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Artichoke (*Cynara scolymus* L.) as cash-cover crop in an organic vegetable system

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ABSTRACT

In organic vegetable systems green manure crops play an important role as a nitrogen source, but they cover the soil for several months without producing a direct income. Globe artichoke (*Cynara scolymus* L.) provides both heads to be harvested and particularly abundant plant residues to be possibly incorporated into the soil, so it may play a double role of cash and cover crop. This paper describes an on-farm study in which seed-propagated artichoke, cultivated as an annual crop, preceded zucchini squash and lettuce cultivated in sequence within a vegetable organic system. Artichoke produced about 7 t ha^{-1} of saleable heads and left, after harvest, 50.3 t ha^{-1} of fresh biomass usable as green manure. Zucchini squash and lettuce following artichoke showed a significant increase in yield when artichoke residues were incorporated into the soil. Furthermore, a residual positive effect of green manure on soil fertility was detected after lettuce harvest.

Key words: organic vegetables, globe artichoke, cover crop, cash crop, green manure, nitrogen

IZVLEČEK

ARTIČOKA (*Cynara scolymus* L.) KOT PRODAJNO ZANIMIVA VRTNINA V EKOLOŠKI PRIDELAVI ZELENJAVE

Zeleno gnojenje ima pomebno vlogo pri ekološki pridelavi zelenjave kot vir dušika, a je problem v tem, da rastline namenjene temu zasedajo prostor v kolobarju več mesecev brez neposrednega dohodka. Artičoka (*Cynara scolymus* L.) daje oboje, tržni pridelek v obliki koškov in veliko organskih ostankov, ki se lahko zaorjejo kot zeleno gnojilo, torej igra dvojno vlogo kot tržna in pokrovna kultura. Prispevek opisuje vzorčno raziskavo kmetije, na kateri pridelujejo iz semen vzgojeno artičok kot enoletno kulturo v ekološkem kolobarju pridelovanja zelenjave za bučkami in vrtno solato. Artičoka je dala okrog 7 t ha^{-1} tržnih koškov in po pobiranju pustila na polju 50.3 t ha^{-1} sveže biomase, ki je uporabna kot podor. Bučke in vrtna solata, ki so v kolobarju sledile artičoki, so dale značilno večji pridelek, kadar so se ostanki artičoke vdelali v tla. Pozitivni učinek zelenega gnojenja na rodovitnost tal je bil ugotovljen še po pobiranju pridelka vrtne solate.

Ključne besede: ekološko pridelana zelenjava, artičoka, pokrovna kultura, tržna kultura, zeleno gnojenje, dušik

1 INTRODUCTION

Organically produced food shows increasing interest throughout the world in relation to concerns about food safety, human health, animal welfare, and environmental safeguard (Yiridoe et al., 2005). In fact, organic farming systems may prevent the occurrence of soil degradation, environmental pollution, biodiversity decline, and food contamination that may possibly originate from conventional agricultural practices like recurrent tillage, monoculture, and intensive administration of agrochemicals (Raviv, 2010).

Most consumers associate organic at first with vegetables and fruit (Padel and Foster, 2005), that

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are also the most frequently purchased organic foods (Werner and Alvensleben, 1984; Hay, 1989; Jolly et al., 1989; Davies et al., 1995; Dimitri and Greene, 2000; O'Donovan and McCarthy, 2002). Probably, that is because there is a strong association between heavy agrochemical use and fruit and, especially, vegetable production, and consequently organic produce consumption is seen as an important mean to reduce exposure to chemicals in the diet (Padel and Foster, 2005).

In Italy, the cultivation of organic vegetables covers an estimated area of 23,405 ha (EC DG, 2013), including both certified-organic and in-conversion areas according to European Union (EU) legislation [Council Regulations (EC) No 834/2007 and No 889/2008 as amended]. Such extent, representing 2.1 % of total Italian area occupied by organic crops, is by far the largest one to be devoted to organic vegetables within the EU, where organic vegetable cultivation covers an overall area of 110,955 ha (EC DG, 2013).

In organic vegetable systems, soil fertility management is a crucial and costly cultural practice, and nitrogen is often the most limiting nutrient to efficient and profitable production (Gaskell and Smith, 2007). Possible sources of nitrogen for organic farmers include fixed nitrogen from legumes and organic matter of different, on-farm or off-farm, origins. When animal husbandry is not included in the organic farming system, which is often the case of vegetable farms, green manure crops (cover crops grown for their nutrient value) play an important role in managing nitrogen without or with reduced use of external inputs (Shennan, 1992; Burket et al., 1997; Thönnissen et al., 2000a; Thorup-Kristensen et al., 2001; Lenzi et al., 2009).

The most commonly used cover crops are legume, cereal, and brassica species, depending on farmer goals and circumstances (Snapp et al., 2005). In fact, cover crops are not only a source of nitrogen, but they provide additional potential benefits, like improved soil structure, erosion control, recycling of nutrients other than nitrogen, increased soil biological activity, and pest and weed suppression (Clark, 2012). On the other hand, adopting cover crops may potentially reduce farm income if cover crops interfere with other attractive crops (Snapp et al., 2005). Thus, time or market constraints and the need to intensively farm high value land may limit their use (Cabilovski et al., 2011).

Globe artichoke (*Cynara scolymus* L.) is a horticultural crop cultivated all over the world, but especially widespread in the Mediterranean basin, where its large immature inflorescences (heads) are an important component of the diet. The species is usually vegetatively propagated, but seed-propagated cultivars are also available (Calabrese et al., 2000, 2004, and 2005; Tesi and Lenzi, 2005a). In Italy, where artichoke cultivation covers an area of about 50,000 ha (INEA, 2013), this species is used as both multi-year and annual crop depending on cultivation area and propagation method. Spring production in northern and central regions derives from multi-year crops that may last up to 6-8 years; for autumn-to-spring production in south regions, annual or biennial cycles are adopted, and seed-propagated artichoke is always an annual crop (Tesi, 2010).

Head production may vary depending on cultivar, plant density, and length of the crop cycle, but, in any case, it represents a small part of the total biomass production by the plants (Lattanzio et al., 2009). A research recently conducted on seventeen Italian artichoke genotypes revealed an average aboveground dry biomass yield of 9.7 t ha^{-1} (Ciancolini et al., 2013).

Since artichoke provides both heads to be harvested and particularly abundant plant residues to be possibly incorporated into the soil, it may play a double role of cash and cover crop. Aiming to find some preliminary evidence to this hypothesis, an on-farm study was conducted in which seed propagated artichoke preceded zucchini squash and lettuce cultivated in sequence within a vegetable organic system.

2 MATERIALS AND METHODS

The experiment was carried out in an organic farm (Bonamici Organic Farm) located in San Martino Ulmiano, Pisa, Italy, along the Tyrrhenian coast of central Italy (lat. 43°46', long. 10°24'). Three crops (seed-propagated artichoke, whose plant residues were removed from the field or incorporated into the soil at the end of the crop cycle, zucchini squash, and lettuce) were organically cultivated in sequence over a 20-month period, with the timing shown in Figure 1.

Plants were cultivated under a high tunnel, 4 m wide and 50 m long, covered with a Long Life Polyethylene film, a type of protection, generally not equipped with heating systems, commonly used in this area for the cultivation of winter vegetables. Monthly average maximum and minimum temperatures during the trial and main soil physical and chemical properties are shown in Figure 1 and Table 1, respectively.

Table 1: Soil characterization of the experimental field (0-30 cm soil depth)

Parameter	Units	
pH		6.89
Organic matter	g kg^{-1}	12
Total N*	g N kg^{-1}	1.45
Available P**	mg P_2O_5 kg^{-1}	120
Exchangeable K	mg K_2O kg^{-1}	185
Sand	%	44
Silt	%	44
Clay	%	12

*Kjeldahl method, ** Olsen method

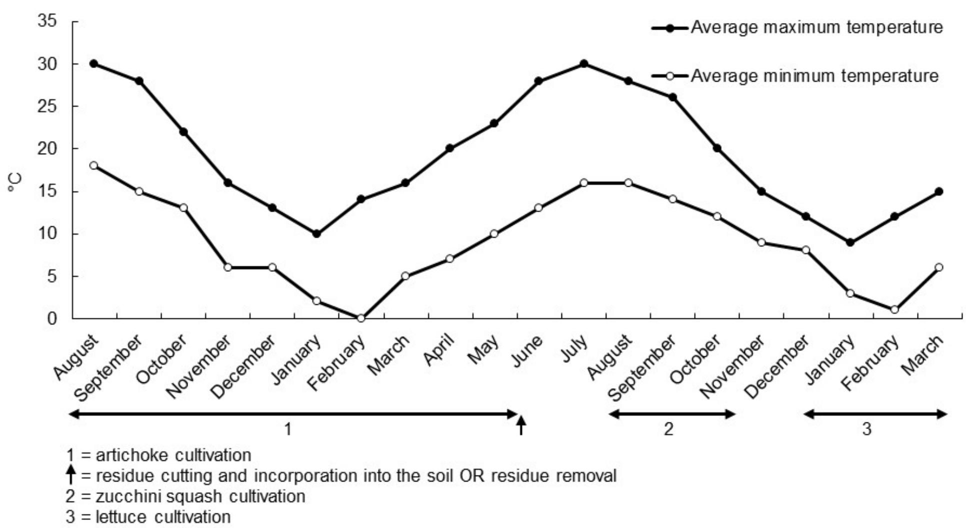

Figure 1: Monthly temperatures in the course of the trial and timing of crop succession

Before artichoke planting, soil was fertilized with 100 g m^{-2} of Guanito (Italpollina, Rivoli Veronese, Italy), a pelleted fertilizer with 6 % total N, 15 % P_2O_5, 55 % organic matter, obtained from guano. No other fertilizer was provided to soil for the whole experiment.

As seed-propagated artichoke, a local selection of the cultivar 'Terom' named 'T3' (Tesi and Lenzi, 2005a) was used. 'T3' plantlets with 3-4 leaves were transplanted in the first week of August in three rows 1.3 m apart with a spacing of 1 m along the rows, resulting in a density of 0.77 plants per m^2. Plants were drip irrigated as needed by means of perforated hoses positioned along each row, and hand-weeding was done twice, at the end of October and of February, respectively. Artichoke heads were harvested from mid-March to end of May.

After artichoke harvest was completed, the experimental area was divided into four plots, each composed of 36 plants (three rows of 12 plants each), in two of which the plants, still green, were cut up by a mulcher for stalks and immediately incorporated into the soil by a spading machine. At the same time, both aerial and underground plant biomass was removed from the other two plots. This plant material was used to estimate the amount of biomass incorporated into the soil and its supply in N, P, and K. With this aim, after weighing the fresh biomass, three samples of both aerial and underground part were oven-dried at 75 °C until constant weight, and dry biomass was analyzed for N, P, and K content.

Zucchini squash (cultivar 'Mora Pisana') followed artichoke crop. 'Mora Pisana' was chosen being a particularly appreciated cultivar on the local market, although characterized by poor yield. At the end of July, after soil was harrowed by a rotary harrow, plantlets of zucchini squash with 3-4 leaves were transplanted into the experimental area in three rows 1.3 m apart with a spacing of 1 m along the rows (plant density of 0.77 plants per m^2). Thus, plants were subjected to two soil treatments (with or without artichoke green manure) repeated twice (two plots per treatment, each plot composed of 36 plants). Zucchini fruits were harvested with attached flowers from September to October excluding, in each plot, the first and the last plant of each row, and their number and weight were recorded.

After the removal of zucchini residue, soil was harrowed again and arranged in beds in order to be prepared for lettuce crop. Plantlets of butterhead lettuce (cultivar 'Cambria') with 4-5 leaves were transplanted into the beds in mid-December in three rows per bed with a 0.3 x 0.3 m spacing within a bed, and 0.5 m between the beds, resulting in a density of about 7.1 plants per m^2. In March, when lettuce heads reached a satisfactory firmness, 30 plants per plot were collected and weighed for yield assessment.

Before zucchini transplant and after lettuce harvest, soil samples were collected at 10-20 cm soil depth and analyzed for pH, electrical conductivity (EC), organic C, total N (Kjeldahl method), available P (Olsen method), and exchangeable K.

Zucchini and lettuce production data and soil data were subjected to analysis of variance (ANOVA) according to a randomized block design with two replicates, and means were compared using the LSD test at $p \leq 0.05$ level of significance.

3 RESULTS AND DISCUSSION

Artichoke produced on average 8.5 heads per plant from mid-March to the end of May (1.5 heads in March, 4 in April and 3 in May), corresponding to 64,450 heads ha^{-1}. Average weight per head was 115 g in March, 110 g in April, and 100 g in May. Although head production per plant, expressed as both number and weight, was consistent with data previously reported for seed-propagated artichoke (Ierna and Mauromicale, 2004; Tesi and Lenzi, 2005a), total yield (7.09 t ha^{-1}) was lower than that observed in the cited studies, where higher plant densities were adopted. Total yield was lower also than the average artichoke yield usually recorded in Italy (about 10 t ha^{-1}) (INEA, 3013), but since in many cases the species is used as a multi-year crop, it must be considered that, in those cases, higher yields are balanced by the costs due to annual agronomic practices like lateral shoot removal at the beginning of a new growing season.

After head harvest, a fresh biomass of 50.3 t ha^{-1} remained usable as green manure (Table 2). The dry biomass yield (10.4 t ha^{-1}, of which 76.6 % represented by aerial parts) was comparable or even higher than that produced by species or their mixes normally used as cover crops (Snapp et al., 2005).

Nutrient value of green manures especially concerns N (Gaskell and Smith, 2007). Nitrogen supplied to soil by cover crops or plant residues depends on biomass production and biomass N concentration, that vary considerably among and even within species. According to different authors, N accumulation in legume cover crops may range from 28 to 238 kg ha^{-1} (Griffen and Hesterman, 1991; Honeycutt et al., 1995; Ranells and Wagger, 1996; Creamer and Baldwin, 2000; Lenzi et al., 2009), and 23 to 348 kg ha^{-1} N were recorded in different grass cover crops (Honeycutt et al., 1995; Ranells and Wagger, 1996; Creamer and Baldwin, 2000; Braz et al., 2004; Crusciol and Soratto, 2009; Lenzi et al., 2009). Variations in biomass production or N content within the same species may be ascribed to differences in soil fertility and/or climatic conditions (Crusciol and Soratto, 2009; Lenzi et al., 2009). Among vegetable residues, the lowest N amounts have been observed in spinach and radish (about 10 kg ha^{-1}) and the highest in Brussel sprouts (260 kg ha^{-1}); anyway, values over 100 kg ha^{-1} are considered high (Tesi and Lenzi, 2005b). In our study, artichoke accumulated 104.4 kg ha^{-1} N in plant residues, that contained also 50.0 kg ha^{-1} P_2O_5 and 156.8 kg ha^{-1} K_2O (Table 2).

Table 2: Biomass and N, P, and K supply from artichoke plant residues

Plant Residue	Fresh biomass (t ha^{-1})	Dry biomass (t ha^{-1})	N supply (kg N ha^{-1})	P supply (kg P_2O_5 ha^{-1})	K supply (kg K_2O ha^{-1})
Aerial part	43.6	8.0	77.3	38.4	146.7
Roots	6.7	2.4	27.1	11.6	10.1
Total	50.3	10.4	104.4	50.0	156.8

Of course, for nutrients to be released in the soil, green manure must undergo mineralization, whose rate depends on residue quality and quantity, soil moisture and temperature, and specific soil factors such as texture, mineralogy and acidity, biological activity, and already present nutrients (Myers at al., 1994). Part of the released nutrients is temporarily immobilized by soil microbes (Jarvis et al., 1996), or, in the case of N, possibly lost through leaching during irrigation or rainy periods (Gaskell and Smith, 2007). Therefore, estimating and predicting the timing of green manure mineralization as well as the amount and timing of nutrient recovery by the subsequent catch crops is very difficult.

In our study, before zucchini transplant artichoke residues were presumably still undecomposed. In fact, no differences in soil chemical parameters were observed between soil supplied with green manure and soil from which plant residues were removed (Table 3).

Table 3: Effect of artichoke green manure (AGM) on soil chemical parameters

Treatment	pH	EC (dS m^{-1})	Organic C (g kg^{-1})	Total N* (g kg^{-1})	Available P** (mg P_2O_5 kg^{-1})	Exchangeable K (mg K_2O kg^{-1})
before zucchini transplant						
With AGM	7.09 a	0.24 a	12.6 a	1.5 a	211.7 a	187.8 a
Without AGM	7.11 a	0.24 a	11.1 a	1.4 a	199.3 a	155.4 b
after lettuce harvest						
With AGM	7.97 a	0.23 a	11.9 a	1.4 a	194.5 a	180.0 a

Without AGM	8.03 a	0.25 a	11.4 a	1.3 b	175.5 b	137.0 b

Values on the same column followed by different letters are significantly different at $p \leq 0.05$
*Kjeldahl method, ** Olsen method

However, zucchini squash and lettuce crops that followed artichoke seemed to take advantage from green manure, as they showed a significant increase in yield (17 % in squash and 19 % in lettuce) when artichoke residues were incorporated into the soil as compared with when they were removed (Table 4). Squash yield increase was due to the production of a higher number of fruits per plant, while fruit weight was the same with and without green manure (Table 4). With green manure, lettuce produced heavier heads (Table 4). An increasing effect of green manure on lettuce yield was observed also by Thorup-Kristensen (2006) when lettuce followed hairy vetch and winter rye crops. Yield increases in vegetable species following green manure crops were also reported for potato (Honeycutt et al., 1996), tomato (Thönnissen et al., 2000b; Sainju et al., 2001; Lenzi et al., 2009), broccoli (Wyland et al., 1996; Burket et al., 1997), carrot and cabbage (Thorup-Kristensen, 2006). The result depended on the used cover crop, and was mainly ascribed to its nutrient supply capacity.

The nutrient supply capacity of artichoke green manure was not completely depleted by zucchini and lettuce crops. In fact, after lettuce harvest soil supplied with artichoke residues still showed higher amounts in total N, available P, and exchangeable K than soil from which plant residues were removed (Table 3).

Table 4: Production of zucchini squash and lettuce cultivated in sequence after artichoke whose residues were cut and incorporated into the soil (with artichoke green manure = with AGM) or removed from the field (without artichoke green manure = without AGM)

	Zucchini squash				Lettuce	
Treatment	Fruits per plant (n)	Fruit weight (g per fruit)	Fruit weight (kg per plant)	Yield (t ha^{-1})	Head weight (g)	Yield (t ha^{-1})
With AGM	18.2 a	65.6 a	1.2 a	9.2 a	333.2 a	23.7 a
Without AGM	15.3 b	66.8 a	1.0 b	7.9 b	279.7 b	19.9 b

For each crop, values on the same column followed by different letters are significantly different at $p \leq 0.05$

4 CONCLUSIONS

Seed-propagated artichoke produced abundant plant residues, comparable to the biomass obtained by the species most usually employed as cover crops, and accumulating similar nutrient amounts. Unlike cover crops, that cover the soil for several months without producing a direct income, artichoke produced, in a 10-month cycle, about 7 t ha^{-1} of saleable heads. This yield, as well as the residue amount, could be possibly increased by increasing plant density.

Green manure obtained by artichoke plant residues had an increasing effect on yield of succeeding zucchini squash and lettuce. Furthermore, a residual positive effect on soil fertility was still detected after lettuce harvest, when soil supplied with artichoke residues showed higher amounts in total N, available P, and exchangeable K than soil from which plant residues were removed.

Therefore, this study suggests that, in Mediterranean area, seed artichoke can be profitably introduced in organic vegetable systems with a double role of cash and cover crop.

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