Korean J. Soil Sci. Fert. **41**(1), 26-33(2008)

Comparison of Soil Nutrient Status in Conventional and Organic Apple Farm

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Soil nutrient status in an organic apple farm was evaluated in relation to a conventional farm to better understand the effects of organic farming system on soil fertility. Soil organic matter, total and mineral N, available P, exchangeable cations, and available micronutrients were monitored at depth of 5-20 cm from May to October in 2006. Average soil organic matter content was 63.3 and 31.0 g kg^{-1} in organic and conventional farm, respectively. Total N content was 3.3 and 1.7 g kg^{-1} in average for organic and conventional farm, respectively. Ammonium and nitrate N in organic farming were maintained at relatively stable levels, but in the conventional farm the levels were very high in early season due to the chemical fertilizer application. In the organic apple farm, available P content in May was lower than that found in the conventional farm, but during the growing season available P content was continuously increased and in August the content was more than 1000 mg P_2O_5 kg^{-1}. The organic farm maintained relatively greater exchangeable K, Ca, and Mg levels than the conventional farm. Available Cu, Fe, and Mn contents in the conventional farm were relatively greater than those found in the organic farm. However, available Zn extracted in 0.1 M HCl was much greater in the organic farm. Nutrient levels above crop needs were observed in both conventional and organic apple farm suggesting a more appropriate management of soil nutrients in organic farming to secure its fundamental functions for the sustainable agriculture.

Key words : Apple orchard, Exchangeable cations, Micronutrients, Nitrogen, Nutrient status, Organic farming, Organic matter, Phosphorus.

Introduction

Industrialized forms of conventional agriculture are dependent on large inputs of fertilizers and pesticides, and these farming systems tend to be unstable ecosystems in which the potential for maximum yield is inevitably associated with a risk due to ecosystem instability (Vogtmann, 1984). Organic farming is often contrasted with conventional farming, and it is a form of agriculture which excludes the use of synthetic fertilizers, pesticides, and other chemical amendments.

Soil fertility management in organic farming systems is based on feeding the soil plant residues, animal manures, and compost. In contrast, conventional agriculture simplifies crop nutrient and soil fertility management by feeding the plant soluble nutrients. Thus crop nutrition in conventional agriculture can be managed by adding the amounts of fertilizer nutrients that need to account for differences between crop nutrient needs and available soil nutrients. However, nutrient management in organic farming systems is more complex. It is very difficult to provide the exact balance of nutrients needed by the plant in organic farming system. Most organic materials, including compost and manure, have only a small component of soluble nutrients and most of their nutrients must be transformed through biological processes before they become available to plants. Also most manures and composts do not have a consistent nutrient content, and contain a ratio of nutrients different from that needed for optimal plant growth. Therefore organic amendments may not provide nutrients in the amounts and at the times needed for optimal plant performance.

Organic farming systems have been found to have a greater soil organic matter and nutrient status than the conventional agricultural systems (Liebig and Doran, 1999; Blaise et al., 2004; Martini et al., 2004; Marriott and Wander, 2006). These results are mostly due to application of organic amendments, less frequent tillage,

Received : December 13. 2007 Accepted : January 12. 2008
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and more diverse crop rotations. The higher levels of C, N and P on organic farms were consistent with deeper topsoil, lower bulk density, greater available water-holding capacity, and more diverse and greater microbial populations and activities (Liebig and Doran, 1999; Reganold, 1988). Organic farming soil, which received five annual applications of composted poultry manure, had significantly higher N, P, and K than conventional plots (Martini et al., 2004). Kim et al. (2001) also found greater accumulation of available P in soils of organic farming plastic film houses. Lee et al. (2004) found that available P and exchangeable cations were above the optimum levels for crop growth due to excessive application of compost in organic farms in Korea. Liebig and Doran (1999) also observed nitrate N and available P levels above crop needs in both organic and conventional farms in Nebraska and North Dakota, USA. However, Gosling and Shepherd (2005) found that soils in England under mixed organic arable rotation were able to maintain soil organic matter and N levels as found under conventional systems but a decline in P and K on conversion to organic farming. Animal manure or various biosolid based composts contain large amounts of mineral micronutrients including Cu and Zn, and compost application can increase the availability of those nutrients in soils (Moreno-Caselles et al., 2005; Ozores-Hampton et al., 2005; Guerra-Rodriguez et al., 2006). And Blaise et al. (2004) reported relatively greater contents of DTPA-extractable Cu, Mn, and Zn in cotton field of organic farming than in conventional farming.

The above results indicate that it is essential to manage appropriate balance of soil nutrients to promote a more sustainable agriculture, whether the farming system is conventional or organic. Levels of nutrients in soil that exceed plant requirements lower nutrient-use efficiency and potentially contribute to non-point source pollution. In our country, the history of organic farming is relatively short and few farms have followed the regulations for organic farming for more than one decade. However, organic farming has been rapidly expanding, and the development of organic farming systems necessarily must be based on value judgments for key properties of importance for farming.

In this study, the soil nutrient levels in conventional and organic apple farm were monitored during the growing season to evaluate how the organic soil management system maintains nutrient status in the soil.

Materials and Methods

Apple orchards Two apple orchards located in Yeongchun, Gyeongbuk (36° 01′ N and 128° 60′ E) were selected for this study. One orchard was managed by organic farming system and the other was a conventional farming orchard. The selected apple orchards were two adjacent fields to ensure the same pedological conditions except management system. The soil type in the area is classified as Daegu series. Daegu soils are loamy skeletal, nonacid, mesic family of Lithic Eutrudepts. The organic based apple orchard has been managed without using of synthetic fertilizers and pesticides since 1999. Soil fertility management of the two fields differs markedly but is representative for the conventional and organic farming (Table 1). Compost used in the organically managed apple orchard was prepared by the farmer using various plant residues and

Table 1. Management practices employed on the conventionally and organically managed apple farms.

Farming system	Organic matter input	Chemical input	Tillage method
Conventional farming	Composted manure application (10 Mg ha^{-1}) in December	1 Mg ha^{-1} (N-P-K=17-21-17) in February and 100 kg ha^{-1} (N-P-K=17-21-17) in June	Frequent ploughing 0.2 m deep
Organic farming	Fermented compost application (30 Mg ha^{-1}) on the surface of the soil within the drip line in December	Several foliar applications of nutrients between May and September	Rye cultivation as cover crop and soil in drip line mulched with organic materials

Table 2. Characteristics of the fermented compost used in the organically managed apple farm.

pH (1:5 H_2O)	EC	Organic matter	Total N	NH_4-N	NO_3-N	Total P
	dS m^{-1}	------------- g kg^{-1} -------------		---------- mg kg^{-1} ----------		g kg^{-1}
7.4	8.9	6.39	33.6	659	70	15.8

animal manures, and characteristics of the compost were listed in Table 2.

Soil sampling Soil samples were collected at the middle spot of the two adjacent trees along the tree line at 5 to 20 cm depth from May to October in 2006. Three sampling sites were selected in both conventional and organic apple farms and two replicated soil samples were collected in each sampling site. Large pieces of raw organic material were removed from the soil surface before collecting samples. Soil samples were air-dried, and ground to pass a 2 mm sieve prior to analyses.

Chemical analyses Organic carbon was determined by dichromate oxidation using Walkley-Black procedure (Nelson and Sommers, 1982). Total nitrogen was determined by Kjeldahl distillation method after sulphuric acid digestion using Se, $CuSO_4$, and K_2SO_4 as catalyst (Bremner and Mulvaney, 1982). Ammonium (NH_4-N) and nitrate (NO_3-N) in the soils were extracted with 2 M KCl and determined using the FIA-5000 autoanalyzer (FOSS Tecator, Höganäs, Sweden). Available P was determined following Lancaster method (NIAST, 1988). Exchangeable cations were determined using Varian Liberty Series II (Mulgrave, Australia) inductively coupled argon plasma emission spectrometer (ICP-ES) following soil extraction with 1 M NH_4OAc (Thomas, 1982). Micronutrients Cu, Fe, Mn, and Zn were determined using ICP-ES after extraction with 0.1 M HCl and DTPA (Soltanpour et al., 1976; NIAST, 1988).

Results and Discussion

Organic matter Soil organic matter content was much greater in the organic farm than in the conventional apple farm (Fig. 1). Average organic matter contents were 63.3 and 31.0 g kg^{-1} in the organic and conventional apple farm soil, respectively. Recommended soil organic matter content is 25-35 g kg^{-1} for fruit trees (NIAST, 1999). Comparing with the recommended level, organic matter content in the conventional farming orchard was in the optimum condition but the organic farming orchard had much higher level of soil organic matter. This result could be due to the higher rate of organic material input in the organically managed apple farm (Table 1).

Although several years of contrasting soil management are not enough to produce a consistent difference in soil organic matter content, the steady use of organic materials on an organic farm is considered important in maintaining the level of soil organic matter (Marinari et al., 2006). Depending on soil type, climate, management, and the capacity of a soil to store organic matter, organic C levels may increase linearly with the amount of organic matter input (Carter, 2002).

Organic matter is an essential component in improving physical, chemical, and biological soil properties. The high organic matter content in the organic farming orchard would be a factor which can enhance the soil quality. However, it should be also considered that the excessive accumulation of mineral nutrients in the soil with the continuous application of compost can deteriorate soil and environmental quality.

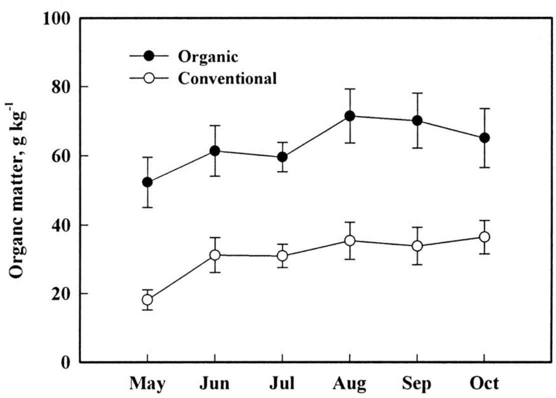

Fig. 1. Organic matter content in the soil of conventional and organic apple farms. Bars represent standard deviation (n=6).

Total and mineral N The organically managed apple farm soil had a higher total N content than the soil of conventionally managed orchard (Fig. 2). Average total N content was 3.3 and 1.7 g kg^{-1} in organic and conventional apple farm soil, respectively. Total N content was not much changed during the growing season, and the relatively higher content of total N in the conventional farming orchard found in May could be due to the basal application of chemical fertilizer. The high total soil N content in organically managed apple farm could be due to the application of organic materials. The higher total N concentration in the organic systems compared with the conventional systems has been reported in many previous researches (Gerhardt, 1997; Blaise et al., 2004; Marriott and Wander, 2006).

Ammonium N in the soil of organic apple farm was 2.6 mg kg^{-1} in average and the content was not much

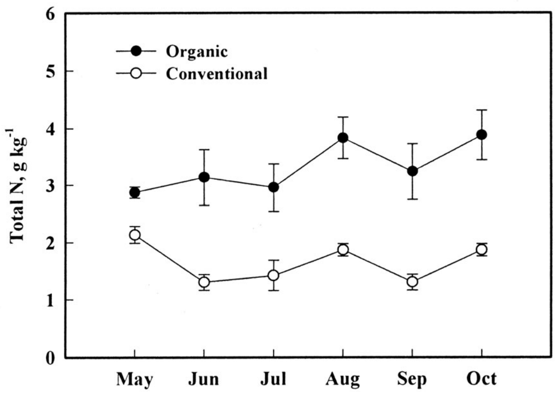

Fig. 2. Total N content in the soil of conventional and organic apple farms. Bars represent standard deviation (n=6).

changed during the growing season (Fig. 3). But in conventional apple farm, NH_4-N in the soil was about 96 mg kg^{-1} in May and declined to 3.3 mg kg^{-1} in August. The greater NH_4-N content in earlier period in conventional apple farm could be due to the applications of chemical nitrogen fertilizer. Nitrate N content was also greater in conventional apple farm soil in May and June, and this result could be due to the nitrification of the

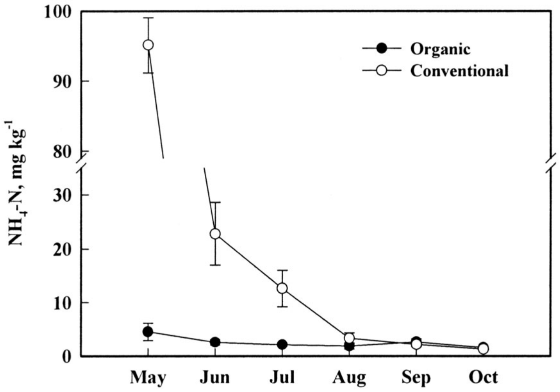

Fig. 3. Ammonium N content in the soil of conventional and organic apple farms. Bars represent standard deviation (n=6).

applied ammonium fertilizer (Fig. 4). The NO_3-N content was lowered to 10 mg kg^{-1} after July. In organic apple farm, NO_3-N content was maintained at the level of around 10 mg kg^{-1} until August and increased after then and the level was greater than that found in conventional apple farm. Blaise et al. (2004) observed relatively greater contents of NH_4-N and NO_3-N in organic farming compared with those found in conventional farming cotton field. However, soil NO_3-N levels in the surface 30.5 cm were higher on conventional farms at most locations in North Dakota and Nebraska, USA (Liebig and Doran, 1999). This inconsistent trends in soil NO_3-N levels between organic and conventional farms could be resulted from the kind and input rate of nutrient source materials, time of soil test, climate of the regions, growing crop and so on.

Available P Available P content in the soil of conventional and organic apple farm was shown in Fig. 5. Conventional farming had greater available P in May and the content of available P was lowered to around 920 mg P_2O_5 kg^{-1} from June to October. The greater available P in earlier season could be due to the input of soluble P through chemical fertilizer application, and later the soluble P level could be lowered by absorption, immobilization, leaching, and fixation. In organic apple farm, available P content in May was lower than that found in conventional farming orchard. But during the growing season available P content was continuously increased and in August the content was more than 1000 mg P_2O_5 kg^{-1}. The increasing pattern of available P in organic farming soil could be due to the mineralization of organic amendments.

There are considerable evidence to suggest that the application of organic material to soil may increase P

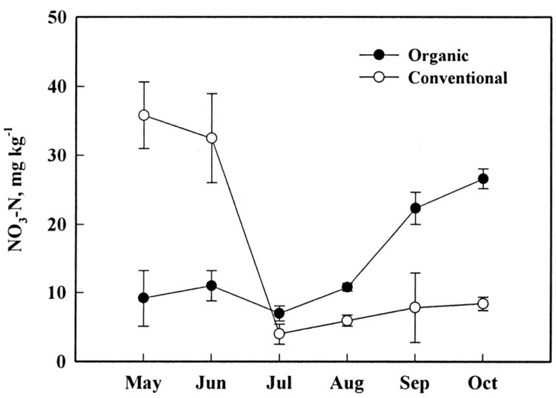

Fig. 4. Nitrate N content in the soil of conventional and organic apple farms. Bars represent standard deviation (n=6).

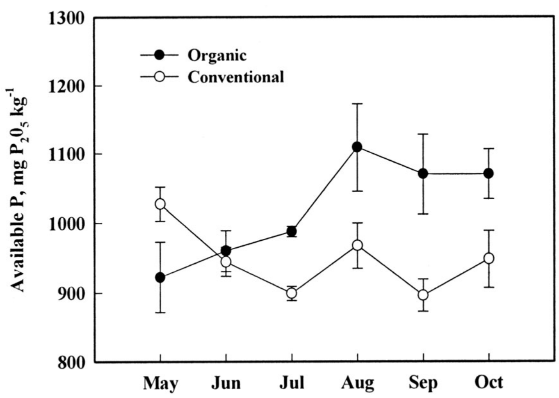

Fig. 5. Available P content in the soil of conventional and organic apple farms. Bars represent standard deviation (n=6).

availability (Kwabiah et al., 2003; Kim et al., 2001; Liebig and Doran, 1999; Edmeades, 2003). The improvement of soil P availability in organic farming can come from either P released from organic inputs or increased availability of native soil P following addition of organic fertilizers. Organic acids produced during the decomposition of organic amendments can effectively reduce P sorption to the soil and increase P availability (Laboski and Lamb, 2003).

The available P contents in the apple farm soils were much greater than the recommended level of 200-300 mg P_2O_5 kg^{-1} for fruit trees (NIAST, 1999). Excessive accumulation of P in organic farming soils is mostly caused by application of animal manure that containing high rate of P (Martini et al., 2004; Liebig and Doran, 1999). In most of manure-based organic farms application of manure on an N basis leads to soils becoming excessively enriched with respect to P. Under this condition greater runoff of P may result, and for soils with low P retention greater leaching losses may occur.

Exchangeable cations Relatively greater contents of exchangeable K, Ca, and Mg were observed in the apple farm soil of organic than conventional farming (Fig. 6). Many other studies have shown that the use of organic amendments relative to inorganic fertilizers can result in soils becoming excessively enriched with K, Ca, and Mg in addition to P (Blaise et al., 2004; Bulluck et al., 2002; Edmeades, 2003; Martini et al., 2004; Reganold, 1988). Considering those previous results and the same inherent soil characteristics of the two apple orchards, the higher contents of exchangeable cations in the organic apple farm soil found in this study could be attributed to the release of cations from organic amendments and increase of exchange sites due to organic matter added.

Available Micronutrients Available Cu, Fe, and Mn extracted in both 0.1 M HCl and DTPA solution were greater in the conventional farming orchard soil compared with those found in the organic farming orchard soil (Fig. 7). However, available Zn extracted in 0.1 M HCl was greater in the organic farming orchard soil than that found in the conventional farming orchard soil. The Zn content extracted in DTPA solution was relatively greater in organic farming orchard during the mid-season, but the difference between conventional and organic farming orchards was not significant.

It is well documented that the availability of Cu, Fe,

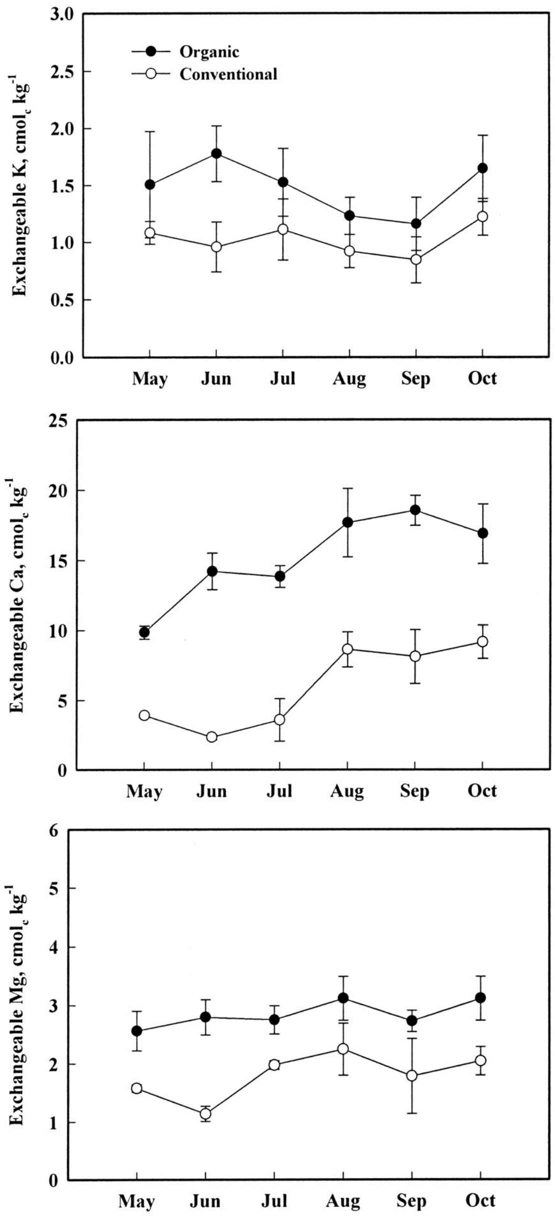

Fig. 6. Exchangeable cation content in the soil of conventional and organic apple farms. Bars represent standard deviation (n=6).

Mn, and Zn is associated with soil pH and organic matter (Kabata-Pendias, 2001). The greater availability of Cu, Fe, and Mn in conventional apple farm observed in this study could be basically resulted from the lower soil pH as compared to organic farming. Average soil pH values of conventional and organic apple farm were 5.4 and 7.8, respectively, during the growing season. Overall solubility of both cationic and anionic forms of Cu, Fe, and Mn decreases at about pH 7 to 8 (Kabata-Pendias, 2001). Also the higher organic matter content in organic farming soil could affect the availability of these micronutrients. It is well known that humic substances strongly immobilize metal ions in direct coordination

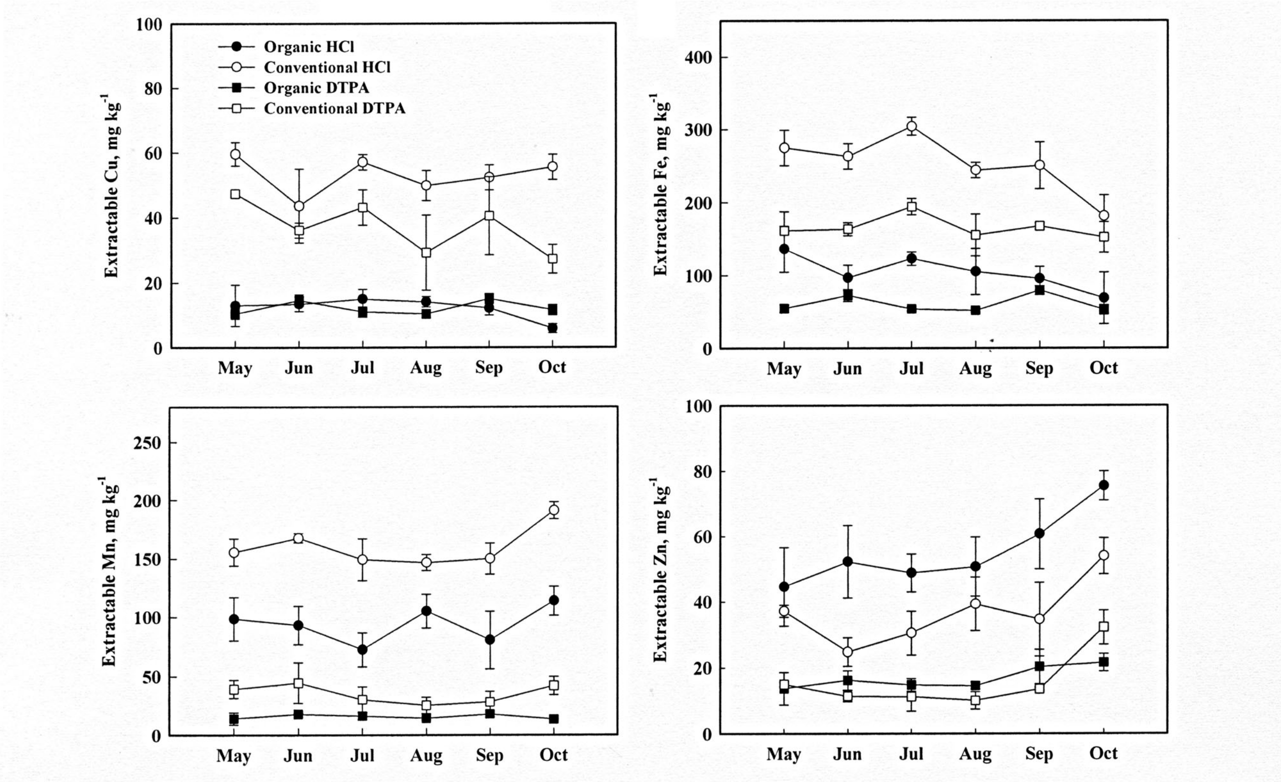

Fig. 7. Micronutrient content extracted in 0.1 M HCl and DTPA solution in the soil of conventional and organic apple farms. Bars represent standard deviation (n=6).

with functional oxygens of the organic substances (McBride, 1982). The stability of metal organic matter complexes increases with increasing pH (Khan, 1969). In the case of Zn, considering soil pH, the solubility should be higher in acidic soil of conventional apple farm, but the extractable Zn was greater in high pH soil of organic apple farm. This result indicates that input of Zn with manure-based compost in organic farming orchard is greater in comparison to the conventional farming system. However, the apparent availability of micronutrients in soil can be controlled by various and complicate reactions, and therefore the difference of micronutrient availability between conventional and organic apple farms cannot be simply explained.

Typical ranges in critical levels for Cu, Fe, Mn, and Zn determined in 0.1 N HCl extracts are 1.0-2.0, 10-16, 1.0-4.0, and 1.0-5.0 mg kg^{-1}, respectively, for most crop plants (Sims and Johnson, 1991). And the suggested critical levels of DTPA extractable Cu, Fe, Mn, and Zn for plant growth are 0.2, 4.5, 1.0, and 0.6 mg kg^{-1}, respectively (Lindsay and Norvell, 1978). Comparing with these critical levels, extractable micronutrients contents in the apple farm soils were found to be in excessive levels in both conventional and organic farming systems. Although any toxicity problems in relation to the micronutrients were not found in the apple farms, more careful management of those nutrients is required.

Conclusions

The results of this study indicate that soil in organic apple farm is able to maintain higher levels of organic matter and total nitrogen than those found under typical conventional system. Soil mineral N levels in conventional system were much higher in early season and lowered after June and this trend was due to the fertilization time, but in organic farming system NH_4-N level was quite stable during the growing season and NO_3-N level was considerably increased in late season. Contents of available P, exchangeable cations, and available micronutrients (except Zn) were also higher in organic farming compared with conventional farming system. And the levels of available P, exchangeable cations, and micronutrients exceeded the suggested critical levels in both organic and conventional farming system.

The excessive enrichment of N, P, and other nutrients in organic farming soil indicates that one production practice is not consistently better at minimizing potential negative off-site impacts due to nutrient loss to the environment. Although organic inputs cannot easily provide the amount and balance of nutrients required by the plant, careful and efficient use of composts under organic farming system is essential to avoid any threat to soil and surrounding environments.

Acknowledgement

This research was supported by the Daegu University Research Grant, 2007.

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유기농업체계가 토양의 비옥도와 지속가능성에 미치는 영향을 파악하기 위하여 유기농 사과과수원 토양의 양분상태를 관행농과 비교하여 조사하였다. 동일한 토양에 조성된 인접한 유기농 및 관행농 사과과수원을 선정하여 2006년 5월부터 10월까지 월별로 5-20 cm 깊이의 토양을 채취하였으며, 유기물, 총 질소 및 무기질소, 유효인산, 교환성 양이온, 가용성 미량원소의 함량을 조사하였다. 평균 유기물 함량은 유기농과 관행농 과수원 토양에서 각각 63.3 및 31.0 g kg^{-1}으로 유기농 과수원 토양에서 훨씬 높았다. 총 질소 함량은 평균값으로 유기농과 관행농 과수원 토양에서 각각 3.3 및 1.7 g kg^{-1}이었다. 유기농 과수원 토양에서는 암모늄 및 질산태 질소 함량이 작기 중에 비교적 안정한 수준을 지속적으로 유지하였으나 관행농 과수원 토양에서는 화학비료 시용으로 인하여 조사 초기에 그 함량이 아주 높았으며 8월까지 급격히 감소하였다. 유기농 과수원의 경우 유효인산은 5월에는 관행농 과수원에 비하여 낮았으나, 작기가 진행되면서 지속적으로 증가하여 8월에는 그 함량이 1000 mg P_2O_5 kg^{-1} 이상으로 나타났다. 유효인산은 관행농과 유기농 과수원 모두에서 적정수준인 200-300 mg P_2O_5 kg^{-1}보다 훨씬 높았다. 교환성 K, Ca, Mg 함량은 관행농에 비하여 유기농 과수원 토양에서 상대적으로 높았다. 가용성 Cu, Fe, Mn 함량은 관행농 과수원 토양에서 높았으며, 0.1 N HCl 가용성 Zn 함량은 반대로 유기농 과수원 토양에서 높았다. 이상의 결과에서 보면 관행농과 유기농 과수원 토양 모두에서 각종 양분함량이 적정수준보다 높은 것으로 나타났으며, 화학비료를 사용하는 관행농에 비하여 유기농 과수원 토양에서 각종 양분 함량이 오히려 높았다. 이러한 양분 과다 현상은 토양과 주변 환경에 부정적인 영향을 미칠 것이며, 유기농업의 근본 목적에도 벗어나는 결과이다.