	56	224	235	146	55	201	118	154	38	192	134	123	19	143	105
4	179	80	259	160	178	82	260	163	160	42	202	133	120	30	150	99
6	181	106	286	124	152	83	235	136	89	66	155	81	176	38	213	139
8	163	113	277	140	153	120	273	155	144	120	264	188	128			
10	197	169	367	200	139	182	321	151	171	138	309	139	142			
12	215	190	405	214	184	212	396	215	124	153	278	116	85			

Nitrogen

	PTS				PWS				STS				SWS			
Time	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.	Cont.	Appl.	Exp.	Found.
2	11.89	4.14	16.03	14.20	14.72	4.09	18.80	9.88	11.82	2.85	14.67	9.22	10.49	1.45	11.95	10.65
4	12.24	5.94	18.18	10.65	11.47	6.09	17.56	12.51	12.71	3.14	15.85	10.68	7.53	2.23	9.77	8.27
6	12.80	7.85	20.65	10.52	10.22	6.15	16.37	9.13	6.83	4.96	11.79	6.02	11.59	2.84	14.43	9.82
8	10.91	8.41	19.32	8.62	9.36	8.90	18.26	10.53	9.36	9.06	18.42	11.13	9.24			
10	13.39	12.54	25.94	11.50	10.84	13.52	24.36	11.70	10.89	10.35	21.25	10.13	8.81			
12	13.98	14.12	28.10	11.30	12.25	15.69	27.94	11.34	7.36	11.53	18.89	6.88	6.26			

PTS – pivot total shadow; PWS – pivot without shadow; STS – sprinkler total shadow; SWS – sprinkler without shadow; Cont. – control values; Appl. – nutrients applied through compost; Exp. – value expected to be on soil; Found – values measured (stocks) on soil at each time.

4 CONCLUSIONS

The compost was lost quickly over time, losses being faster under central pivot irrigation so that element half-lives were shorter than under sprinkler. Total shadowing produced higher rates of decomposition than no shadow, consequently, losses of nutrients were high with loss rates of P and K, being faster than mass loss. The amounts of nutrients recovered in the soil were mostly very small compared to the amounts applied. Probably insects removed this material faster than it was decomposed and mineralized to become incorporated in the soil and available to plants.

The managers of this plantation anticipate that amount of organic material applied to these soils should improve soil fertility largely than was found here. It is necessary to investigate the actions of micro and meso fauna to determine the rates at which they remove plant materials from compost as the cost of composting is substantial.

4.1 Acknowledgements

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CONSIDERAÇÕES FINAIS

Diante desses resultados verificou-se que o aporte de grandes quantidades de matéria orgânica aos solos por períodos prolongados não causou o efeito esperado, uma vez que as quantidades de nutrientes e matéria orgânica encontradas não condizeram com as quantidades aplicadas ao longo dos anos, no entanto o sistema conseguiu se manter em equilíbrio e suprir as necessidades do agricultor. Contudo, a eficiência do sistema pode ser revista e valores de aplicações podem ser ajustados, resultando em economia de recursos financeiros e naturais.

Recomenda-se outros estudos na área principalmente no que discerne a fauna presente, para um melhor entendimento dessa dinâmica da matéria orgânica, nas condições estudadas.

APÊNDICE A – CLASSIFICAÇÃO DOS SOLOS DA FAZENDA NUTRILITE FEITA PARA CARACTERIZAO E ESCOLHA DA ÁREA DE ESTUDO

A – DESCRIÇÃO GERAL

PERFIL 1

DATA: 22.03.2011

CLASSIFICAÇÃO: LATOSSOLO AMARELO Eutrófico argissólico

LOCALIZAÇÃO: Chapada da Ibiapaba, Rodovia BR 222, Km 334, Fazenda Amway Nutrilite, Bloco C, Quadra 11. Ubajara, Ceará, Brasil, 3°52’2.82” S e 41° 5’35.82” W.

SITUAÇÃO, DECLIVE E COBERTURA VEGETAL SOBRE O PERFIL: Amostras coletadas em trincheira aberta sob plantio de acerola *(Malpighia punicifoilia*L.)

ALTITUDE: 769 m

LITOLOGIA: Arenito branco, grosseiro, conglomerático, com leitos de conglomerado oligomítico e seixos do quartzo na base.

FORMAÇÃO GEOLÓGICA: Formação Serra Grande, Arenitos.

CRONOLOGIA: Siluriano Devoniano Inferior.

MATERIAL ORIGINÁRIO: Produto de alteração do material supracitado.

PEDREGOSIDADE: Não-pedregoso.

ROCHOSIDADE: Não-rochoso.

RELEVO LOCAL: Plano.

RELEVO REGIONAL: Suave ondulado.

EROSÃO: Laminar não aparente.

DRENAGEM: Fortemente drenado.

VEGETAÇÃO PRIMÁRIA: Vegetação de transição entre floresta e caatinga

USO ATUAL: Cultivo de Acerola (*Malpighia punicifoilia* L.).

CLIMA: Amw, Classificação de Koppen

DESCRITO E COLETADO POR: Gustavo Valladares, Teógenes S. de Oliveira, Daniela Zuliane e Janine Gadelha.

B – DESCRIÇÃO MORFOLÓGICA

AP_1 0-7 cm, bruno-escuro (7.5YR 3/2, úmido), bruno-acinzentado muito escuro (10YR 3/2, seco); areia franca;fraca pequena granular; muito friável; não pegajosa, ligeiramente plástica; transição plana e abrupta.

AP_2 7-13 cm, bruno-acinzentado muito escuro (10YR 3/2, úmido), bruno (10YR 4/3, seco); areia franca;moderado pequenos blocos subangulares; friável; não pegajosa, ligeiramente plástica; transição plana e abrupta.

AP_3 13-22 cm, bruno-acinzentado-escuro (10YR 4/2, úmido), bruno (10YR 4/3, seco); areia franca;moderado pequenos blocos subangulares; friável; não pegajosa, ligeiramente plástica; transição plana e abrupta.

B/A 22-49 cm, bruno-amarelado- escuro (10YR 4/4, úmido), bruno-amarelado (10YR 5/4, seco); areia;fraco pequenos blocos subangulares de aspecto maciço; muito friável; não pegajosa, ligeiramente plástica; transição plana e gradual.

BW_1 49-88 cm, bruno-amarelado (10YR 5/4, úmido), amarelo-brunado (10YR 6/6, seco); franco arenosa;moderado médios blocos subangulares; muito friável; ligeiramente pegajosa, ligeiramente plástica; transição plana e difusa.

BW_2 88-122 cm, bruno-amarelado (10YR 5/6, úmido), amarelo-brunado (10YR 6/6, seco); franco argilo-arenosa;moderado a forte pequenos e médios a muito pequenos blocos subangulares a granular; muito friável; ligeiramente pegajosa, ligeiramente plástica; transição plana e difusa.

BW_3 122-160 cm+, bruno-amarelado (10YR 5/6, úmido), amarelo-brunado (10YR 6/6, seco); franco argilo-arenosa;moderado a forte pequenos e médios a muito pequenos blocos subangulares a granular; muito friável; ligeiramente pegajosa, plástica.

RAÍZES – Muitas finas nos horizontes AP_1, AP_2 e AP_3; comuns finas no horizonte B/A; poucas finas nos horizontes BW_1 e BW2; raras finas em BW_3.

OBSERVAÇÕES – Em todo perfil observa-se mosqueado distinto da cor do horizonte AP_3 com diâmetro entre 2-5mm com no máximo 1% da área exposta.

- Entre AP_3 e B/A aparência indica compactação.

- Carvão aparente até BW_1.

C – ANÁLISES FÍSICAS E QUÍMICAS

Horizonte		Granulometria da Terra Fina			Argila Disp. em $H_2$0	Grau de Floc.		C.E	pH (1:2,5)	P	K
Símb.	Prof.	Areia	Argila	Silte				dS/m	Agua	mg/dm^3	
	Cm	g kg^{-1}									
AP$_1$	0 -7	816	116	68	27	769		0,14	7,32	350,2	176
AP$_2$	7-13	821	126	52	36	714		0,087	7,45	227,4	31
AP$_3$	13-22	845	119	36	57	519		0,077	7,44	215,1	13
B/A	22-49	852	115	33	78	316		0,06	7,36	5,9	3
BW$_1$	49-88	765	191	43	145	242		0,062	6,97	2,5	5
BW$_2$	88-122	746	212	43	155	267		0,069	6,54	2,3	9
BW$_3$	122-160+	735	219	46	157	283		0,078	5,49	2,2	13
Horizonte	Ca^{2+}	Mg^{2+}	Al^{3+}	H + Al	SB	(t)	(T)	V	m	MO	P-REM
	cmol$_c$ dm^{-3}							%		dag kg^{-1}	mg L^{-1}
AP$_1$	8,64	2,96	0	1,1	7,32	12,05	13,15	91,6	0	5,27	49,3
AP$_2$	6,72	1,88	0	1,3	7,45	8,68	9,98	87	0	2,9	58,8
AP$_3$	5,28	1,33	0	1,3	7,44	6,64	7,94	83,6	0	1,19	56,8
B/A	2,17	0,65	0	0,8	7,36	2,83	3,63	78	0	0,53	53,8
BW$_1$	1,72	0,79	0	1,6	6,97	2,52	4,12	61,2	0	0,4	53,5
BW$_2$	1,42	0,65	0	1,4	6,54	2,09	3,49	59,9	0	0,26	48,8
BW$_3$	0,75	0,44	0,1	1,8	5,49	1,32	3,02	40,4	7,6	0,26	44,4

A – DESCRIÇÃO GERAL

PERFIL 2

DATA: 23.03.2011

CLASSIFICAÇÃO: NEOSSOLO QUARTZARÊNICO Órtico êutrico

LOCALIZAÇÃO: Chapada da Ibiapaba, Rodovia BR 222, Km 334, Fazenda Amway Nutrilite, Bloco A Quadra 3. Ubajara, Ceará, Brasil, 3°52’56.82” S e 41° 5’58.74” W.

SITUAÇÃO, DECLIVE E COBERTURA VEGETAL SOBRE O PERFIL: Amostras coletadas em trincheira aberta sob plantio de acerola (*Malpighia punicifoilia* L.)

ALTITUDE: 759 m

LITOLOGIA: Arenito branco, grosseiro, conglomerático, com leitos de conglomerado oligomítico e seixos do quartzo na base.

FORMAÇÃO GEOLÓGICA: Formação Serra Grande, Arenitos.

CRONOLOGIA: Siluriano Devoniano Inferior.

MATERIAL ORIGINÁRIO: Produto de alteração do material supracitado.

PEDREGOSIDADE: Não-pedregoso.

ROCHOSIDADE: Não-rochoso.

RELEVO LOCAL: Plano.

RELEVO REGIONAL: Suave ondulado.

EROSÃO: Laminar não aparente.

DRENAGEM: Fortemente drenado.

VEGETAÇÃO PRIMÁRIA: Vegetação de transição entre floresta e caatinga

USO ATUAL: Cultivo de Acerola (*Malpighia punicifoilia* L.).

CLIMA: Amw, Classificação de Koppen

DESCRITO E COLETADO POR: Gustavo Valladares, Teógenes S. de Oliveira, Daniela Zuliane e Janine Gadelha.

B – DESCRIÇÃO MORFOLÓGICA

AP$_1$ 0-8 cm, bruno-acinzentado muito escuro (2.5YR 3/2, úmido), bruno-acinzentado escuro (10YR 4/2, seco); areia;fraca pequena granular; solta; não pegajosa, não plástica; transição plana e abrupta.

AP_2 8-17 cm, bruno-acinzentado muito escuro (10YR 3/2, úmido), bruno (10YR 5/3, seco); areia;fraca pequena granular; solta; não pegajosa, não plástica; transição plana e abrupta.

CA 17-29 cm, bruno (10YR 4/3, úmido), bruno-claro-acinzentado (10YR 6/3, seco); areia;simples; solta; não pegajosa, não plástica; transição plana e clara.

C_1 29-64 cm, bruno-amarelado (10YR 5/4, úmido), bruno muito claro-acinzentado (10YR 7/4, seco); areia;simples; solta; não pegajosa, não plástica; transição plana e difusa.

C_2 64-106 cm, bruno-amarelado-claro (2.5YR 6/4, úmido), bruno muito claro-acinzentado (10YR 7/4, seco); areia;simples; solta; não pegajosa, não plástica; transição plana e difusa.

C_3 106-151 cm+, amarelo (10YR 7/6, úmido), bruno muito claro-acinzentado (10YR 7/4, seco); areia franca;fraca médios e pequenos blocos subangulares e angulares; solta; não pegajosa, ligeiramente plástica.

RAÍZES – Comuns finas nos horizontes AP_1, AP_2; comuns finas e médias no horizonte CA; raras finas nos horizontes $C_{1,}$ C_2 e C_3.

OBSERVAÇÕES – Em todo perfil observa-se mosqueado da cor do horizonte AP_2.

C – ANÁLISES FÍSICAS E QUÍMICAS

Horizonte		**Granulometria da Terra Fina**			**Argila Disp. em $H_2$0**	**Grau de Floc.**	**C.E**	**pH (1:2,5)**	**P**	**K**
Símb.	**Prof.**	**Areia**	**Argila**	**Silte**			**dS/m**	**Agua**	**mg/dm^3**	
	Cm	**g kg^{-1}**								
AP$_1$	0 -8	874	62	64	21	658	0,253	6,95	382,8	265
AP$_2$	8-17	908	58	34	23	609	0,153	7,12	319,5	128
CA	17-29	943	43	14	37	140	0,082	7,25	120,5	63
C$_1$	29-64	931	54	15	49	86	0,078	6,95	22,9	41
C$_2$	64-106	890	84	26	71	156	0,067	5,67	10,8	23
C$_3$	106-151+	858	94	48	86	91	0,056	5,2	3	19

Horizonte	**Ca^{2+}**	**Mg^{2+}**	**Al^{3+}**	**H + Al**	**SB**	**(t)**	**(T)**	**V**	**m**	**MO**	**P-REM**
	cmol$_c$ dm^{-3}							**%**		**dag kg^{-1}**	**mg L^{-1}**
AP$_1$	9,53	3,57	0	1,6	13,78	13,78	15,38	89,6	0		43,6
AP$_2$	5,44	1,75	0	1,3	7,52	7,52	8,82	85,3	0	2,37	38,5
CA	2,11	0,53	0	1	2,8	2,8	3,8	73,7	0	0,4	48,9
C$_1$	0,93	0,35	0	1,3	1,38	1,38	2,68	51,5	0	0,13	50,8
C$_2$	0,6	0,35	0	1,6	1,01	1,01	2,61	38,7	0	0,26	50,3
C$_3$	0,19	0,22	0,29	2,1	0,46	0,75	2,56	18	38,7	0,13	41,3

A – DESCRIÇÃO GERAL

PERFIL 3

DATA: 23.03.2011

CLASSIFICAÇÃO: ARGISSOLO ACINZENTADO Distrófico arênico.

LOCALIZAÇÃO: Chapada da Ibiapaba, Rodovia BR 222, Km 334, Fazenda Amway Nutrilite, Bloco B, Quadra 5. Ubajara, Ceará, Brasil, 3°53’38.70” S e 41° 5’41.70” W.

SITUAÇÃO, DECLIVE E COBERTURA VEGETAL SOBRE O PERFIL: Amostras coletadas em trincheira aberta sob plantio de acerola (*Malpighia punicifoilia* L.)

ALTITUDE: 762 m

LITOLOGIA: Arenito branco, grosseiro, conglomerático, com leitos de conglomerado oligomítico e seixos do quartzo na base.

FORMAÇÃO GEOLÓGICA: Formação Serra Grande, Arenitos.

CRONOLOGIA: Siluriano Devoniano Inferior.

MATERIAL ORIGINÁRIO: Produto de alteração do material supracitado.

PEDREGOSIDADE: Não-pedregoso.

ROCHOSIDADE: Não-rochoso.

RELEVO LOCAL: Plano.

RELEVO REGIONAL: Suave ondulado.

EROSÃO: Laminar não aparente.

DRENAGEM: Fortemente drenado.

VEGETAÇÃO PRIMÁRIA: Vegetação de transição entre floresta e caatinga

USO ATUAL: Cultivo de Acerola (*Malpighia punicifoilia* L.).

CLIMA: Amw, Classificação de Koppen

DESCRITO E COLETADO POR: Gustavo Valladares, Teógenes S. de Oliveira, Daniela Zuliane e Janine Gadelha.

B – DESCRIÇÃO MORFOLÓGICA

AP 0-12 cm, bruno-acinzentado muito escuro (10YR 3/2, úmido), bruno-acinzentado escuro (10YR 4/2, seco); areia;fraca pequena granular; muito friável; não pegajosa, ligeiramente plástica; transição plana e clara.

BA 12-56 cm, bruno (10YR 5/3, úmido), cinzento-claro (10YR 7/2, seco); areia;fraca pequena blocos subangulares; solta; não pegajosa, ligeiramente plástica; transição plana e gradual.

BW_1 56-92 cm, cinzento-brunado -claro (10YR 6/2, úmido), cinzento-claro (10YR 7/2, seco); areia franca;moderado pequenos blocos subangulares; friável; não pegajosa, ligeiramente plástica; transição plana e abrupta.

BW_2 92-152 cm+, bruno-amarelado- escuro (10YR 4/4, úmido), bruno-amarelado (10YR 5/4, seco); areia franca;moderado pequenos blocos subangulares; muito friável; ligeiramente pegajosa, ligeiramente plástica.

RAÍZES – Poucas finas nos horizontes AP e BA; raras finas nos horizontes BW_1 e BW_2.

OBSERVAÇÕES – Em todo perfil observa-se mosqueado distinto da cor do horizonte AP sendo mais evidenciado no perfil BA.

C – ANÁLISES FÍSICAS E QUÍMICAS

Horizonte		**Granulometria da Terra Fina**			**Argila Disp. em $H_2$0**	**Grau de Floc.**	**C.E**	**pH (1:2,5)**	**P**	**K**
Símb.	**Prof.**	**Areia**	**Argila**	**Silte**			**dS/m**	**Agua**	**mg/dm^3**	
	Cm	**g kg^{-1}**								
AP	0 -12	895	48	57	18	619	0,192	7,22	369,3	270
BA	12-56	875	97	28	89	87	0,08	6,87	31,4	34
BW_1	56-92	839	135	26	102	247	0,069	5,4	22,4	18
BW_2	92-152+	787	155	57	131	157	0,063	4,93	11,3	21

Horizonte	**Ca^{2+}**	**Mg^{2+}**	**Al^{3+}**	**H + Al**	**SB**	**(t)**	**(T)**	**V**	**m**	**MO**	**P-REM**
	$cmol_c$ dm^{-3}							**%**		**dag kg^{-1}**	**mg L^{-1}**
AP	6,38	2,51	0	1,1	9,58	9,58	10,68	89,7	0	3,42	47,8
BA	1,58	0,5	0	1,3	2,17	2,17	3,47	62,5	0	0,4	45,9
BW_1	0,41	0,34	0,29	2,1	0,8	1,09	2,9	27,6	26,6	0,4	45,1
BW_2	0,15	0,17	0,49	2,4	0,37	0,86	2,77	13,4	57	0,26	42,9

A – DESCRIÇÃO GERAL

PERFIL 4

DATA: 23.03.2011

CLASSIFICAÇÃO: LATOSSOLO AMARELO Distrófico argissólico

LOCALIZAÇÃO: Chapada da Ibiapaba, Rodovia BR 222, Km 334, Fazenda Amway Nutrilite, Bloco E, Quadra 18. Ubajara, Ceará, Brasil, 3°54’3.06” S e 41° 5’45.12” W.

SITUAÇÃO, DECLIVE E COBERTURA VEGETAL SOBRE O PERFIL: Amostras coletadas em trincheira aberta sob plantio de acerola (*Malpighia punicifoilia* L.)

ALTITUDE: 759 m

LITOLOGIA: Arenito branco, grosseiro, conglomerático, com leitos de conglomerado oligomítico e seixos do quartzo na base.

FORMAÇÃO GEOLÓGICA: Formação Serra Grande, Arenitos.

CRONOLOGIA: Siluriano Devoniano Inferior.

MATERIAL ORIGINÁRIO: Produto de alteração do material supracitado.

PEDREGOSIDADE: Não-pedregoso.

ROCHOSIDADE: Não-rochoso.

RELEVO LOCAL: Plano.

RELEVO REGIONAL: Suave ondulado.

EROSÃO: Laminar não aparente.

DRENAGEM: Fortemente drenado.

VEGETAÇÃO PRIMÁRIA: Vegetação de transição entre floresta e caatinga

USO ATUAL: Cultivo de Acerola (*Malpighia punicifoilia* L.).

CLIMA: Amw, Classificação de Koppen

DESCRITO E COLETADO POR: Gustavo Valladares, Teógenes S. de Oliveira, Daniela Zuliane e Janine Gadelha.

B – DESCRIÇÃO MORFOLÓGICA

AP 0-10 cm, bruno-acinzentado (10YR 5/2, úmido), cinzento-brunado-claro (10YR 6/2, seco); areia franca;moderado muito pequena blocos subangulares; muito friável; não pegajosa, plástica; transição plana e clara.

AB 10-23 cm, bruno-acinzentado (10YR 5/2, úmido), cinzento-brunado-claro (10YR 6/2, seco); franca arenosa;moderado muito pequena blocos subangulares; muito friável; não pegajosa, plástica; transição plana e clara.

BW_1 23-53 cm, bruno (7.5YR 5/2, úmido), cinzento-rosado (7.5YR 7/2, seco); franco arenosa;moderado pequenos e médios blocos subangulares; muito friável; não pegajosa, plástica; transição plana e difusa.

BW_2 53-120 cm, bruno-acinzentado (10YR 5/2, úmido), cinzento-claro (10YR 7/2, seco); franco argilo-arenosa;moderado médios blocos subangulares que se desfazem em moderada muito pequena e granular; muito friável; não pegajosa, plástica; transição plana e difusa.

BW_3 120-153 cm+, cinzento-rosado (7.5YR 6/2, 7.5YR 7/2); franco argilo-arenosa;moderado médios blocos subangulares; muito friável; pegajosa, plástica.

RAÍZES – Comuns finas nos horizontes AP, AB; raras finas nos horizontes $BW_{1,}$ BW_2 e BW_3.

OBSERVAÇÕES – Em todo perfil observa-se mosqueado distinto da cor do horizonte AP_3 com diâmetro entre 2-5mm com no máximo 1% da área exposta.
- Entre AP_3 e B/A aparência indica compactação.
- Carvão aparente até BW_1.

C – ANÁLISES FÍSICAS E QUÍMICAS

Horizonte		**Granulometria da Terra Fina**			**Argila Disp. em $H_2$0**	**Grau de Floc.**		**C.E**	**pH (1:2,5)**	**P**	**K**
Símb.	**Prof.**	**Areia**	**Argila**	**Silte**				**dS/m**	**Agua**	**mg/dm^3**	
	cm	**g kg^{-1}**									
AP	0 -10	805	107	88	102	44		0,126	7,26	154	123
AB	10-23	774	187	39	131	297		0,053	6,12	8,4	59
BW_1	23-53	700	201	99	124	385		0,051	4,94	4,5	30
BW_2	53-120	668	289	43	144	502		0,048	4,53	2,9	19
BW_3	120-153+	666	285	49	3	989		0,055	4,25	2,5	8
Horizonte	**Ca^{2+}**	**Mg^{2+}**	**Al^{3+}**	**H + Al**	**SB**	**(t)**	**(T)**	**V**	**m**	**MO**	**P-REM**
	$cmol_c$ dm^{-3}							**%**		**dag kg^{-1}**	**mg L^{-1}**
AP	3,65	0,67	0	0,8	4,63	4,63	5,43	85,3	0	1,84	54,3
AB	1,02	0,32	0	2,6	1,49	1,49	4,09	36,4	0	1,05	50,5
BW_1	0,19	0,14	0,59	4	0,41	1	4,41	9,3	59	0,92	40,2
BW_2	0	0,06	0,88	3,5	0,11	0,99	3,61	3	88,9	0,53	39,5
BW_3	0	0,05	0,88	3,2	0,07	0,95	3,27	2,1	92,6	0,53	35,1

A – DESCRIÇÃO GERAL

PERFIL 5

DATA: 23.03.2011

CLASSIFICAÇÃO: LATOSSOLO AMARELO Distrófico típico

LOCALIZAÇÃO: Chapada da Ibiapaba, Rodovia BR 222, Km 334, Fazenda Amway Nutrilite, Bloco E, Quadra 17. Ubajara, Ceará, Brasil, 3°54’11.82” S e 41° 5’57.66” W.

SITUAÇÃO, DECLIVE E COBERTURA VEGETAL SOBRE O PERFIL: Amostras coletadas em trincheira aberta sob plantio de acerola (*Malpighia punicifoilia* L.)

ALTITUDE: 760 m

LITOLOGIA: Arenito branco, grosseiro, conglomerático, com leitos de conglomerado oligomítico e seixos do quartzo na base.

FORMAÇÃO GEOLÓGICA: Formação Serra Grande, Arenitos.

CRONOLOGIA: Siluriano Devoniano Inferior.

MATERIAL ORIGINÁRIO: Produto de alteração do material supracitado.

PEDREGOSIDADE: Não-pedregoso.

ROCHOSIDADE: Não-rochoso.

RELEVO LOCAL: Plano.

RELEVO REGIONAL: Suave ondulado.

EROSÃO: Laminar não aparente.

DRENAGEM: Fortemente drenado.

VEGETAÇÃO PRIMÁRIA: Vegetação de transição entre floresta e caatinga

USO ATUAL: Cultivo de Acerola (*Malpighia punicifoilia* L.).

CLIMA: Amw, Classificação de Koppen

DESCRITO E COLETADO POR: Gustavo Valladares, Teógenes S. de Oliveira, Daniela Zuliane e Janine Gadelha.

B – DESCRIÇÃO MORFOLÓGICA

AP 0-9 cm, bruno-acinzentado muito escuro (10YR 3/2, úmido), bruno-acinzentado escuro (10YR 4/2, seco); areia franca;moderado a forte pequena granular; muito friável; ligeiramente pegajosa, plástica; transição plana e clara.

AB 9-21 cm, bruno-amarelado (10YR 5/4, úmido), bruno-amarelado-claro (10YR 6/4, seco); franco arenosa;moderado pequenos blocos subangulares; friável; ligeiramente pegajosa, plástica; transição plana e gradual.

BA 21-41 cm, bruno-amarelado (10YR 5/4, úmido), bruno muito claro-acinzentado (10YR 7/4, seco); franco arenosa;moderado pequenos e médios blocos subangulares; friável; pegajosa, plástica; transição plana e gradual.

BW_1 41-84 cm, amarelo-brunado (10YR 6/6, úmido), amarelo (10YR 7/6, seco); franco argilo-arenoso;moderado médios blocos subangulares que se desfazem em forte muito pequenos granular; muito friável; pegajosa, plástica; transição plana e difusa.

BW_2 84-150 cm+, amarelo-brunado (10YR 6/6, úmido), amarelo (10YR 7/6, seco); franco argilo-arenoso;forte muito pequenos granular; muito friável; pegajosa, plástica.

RAÍZES – Muitas finas no horizonte AP; comuns finas e médias nos horizontes AB e BA; poucas finas e médias no horizonte BW_1; raras finas em BW_2.

OBSERVAÇÕES – O horizonte AB é mais compactado.

C – ANÁLISES FÍSICAS E QUÍMICAS

Horizonte		**Granulometria da Terra Fina**			**Argila Disp. em $H_2$0**	**Grau de Floc.**		**C.E**	**pH (1:2,5)**	**P**	**K**
Símb.	**Prof.**	**Areia**	**Argila**	**Silte**				**dS/m**	**Agua**	**mg/dm^3**	
	cm	**g kg^{-1}**									
AP	0 -9	834	117	49	48	588		0,215	6,06	103,4	385
AB	9-21	787	165	48	102	384		0,153	5,14	22,4	105
BA	21-41	736	184	80	143	223		0,166	4,77	11,9	91
BW_1	41-84	680	256	67	130	490		0,136	4,41	3,1	60
BW_2	84-150+	688	254	58	4	986		0,105	4,1	2,3	42
Horizonte	**Ca^{2+}**	**Mg^{2+}**	**Al^{3+}**	**H + Al**	**SB**	**(t)**	**(T)**	**V**	**m**	**MO**	**P-REM**
	cmol$_c$ dm^{-3}							**%**		**dag kg^{-1}**	**mg L^{-1}**
AP	5,23	2,62	0	4,2	8,83	8,83	13,03	67,8	0	5,66	55,5
AB	1,1	0,59	0,1	2,9	1,96	2,06	4,86	40,3	4,9	0,92	54,1
BA	0,66	0,57	0,2	3,2	1,46	1,66	4,66	31,3	12	0,92	51,1
BW_1	0,22	0,3	0,49	2,9	0,67	1,16	3,57	18,8	42,2	0,53	46,5
BW_2	0	0,14	0,59	2,7	0,25	0,84	2,95	8,5	70,2	0,4	36,4