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Processing Tomato–Durum Wheat Rotation under Integrated, Organic and Mulch-Based No-Tillage Organic Systems: Yield, N Balance and N Loss

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Abstract: In a 4-year study, the biannual crop rotation processing tomato–durum wheat was applied to three cropping systems: (i) an innovative organic coupled with no-tillage (ORG+) where an autumn-sown cover crop was terminated by roller-crimping and then followed by the direct transplantation of processing tomato onto the death-mulch cover; (ii) a traditional organic (ORG) with autumn-sown cover crop that was green manured and followed by processing tomato; and (iii) a conventional integrated low-input (INT) with bare soil during the fall–winter period prior to the processing tomato. N balance, yield and N leaching losses were determined. Innovative cropping techniques such as wheat–faba bean temporary intercropping and the direct transplantation of processing tomato into roll-crimped cover crop biomass were implemented in ORG+; the experiment was aimed at: (i) quantifying the N leaching losses; (ii) assessing the effect of N management on the yield and N utilization; and (iii) comparing the cropping system outputs (yield) in relation to extra-farm N sources (i.e., N coming from organic or synthetic fertilizers acquired from the market) and N losses. The effects of such innovations on important agroecological services such as yield and N recycling were assessed compared to those supplied by the other cropping systems. Independently from the soil management strategy (no till or inversion tillage), cover crops were found to be the key factor for increasing the internal N recycling of the agroecosystems and ORG+ needs a substantial improvement in terms of provisioning services (i.e., yield).

Keywords: cover crops; mulch-based system; N leaching; no-till organic system; intercropping; ecological intensification

1. Introduction

Several studies have pointed out the urgent requirement to reduce the impact of the food system on the environment, and such a challenge has to be faced in the framework of climate change [1] and the increasing world population [2]. Complex strategies involving agricultural, social, economic and political components at local, national and global scale are needed [3].

Focusing on the farming system, an increasing importance has been attributed to a number of agroecological services (other than yield) that could be supplied and/or enhanced by implementing appropriate technical choices in cropping system management [4]. Among the most interesting practices, the introduction of cover crops (CCs) in the crop rotation represents a key strategy to ensure several agroecosystem services [5]. CCs are particularly important when dealing with organic farming as they are a crucial element for fertility management and weed control [6,7]. In organic farming systems, CCs are usually terminated before the establishment of the following cash crop by cutting and chopping the plant biomass and incorporating it into the soil (i.e., via green manuring [6]). An emerging alternative to green manuring, that aims at reducing the drawbacks related to the intensive soil tillage (i.e., mainly nonrenewable fuel consumption, soil organic matter and soil biodiversity decrease), is represented by the cover crop mulch-based no-tillage management (MBNT, [8]). In MBNT, the CC is mechanically terminated by one or more roller-crimper passages, thus the devitalized biomass acts as a soil-anchored mulch where the following cash crop is directly sown/transplanted. The adoption of MBNT practice in organic cropping systems has the potential to merge the environmental benefits of no-tillage and organic farming [8].

A small volume of research on this topic is available. Nonetheless, several advantages have emerged: the improvement of soil biodiversity [9], the increase in water and nutrient availability [10], increase in carbon sequestration [11] and the reduction of greenhouse gas emission [12]. In contrast, weed competition (from both volunteer plants and CC regrowth) has emerged to be the most critical challenge to be faced in the adoption of MBNT management in organic systems [13,14]. Beside such challenge, to our present knowledge, information is lacking on N balance and N use efficiency in MBNT organic systems, even if it is well known that such issues are of paramount importance [15]. In particular, the N balance of a given crop rotation is greatly influenced by the N leaching loss which in turn determines the extent of the overall N self-sufficiency [16]. The present study is based on a 4-year experiment, where the same cash crop rotation was applied to three cropping systems, at increasing ecological intensification: a conventional integrated system (INT) with bare soil during the fall–winter period prior to the processing tomato; an organic system with autumn-sown cover crop and traditional inversion tillage (ORG); and an innovative MBNT organic systems (ORG+) where processing tomato was directly transplanted onto the death-mulch cover obtained by roller-crimping the cover crop biomass.

The research was aimed at:

Quantifying the N leaching loss occurring in the three cropping systems in relation to the management strategies.

Assessing the effect of N management (i.e., cover crop termination technique and fertilization strategies) on the yield and N utilization efficiency of the cash crops.

Comparing the cropping system outputs (yield) in relation to extra-farm N sources and N losses.

2. Materials and Methods

2.1. Experimental Site and Management of the Cropping Systems

Field experiments were carried out in four consecutive years (2013/14, 2014/15, 2015/16, and 2016/17) at the experimental station (FieldLab) of the Department of Agricultural, Food and Environmental Sciences of the University of Perugia, Italy. The FieldLab is located in the Tiber river alluvial plain at 42.956°N, 12.376°E, 163 m asl. The soil is a typical Fluventic Haplustept clay-loam (20% sand, 46% silt and 34% clay, 1.4 Mg m^{-3} bulk density), sub-alkaline (pH_{H2O} = 7.8), poor in organic matter (12 g om kg^{-1}, C/N ratio = 11) and in extractable phosphorus (29.9 mg P_2O_5 kg^{-1}, Olsen method) and rich in exchangeable potassium (258 mg K_2O kg^{-1}, int. method).

During the four experimental years, two cycles of the same two-year rotation involving durum wheat (*Triticum durum* Desf., cv Dylan) and processing tomato (*Solanum lycopersicum* L., cv PS1296) were carried out. The same rotation was applied to three cropping systems (treatments) following an increased ecological intensification: conventional integrated (INT), traditional organic (ORG) and innovative organic (ORG+) where a cover crop mulch-based no-tillage system was implemented. Both cash crops were present each year on two adjacent fields (A and B) and they were switched every year from field A to field B. Each field was divided into two blocks where the three treatments were randomly allocated. The dates when all the agronomic operations took place were recorded across the

4-year period (Table S1). The plot size was 540 m^2. The weather data during the whole growing season were obtained from an automatic meteorological station inside the experimental site.

2.1.1. Processing Tomato

In ORG and ORG+, processing tomato was preceded by an autumn-sown cover crop of field pea (*Pisum arvense* L., cv Arkta) and barley (*Hordeum vulgare* L., cv Amyllis) in mixture (barley at 25% + pea at 75% of their ordinary full sowing rates, i.e., 100 and 75 seeds m^{-2}, respectively) while, in INT, the soil was left bare and weed-free (by mechanical control). Cover crop termination was carried out traditionally in ORG: aboveground biomass of the mixture was mowed, finely chopped (0.02–0.1 m) and immediately incorporated into the soil (0.2 m depth) by a rotary cultivator equipped with tines and a back-roller. In ORG+, cover crop biomass was roll-crimped and left on the soil surface as dead mulch. Cover crop termination in ORG+ was generally postponed compared to ORG, because of the slower plant development in the conservative system (Table S1). The processing tomato was transplanted at 3.3 plants m^{-2} into single rows 1 m apart by a standard machinery in the INT and ORG and a no-till direct transplanter in ORG+.

All systems received a fertilization of 150 kg N ha^{-1}, which was distributed by means of fertigation (details on rate, scheduling and methods in Farneselli et al. [17]) using a synthetic fertilizer (Radicon N30, Green Has Italia spa, Italy) in the INT system and an organic fertilizer (Ilsadrip Forte, Ilsa spa, Italy) in the ORG and ORG+ systems. In the case of ORG, N content in the legume component of the CC (pea) was measured prior to termination and the corresponding amount was subtracted from the aimed rate of 150 kg N ha^{-1}. This difference was distributed to the cash crop. In the case of ORG+, only 50% of N accumulation in pea was subtracted from the aimed rate, in order to account for the lack of CC biomass incorporation into the soil [18].

Concerning the other macronutrients, 150 kg ha^{-1} of P_2O_5 and K_2O were broadcast at cover crop sowing (in ORG and ORG+) and at final seedbed preparation in INT.

2.1.2. Durum Wheat

Durum wheat was grown as the sole crop in the INT and ORG (single rows 0.15 m apart); in ORG+, durum wheat was temporary intercropped (TIC, Guiducci et al. [19]) with faba bean (*Vicia faba* L. var. *minor* Beck. cv Scuro di Torrelama) in alternate rows, 0.45 m apart with faba bean sown in the middle of the wheat inter-row space. Sowing density was 400 kernels m^{-2} for wheat (in all systems) and 90 seeds m^{-2} for faba bean (in ORG+).

Concerning wheat N fertilization, in the INT system, 160 kg N ha^{-1} was applied as urea in two applications (half dose at tillering and half at shooting, following the regional recommendation for durum wheat N fertilization management). In ORG, 40 kg N ha^{-1} was broadcast just before seedbed preparation as poultry manure (N = 4%). In ORG+, at the beginning of wheat shooting (Table S1), faba bean plants were incorporated into the top soil (0.10 m depth) by split rotary hoeing. Thus, in ORG+, durum wheat N fertilization came entirely from the incorporated faba bean plants (relying on an expected amount of approximately 50 kg N ha^{-1} [19])

2.2. Plant Sampling

Each year, the aboveground biomass accumulation of cash crops was determined before harvest by sampling plants from two subplots with 1.2 m^2 area per plot. The harvested aboveground biomass was separated in residues (straw, non-marketable fruits and vegetative parts) and yield (grains and marketable fruits). The cover crop and faba bean biomass was determined just before the termination (pea and barley in the mixture were kept separated). Weed biomass was also determined at each sampling operation. Plant samples were oven dried at 80 °C to determine dry matter content, then ground to a fine powder and stored. A reduced-N concentration of Kjeldhal digests, prepared following the method proposed by Isaac and Johnson [20], was measured by using an automatic analyzer (FlowSys, Systea, Italy).

2.3. NO_3-N Leaching, N Balance and N Use Efficiency

Every year, two lysimeters consisting of porous, ceramic cups (32 mm external diameter by 95 mm length) were installed [21] in the core part of each plot at a depth of 0.9 m. The cups were installed just after sowing by drilling the soil vertically at a depth of approximately 1.0 m. The excavated topsoil and lower subsoil were kept separate. Before placing the porous cup, thick slurry prepared from the lower subsoil was poured into the hole. The repacked soil was then added and consolidated with care in order to avoid preferential water flow. The ceramic cups (SDEC, Tauxigny, France) were joined to a capillary tube, long enough to emerge from the soil surface and sealed at the end by an iron clamp. Samples of the soil solution at 0.9 m were taken using a portable vacuum pump, and then transferred to a storage pot. The NO_3-N concentration in the soil solution was determined by an ion-specific electrode meter (Cardy, Spectrum Technologies, Inc., Plainfield, IL, USA), calibrated at the beginning of each measurement and set by using the standard solutions provided with the testing kits [22]. According to the method proposed by Gabriel et al. [23], NO_3-N concentration data were recorded only when all soil lysimeters could provide drainage water, which occurred after rainfall events of adequate intensity.

A simplified model was adopted to estimate the drainage volumes (for further details see Tosti et al. [22]). As proposed by Gabriel et al. [23], the NO_3-N leached over the time intervals between soil solution samplings was calculated as the product of mean NO_3-N concentration in the soil solution and the daily drainage obtained for the sampling interval.

As reported by De Notaris et al. [16], N balance was calculated as the difference between N input and output. The input included: N in manure or mineral fertilizer (i.e., extra-farm N), atmospheric N deposition [24], N derived from atmosphere via symbiotic fixation (Ndfa) and N in seeds. The output consisted of N removed from the field (i.e., leaching losses and N in yield). The N surplus was generated by the combination of the input and output values. For each year, inputs and outputs were determined, for each system, as averages across crops.

Ndfa was considered equal to 90% of the total N accumulation in the pea and faba bean above-ground biomass, according to the findings reported by Antichi [25] and Saia et al. [26] for similar climatic conditions. N use efficiency at system scale was assessed by two indices: yield to N leaching loss ratio (Y/Nloss, kg kg^{-1} N) and yield to extra-farm-N input (Y/Nextra, kg kg^{-1} N).

2.4. Statistical Analysis

Data were analyzed by using the following linear mixed model, following the rules suggested by Onofri et al. [27]. In particular, the field (two levels), the year (four levels) and the system (three levels) were added as fixed effects with all their two- and three-way interactions. It should be noted that the 'year × field' interaction corresponds to the crop effect, as the crops are univocally identified by one specific field in one specific year. The blocks within fields and the plots within blocks within fields were added as random effects to account for blocking units and repeated measures. The 'field × year × system' interaction was always significant and the corresponding means were compared by using a generalized multiple comparison procedure with multiplicity adjustment [28]. All analyses were conducted by using the R statistical environment [29].

3. Results

3.1. Weather Conditions

During the 4-year experiment (September 2013–August 2017), the average annual temperature was 15.3 °C, and the cumulated yearly precipitation was 865 mm. In all years, most rainfall events were observed from September to April (wet period, on average 602 mm cumulated rainfalls), and during this period, there was a clear gradient going from 2013/14 (extremely wet, 822 mm) to 2014/15 (highly wet, 645 mm), to 2015/16 (dry, 522 mm) and 2016/17 (very dry, 420 mm).

Two extreme events were recorded in the first and last years: a severe hail was recorded on 12 June 2014 and a late frost event with temperature of −1.44 °C was recorded on 22 April 2017 (Figure 1).

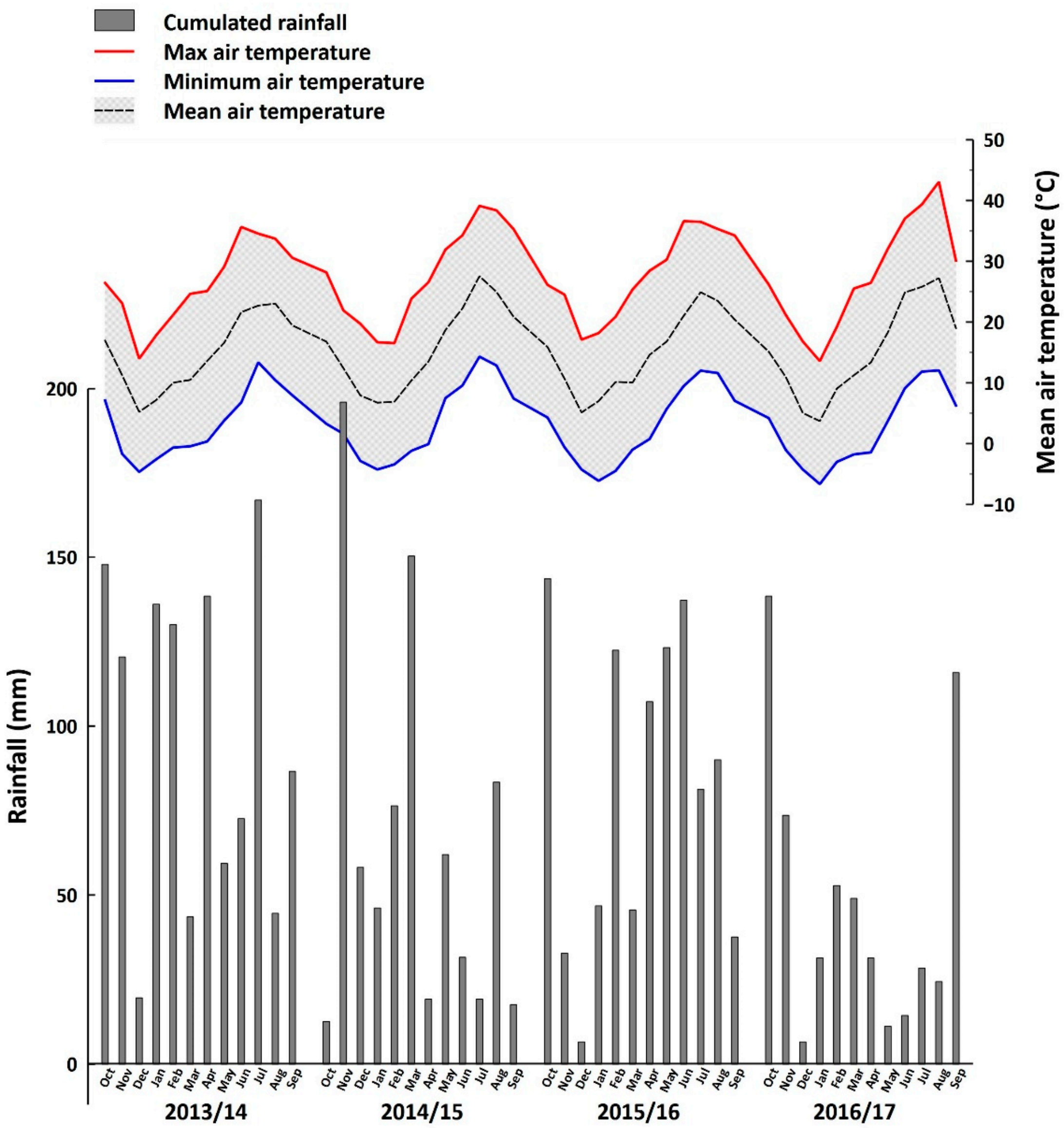

Figure 1. Monthly rainfall (mm) and mean, max and minimum air temperature values recorded at the experimental field station 'FieldLab' (Papiano, Perugia, Italy) during the 4-year experiment.

3.2. N Balance

In order to give an overview of the whole cropping system scale, N budgets were calculated for each cropping system as yearly averages on a 4-year basis (2013/14–2016/17, Table 1; the data for each main crop are reported in Table S2). The INT received a fixed amount of 155 kg N ha^{-1} yr^{-1} of extra-farm N fertilizer distributed to durum wheat (160 kg N ha^{-1} yr^{-1}) and processing tomato (150 kg N ha^{-1} yr^{-1}). The ORG received a fixed amount of N as poultry manure at durum wheat sowing, and a variable amount of extra-farm N via fertigation to the processing tomato (see Materials and methods section for details). Therefore, the yearly average of extra-farm N fertilizer added to ORG was 69.8 kg N ha^{-1} yr^{-1}. In ORG+, durum wheat was not fertilized with extra-farm source, however the N rates applied with fertigation to the processing tomato were generally higher than those in ORG; therefore, the yearly amount of N fertilizer added to ORG+ was, on average, 66.16 kg N ha^{-1} yr^{-1} (i.e., not statistically different from ORG, $p < 0.01$).

Table 1. Annual mean values (2-crop and 4-year basis, kg N ha^{-1} yr^{-1}) of Nitrogen inputs (Ninput), outputs (Noutput), surplus (Nsurplus) and N lost by leaching (Nleaching) during the experiment for the three cropping systems: integrated (INT), traditional organic (ORG) and innovative organic (ORG+). On the same row, values followed by different letters are statistically different ($p < 0.05$).

	INT		ORG		ORG+	
Ninput						
Fertilizers	155.0	a	69.8	b	66.2	b
Ndfa	0.0	-	25.2	b	34.2	a
Seeds	2.0	c	4.2	b	11.5	a
Deposition	5.0	a	5.0	a	5.0	a
Total Ninput	162.0	a	104.2	c	116.8	b
Noutput	104.0	a	75.7	b	44.0	c
Nsurplus	58.1	a	28.6	b	72.8	a
Nleaching	67.2	a	29.9	b	24.7	b

The highest Ndfa and N supplied with seeds were observed in ORG+ (legume component of CC + faba bean in TIC) followed by ORG. While the INT had no CC, neither legume was in crop rotation so the Ndfa was zero and the N added with the seeds was the lowest.

The INT was the system with the highest overall N input, while ORG had the lowest input. The average N output ranged from 44 kg N ha^{-1} yr^{-1} in ORG+ to 104 kg N ha^{-1} yr^{-1} in INT, while ORG showed an intermediate value of 76 kg N ha^{-1} yr^{-1}. INT and ORG+ had the highest N surplus values (58.1 and 72.8 kg N ha^{-1} yr^{-1}, respectively) while ORG the lowest (28.6 kg N ha^{-1} yr^{-1}). The N lost by leaching in INT was twofold compared to that observed in ORG and ORG+ (27.3 kg N ha^{-1} yr^{-1} on average, Table 1).

3.3. Yield and N Leaching

In all systems, durum wheat yield was low in 2013/14 and 2016/17 (due to a severe hail event and a late frost, respectively). In these two years, the systems did not show any significant difference in terms of yield (Figure 2A). In 2014/15 and 2015/16, the yields were generally higher and the ranking among systems was the same (i.e., INT > ORG > ORG+, $p < 0.05$).

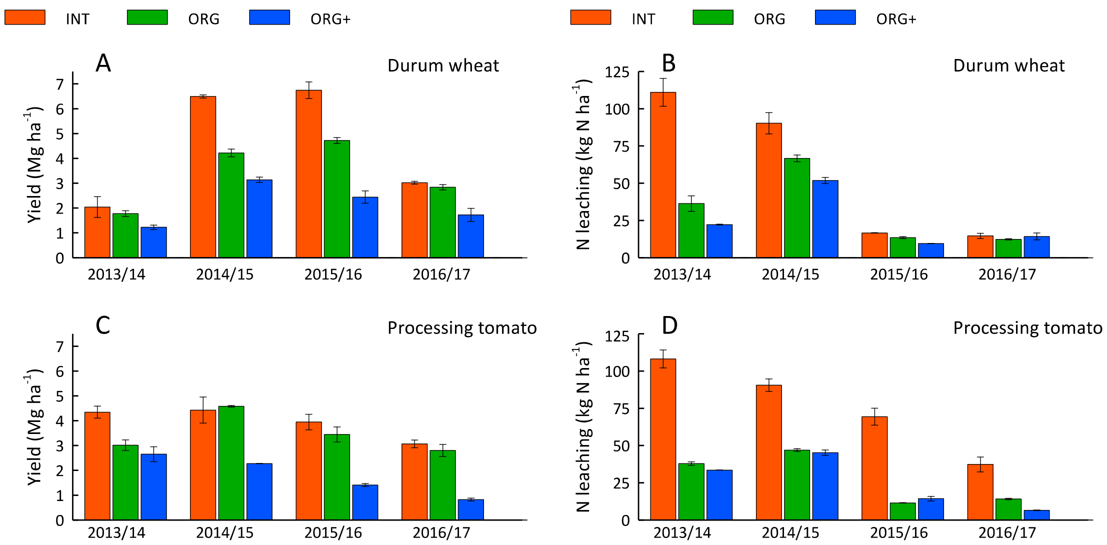

Figure 2. Yield (Mg ha^{-1}) and N leaching (kg N ha^{-1}) of durum wheat (top: (**A**) and (**B**), respectively) and processing tomato (bottom: (**C**) and (**D**), respectively) in the three cropping systems: integrated (INT), traditional organic (ORG) and innovative organic (ORG+). Bars represent the standard errors.

The N lost by leaching under durum wheat was significantly ($p < 0.001$) influenced by the systems in the first two (rainy) years, with the INT showing higher values as compared to both ORG and ORG+. In the latter two (drought) years, the N leaching values were generally low and the differences among systems were not significant (Figure 2B).

Processing tomato yield was compromised by the above-mentioned hail event in 2013/14, and the damages to the plants were particularly severe in ORG (Figure 2C). During the following years, yield values observed in INT and ORG were not different, while ORG+ always showed the lowest values. From 2014/15, the processing tomato yield showed a decreasing trend, particularly in ORG+, due to attacks of late blight disease (*Phytophthora infestans* (Mont.) de Bary) of increasing severity over time (Figure 2C).

In INT, where the soil was left bare during the autumn and winter seasons, N leaching in processing tomato decreased linearly across years as rainfall amount decreased (Figure 2D). Otherwise, irrespective of CC management strategies, both ORG and ORG+ showed similar N leaching values, which were significantly lower as compared to those observed in INT ($p < 0.001$).

3.4. N Loss and Extra-Farm N Input Per Yield Unit

In 2013/14 and 2014/15, the yield to N loss ratio (Y/Nloss, kg kg^{-1} N) of durum wheat was rather low (53 ± 3.8 kg kg^{-1} N) and it was not affected by the systems (Figure 3A). In 2015/16 and 2016/17, Y/Nloss was statistically similar in INT and ORG, which were significantly higher than ORG+. As for wheat, the Y/Nloss values of processing tomato (Figure 3C) observed in 2013/14 and 2014/15 were low in all systems: in 2013/14, the INT showed halved values as compared to ORG and ORG+, while in 2014/15 the systems did not show any significant difference (due to the high variability observed in INT). During 2015/16 and 2016/17, the Y/Nloss values observed in ORG were higher ($p < 0.001$) as compared to both the INT and ORG+, which were not significantly different from each other (Figure 3C).

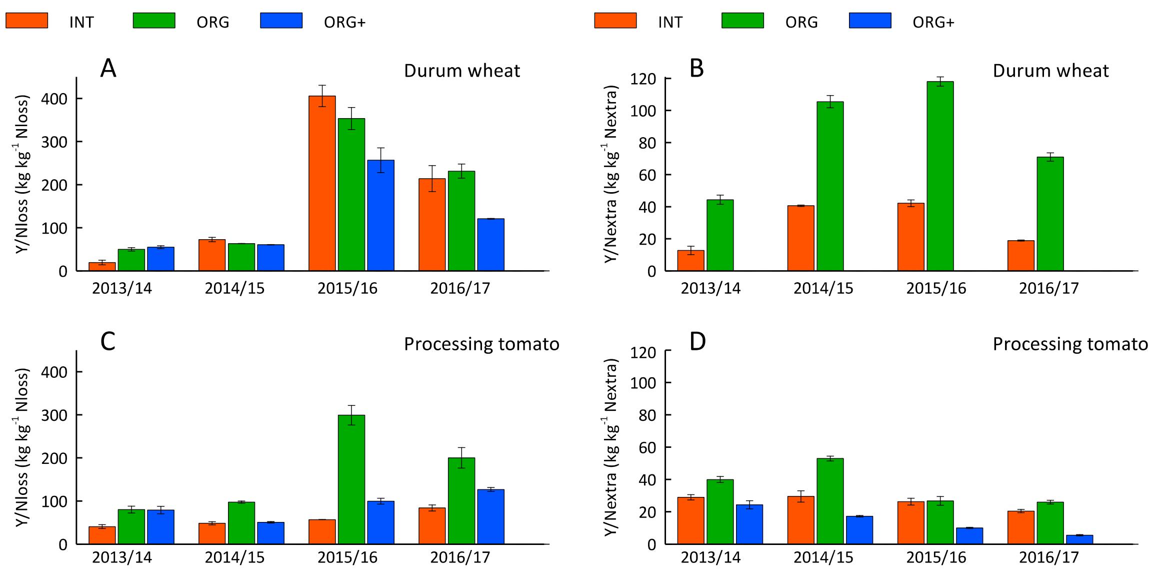

Figure 3. Yield per unit of N leached (Y/Nloss, kg kg^{-1} N), yield per unit of extra-farm N (Y/Nloss, kg kg^{-1} N) in durum wheat (top: (**A**) and (**B**), respectively) and processing tomato (bottom: (**C**) and (**D**), respectively) in the three cropping systems: integrated (INT), traditional organic (ORG) and innovative organic (ORG+). Bars represent the standard errors.

The yield to extra-farm–N input ratio (Y/Nextra, kg kg^{-1} N) of durum wheat was calculated just for INT and ORG systems, as the wheat in ORG+ did not receive any extra-farm N input (Figure 3B). Across the entire experimental period, the values observed in ORG were always significantly ($p < 0.001$) higher as compared to the INT. Concerning the Y/Nextra of processing tomato, in 2013/14 and 2014/15 the observed values in INT and ORG+ were not significantly different, but they were both lower than in ORG. In 2015/16 and 2016/17, ORG and INT were similar and higher than ORG+ (Figure 3D).

4. Discussion

The N balance (Table 1) allows the comparison between the three systems as it was computed by averaging the variations related to the conditions in individual years and crops [30]. The adoption of TIC in ORG+ considerably improved the N self-sufficiency of this system [31], raising (+35%) the Ndfa as compared to ORG. As expected, the Noutput values confirmed the gap between organic and conventional farming systems [32]; the Noutput values observed in ORG+ were the lowest in accordance with the finding of Knapp and van der Heijden [33] and Cooper et al. [34]. Nsurplus was high in both INT and ORG+, but such effects resulted from different reasons: in INT, there was a very high Ninput and a high Noutput, while in ORG+ there was high Ninput coupled with low Noutput. In contrast, Nsurplus in ORG was the lowest. The relation between N leaching and N surplus was consistent at the crop rotation level only in the INT, confirming that the management strategies to retain N in the system (e.g., by using catch crops and organic N fertilizers) are of paramount importance for reducing N leaching risk [16,35].

Wheat production in INT was the most variable across years, and such variability was associated with high N loss from the system when the climatic conditions were favorable to N leaching (high rainfall after side-dress fertilization and/or slow crop growth as recorded in the former two years, Figure 1). TIC was proved to reduce N leaching loss as compared to traditional management in organic wheat production [19,22]. Non-inversion soil management is known for reducing nutrient loss [36], thus its combination with TIC was expected to significantly improve the N retention in ORG+. However, such reduction (as compared to ORG) was not observed in our experiment, probably because the yield (and Noutput) was remarkably reduced in ORG+.

From 2014/15, a general reduction of processing tomato yield has been observed in all systems, probably due the short biannual rotation [37]. This effect was particularly evident in ORG+, where the short rotation problems were attributed to the typical decrease in crop productivity, during the transition from inversion to non-inversion soil till management [38]. In our case, the termination efficiency towards the CC, that is already known to be one of the critical issues in MBNT systems [8], was further reduced by the no-till soil management. However, processing tomato confirmed its good adaptability to organic practice [39] as the yields obtained in ORG were not statistically different from those observed in INT in 3 out of 4 years. As observed by other studies [32], when N-inputs are similar (such as for processing tomato), the yield gap between organic and conventional systems is lower (12% ± 5.0%) than when N-inputs differ (such as in durum wheat, 21% ± 4.8%). The introduction of winter-sown CC in crop rotation was confirmed to be a very effective practice to prevent N leaching [17,40]; the N loss in INT was proportionate to the rainfall amount during the rainy season (October to March, $R^2 = 0.854$, $n = 8$), while in ORG and ORG+ it was constantly low confirming the essential importance of CC for building agricultural systems with high N self-sufficiency and internal N recycling [41].

Recently, the yield gap in conventional and organic systems has been intensely debated [32,42]. In accordance with Wilbois and Schmidt [43], it is important to reframe this debate by taking into account the appropriate benchmarks. Thus, a comparison of the output in the three cropping systems cannot exclude the extra-farm–N input transformation efficiency (Y/NExtra) and the environmental cost (in terms of N lost from the system) per unit of yield (Y/NLoss).

In both wheat and processing tomato, ORG showed the best balance between economic output (yield) and water protection service as it showed the highest values of Y/NLoss in five cases out of eight (and in the three remaining cases the difference among systems was not significant). When favorable conditions for N leaching loss were present, the Y/Nloss observed in durum wheat was not affected by systems, while concerning processing tomato, the effect of the cover crop on N leaching reduction was predominant [44]. Therefore, although the INT showed the highest yield, the Y/Nloss ratio was not different from the very low yielding ORG+; on the other hand, ORG was the most interesting system in terms of environmental impact of the yield unit [45].

This interesting finding is confirmed by the Y/Nextra ratio (Figure 3B,D): considering durum wheat, the ORG efficiency in converting an extra-farm–N source to yield was largely above that showed by INT, while ORG+ was not considered, as it did not receive any external N input for wheat production. The efficiency of ORG+ was tested only in processing tomato, where it showed the lowest Y/Nextra values, due to the very low yield achieved by such system. Thus, at the cropping system level (i.e., considering both cash crops), this fact downplayed the impact of the complete N–self-sufficiency of ORG+ for durum wheat production. Thanks to its high yield, ORG showed Y/Nextra values that were not different (2013/14, 2015/16 and 2016/17) or even higher (2014/15) than those observed in INT.

5. Conclusions

Our results demonstrate that N recycling at the agroecosystem level was greatly improved by CC practice, independently from the soil management strategy (no till or inversion tillage). The improved Nsurplus was not retained in the system without CC (INT), so high yield (and Noutput) was not a sufficient condition to guarantee a high environmental efficiency of INT. On the contrary, the practices adopted in ORG+ (cover crop and temporary intercropping) considerably improved the N self-sufficiency of the system, thus the Nsurplus did not give rise to N loss, but the low Noutput (Yield) consistently reduced the efficiency of the external N input (Y/Nextra). The yield obtained per unit of N lost by leaching suggests that ORG was the most interesting system, while the potential sustainability of MBNT systems (i.e., ORG+) needs a substantial improvement, otherwise the great potential for the regulation and maintenance of ecosystem services can hardly be expressed.

Supplementary Materials: The following are available online at http://www.mdpi.com/2073-4395/9/11/718/s1, Table S1: Dates of the agronomic operations, Table S2: N balance with separate main crops.

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