Chapter 26
Soil Fertility Management in Organic Potato: The Role of Green Manure and Amendment Applications

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Abstract During the last decade in the European Union, the organic food and farming (OFF) sector has grown considerably. The potato (*Solanum tuberosum* L.) crop plays an important role in organic farming systems, being one of the most highly demanded products on the market for organic produce. In this chapter, the role of green manure and organic amendments application for soil fertility management in agro-ecosystems based on organically managed potato crop is discussed in the light of the most relevant scientific literature. Moreover, as a case study, the results of a field experiment designed to evaluate the combined effects of green manure and organic amendment applications on organic potato yield, nitrogen (N) use efficiency and soil mineral N dynamic are presented. Our results indicated that legume green manure management and the recycling of organic materials may provide a valid alternative to the conventional synthetic fertilizer-based management system to sustain potato yield without enhancing potential environmental risks due to N leaching. Our study demonstrated that ecofunctional intensification of potato-based organically managed cropping systems is achievable through the exploitation of the combined effect of legume green manure with organic amendments application.

26.1 Introduction

During the last decade, in the European Union, the organic food and farming (OFF) sector has grown considerably and great interest has been directed to its capacity to provide safe, quality food, while preserving the environment and addressing the

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Table 26.1 Area under organic potato production, percentage of organic potato in total organic and total potato production in selected EU (European Union) and extra EU countries (years 2007–2008)

Country		Area under organic potato(ha)	Organic potatoes in total organic production(%)	Organic potatoes in total potato production(%)
EU countries	Denmark	1,268	0.84	3.08
	Germany	8,150	0.90	2.96
	Italy	1,014	0.10	1.41
	Netherland	1,271	2.52	0.79
	Poland	1,861	0.59	0.33
	Romania	143	0.10	0.01
	United Kingdom	3,270	0.44	2.35
Extra EU countries	Azerbaijan	251	1.18	0.37
	Canada	447	0.07	0.28
	Morocco	50	1.45	0.08
	South Africa	398	0.91	0.69
	Turkey	136	0.12	0.09
	Ukraine	79	0.03	0.01
	United States	3,348	0.17	0.73

socio-cultural and economic requirements of farmers and society (European Commission 2010). The total organic area in EU-27 continues to show an upward trend and the fully converted and under conversion area was 7,764,722 ha in 2008, revealing an increase of 7.4% relative to 2007 (Eurostat 2010).

The potato (*Solanum tuberosum* L.) crop plays an important role in organic farming systems, being one of the most highly demanded products on the market for organic produce (Tamm et al. 2004). According to the data reported by FAO and organic-world.net statistics, in many countries, organic potato cultivation represents an important crop within organic agriculture (Table 26.1).

According to the International Federation of Organic Agricultural Movements (IFOAM), basic principles for soil health and quality management in organic farming rely on the returns of microbial, plant, and animal organic material to the soil. Cultivation techniques should contribute to increasing soil biological activity and nutrient inputs and must be applied in a way that does not harm soil, water, and biodiversity (IFOAM 2010). Accumulation and decomposition of soil organic matter are, therefore, at the basis of fundamental life-promoting processes representing a key issue of organic production. With a similar approach, the current European Regulation for organic food and farming (EC Regulation 834/2007) established that soil fertility management is based on multi-annual crop rotation, recycling organic materials, choice of appropriate – locally adapted – plant species, crop varieties and cultivation techniques. Additional inputs for fertility management (i.e. fertilizers and soil conditioners) should be used only if they are compatible with the objectives and principles of organic production (i.e. the use of chemically synthesized inputs is strictly limited).

Under this conceptual-regulative framework, wastes and by-products of plant and animal origin should be recycled to return nutrients and organic carbon (C) to soils. Organic amendments (i.e. manure and compost) are thus a useful tool for soil fertility management and long-term sustainability of crop production. Indeed, many studies have noted the benefits of organic sources in improving soil structure, water holding capacity, root development and soil microbial activity (Sommerfeldt et al. 1988; Gilley and Risse 2000; Grandy et al. 2002; Lynch et al. 2008).

Similarly, utilisation of cover crops within cropping systems is consistent with the main organic principles, and they are introduced in the rotation with the primary aim of increasing soil organic matter content and/or nutritive elements availability to crops (Doran and Smith 1991; Lu et al. 2000; Dabney et al. 2001; Lenzi et al. 2009).

In this chapter, the role of green manure and organic amendment applications for soil fertility management in agroecosystems based on organically managed potato crop is discussed, in light of the most relevant scientific literature. Moreover, as a case study, results from a field experiment designed to evaluate the combined effects of green manure and organic amendment applications on organic potato yield, nitrogen (N) use efficiency and soil mineral N dynamic are presented.

26.2 Organic Potato Research in Europe

In accordance with the importance of the crop, a large number of studies about organically grown potatoes have been carried out in the last several years (i.e. Mirabelli et al. 2005; Speiser et al. 2006; Flier et al. 2007; Hagman et al. 2009). In more depth, American Journal of Potato Research and Potato Research published 63 papers on organic potato between 2001 and 2010. Furthermore, the bibliographic research carried out by the Springerlink search engine showed that among all the found papers dealing with organic potatoes cultivation, 27 (43%) were referred to European experiences, 7 (11%) dealt with control of pests and diseases, 6 (10%) had potato breeding as main subject and 6 (10%) were related to agronomical strategies. Likewise, looking for the keywords "organic farming" and "potato" between 2000 and 2011 in the SCIRUS search engine, 15 papers were found. Fourteen of them focused on researches carried out in the EU: among these, 5 referred to cultivation techniques, 2 to pest and disease control and 2 to plant breeding for organic agriculture.

As far as soil fertility management is specifically concerned, a number of recent studies were performed by several authors with particular attention to N management (i.e. Döring et al. 2005; Haase et al. 2007a, b). Tuber yield response was indeed dependent on the rate at which N was released from precedings crops residues (Stockdale et al. 1992; Köpke 1995; van Delden 2001) and highly responsive to N fertilization, cover crop and manure treatments (Reents and Möller 2000; Bélanger et al. 2001; Sincik et al. 2008; Zelalem et al. 2009). At the same time, efficient use of N fertilizer was found to be essential to increase the economic return of the crop and minimize potentially negative effects on water and air quality (Harris 1992). Thus, the typical organic potato production was characterized by extended rotations involving leguminous crops as green manures and/or organic amendments utilization (Lynch et al. 2008).

26.3 Green Manure Utilisation in Potato-Based Crop Rotations

Cover crops help to maintain soil organic matter, improve soil health, prevent and slow erosion and assist in nutrient management, enhancing their availability (Lu et al. 2000; Dabney et al. 2001; Lenzi et al. 2009). They can also contribute to weed management (Creamer et al. 1996; Teasdale 1996; Lu et al. 2000; Davis 2010), increase water infiltration (Dabney et al. 2001), maintain or increase populations of beneficial fungi (Galvez et al. 1995), and help with the management of insect pests, diseases and nematodes (Mojtahedi et al. 1991; Johnson et al. 1992; Tillman et al. 2004; Larkin et al. 2010). Cover crop utilisation and management are hence an important research lode for organic agriculture.

As a function of the different types of services provided by cover crops and in relation to the agro-ecosystem characteristics in which they are implemented, a range of cover crop families and species have been introduced in organic potato agro-ecosystems. In general, non-leguminous cover crops (sunflower; crucifer; cereals, such as rye and barley) are beneficial because they generate organic matter, compete with weeds and help in preventing soil erosion. They may be utilized as a N catch crop when planted either before and after potato, optimizing N utilisation during the whole rotation system (i.e. rye; Evanylo 1991; Reents and Möller 2000; Larkin and Griffin 2007). In particular, planted after cash crops (i.e. potato), when the soil is still warm and microbes are releasing nitrates, they capture N that otherwise might be leached from the soil (Jégo et al. 2008). Moreover, some non-leguminous cover crops, such as winter rye, ryegrass, brassicas and buckwheat, have also been shown to reduce soil-borne diseases when used in rotation with potatoes (Edwards 1986; Boydson and Hang 1995).

On the other hand, leguminous crops can be planted as full season cover crops with a cereal nurse crop (e.g.: small red clover undersown in oats, barley or wheat) or as the sole cover crop in the year before potatoes (Odland and Sheehan 1957; Schmidt et al. 1999). They are commonly terminated as green manures, and it has been estimated that the effect of a preceding leguminous cover crop was equivalent to the application of N fertilisers for a total of about 20–150 kg N ha^{-1} (Doran and Smith 1991; Ledgard 2001). Indeed, it is generally accepted that the release of N from decomposing green manure residues may be well-timed with plant uptake, possibly increasing N uptake efficiency and crop yield while reducing N leaching losses (Bath et al. 2006). For these reasons, they are particularly useful when preceding potato, which require high N levels (Sincik et al. 2008).

26.4 Organic Amendment Utilisation in Potato Crops

Potato rotations are often characterized by low levels of soil organic matter and consequently exhibit a poor soil physical condition. This is attributable to relatively low organic C inputs and the sandy soil types generally associated with potato production, which have a limited capability to retain organic C (Carter et al. 2003). Mallory and Porter (2007), in a long-term experiment carried out in Maine (USA), found that soil management based on the addition of organic amendments enhanced potato yield and reduced year-to-year variability of those yields. Consequently, the use of organic amendments is a common feature in intensive potato production systems (e.g., Gagnon et al. 2001; Grandy et al. 2002). Crops grown on soil that received organic amendments have been shown to have access to greater soil moisture and to be more resistant to weed and insect pressure (Gallandt et al. 1998; Liebig and Doran 1999; Lotter et al. 2003; Alyokhin et al. 2005). On the other hand, Lynch et al. (2008), evaluating the nutritive effects of N applied by organic amendments to an organic potato field, observed that tuber yield was decreased by the application of a swine manure-sawdust compost with a C/N ratio of 22 and attributed this effect to N net immobilization. In fact, the C/N ratio is generally considered to be a useful, if only approximate, guide to likely net mineralization, and it is generally accepted that easily decomposable organic materials, characterized by a C/N ratio below 20, release N on decomposition, but that material with a C/N above 20, immobilizes N temporarily (Whitmore 2007). Organic amendment use in consolidated production practices, therefore, requires some knowledge of N rate of release. In particular, for compost, a large fraction of total N (>90%) is not easily available for plant uptake (Amlinger et al. 2003). The greatest fraction is bound to the organic N-pool, while mineral, readily plant available N represents less than 2% of the total N content (Day and Shaw 2001). Indeed, according to the literature, in the first year after compost addition to the soil, available N is less than one fifth of the total N applied (Hadas and Portnoy 1994; Coutinho et al. 2006; Zhang et al. 2006). Therefore, in the short-term, compost does not fulfill the N needs of crops, so its use as the sole source of N for crops is not recommended. In their study on different composts as N source on a crop succession including potato and catch crops, Passoni and Borin (2009) found that crop response and N uptake were scarcely affected by compost fertilization. On the other hand, Carter et al. (2004), in their experiment aiming to test the influence of compost application on a potato rotation, found an increase in tuber yield, even above the maximum yield obtained with N application. This "non-nitrogen" compost yield effect was proposed to be related to the slight, but significant, improvement in soil water-holding capacity.

Similarly, farmyard manure (FYM) in organic farming systems plays a very important role for crop nutrition and the maintenance of soil fertility (Mäder et al. 2002). However, different authors reported the use of manure in organic agriculture hampered the optimization of more than one nutrient in terms of the nutrition of the potato crop (Dewes and Hünsche 1998; Shepherd et al. 2002). In particular, they showed the low potential of manure to increase plant available N and tuber N uptake. Indeed, Stein-Bachinger and Werner (1997) stated that N from FYM is usually not readily available in the season of application. Consequently, the utilisation of organic amendments can give the best performance on crop productivity when they are not utilised as the only input resources in soil fertility management strategies for the potato crop. Thus, combined applications of manure/compost with cover crop/green manures could potentially enhance the effectiveness of organic amendment fertility and improve yields and soil fertility, while at the same time reducing the risk of nutrient (i.e. N) leaching (Singer et al. 2008; Cambardella et al. 2010).

26.5 Effects of Green Manure-Soil Amendment Interactions on N Availability for Organic Potatoes

As is already well-known, restricted availability of any one of the needed nutrients will result in growth reductions that may also reduce crop quality and yield. To avoid this risk, nutrients must be available from the soil in amounts that meet the minimum requirements for the whole plant. This requirement is much higher than just the nutrients removed from the harvested yield. All the plant parts require nutrients at specific times during plant growth and development. Nutrients such as N and phosphorus (P) often move beyond the bounds of the agricultural field because the management practices used fail to achieve good congruence between nutrient supply and crop nutrient demand (van Noordwijk and Cadisch 2002). Soil fertility management should be optimized to supply nutrient requirements at the appropriate time and at sufficient levels, to support healthy plant growth. In this context, timing of organic amendment (e.g. compost) application within the rotation may contribute to achieve these results (Willson et al. 2001). In this regard, agro-ecosystem management strategies should be balanced to obtain high short-term efficiency as well as maximizing the cumulative crop yield response over time (Dobermann 2007).

Concerning N, synchronizing its release with plant requirements is indeed important with the double aim to promote yield and limit N leaching (Bath 2000). Potato crops show a relatively low ability to take up available soil mineral nitrogen (SMN), (Tyler et al. 1983; Dilz 1987). Since it is impossible to accurately predict the total crop N requirements and soil mineral N supply during the growing season, in conventional farming splitting of N fertilizer application is a suitable approach to better match N need and supply (Vos and MacKerron 2000; Goffart et al. 2008). With reference to organically managed cropping systems, where the use of high soluble/easy mineralisable inputs for fertility management is not promoted (EC Regulation 834/2007), Sikora and Enkiri (2000) observed that to optimize the use of nutrient sources, to enhance N supply in relation to crop demand and to achieve maximum crop yields, the combination of different N sources as cover crop residues, manures and composts may be an effective approach. Accordingly, Nyiraneza and Snapp (2007) reported that potato N uptake and mineralization of N from organic sources could be synchronized if a mixture of different residue qualities are used, including low N (high C/N ratio, such as compost) and high N (low C/N ratio, such as legume green manure) tissues.

In light of the above reported consideration, and despite the potential of organic amendments and legume green manure cover crops in managing soil N fertility, only a few studies have investigated the combined effect of green manure and different types of amendment applications on organic potato yield and environmental impact (Bath et al. 2006; Nyiraneza and Snapp 2007). Moreover, none were carried out under Mediterranean conditions.

26.6 Organic Potato Under Mediterranean Conditions: A Case Study

As already mentioned above, the primary challenge in organic potato systems, and perhaps even more so in general organic agriculture, is synchronizing nutrient release from organic sources, particularly N, with crop requirements. In this context, a field experiment was carried out in Tuscany (Central Italy) with the objective to assess the contribution of farmyard manure and compost utilised in combination with a green manure legume cover crop (*Trifolium subterraneum* L.) to potato crop nutrition, evaluating potato yield, N uptake and use efficiency (Canali et al. 2010). In the experiment, SMN dynamic was also studied to evaluate the potential impact on the environment.

Climate in the area is typical Mediterranean; the monthly mean minimum (January) and maximum (July) temperatures are 9°C and 20°C respectively. Rainfall (average 900 mm year^{-1}) is unevenly distributed during the year, being concentrated mainly in the winter months.

The experimental field, according to a split-plot layout was divided into two main strips, representing different management systems, in which a subterranean clover (*Trifolium subterraneum* L.) green manure was cultivated (GM+) or not (GM−). Within each strip, elementary plots, which received farmyard manure (FYM) or green compost (C) at three different rates, corresponding to an amount of 0, 50 and 100 kg N ha^{-1} (0, 50 and 100), were randomly distributed (Fig. 26.1). N applied to the soil by the green manure accounted for about 20 kg ha^{-1}. Compost was produced starting from green (garden) residues collected in the area. The compost heavy metals concentration complied with the European Regulation on organic farming (EC 834/2007) and the Italian regulation on organic fertilizers and amendments (Legislative Decree 217/2006). Cattle farmyard manure was obtained from an organic animal farm located close to the experimental site. The main characteristics of the two amendments used are reported in Table 26.2.

During the cropping cycle and at harvest, potato yield, total and above-ground biomass, and total N content (Bremner and Mulvaney 1982) were determined, allowing the calculation of Total N uptake (N content x biomass dry matter). On the basis of these measurements, the following parameters were calculated:

- harvest index (HI) as the ratio of the tuber yield to total biomass (Jennings 1964);
- N harvest index (NHI) as the ratio of the tuber N uptake to total N (Montemurro 2009);
- N utilization efficiency (NUE) as the ratio of tuber yield to total N uptake (Montemurro 2009).

Fig. 26.1 Farmyard manure (FYM) and Compost (C) application to the plots in the experimental site

Table 26.2 Main chemical characteristics of organic amendments (on dry matter basis) (Canali et al. 2010)

	FYM	C
Total C[a] (g kg^{-1})	386	285
Total N[b] (g kg^{-1})	23	12
C/N	17	24
pH	8.9	7.9
Ashes[c] (g kg^{-1})	228	480
Cd[d] (mg kg^{-1})	0.1	0.3
Hg[d] (mg kg^{-1})	<1.5	<1.0
Cu[d] (mg kg^{-1})	20.1	22.3
Zn[d] (mg kg^{-1})	117.9	128.9
Ni[d] (mg kg^{-1})	7.5	22.3
Pb[d] (mg kg^{-1})	5.0	76.9
Cr VI[d] (mg kg^{-1})	<0.5	<0.5

All analytical data are reported as the mean of three replicate determinations

FYM cattle farmyard manure, *C* green wastes compost (crop residues, pruning materials and lawn mowing)

[a]Springer and Klee (1954)

[b]Kjeldahl method (Bremner and Mulvaney 1982)

[c]residue to weight loss at 400°C

[d]ICP-AES after incineration of compost samples at 400°C for 24 h and elemental extraction in acidic environment

Table 26.3 Mean effects of management system, type of amendment and dose on tuber yield, above-ground biomass, total biomass, harvest index, and N indexes on potato (Canali et al. 2010)

	Tuber yield(t ha^{-1})	Aboveground biomass(t ha^{-1})	Total biomass (t ha^{-1})	HI(%)	NHI(%)	NUE
Management system						
GM+	6.80 a	2.90 a	9.70 a	70.4	65.1 b	222 b
GM−	5.55 b	1.78 b	7.33 b	73.5	68.9 a	269 a
Amendment						
FYM	6.86 a	2.16	9.02	74.5 a	71.6 a	263 a
C	5.48 b	2.53	8.01	69.5 b	62.4 b	227 b
Dose						
0	5.27 b	2.33	7.60	69.5	70.1	225 b
50	5.70 b	2.24	7.94	72.0	65.0	249 a
100	7.55 a	2.45	10.0	74.4	66.0	263 a
Means	6.17	2.35	8.51	72.0	67.0	246

The mean values in each column followed by a different letter are significantly different according to LSD and DMRT (two and more than two comparison. respectively) at the $P \leq 0.05$ probability level *GM+* rotation including green manure, *GM−* rotation without green manure, *FYM* farmyard manure, *C* compost, *HI* harvest index (tuber yield/total biomass), *NHI* N harvest index (tuber N uptake/total N uptake), *NUE* N utilization efficiency (tuber yield/total N uptake)

At the same sampling times SMN was measured: NO_3^--N and NH_4^+-N were extracted by 2 M KCl and determined by continuous flowing system (Henriksen and Selmer-Olsen 1970; Krom 1980).

Results were analyzed using univariate analysis of variance (ANOVA) considering the management system (GM+ and GM−), amendment (FYM and C) and dose (0, 50, and 100 kg ha^{-1}) as fixed factors. Means comparison was carried out according to the Least Square Difference (LSD) test and the Duncan Multiple Range Test (DMRT), both at $P \leq 0.05$ probability level, for two and more than two comparisons, respectively.

26.6.1 Combining Green Manure and Organic Amendments: Effects on Yield and N Dynamics

The GM+ system presented significantly higher values of above-ground biomass (62.9%) and total biomass (32.3%) relative to the GM−. Similarly, the total potato yield showed an increase of 22.5 and 25.1% of the GM+ treatment with respect the GM− treatment and of the FYM in comparison with C, respectively (Table 26.3). These results are in accordance with the study of Sincik et al. (2008) in which the responses of potato to green manure cover crops, combined with different N fertilization rates, was evaluated. In their experiment, they reported that green manure legume cover crops resulted in a 35% increase on tuber yield compared with potatoes following winter wheat, when no N fertilizer was applied.

These results showed an increase of 43.3 and 16.9% for potato production and N use efficiency for the highest dose of organic amendments relative to the unfertilised control (Table 26.3). Tuber yield also showed significant differences between the amendment with higher value for FYM than the C treatment. This achievement is probably related to the greater capability of the FYM to release mineral N in accordance with the lower C/N ratio with respect to C (Table 26.2). These results seemed to be in discordance with findings of Willekens et al. (2008) who, in their 4-year rotation comparison trial between farmyard manure and compost, found significantly higher tuber yield in treatments with compost addition. However, they explained this achievement as due to the higher N input by manure which promoted the plant growth and the subsequent leaf blight infection (*Phytophtora infestans;* Möller and Reents 2007).

As far as the HI is concerned, results obtained in the whole experiment showed a high average value (72.0%), similar to the results of Neele (1990) and higher than those reported by Mussaddak (2007), which ranged from 42% to 56% and from 50% to 63% for spring and fall potato, respectively. No significant differences were observed for the amendment dose and the management system treatments, whereas, HI was significantly higher for FYM than for C. Significant increase of both NUE and NHI indices was found in GM− treatment with respect to GM+, showing that there was a higher efficiency in translocation of the absorbed N in the yield components under lower N levels in the soil, which occurred when clover green manure was not previously cultivated. Similarly, the FYM showed a significant increase in NUE and NHI relative to the C treatment, which followed the same pattern regarding tuber yield. No significant differences were observed between the amendment dose treatments for NHI. Meanwhile, NUE showed similar values for the 50 and 100 doses, significantly higher than control (0 dose). This findings suggested the lack of differences in translocation ability when different doses of amendments were applied (NHI), while the absence of differences of NUE in the 50 and 100 kg amendment treatments may reflect a poor crop use of added N at the highest dose.

SMN content showed a similar trend in all doses, with an increase between 6 and 34 DAP, probably due to organic materials mineralization, followed by a decrease from 34 to 82 DAP (harvest) (Fig. 26.2). As reported by Paré et al. (1995) and Jowkin and Schoenau (1998), progressive SMN depletion can be attributable to the increasing plant N uptake along the potato cropping cycle. At the end of potato cropping cycle a slight and significant difference in SMN (about 10 kg N ha^{-1}) was found among the three amendment dose treatments, with the control (dose 0) having the lowest value. However, at the end of the cropping cycle the combination of clover green manure and amendment applications did not increase the SMN (no significant interaction between the two factors, data not showed). These results demonstrated that the combination of legume green manure with amendment applications did not contribute to increasing the potential environmental risks due to N leaching.

Average values of above-ground biomass, tubers and whole plant N uptake measured throughout the potato cropping cycle are reported in Fig. 26.3. In accordance with the low tuber yield obtained (average of 6.17 t ha^{-1}respect to the Italian average marketable yield for the conventional crop estimated in 23.6 t ha^{-1}; Table 26.3) a low level of tuber N uptake at harvest was found, ranging between 11 for GM− and

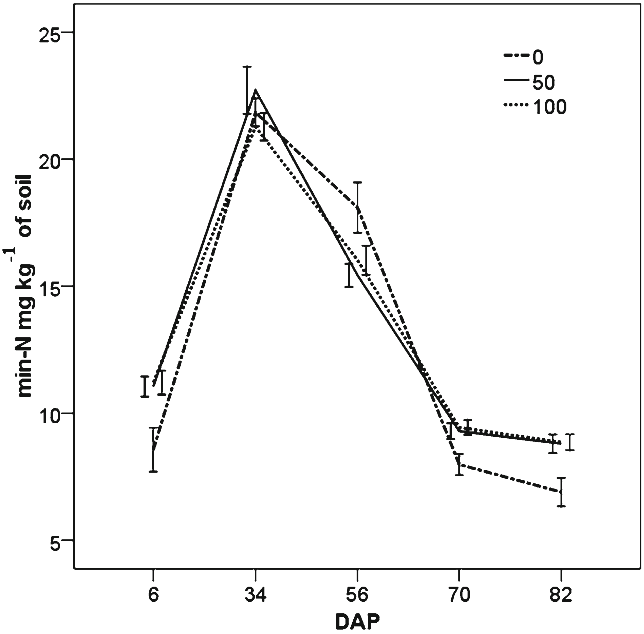

Fig. 26.2 Mineral soil N divided per dose (0, 50, 100 kg ha^{-1}). Data are obtained considering the mean of system and amendment treatments. (Note: *DAP* days after planting; bars represent the confidence interval at the $P \leq 0.05$ probability level) (Canali et al. 2010)

20 kg ha^{-1} for GM+ (significant difference). Similarly, the above-ground biomass and tubers N uptake showed the same trend in all systems and amendment treatments. In particular, above-ground biomass N were 10 and 5 kg ha^{-1} for GM+ and GM− and 9 and 6 kg ha^{-1} for C and FYM, respectively. Considering the whole cropping cycle, total N uptake showed a similar trend in all the system x amendment combinations (Fig. 26.3a–d), resulting in a consistent increase of N uptake over time. At harvest the GM+ treatments showed significantly higher values with respect to the GM− systems (33% higher), explainable through the higher amount of N supplied by clover in GM+. This result was in accordance with the findings of Ten Holte and van Keulen (1989), who carried out an experiment to evaluate the responses of potato and sugarbeet to different levels of N fertilization and different green manures. Their results showed that N supplied by green manure to the potato crop became available over time, matching the potato needs during its cropping cycle. Looking to the whole cropping cycle, in all system x amendment combinations, up to 56 days after planting (DAP), above-ground biomass N was higher than tuber N uptake. Afterwards, the above-ground biomass N decreased and tuber uptake showed an opposite trend. N uptake by the above-ground biomass and tubers became approximately equal at 70 DAP. This pattern was due to N translocation from above to below ground biomass, and at harvest, the average N contained into the above-ground biomass and tubers was respectively 33% and 67% of total N uptake by the crop. This is in accordance with the study by Alva et al. (2002)

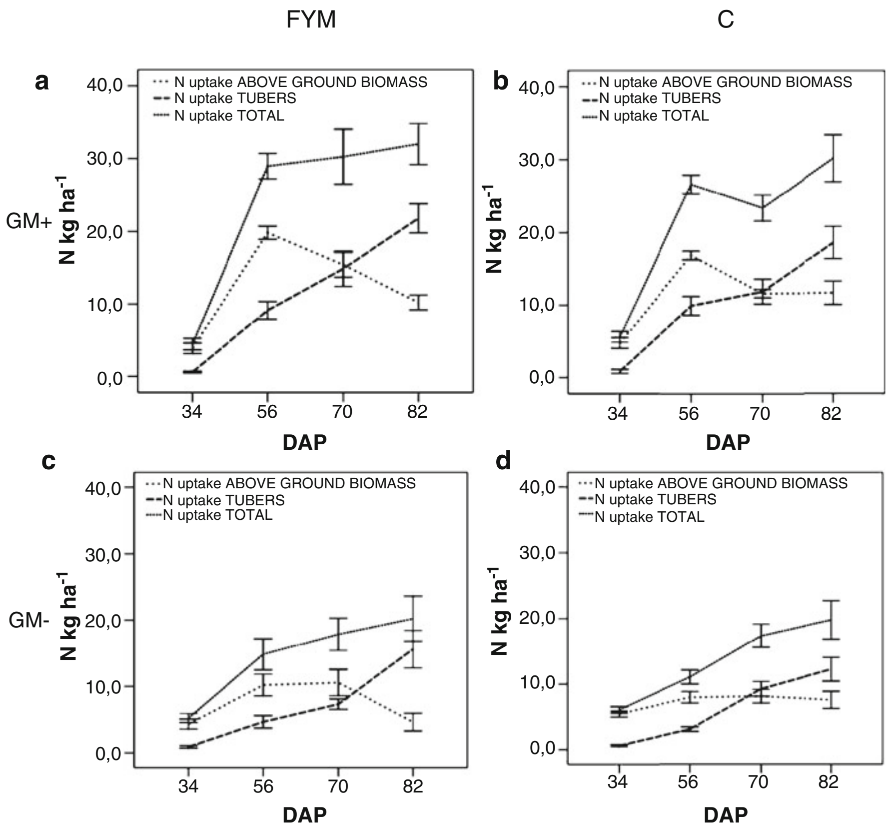

Fig. 26.3 Total N uptake, tubers N uptake and above-ground N uptake of potato as affected by amendment and system treatments. (Note: *DAP* days after planting, *FYM* farmyard manure, *C* compost, *GM+* green manure system, *GM−* no green manure. Bars represent the confidence interval at the $P \leq 0.05$ probability level) (Canali et al. 2010)

regarding N accumulation and partitioning in potato, in which an increase in tuber weight was recorded during 60–100 DAP, whereas the above-ground biomass decreased rapidly in the second half of the cropping cycle. Comparing the different system x amendment combinations, the results underlined the absence of influence of green manure and organic amendment on potato N nutrition physiology, indicating the lack of potential synergic effects of N deriving from green manure and organic soil amendments on N uptake plant physiology.

26.6.2 Conclusions

Typically, potato above-ground biomass is recycled into soil and the nutritive element applied to soil by this technique represents a valuable contribution to the N nutrition of the next crops, especially in organically managed cropping system, where N may become a limiting factor for crop nutrition. In confirmation of this, in the above reported experience, the results showed that the legume green manure management and the recycling of organic materials could represent valid alternatives to the conventional – synthetic fertilizers based – management to sustain potato yield. In particular, the combination of different sources of N seems to enhance the crop performance providing higher availability of the nutrient during the cropping cycle. Simultaneously, this approach did not enhance potential environmental risks due to N leaching. Thus our study demonstrated that ecofunctional intensification of organically managed cropping systems based on potato is achievable through the exploitation of the combined effect of legume green manure with organic amendments application.

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