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Article

Relationship Between Soil Water-Stable Aggregates and Physico-chemical Soil Properties

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Soil aggregation has been considered as an important factor not only for increasing soil productivity and soil quality but also improving nutrient use availability and water use efficiency. However, the relationship between soil aggregation and soil properties hasn't well reported for Korean soils. Objective of this research was to identify the relationship among soil water-stable aggregate (WSA), soil properties and soil dispersion ratio. Soil samples were analyzed for water-stable aggregate, Middleton's dispersion ratio, and soil physical and chemical properties. Water-stable aggregate was significantly correlated to soil textural properties, soil organic matter, and exchangeable cations. Middleton's dispersion ratio was significantly correlated with water-stable aggregate ($r=-0.76^{***}$). Regression equation for water-stable aggregate was estimated by Middleton's dispersion ratio ($Y=-0.79X + 96.49$; $r^2=0.58^{**}$). In this research, we conclude that water-stable aggregate was significantly correlated with some soil properties and was able to be estimated by rapid and easily measurable Middleton's dispersion ratio.

Key words : Water-stable aggregate, Middleton's dispersion ratio, Soil aggregate

Introduction

Soil aggregation structure, which is complex with soil organic and mineral component, is often measured by water-stable aggregate and has long been considered as an ideal soil structure for plant growth (Braunack, 1995; Wright et al., 2004). Soil aggregates often represent as a resistance against to the external breakdown (Grandy et al., 2006). Soil aggregates may greatly influence to ground water infiltration, water move, water holding capacity, water drainage, soil aeration, rhizosphere development and infiltration of soil water (Ruiz-Vera et al., 2006).

Water-stable soil aggregates were formed with dehydration and compression by living plant root prior to bonding processes of plant roots and soil particles (Kong et al., 2005, Yamane, 1960). Water-stable aggregates were influenced by cations, organic matter, soil biota, plant root and soil amendments (Jo et al, 1985; Cho et al, 1992; Ryu et al, 1995; Sakamoto et al, 1996; Zotarelli et al., 2006).

Myers (1937) reported that soil organic matter may contribute to form of soil aggregates. Wilson (1945) found positive correlation between soil organic matter contents and soil aggregates in the silt loam soil. Chaney and Swift (1984) also found the positive linear relationship between soil water-stable aggregates and soil organic matter content for 26 different soil samples. Peele and Beale (1943) reported that soil aggregates were greater in organic matter applied soil compared to the control soil.

Numerous studies show that soil water-stable aggregate is highly related to soil chemical properties, such as soil organic matter content, exchangeable cations (i. e., Ca, K, Mg) and cation exchange capacity (Myear, 1937; Wilson, 1945; Chaney and Swift, 1984; Peele and Beale, 1943; Oh, 1984 ; Park and Lee, 1990; Gupta and Sen, 1962; Chester et al., 1957; Jung and Yoo, 1973). Exchangeable calcium could accelerate soil organic carbon by flocculation (Oh, 1984). Park and Lee (1990) reported that soil aggregates were higher in calcareous soil because of higher content of exchangeable calcium. Gupta and Sen (1962) also reported that calcium is an important factor for soil aggregates. Chester et al. (1957) reported that iron (Fe) affects to soil aggregates as a bonding agent. Aluminum, also contributes to aggregate soil particles (El-Swaify and Emerson, 1975). A few studies reported the relationship between soil aggregateion and soil properties for Korean upland soils.

Objectives of this research were i) to evaluate

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relationship between water-stable aggregates and soil properties, and ii) to estimate water-stable aggregates from the measurement of Middleton's dispersion ratio.

Materials and Methods

Sixty two sampling sites were randomly selected from various upland farms. Soil samples were taken with the top 20-cm soil from the surface from April to May in 2000. Selected soil physical and chemical properties were analyzed in addition to water-stable aggregates (WSA), Middleton's dispersion ratio. Soil samples were prepared with air dried, and sieved with a 4-mm diameter screen for analysis of water-stable aggregates. Soil samples were shook in a up-and-down motion (30 times per minute) with five-layered screen (i.e., 2-mm, 1-mm, 0.5mm, 0.25-mm, and 0.1-mm in diameter) within a water filled bath (water temperature sustained in 25℃). Supernatant of each screen was dried in the oven at 105℃ temperature and weighed. Dispersion agent (sodium hexameta phosphate plus sodium carbonate anhydrous) was added and washed within the screen with water to disperse soil aggregates. Supernatants on each screen was dried and weighed. Water-stable aggregate was calculated by the following equation.

$$\text{WSA} = \frac{\text{mass of aggregates - mass of single particles}}{\text{mass of dried soil}} \times 100$$

Clay, silt, and sand content were determined by the hydrometer method (NIAST, 2000). Middleton's dispersion ratio (MDR) was analyzed by weighing soil particles less than 0.05-mm in diameter by hydrometer method (ELE 152H) and calculated by the difference in proportion of mass of soil particles after dispersed with distilled water to mass of soil particles after dispersed with dispersion agent (i.e., sodium hexameta phosphate plus sodium carbonate anhydrous). Middleton's dispersion ratio was determined with the specific gravity measured for 30, 60, and 90 seconds (Cho et at., 1992).

Soil chemical properties were analyzed following the NIAST analysis standard (2000). Soil pH was determined by glass electrode method (Orion 900A). Soil organic matter was determined by the digestion of solution $K_2Cr_2O_7$ after heating at the 200℃ for 2 hours and titrated using diphenylamine indicator. Available phosphorus was determined by Lancaster method. Exchangeable cations and cation exchange capacity(CEC) were analyzed with ICP (GBC Integra XMP) after 1N-Ammonium acetate extract. Fe and Al were determined with ICP after 0.1N-HCl extract.

Results and Discussion

Characteristics of soil properties Descriptive statistics of soil properties were shown in Table 1. Soil used compare with average of upland soil of our country(Jo et al., 1999). Available phosphorus, exchangeable cations of samples were similar to the average value of Korean upland soils (Jo et al., 1999) while soil organic matter showed 16 g kg^{-1} which is lower than the average of Korean upland soils(i.e., 24 g ka^{-1}). Exchangeable Na ranged from 0 cmol$^+$ kg^{-1} to 0.6 cmol$^+$ kg^{-1} and Fe ranged from 21 mg kg^{-1} to 297 mg kg^{-1} which

Table 1. Descriptive statistics of soil properties, the number of used soil samples is 62.

Properties	avg.	min.	max.	SD[†]
Soil texture				
Sand, %	56.0	12.2	90.4	17.9
Silt, %	44.1	9.6	87.8	17.9
Clay, %	12.9	3.1	36.3	8.0
OM, g kg^{-1}	16	4	48	10
Av. P_2O_5, mg kg^{-1}	538	26	2,606	365.9
Exchangeable cations				
Ca, cmol$^+$ kg^{-1}	4.2	1.0	13.3	2.4
K, cmol$^+$ kg^{-1}	0.69	0.11	4.49	0.68
Mg, cmol$^+$ kg^{-1}	1.2	0.3	5.2	0.99
Na, cmol$^+$ kg^{-1}	0.08	0.0	0.6	0.14
CEC, cmol$^+$ kg^{-1}	10.1	3.0	23.6	4.0
Al, mg kg^{-1}	476	182	1,903	246.0
Fe, mg kg^{-1}	86	21	297	46.7

[†] Standard deviation

were lower than the average of Korean upland soils.

Soil water-stable aggregates distribution Soil water-stable aggregates by aggregation size were shown in Fig 1. The smaller soil aggregation size was the higher in soil water-stable aggregate . The average soil water-stable aggregate was the highest in aggregation size of 0.25 to 0.5-mm in diameter and was the lowest in aggregation size of 1.0 to 2.0-mm in diameter. No significant difference among the soil aggregation size was found from this research.

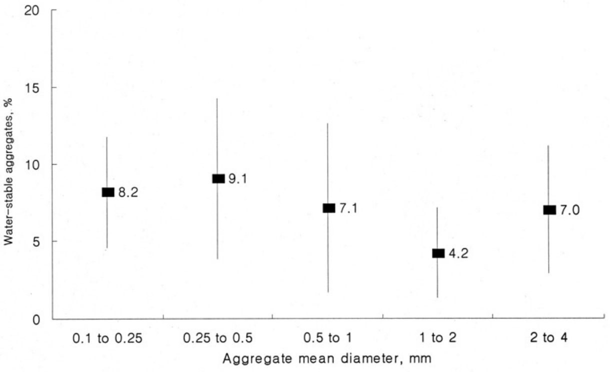

Fig. 1. Water-stable aggregates by aggregate size. Vertical line represents standard deviation of water-stable aggregate.

Relationship between Water-stable aggregate and soil properites Water-stable aggregate was negatively correlated with sand content(r = -0.82***) and positively correlated with silt(r = 0.82***) and clay content(r = 0.75***) (Fig. 2). Water-stable aggregates tend to decrease with the increasing of sand content. This could be explained that the sand is mainly consists of quartz, which is the primary mineral and not well form flocculated C-P-OM (C:clay, P:polyvalent cations, OM:organic matter) complex (Edward and Bremner, 1986). Water-stable aggregates were increased with the increasing of clay content. Clay charged negatively and it has been considered as a main parts of soil aggregates with exchangeable Ca and C-P-OM complex. From this research, silt content was significantly correlated with water-stable aggregate. This result was unlike to the other studies (Japan soil engineering society, 1972). Number of soil water-stable aggregates were significantly correlated to the exchangeable cations (i.e., Ca, K, Mg). Soil water-stable aggregate tend to increase with the increasing of organic matter content. Cation exchange capacity increased soil water-stable aggregate. Aluminum content was significantly correlated to the soil water-stable aggregate. These results were correspondant with the other studies (Chester et al., 1957; Arca et al.,. 1965 ; El-Swaify and Emerson, 1975)

Soil water-stable aggregates prediction model Soil water-stable aggregate was very significantly regressed by soil physical, chemical, and physio-chemical properties (Table 2). In the soil physical properties model, the clay content was selected to predict soil water-stable aggregates by the stepwise regression, which is to fit with the highest coefficient of determination (i.e., R^2=0.56***) of the estimated model and probability of significance ($p<0.01$). In the soil chemical propertiesl, organic matter and exchangeable calcium were used to predict soil water-stable aggregates (R^2=0.35**). In the combined model of physical and chemical properties, clay content, soil organic matter, and exchangeable calcium were selected to predict soil water-stable aggregates (R^2=0.62***). We found that some soil properties, such as clay content, soil organic matter, and exchangeable calcium, may predict soil water-stable aggregate.

Table 2. Regressive expressions in the estimable soil water-stable aggregates.

Parameter	Regression equation for WSA[†] prediction
Physical	16.61 + 1.47 Clay (R^2 = 0.56***)
Chemical	18.24 + 3.53 OM + 2.82 Ca (R^2 = 0.35**)
Physico-chemical	12.48 + 1.25 Clay - 0.44 OM + 1.84 Ca (R^2 = 0.62***)

[†] Water-stable aggregates

Soil water-stable aggregate and Middleton's dispersion ratio Soil physical and chemical properties were significantly correlated to the Middleton's dispersion ratio (Fig. 3). The sign of correlation coefficient between soil properties and Middleton's dispersion ratio showed exactly opposite compared to that between soil properties and water-stable aggregate. Soil water-stable aggregate determination may took a long hours by sieving physically and weighing dried samples. But, the determination of the Middleton's dispersion ratio is rapid and relatively easy (measure specific gravity for 30, 60, 90 sec). In this research, Middleton's dispersion ratio was determined identically for the same samples. The relationship between soil

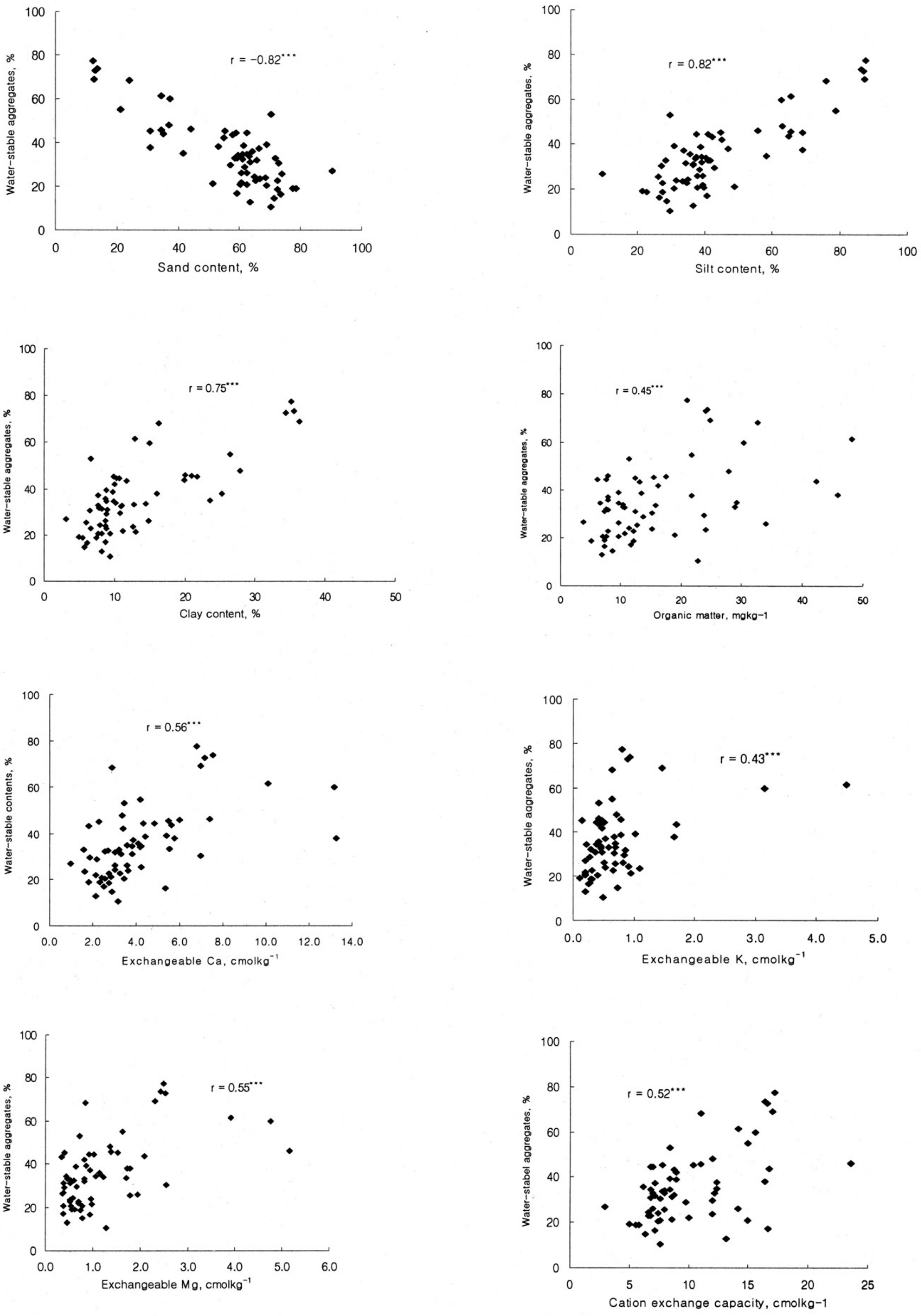

Fig. 2. Relationship of selected soil properties to water-stable aggregates.

water-stable aggregate and Middleton's dispersion ratio is significantly correlated. Regression equation of Middleton's dispersion ratio was estimated to predict soil water-stable aggregate ($Y=-0.79X + 96.49$; $r^2=0.58$***) (Fig. 4). Determining soil water-stable aggregate has been hesitated because measuring water-stable aggregate takes time and labor. However, Middleton's dispersion ratio was relatively easy and rapid for determination and was able to estimate soil water-stable aggregate. Therefore, the Middle's dispersion ratio is recommended to determine soil water-stable aggregate as a convenience and a rapid method.

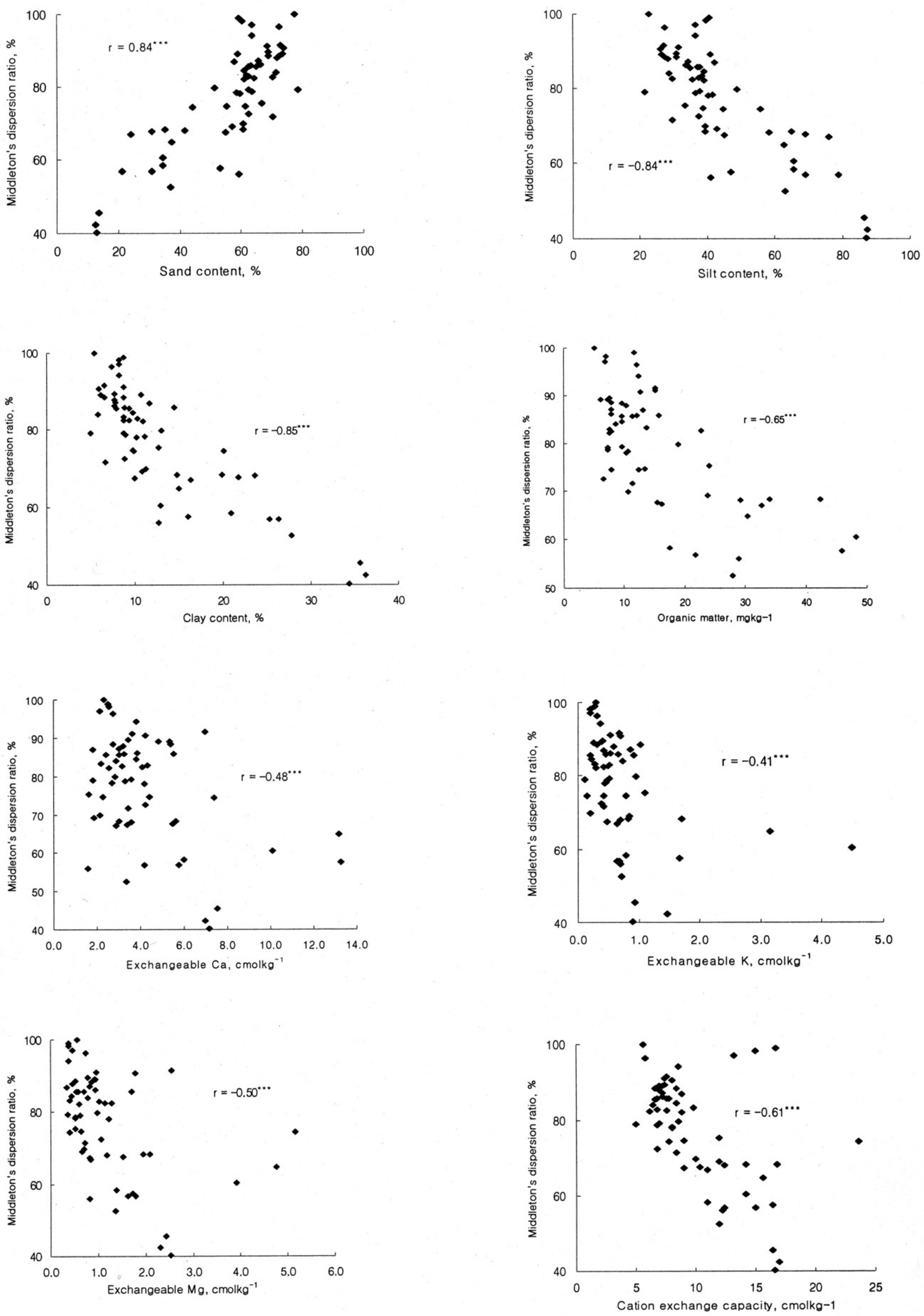

Fig. 3. Correlation relationship of selected soil properties to Middleton's dispersion ratio.

Conclusion

In this research, we examined the relationship between soil water-stable aggregate and soil properties and predicted soil water-stable aggregate from the Middleton's dispersion ratio. Through the results, We conclude that Water-stable aggregate was significantly correlated with soil textural properties, soil organic matter, and exchangeable cations and was able to be estimated by rapid and easily measurable Middleton's dispersion ratio. These results may contribute to help understanding of soil aggregation mechanism and the relationship of soil water stable aggregate and soil properties. The Middleton's dispersion ratio may be used

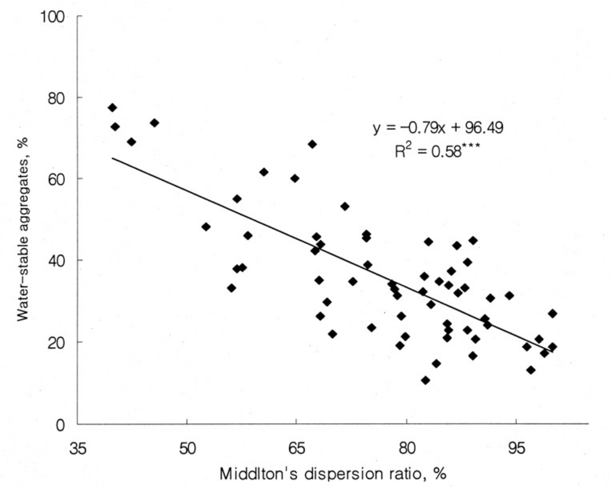

Fig. 4. Correlation between Middleton's dispersion ratio and water-stable aggregates.

to determine soil water-stable aggregate for a convenience.

References

Arca, M.N. and S.B. Weed. 1966. Soil aggregation and porosity in relation to contents of free iron oxide and clay. Soil Sci. 101:164-170

Braunack, M.V. 1995. Effect of aggregate size and soil water content on emergence of soybean(Glycine max, L. Merr.) and maize (Zea mays, L.). Soil & Tillage Research 33:149-161.

Chaney, K. and R.S. Swift. 1984. The influence of organic matter on aggregate stability in some British soils. J. Soil Sci. 35:223-230

Chesters, G., O.J. Attoe, and O.N. Allen. 1957. Soil aggregation in relation to various soil constituents. Soil. Sci. Soc. Am. Proc. 21:272-277

Cho, B.H., S.J. Cho., C.S. Park., and D.I. Eom. 1992. Samjeong Soils. p. 66-70. Hyangmunsa, Seoul, Korea.

Edwards, A.P and J.M. Bremner. 1967. Microaggregates in soils. J. of Soil. Sci. 18:64-73

El-Swaify and W.W. Emerson. 1975. Changes in the physical properties of soil clays due to precipitated aluminum and iron hydroxides : Ⅰ. Swelling and aggregate stability after drying. Soil Sci. Soc. Am. Proc. 39:1056-1062.

Grandy, A.S. and G. P. Robertson. 2006. Aggregation and organic matter protection following tillage of a previously uncultivated soil. Soil Sci. Soc. Am. J. 70:1398-1406.

Gupta, K.G. and Abhiswar Sen. 1962. Agregation of soil due to growth of rhizobium sp. from some common, cultivated legumes. Soil Sci. 94:345-348

Japan soil engineering society. 1972. Manual of soil experiment and survey. Soil aggregate experiment.

Jo, I.S., S.J. Cho., H. Verplanke, R. Hartmann, and M. De Boodt. 1985. Effect of soil aggregate stability and wettability on infiltration and evaporation. Korean J. Soil Sci. Fert. 18:121-127

Jo. I.S., B.K. Jung., G.B. Jung., B,M. Lee., and J.H. Kim. 1999. The study on agricultural environment changing countermeasure (Reports of 3rd year). p. 13. National Institute of Agricultural Science and Technology, Suwon, Korea.

Jung, Y.S., and S.H. Yoo. 1973. The study on soil physical properties of green house soil. (Ⅰ. Several factor affect on changing of soil aggregates). Proceeding 11. p. 4. Korean Soc. Soil Sci. Fert. Suwon, Korea.

Kong, A.Y., J. Six, D.C. Bryant, R.F. Denison, and C. van Kessel. 2005. The relationship between carbon input, aggregation, and soil organic carbon stabilization in sustainable cropping systems. Soil Sci. Soc. Am. J. 69:1078-1085.

Myers, H.E. 1937. Physio-chemical reactions between organic and inorganic soil colloids as related to aggregate formation . Soil. Sci. 44:331-357

National Institute of Agricultural Science and Technology. 2000. Analysis method of soil and plant. p. 202. National Institute of Agricultural Science and Technology, Suwon, Korea.

Oh, W.K. 1984. Newly Soils. Iljogag, Seoul, Korea.

Park, K.S., and S.O. Lee. 1990. The study on the soil aggregation affected by organic matter in forest soils. Korean Forest Society. 79:367-375.

Peele, T.C. and O.W. Beale. 1943. Microbial activity and soil aggregate formation during the decomposition of organic matter. Soil Sci. Soc. Proc. Proceeding. 8:254-257

Ruiz-Vera, V.M. and L. Wu. 2006. Influence of sodicity, clay mineralogy, prewetting rate, and their interaction on aggregate stability. Soil Sci. Soc. Am. J. 70:1825-1833.

Ryu, I, S., J. L. Han. , and I. S. Jo. 1995. Effects of Some Soil Conditioners on Soil Physical Properties and Lettuce Growth. Korean J. Soil Sci. Fert. 28:249-255

Sakamoto, Ochuca, Yoshida. 1996. Effect on sol microbes by soil aggregates size. Japan Soc. of Soil Sce. & Fert. 7:310-313

Wilson, H. A. and W. C. Fisher. 1945. Aggregate increase and stability in two Lousiana soils. Soil Sci. Soc. Proc. 10:30-33

Wright, A .L. and F. M. Hons. 2004. Soil aggregation as carbon and nitrogen storage under soybean cropping sequences. Soil Sci. Soc. Am. J. 68:507-513.

Yamane. 1960. Basis and application of soils. Association of Agri-forestry- fishery-vaillage corporation. p 84

Zotarelli L., B.J.R. Alves, S. Urquiaga, E. Torres, H.P. dos Santos, K. Paustian, R.M. Boddey, and J. Six. 2006. Impact of tillage and crop rotation on aggregate-associated carbon in two oxisols. Soil Sci. Soc. Am. J. 69:482-491.

토양 내수성 입단과 토양특성과의 관계

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토양의 입단은 토양의 물리적 구조를 형성함에 있어서 매우 중요한 특성이며 토양의 양분 및 수분의 이동 및 토양관리방법 등과 매우 밀접한 연관이 있다. 그러나 토양의 입단과 토양특성에 대한 상호관계에 관한 연구가 매우 미흡하다. 본 연구에서는 토양의 내수성 입단과 토양 물리화학적 특성관계를 구명하고자 토양의 토양물리 화학성과 함께 내수성 입단을 측정하여 상관관계를 분석한 결과, 토양의 내수성 토양입단형성에 미치는 토양물리성 입자 중 미사($r = 0.82^{***}$)와 점토($r = 0.75^{***}$) 함량은 유의성이 있는 정의 상관을 보였으며, 모래($r = -0.82^{***}$)는 유의성 있는 부의 상관을 나타내었다. 토양화학적 특성은 Ca 〉 Mg 〉 CEC 〉 OM 〉 K 〉 Al 순으로 내수성 토양입단 함량과 통계적으로 유의한 상관성을 나타내었다. Middleton의 분산율 (0.05mm 이하)과 내수성 토양입단함량과는 통계적으로 유의한 상관 ($r = -0.76^{***}$)을 나타내었다. 내수성 입단 함량 추정을 위한 Middleton의 분산율의 유의한 회귀모형이 산출되었다 ($Y = -0.79X + 96.49$; $r^2 = 0.58^{**}$). 결론적으로, Middleton의 분산율을 이용하여 토양의 내수성 토양 입단함량을 간편하고 빠르게 측정할 수 있었다.