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Impacts of Oyster Shell and Peat Treatments on Soil Properties in Continuous Watermelon Cropping Greenhouse Plots

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Soils in continuous monoculture cropping system generally have a number of physical and chemical problems. Thus, we studied to investigate selected soil properties in continuous watermelon cropping plots with applications of different soil management practices: 1) conventional farming practice (CFP), 2) chemical fertilizer management practice (FMP), the FMP with different amounts, 0.5, 1.0, and 1.5 t ha^{-1}, of oyster shell meal application (FMP-OS 0.5, 1.0, and 1.5 t ha^{-1}), and 3) the FMP with different amounts, 2.0, 3.0, and 4.0 t ha^{-1}, of peat application (FMP-PT 2.0, 3.0, and 4.0 t ha^{-1}) and also to evaluate watermelon quality. Soil pH slightly increased only in the FMP-OS 1.5 t ha^{-1} plot, while it was not changed or decreased a little in other plots. The contents of soil organic matter (SOM) expectedly increased in the FMP-PT plots, whereas it markedly decreased in the FMP-OS plots. The concentrations of exchangeable cations, Ca^{2+}, Mg^{2+}, and K^+, in soils were mostly dropped down in most of the FMP and FMP-PT plots. Otherwise, the exchangeable Ca^{2+} concentration increased a bit in the FMP-OS plots. Also, the concentrations of water-soluble anions, NO_3^-, Cl^-, SO_4^{2-}, and PO_4^{3-}, in soils mostly declined in all the plots applied with the different management practices during the study years. Due to the cation and anion decreases, the electrical conductivity (EC) values in the soils were greatly reduced in the plots. Thus, the soil management practices applied, especially oyster shell meal and peat treatments, might be useful to control soil conditions. However, watermelon quality, such as sugar content and fruit weight, would not be associated with the soil management practices applied.

Key words: Greenhouse soil, Management practice, Exchangeable cation, Water-soluble anion, Watermelon quality

Introduction

Some of many farmers in Korea are producing watermelon (*Citrullus lanatus* Thunb.) as a special agricultural product because watermelon is profitable and in great demand. However, for cultivating the watermelon plants, especially in continuous cropping system, heavy chemical fertilizer application was used in most areas of farm lands, indoor and outdoor fields. For this reason, soils in the fields have been damaged with physical and chemical problems such as nutrient deficiencies and toxicities, soil salinity, etc. In particular, calcium deficiency of watermelon generally causes the reduction of its sugar content (Park et al., 1999); and also if the contents of other cations are abnormally high in soil, the uptake of calcium from the soil by watermelon plant decreases, so that the calcium deficiency can be occurred. Therefore, to prevent those soil problems, proper soil management practices are necessary. In this aspect, to control the nutrient balance, oyster shell meal might be applicable solution because it contains high contents of calcium and boron as macro- and micronutrient, respectively (Lee et al, 2005a). Fortunately, Korea has a great amount of oyster shell resources (approximately 0.3 million tons per year) because Korean oyster farmers have been confronted with the problem of disposal of huge amounts of oyster shell waste (Lee et al., 2005a and 2005b). Studies related to oyster shell application in soil has been limited. Lee et al. (2005a) and Lee et al. (2008) reported that the application of oyster shell in soils enhanced the productivity of Chinese cabbage. Most

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of other studies associated with the oyster shell application were to solve acidic soil problems with increasing soil pH. On the other aspect, the soils damaged with high concentrations of cations and anions might negatively influence the solubility of other essential nutrient ions in soil-solution system (Lindsay, 1979), and the high salinity in the soils would affect to decrease the nutrient uptake and plant growth (Elrashidi et al., 2010). Thus, the application of organic materials, such as peat, can reduce the negative impacts and improve soil productivity by the buffering effects for competitive ions. Our previous study (Ahn et al., 2010) found that the application of rice straw as an organic material improved soil conditions and watermelon growth condition.

Therefore, objective of this study was to investigate soil properties and watermelon qualities as influenced by different soil management practices, especially soils amended with oyster shell meal and peat, including conventional farming practice and chemical fertilizer management practice as well.

Materials and Methods

Site description Experimental site is located at Vegetable Research Institute in Jeollabuk-do Agricultural Research and Extension Services, Kochang, Korea. Experimental plots were used for a long-term watermelon monoculture cropping. The plots were set up in plastic-film covered greenhouses, and each plot size was 6 x 24 m (144 m^2) in area. Soils in the plots are sandy clay loam containing 54.0% sand, 22.0% silt, and 24.0% clay in average.

Soil, oyster shell meal, and peat analyses Soil samples in the plots were collected after harvesting watermelon. The soil samples were air-dried and crushed to pass through a 2-mm sieve. The samples were analyzed for the selected physical and chemical properties (Table 1) using the procedures proposed by Rural Development Association (RDA), Korea (2000) and showed by Ahn et al. (2010). Oyster shell was purchased from a manufacture in Jindo County, Korea, which contained 640 g kg^{-1} of calcium oxide (CaO) in average. It was normally prepared that powdered oyster shell combusted at a temperature above 700℃, at that point calcium carbonate ($CaCO_3$) of oyster shell transformed CaO (Nakatani et al., 2009). Peat was imported from a company from Malaysia. The peat samples were air-dried for 7 days and roughly ground to determine chemical properties using the methods proposed by RDA (2000). The peat samples were pH 4.2 and contained 900.7 g kg^{-1} of organic matter, 8.1 g kg^{-1} of nitrogen (N), 6.8 g kg^{-1} of P_2O_5, 1.7 g kg^{-1} of K_2O, 3.9 g kg^{-1} of CaO, 1.6 g kg^{-1} of MgO, and 1.5 g kg^{-1} of Fe.

Fertilizer, oyster shell meal, and peat applications The experimental plots prepared were similar to the experimental design reported by Ahn et al. (2010). The plots were prepared in eight different conditions: 1) a plot under conventional farming practice (CFP), 2) a plot

Table 1. Selected properties of soils used in this study.

Exp. plot	Management practice†	pH (1:5)	EC (dS m^{-1})	SOM (g kg^{-1})	Exch. Cation ($cmol_c$ kg^{-1}) Ca^{2+}	Mg^{2+}	K^{+}
Plot 1	CFP	6.9	6.84	33.1	6.7	4.0	4.1
Plot 2	FMP	6.8	6.75	32.7	6.8	4.2	4.2
Plot 3	FMP-OS 0.5 t ha^{-1}	6.6	5.50	33.0	5.4	3.4	3.9
Plot 4	FMP-OS 1.0 t ha^{-1}	6.6	6.85	33.0	5.5	3.5	3.4
Plot 5	FMP-OS 1.5 t ha^{-1}	6.7	4.85	33.0	5.9	3.7	3.6
Plot 6	FMP-PT 2.0 t ha^{-1}	6.6	7.25	32.0	6.8	5.0	3.5
Plot 7	FMP-PT 3.0 t ha^{-1}	6.0	5.15	29.0	6.2	5.6	2.4
Plot 8	FMP-PT 4.0 t ha^{-1}	6.6	4.90	27.0	5.7	3.4	3.1
OLWC	-	6.0~6.5	< 2.0	20~30	5.0~6.0	1.5~2.0	0.7~0.8

† CFP: conventional farming practice, FMP: fertilizer management practice, FMP-OS: fertilizer management practice with 0.5, 1.0, and 1.5 t ha^{-1} of oyster shell applications, FMP-PT: fertilizer management practice with 2.0, 3.0, and 4.0 t ha^{-1} of peat applications.

‡ OLWC: optimal levels of soil properties for watermelon cultivation.

under nitrogen-phosphorus-potassium (NPK) fertilizer management practice (FMP), 3) three plots under the FMP with different amounts of oyster shell meal treatments (FMP-OS), and 4) three plots under the FMP with different amounts of peat treatments (FMP-PT) .

Fertilizer treatment methods for the CFP and FMP plots are described as follows. In the CFP plot, the NPK Fertilizers were applied at 138-49-87 kg ha^{-1} as N-P_2O_5-K_2O, without adjusting the fertilizer application rates by soil testing results. However, In the FMP, FMP-OS, and FMP-PT plots, the amounts of NPK fertilizers applied, the rates of 138-49-87 kg ha^{-1}, were estimated by using Soil Management and Fertilizer Recommendation System (Version 2002) supplied by National Institute of Agricultural Science and Technology, RDA, Korea. Total amount of phosphorus fertilizer estimated were applied as base-dressing, while nitrogen and potassium were treated in different ratios: 50% of the fertilizers were applied as base-dressing and other 50% were treated as top-dressing. A specific amount of the NPK fertilizers were applied based on the fertilizer requirements for watermelon plant estimated by soil testing at every application periods with adding 0.5, 1.0, and 1.5 t ha^{-1} of oyster shell meal and 2.0, 3.0, and 4.0 t ha^{-1} of peat in the separated experimental plots.

Watermelon Cultivation A cultivating method for watermelon plants is described in the method reported by Ahn et al. (2010). Seeds of watermelon (*Citrullus lanatus* Thunb.) and bottle gourd (*Lagenaria leucanth* Standl) cultivar FR-Dantos (Dongbu Hannong Seed, Korea) were simultaneously germinated. Both plant seedlings were grown in a plant nursery for 15 days, and then the watermelon plant tops were grafted. The grafted watermelon plants were grown for approximately 30 more days in the nursery. After 45 days in the nursery, the plant was transplanted into the greenhouse plots using two different cultivation methods, a semi-forcing and retarding culture. Watermelons were harvested at 90 to 95 days after transplantation, and then twenty samples of watermelon were randomly collected from each plot to determine fruit weight and sugar content. The watermelon fruit weight was weighed using a table top balance, and the sugar content of watermelon was measured using a potable Brix meter (Atago, PR-40DMF, Japan).

Results and Discussion

Soils in the experimental plots contained higher levels on most of the selected soil chemical properties as compared to their optimum levels for watermelon cultivation, except the concentrations of exchangeable Ca^{2+} (Table 1). Therefore, to improve the soil conditions for watermelon cultivation, we applied three major different farming practices, such as chemical fertilizer management practice (FMP), the FMP with different amounts of oyster shell meal application (FMP-OS) and peat application (FMP-PT), and then they were compared with conventional farming practice (CFP).

As the results of a previous report (Ahn et al, 2010), the soil pH values in the CFP and FMP plots were no or slightly changed, and also the values in the plots of FMP with 0.5 and 1.0 t ha^{-1} of oyster shell meal (FMP-OS 0.5 and 0.1 t ha^{-1}) applications showed similar trend, but in the FMP with 1.5 t ha^{-1} of oyster shell meal treatment plot (FMP-OS 1.5 t ha^{-1}), the soil pH value gradually increased during the three experimental years. The results show that relatively higher amounts of calcium oxide in the oyster shell meal can increase pH value in the sandy clay loam soil plots. On the other hand, the soil pH values decreased in the all plots of FMP-PT (2.0, 3.0, and 4.0 t ha^{-1} of peat applications, FMP-PT 2.0, 3.0, 4.0 t ha^{-1}) because organic matter (peat) mineralization resulted in the formation of organic and inorganic acids, which provide hydrogen ion

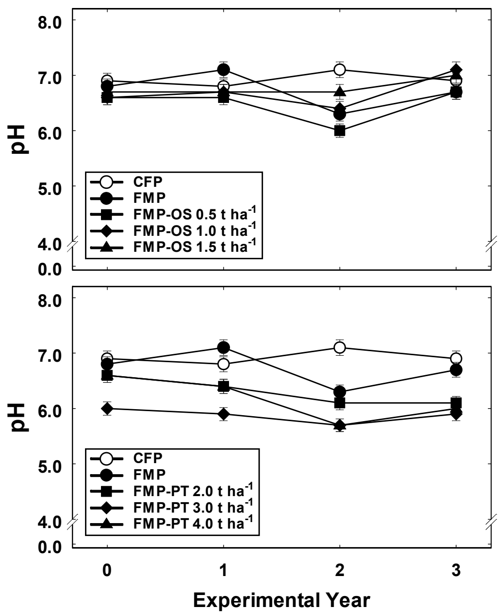

Fig. 1. Changes in soil pH in the experimental plots as affected by different management practices. CFP: conventional farming practice, FMP: chemical fertilizer management practice, FMP-OS: FMP with different amounts of oyster shell meal application, FMP-PT: FMP with different amounts of peat application.

(H^+) to the soil (Figure 1).

Figure 2 shows the influences of oyster shell meal and peat applications on SOM contents in the experimental plots. SOM content did not change in the CFP plot, but in the FMP and FMP-OS plots expectedly declined, whereas it increased in the FMP-PT plots because application of peat containing 900.7 g kg^{-1} of organic matter effectively affected to increase SOM content in the plots. Also, the higher the peat application, the greater the SOM contents in the plots during the study years.

Influences of the various management practice applications on the changes in the concentrations of selected exchangeable cations, Ca^{2+}, Mg^{2+}, and K^+, in soils are shown in Figure 3. In the CFP plots the cation concentrations were not changed, but in the FMP plots they gradually reduced during the three experimental years. However, in the FMP-OS plot, the concentrations of exchangeable Ca^{2+} and Mg^{2+} decreased in the first year, but they increased from the second year. In particular, the increases of exchangeable Ca^+ were dependent upon the amounts of OS applications, which was that the higher the OS application, the more the exchangeable Ca^+ concentration in the soils. The concentration of exchangeable K^+ in the plot slightly decreased during the study years even though it slightly increased in the second year, which showed similar trend to that in the FMP only plot. Lee et al. (2005b) reported similar trends that the concentration of exchangeable Ca^{2+} slightly increased at 180 and 300 days after OS application, and it decreased at 570 days after the OS treatment; however, the concentrations of exchangeable K^+ and Mg^{2+} declined at 180 days, increased at 300 days, and then dropped down again at 570 days after OS applications. On the other hand, in the FMP-PT plot, the concentrations of the exchangeable cations markedly decreased in the first year, and then gradually kept decreasing till the last study year. These results might be caused by following reasons: 1) peat made to increase plant available cations that were up-taken by watermelon plants and/or 2) it escalated for losing the cations by leaching from the saline soils because it's application improved soil physical properties, such as an increase of porosity, even though it is usually working for holding nutrients to prevent them from leaching from normal soils (Cooperband, 2002).

Impacts of the different management practices on the concentrations of water soluble anions, NO_3^-, Cl^-, SO_4^{2-}, and PO_4^{3-}, in soils are shown in Figure 4 and 5. In the CFP plots, changes in NO_3^- and Cl^- concentrations showed

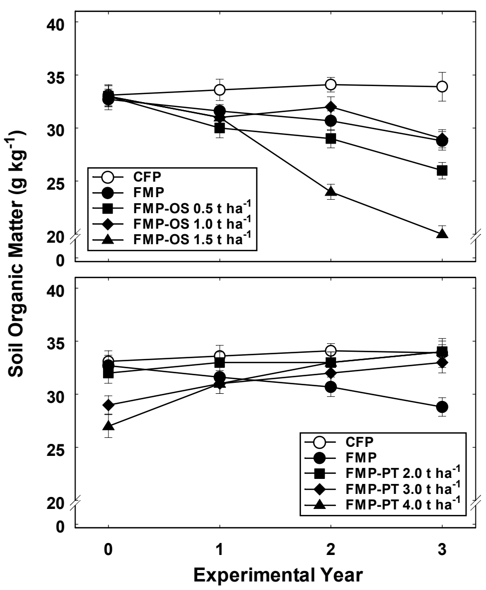

Fig. 2. Changes in soil organic matter content in the experimental plots as influenced by different management practices. CFP: conventional farming practice, FMP: chemical fertilizer management practice, FMP-OS: FMP with different amounts of oyster shell meal application, FMP-PT: FMP with different amounts of peat application.

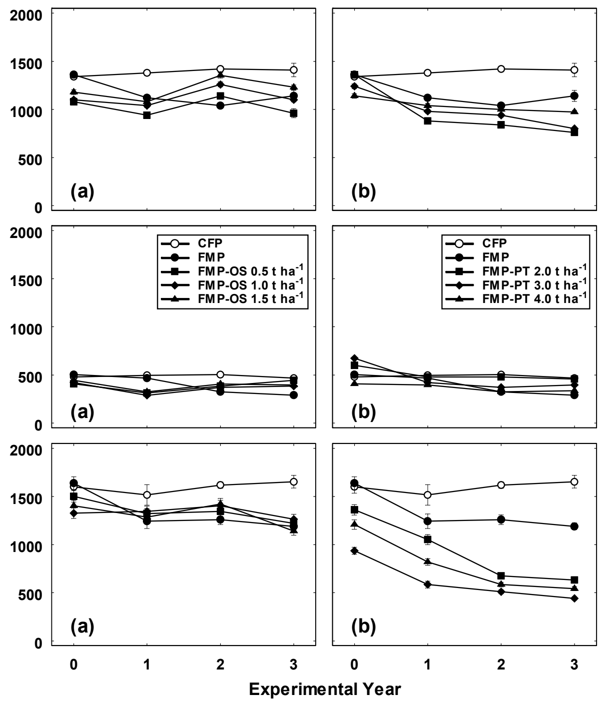

Fig. 3. The concentrations of exchangeable cations (Ca^{2+}, Mg^{2+}, and K^+) in soils as affected by (a) oyster shell meal and (b) peat application practices. CFP: conventional farming practice, FMP: chemical fertilizer management practice, FMP-OS: FMP with different amounts of oyster shell meal application, FMP-PT: FMP with different amounts of peat application.

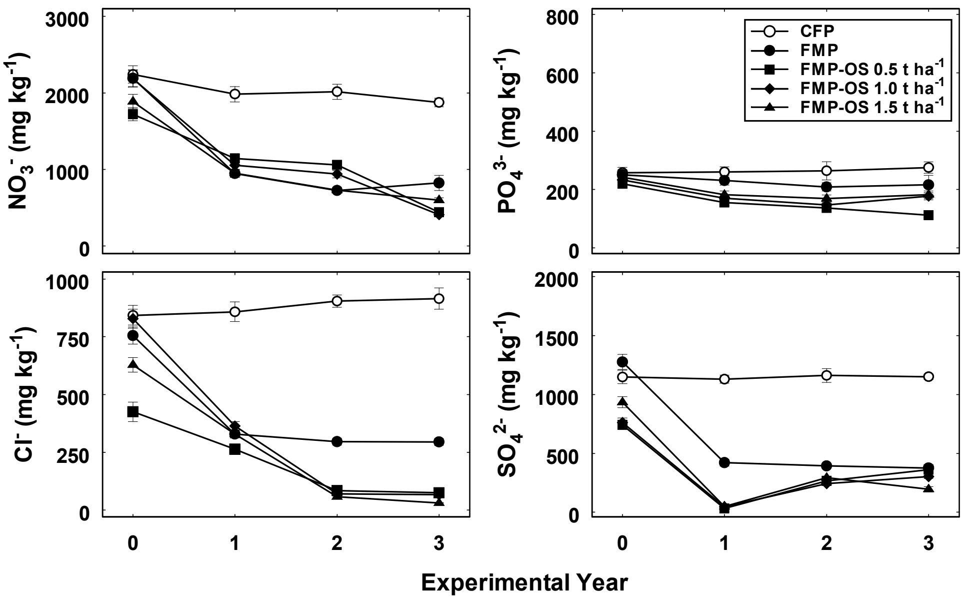

Fig. 4. The concentrations of water-soluble anions (NO_3^-, Cl^-, SO_4^{2-}, and PO_4^{3-}) in soils as affected by oyster shell application practice. CFP: conventional farming practice, FMP: chemical fertilizer management practice, FMP-OS: FMP with different amounts of oyster shell meal application, FMP-PT: FMP with different amounts of peat application.

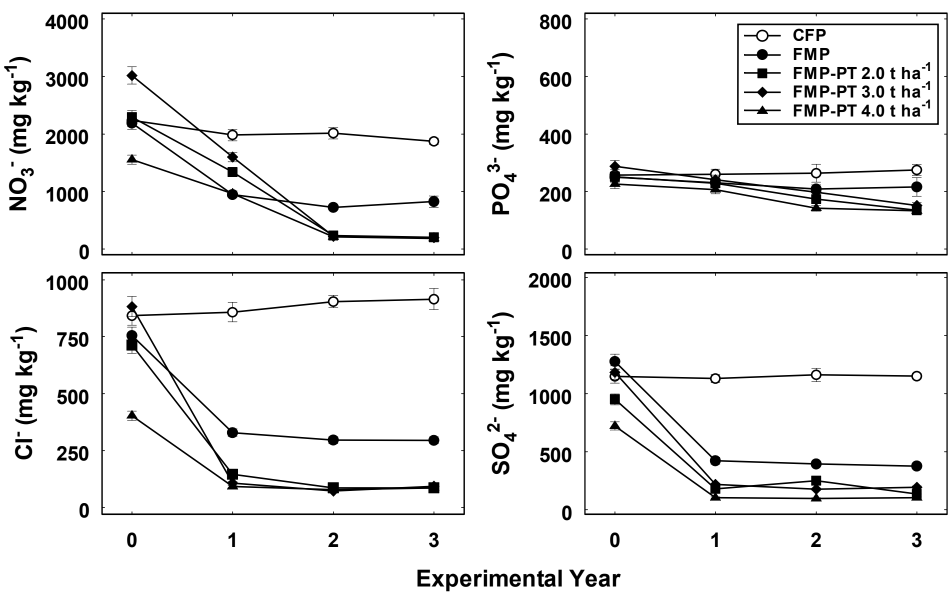

Fig. 5. The concentrations of water-soluble anions (NO_3^-, Cl^-, SO_4^{2-}, and PO_4^{3-}) in soils as affected by peat application practice. CFP: conventional farming practice, FMP: chemical fertilizer management practice, FMP-OS: FMP with different amounts of oyster shell meal application, FMP-PT: FMP with different amounts of peat application.

different trends: the former slightly increased while the latter declined a little during the study years, but SO_4^{2-} and PO_4^{3-} concentrations had not been changed. In the FMP plots, the anion concentrations dropped down in the first year, except PO_4^{3-}, and then they were no more decreased during the last two years. However, in the FMP-OS and FMP-PT plots, the concentration changes of anions in the soils were different depended on each anion species with the two different additional treatments, oyster shell meal and peat. In the FMP-OS plots, the concentrations of NO_3^- were drastically lowered till the last study year. The concentrations of PO_4^{3-} gradually decreased a little during the three years. However, the Cl^- concentrations markedly declined till the second year, and then remained at the point of the concentration in the third year. The concentrations of SO_4^{2-} were dropped down in the first year, but then increased from the second year even though the concentration slightly reduced with FMP-OS 1.5 t ha^{-1}

treatment at the third year. In addition, the different amounts of oyster shell meal applied in this study did not affect the rate of anion concentration changes in the plots. On the other hand, in the FMP-PT plots, the concentrations of NO_3^- sharply decreased till the second year, the Cl^- and SO_4^{2-} concentrations were dropped down only at the first year, and then those concentrations are stable from the second and first year, respectively, until the third year. In these plots, the concentrations of PO_4^{3-} also generally declined a little during the study years. The decrease rates of anion concentrations had not been affected by different amounts of peat applications.

Changes in electrical conductivity (EC) values in the experimental plot soils are presented in Figure 6. The EC values were not changed in the CFP plot during the three study years. However, in the FMP, FMP-OS, and FMP-PT plots, they showed general decrease during the study years even if they slightly increased in the FMP-OS plots at the second year and also remained at similar EC value in the FMP-PT plots after the first study year. The EC value is closely related to soluble/exchangeable cations and anions in soil-solution system. In the FMP-OS plots, the changes of EC values showed similar trends to the concentration changes of exchangeable cations, especially at the second experimental year. Also, the decreases of EC value might be greatly affected by the high reduction of anion concentrations in the soils with oyster shell meal and peat applications. However, any specific impacts had not been observed between the low and high amounts of oyster shell meal or peat treatments for the decrease rate of EC values.

Influences of the different management practice applications on watermelon fruit quality, sugar content and fruit weight, in the plots are shown in Table 2. The sugar contents of watermelon ranged between 10.8 and 12.4 °Bx, and the watermelon weight ranged from 6.82 to 7.79 kg each. Those indices for watermelon quality were not closely associated to the different soil management practices; but even so, those values were relatively a bit lower in the FMP-OS 0.5 and 1.0 t ha^{-1} plots than in other plots, especially at the first study year.

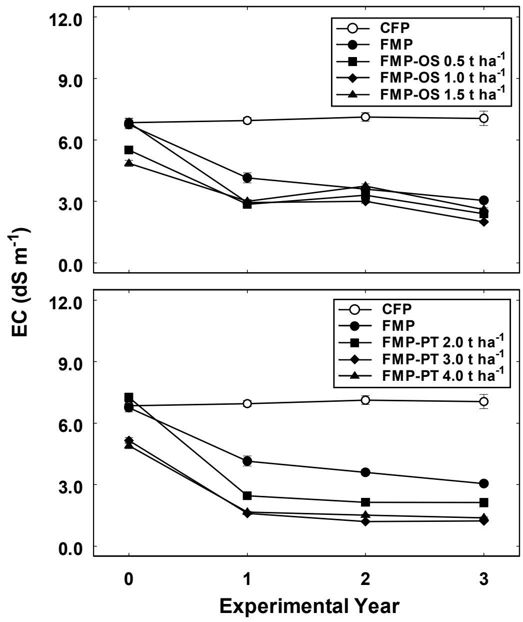

Fig. 6. The values of EC in soils as affected by different management practices. CFP: conventional farming practice, FMP: chemical fertilizer management practice, FMP-OS: FMP with different amounts of oyster shell meal application, FMP-PT: FMP with different amounts of peat application.

Table 2. Effects of different management practices on watermelon fruit quality during the three experimental years.

Exp. plot	Management practice†	Sugar content (°Bx)			Fruit weight (kg each)		
		Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Plot 1	CFP	11.2	11.5	11.4	7.12	7.24	7.20
Plot 2	FMP	11.0	11.3	10.9	7.04	7.11	7.15
Plot 3	FMP-OS 0.5 t ha^{-1}	10.8	10.9	10.8	6.96	7.24	7.28
Plot 4	FMP-OS 1.0 t ha^{-1}	10.9	11.5	12.4	6.82	7.41	7.41
Plot 5	FMP-OS 1.5 t ha^{-1}	11.3	11.2	11.8	7.52	7.40	7.38
Plot 6	FMP-PT 2.0 t ha^{-1}	11.5	11.2	11.0	7.67	7.18	7.34
Plot 7	FMP-PT 3.0 t ha^{-1}	11.3	11.6	11.0	7.72	7.27	7.19
Plot 8	FMP-PT 4.0 t ha^{-1}	11.8	11.8	11.2	7.79	7.15	7.42

† CFP: conventional farming practice, FMP: fertilizer management practice, FMP-OS: fertilizer management practice with 0.5, 1.0, and 1.5 t ha^{-1} of oyster shell applications, FMP-PT: fertilizer management practice with 2.0, 3.0, and 4.0 t ha^{-1} of peat applications.

Conclusion

In this study, we compared three different soil management practices, such as chemical fertilizer management practice (FMP), the FMP with different amounts of oyster shell meal application (FMP-OS) and peat application (FMP-PT), with conventional farming practice (CFP) to improve the soil conditions for long-term watermelon cultivation plots. Soil pH was not or slightly changed in the plots of CFP, FMP, and FMP with lower amounts of oyster shell meal applications (FMP-OS 0.5 and 1.0 t ha^{-1}). The soil pH slightly increased only in the plot of FMP with relatively higher amount of oyster shell meal treatment (FMP-OS 1.5 t ha^{-1}). However, it decreased in the all plots of FMP-PT applications. In contrast to the changes in soil pH values, the content of soil organic matter (SOM) expectedly increased in the FMP-PT plots, whereas it markedly decreased in the FMP-OS plots, especially in the FMP-OS 1.5t ha^{-1} plot. The concentrations of exchangeable cations, Ca^{2+}, Mg^{2+}, and K^{+}, in soils slightly or gradually decreased in the FMP and FMP-PT plots and were not changed in CFP plot, while the concentrations of Ca^{2+} in the FMP-OS plots increased. On the other hand, the concentrations of water-soluble anions, NO_3^-, Cl^-, SO_4^{2-}, and PO_4^{3-}, in soils were mostly dropped down in all the plots, except in the CFP plot. Besides decreasing the cation and anion concentrations affected to decrease electrical conductivity (EC) in soil-solution system in the plots. Therefore, the soil management practices, especially FMP-OS and FMP-PT, would be applicable to improve soil conditions.

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패화석 및 이탄 처리가 수박 연작지 토양의 특성에 미치는 영향

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단일작물 연작지에서는 일반적으로 토양의 물리·화학적 특성에 많은 문제점을 가지고 있다. 그러므로 본 연구에서는 수박 연작지 토양을 선정하여 관행구, 시비관리구, 시비관리 및 패화석 또는 이탄을 처리한 후 토양의 특성변화를 조사하고, 수박의 품질과 관련된 당도 및 과중량의 변화를 조사하였다. 토양 pH는 시비관리-패화석 1.5 t ha^{-1} 처리구에서 약간 증가하는 경향이 있었으나, 모든 다른 처리구에서는 변하지 않거나 약간 감소하였다. 토양유기물함량은 예상되었던 바와 같이 모든 이탄 처리구에서 증가하였고, 패화석 처리구에서는 지속적으로 감소하였다. 토양 중 치환성 양이온 Ca^{2+}, Mg^{2+}, K^{+}의 농도는 시비관리구 및 시비관리-이탄 처리구에서 감소하였으나, Ca^{2+}의 농도만은 시비관리-패화석 처리구에서 약간 증가하였다. 또한 토양 중 수용성 음이온 NO_3^-, Cl^-, SO_4^{2-}, PO_4^{3-}의 농도는 모든 처리구에서 지속적으로 감소하는 경향을 보였다. 그러므로 이러한 양이온과 음이온의 농도 감소로 인하여 관행구를 제외한 모든 처리구에 전기전도도(EC)의 감소로 나타났으며, 이러한 결과는 시비관리, 시비관리-패화석, 시비관리-이탄 처리가 토양조건을 양호한 상태로 변화 시킬 수 있다는 근거를 제공하고 있다. 그러나 이러한 처리는 수박의 품질에는 뚜렷한 영향을 주지 않았다.