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Effect of the anaerobic digestion residues use on lettuce yield and quality

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A B S T R A C T

In the last years, fertilization has become an agricultural practice with several different aspects. This paper suggests the use of a distillery residue as an organic nitrogen fertilizer. It derives from the process of anaerobic digestion of fruits and dregs (ADRs), both used to produce biogas.

The field experiment was conducted on two spring-summer varieties of lettuce (butterhead and open batavia). Five fertilization treatments were tested supplying nitrogen in mineral form and with different ADRs rates. Dry matter content, antioxidant capacity, concentrations of total phenols, ascorbic acid, phenolic acids, organic nitrogen, nitrates and heavy metal, and some nitrogen use indexes were evaluated.

The use of ADRs as organic nitrogen fertilizer produces no negative effect on plant growth, maintaining the qualitative aspects unchanged. Nitrate contents were below the most stringent limits imposed by the EU regulation in all treatments and ADRs showed no contraindications to their use for organic fertilization of this vegetable. The benefits of using this product are related to the addition of organic matter in the soil, reducing fertilizer and environmental costs.

1. Introduction

Intensive agriculture has caused social and environmental problems worldwide over the few past decades and some of the most important impacts are loss of soil organic matter, soil erosion and water pollution (Zhao et al., 2009). In the last years interest in the use of organic matrices in agriculture has been increasing due to the high cost of mineral fertilizers and new environmental regulations that limit their use. The recycling of organic waste materials can help maintain soil nutrient levels, and has been shown to stimulate various aspects of soil fertility (Levi-Minzi et al., 1986; Elsgaard et al., 2001). The application of organic wastes, such as composted municipal wastes and sewage sludge, could be a way of solving two problems, waste disposal and the correction of the low organic matter content in many agricultural soils (Debosz et al., 2002; Mantovi et al., 2005). Using wastes in agriculture is also an economical way to dispose of these materials, and is worthwhile from an ecological point of view as it reduces negative effects on the environment. Among different sources of organic matter, there are interesting agro-industrial matrices, including the anaerobic digestion residues (ADRs). ADRs are obtained from the biological process by which organic matter is converted into biogas (in absence of oxygen) in order to produce energy or heat (Tambone et al., 2009). ADRs come from a vast number of heterogeneous matrices (e.g. sewage sludge, organic fraction of municipal wastes, agricultural by-products). Their production is increasing in Italy and also in Europe with more than 10 million tons (dry matter) in 2009, 37% of which was recycled in agriculture. However, the proportion of sludge recycled in agriculture varies widely between different Member States and regions. ADRs obtained from these processes present a low C/N ratio and high nutrient levels, so can be used as fertilizers or amendments for industrial crops or horticulture (Salminen et al., 2001). This kind of biomass has already been studied for industrial crops like maize, soybean, turfgrass and some horticultural crops in a controlled environment (Salminen et al., 2001). Other sources of organic matter that undergo anaerobic digestion can derive from residues of the distillation process of fruit and the dregs. The residue is called anaerobic digestate of fruit and wine distillery wastes and is an innovative product that has not yet been registered as a fertilizer or organic nitrogen fertilizer. The trial described in this paper is part of a wider and more complex project that is taking place over several years with different crop rotations. The trial involved the field cultivation of two cycles of lettuce, aimed at assessing yield and qualitative traits with different fertilization methods and rates.

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Table 1
Anaerobic digestion residues (ADRs) and mineral fertilizer supply for different fertilization treatments on lettuce.

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	60	0	110
T50	3400	40	40	14	46	4	106
T75	5100	60	20	20	40	6	104
T100	6800	80	0	27	33	8	102

Fertilization treatments were tested using ADRs to substitute mineral N crop requirements: 50% N through ADRs and 50% N through mineral fertilizer (T50), 75% N through ADRs and 25% N through mineral fertilizer (T75); 100% N through ADRs (T100); unfertilized (T0); mineral control (TMIN).

2. Materials and methods

2.1. Setting up the experiment

The experiment was conducted at the Experimental Station "L. Toniolo" of Padova University (45°21′ N; 11°58′ E; 8 m a.s.l.); meteorological data recorded during the trial period are reported in Fig. 1. Five fertilization treatments were tested using ADRs to substitute mineral N crop requirements: one fertilized with 50% N through ADRs and 50% N through mineral fertilizer (T50), one with 75% N through ADRs and 25% N through mineral fertilizer (T75), and one with 100% N through ADRs (T100); there were also two controls, 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. ADRs used in this trial derived from a process of anaerobic digestion 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 1 and 2. N, P and K rates from mineral fertilizers were supplied according to standard recommendations in the area for lettuce crop: 80, 60, 110 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 was supplied on April 5 and immediately incorporated by rotavator. Information about the soil where the trial was performed is given in Table 3.

A randomized block experimental design with three replications was used and plots were 60 m^2 wide (15 m × 4 m). Each plot was split into two subplots of 30 m^2 (7.5 m × 4.0 m) and two lettuce cultivars were grown: var. "Marenia" (Rijk Zwaan) a butterhead lettuce and var. "Funtime" (Syngenta) an open batavia. The tests performed on the lettuces are considered independent.

Transplanting was on different dates: April 10 for Marenia and May 11 for Funtime. It was done in three rows on a mulched bed with black PE film 0.15 mm thick. Plant spacing of 0.5 m between rows and 0.33 m on the row (6 plants m^{-2}) was adopted for both varieties. A micro-irrigation drip system was set up (drippers of 1.2 L h^{-1} every 0.30 m) stretching tapes under the mulching film, in order to maintain the watering of the two crops independent. During the crop cycle one fungicide treatment "Ramedit Combi WG" (a.i. cymoxanil 4.2%, copper oxychloride 39.75%) at 2.5 g L^{-1} was applied on both lettuces. Harvesting, at full crop marketable maturity, was on May 25 and June 18 for Marenia and Funtime respectively. In both cases 10 plants per plot were considered. The height and diameter of the plant head, fresh and dry weight of plants, the amount of waste product and number of leaves were measured. Once washed and dried, the marketable fraction was cut into small pieces and mixed in order to obtain a homogeneous sample for each plot. A sub-sample for each treatment and replication was weighed before and after oven drying (65 °C for 48 h)

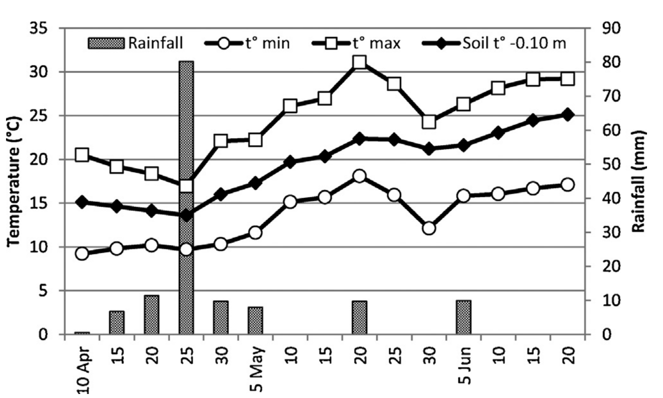

Fig. 1. Five-day averages of maximum and minimum air temperatures, soil temperature at −0.10 m depth and five-day cumulative rainfall collected during lettuce growing cycle.

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

Parameters	ADRs	
	Water extract	Ash content
pH	7.68	
EC (μS m^{-1})	1.462	
Total organic matter (%)	49.94	
Organic carbon (%)	28.97	
Total N (%)	1.18	
C/N	24.55	
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	19,189
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})	0	0
Cr (mg kg^{-1})	0.006	6.72
Cu (mg kg^{-1})	0.371	488
Pb (mg kg^{-1})	0	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