Scientia Horticulturae 225 (2017) 38–47

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Distillery anaerobic digestion residues: A new opportunity for sweet potato fertilization

Carlo Nicoletto*, Aline Galvao, Carmelo Maucieri, Maurizio Borin, Paolo Sambo

Department of Agronomy, Food, Natural resources, Animals and Environment (DAFNAE), University of Padova, Agripolis Campus, Viale dell'Università, 16 – 35020 Legnaro, PD, Italy

ARTICLE INFO

Keywords:
Ipomoea batatas
Yield
Quality
Sugars
Digestates
Nitrogen use efficiency

ABSTRACT

This paper represents an union point between two emerging issues: the productive potential derived from anaerobic digestion residues (ADRs) and the cultivation of sweet potato, an innovative species in Europe. The trial was carried out in open field condition in 2014 and 2015 comparing three fertilization treatments. ADRs were used to partially or completely substitute mineral N crop requirements: i) 50% N through ADRs and 50% N through mineral fertilizer (T50); ii) 75% N through ADRs and 25% N through mineral fertilizer (T75); iii) 100% N through ADRs (T100). Two controls treatments were also predisposed, one unfertilized (T0), and one with only mineral fertilization (TMIN).

The highest significant aerial biomass yield (> 57 t ha^{-1}) was showed by T75 whereas no differences were found among other treatments (46 t ha^{-1}). The highest significant marketable yield was showed by T75 and T100 (16 t ha^{-1}). The marketable yield showed the highest value in 2015 with almost 16 t ha^{-1} with an year effect on root size. During the experiment harvest index ranged from 20.5% (TMIN) to 26.9% (T100).

The nitrogen agronomic efficiency was greatly lower (−59.1%) in 2014 as a result of the high rainfall amount compared to 2015. T75 treatment showed the highest nitrogen agronomic efficiency, apparent recovery efficiency and utilization efficiency. The highest content of nitrates in aerial biomass was detected in combination with the N organic treatments.

The storage roots harvested in 2014 presented a higher concentration of glucose (+19.7%) and fructose (+29.4%) than that harvested in 2015. The concentration of glucose and fructose increased with the amount of nitrogen supplied with ADRs. The obtained results offer potentially useful data for producers order to demonstrate the usability of ADRs as an alternative to traditional mineral fertilization in sweet potato cultivation.

1. Introduction

The reduced supply of organic matter and the intensification of agro-ecosystems has led to several issues, among which one of the most important is the loss of soil carbon (Shrestha et al., 2015) with the increase of greenhouse gas emission and negative effect on global warming. In this context the fertilization with organic materials such as digestate, residue of anaerobic digestion, represents an alternative for sustainable agriculture (Vaneeckhaute et al., 2013). Traditional amendments such as manures, composts and sewage sludge have been studied extensively in the past (Gallardo-Lara and Nogales, 1987; Edmeades, 2003; Diacono and Montemurro, 2010; Liang et al., 2012) whereas applications of anaerobic digestion residues (ADRs) and their impacts on the environment and human health are still partially unexplored (Nkoa, 2014). The production of ADRs in Europe and in Italy is increasing by the growing presence of digesters for biogas production (Carrosio, 2013). The bulk of research on anaerobic digestates has been mainly focused on the evaluation of their stabilities with the objective to reduce their pathogenicity, foul odors and putrescibility (Kirchmann and Bernal, 1997; Gómez et al., 2005, 2007; Sanchez and Cardona, 2008; Drennan and DiStefano, 2010). There has been limited research on the chemical, biochemical and biological properties that would underline digestate agricultural functions (Tambone et al., 2009, 2010; Teglia et al., 2011). Only few studies reported information about ADRs use in horticulture underlining the good fertilizing properties of ADRs that appear to be effective in supporting vegetables yield (Montemurro et al., 2010; Alburquerque et al., 2012; Nicoletto et al., 2012, 2014; Maucieri et al., 2017). Thus, many question marks pertaining to digestate agronomic functions remain unanswered. Furthermore, most of the studies that have employed digestates in agronomic field have used animal matrices, while digested products of plant origin have not yet been extensively studied.

* Corresponding author.
E-mail address: carlo.nicoletto@unipd.it (C. Nicoletto).

http://dx.doi.org/10.1016/j.scienta.2017.06.048
Received 2 August 2016; Received in revised form 9 May 2017; Accepted 21 June 2017
Available online 04 July 2017
0304-4238/

Besides the challenge posed by the ADRs use in the cultivation of vegetable crops, within the vegetable crops context the interest in the sweet potato is definitely increasing in Europe. The import and consumption are rapidly expanding, increasing by 100% over the last five years. European supermarkets are catering to a growing demand of exotic and ethnic food. Important destinations in Europe are the UK and the Netherlands (CBI, 2015). This is mainly attributable to the significant migratory flows that we are recording in recent years. Sweet potato (*Ipomoea batatas* (L.) Lam.) is the seventh most important food crop in the world in terms of production. It is grown on about 8 million hectares, yielding almost 104.5 million tons (Faostat, 2014). This crop is mainly grown in developing countries, which accounts for over 97% of world output (Loebenstein and Thottappilly, 2009). Sweet potato, often considered as an "almost perfectly nourishing food", contains vitamins, iron, calcium, zinc, proteins, minerals and many other nutrients at favorable ratios (Woolfe, 1992) extremely useful for low quality diets. At European level, the cultivation of this species is predominantly localized in the countries of southern Europe as a result of high thermal requirements needed during the crop cycle. In Italy it is a niche crop, but continuously increasing, mainly based on white fleshed varieties cultivated essentially in the north (Nicoletto et al., 2010; Nicoletto et al., 2010, 2017).

As part of fertilization techniques, only few information are present in the literature on the use of ADRs in the management of this crop (Li et al., 2013). This study is part of a long-term project, where several vegetables crop cycles were tested, aimed to improve sustainable techniques of open-field horticulture. Particularly, the aim of this study was to evaluate the productive potential derived from ADRs used to partially or completely replace the mineral fertilization of sweet potato, an innovative species in the European continent, potentially strategic for the market in the coming years.

2. Material and methods

2.1. Experiment setting up

The experiment was carried out at the Experimental farm "L. Toniolo" of Padova University (45°21′ N; 11°58′ E; 8 m a.s.l.) in 2014 and 2015 spring/summer growing cycles. Information about the soil where the trial was performed are reported in Table 1. Three fertilization treatments were tested using ADRs to partially or completely substitute mineral N crop requirements: one with 50% N through ADRs and 50% N through mineral fertilizer (T50), one with75% N through ADRs and 25% N through mineral fertilizer (T75) and one with 100% N through ADRs (T100). Two controls treatments were also predisposed, one unfertilized (T0), and one with only mineral fertilization (TMIN). The P and K content in the ADRs were taken into consideration to calculate the amount of P and K minerals to supply in the different treatments the same quantity of these macronutrients. ADRs used in this trial derived from an anaerobic digestion process of fruits and distillery by-products used to produce biogas. ADRs chemical properties and the amount of macronutrients provided with each fertilization treatment are reported in Tables 2 and 3. N, P and K rates from mineral fertilizers were supplied according to standard recommendations in the area for sweet potato crop (Perelli et al., 2009): 80, 70, 210 kg ha^{-1} respectively for N, P_2O_5 and K_2O using urea (46%), triple superphosphate (46%) and potassium sulfate (50%). Both mineral and organic fertilization were supplied on May 20 and May 18 respectively in 2014 and 2015 and immediately incorporated by rotavator. After fertilization experimental area was set up with built up rows 0.80 m spaced on witch to transplant. A randomized block experimental design with three replications was used and plots were 60 m^2 wide (15 m × 4 m).

Table 1
Chemical properties of soil used for the experiment at different deep on dry matter basis.

Parameters		Soil deep	
		0–0.20 m	0.20–0.40 m
pH		7.35	7.30
EC	μS cm^{-1}	250	250
NO_3^-	mg kg^{-1}	101	87
K	mg kg^{-1}	94	61
PO_4^{3-}	mg kg^{-1}	100	213
Na	mg kg^{-1}	2921	2283
NH_4^{+-}	mg kg^{-1}	49	24
Cl^-	mg kg^{-1}	187	228

EC: electrical conductivity.

Table 2
Chemical properties of anaerobic digestates residues (ADRs) used for the experiment on dry matter basis.

Parameters		ADRs	
		Water extract	Ash content
pH		7.68	
EC	μS cm^{-1}	1.462	
Total organic matter	%	49.94	
Organic carbon	%	28.97	
Total N	%	3.48	
C/N		8.32	
Ash	%	50.06	
Dry matter	%	30.21	
P	mg kg^{-1}	42.6	5824
K	mg kg^{-1}	1942	3044
Ca	mg kg^{-1}	134	19189
Mg	mg kg^{-1}	14.7	941
Mn	mg kg^{-1}	0.038	63.7
Al	mg kg^{-1}	0.363	3125
Fe	mg kg^{-1}	0.238	1659
Na	mg kg^{-1}	126	2039
Co	mg kg^{-1}	0.006	0.42
Cd	mg kg^{-1}	nd	nd
Cr	mg kg^{-1}	0.006	6.72
Cu	mg kg^{-1}	0.371	488
Pb	mg kg^{-1}	nd	1.81
Ni	mg kg^{-1}	0.054	3.96
Zn	mg kg^{-1}	0.904	56.8
As	mg kg^{-1}	0.038	0.75
B	mg kg^{-1}	4.11	64.6
Li	mg kg^{-1}	0.665	6.79
Mo	mg kg^{-1}	0.018	0.60
S	mg kg^{-1}	72.3	1509
Sb	mg kg^{-1}	0.031	0.25
Se	mg kg^{-1}	0.031	0.25
Sn	mg kg^{-1}	0.018	1.73
Sr	mg kg^{-1}	0.542	56.4
Ti	mg kg^{-1}	0.006	23.3
V	mg kg^{-1}	0.012	3.97

nd: not detected.

Table 3
Anaerobic digestates residues (ADRs) and mineral fertilizer supply for different fertilization treatments on sweet potato.

Treatments	ADRs (kg ha^{-1})	Nutrients supply					
		N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})	
		From ADRs	From mineral fertilizer	From ADRs	From mineral fertilizer	From ADRs	From mineral fertilizer
T0	0	0	0	0	0	0	0
TMIN	0	0	80	0	70	0	210
T50	3809	40	40	7.6	62.4	3.8	206.2
T75	5714	60	20	11.4	58.6	5.7	204.3
T100	7619	80	0	15.2	54.8	7.6	202.4