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Effect of Different Organic Fertilizers on Fruit Quality in a Pear Orchard

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유기질 비료의 시용이 배 과실의 품질특성에 미치는 영향

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Abstract

This study was conducted using 8-year-old 'Niitaka' (*Pyrus pyriforia*) pear trees to investigate the effect of different organic fertilizers on fruit quality and level of total phenolicsin a conventionally managed orchard. Trees were treated with one of five different fertilizers: 1) control (60 g of chemical fertilizer [16N-11P-12K] per tree) 2) rice bran (RB, 10 kg per tree); 3) coffee bran compost (CBC, 10 kg per tree); 4) chitin-incubated compost (CIC, 10 kg per tree); or 5) RCC (RB+CBC+CIC, 30 kg per tree). Soluble solid content, hardness, and titratable acidity were significantly higher in fruit from RCC-treated trees compared with fruit from trees exposed to other treatments. Overall, control fruit had smaller stones and lower calcium concentration than had organically fertilized fruit. Also, control fruit showed a reduced level of total phenolic compounds and lower antioxidant activity in both peel and flesh than did organically fertilized fruit. Compost-treated trees yielded fruit of enhanced edibility and with longer shelf-life owing to a reduction in stone size and increased calcium concentration, respectively. Overall, fruit from trees treated with organic fertilizers was of higher quality and had greater antioxidant levels compared with fruit from trees treated with chemical fertilizer.

Key words : organic fertilizer, fruit quality, stone cell, total phenolic contents, antioxidant, calcium

Introduction

As their living standards improve, people have gradually become interested in health concerns and are looking to buy an “environmentally friendly” organically grown fruit with no chemical input in the orchard(1). Although several scientific researchers have conducted the fruit quality and antioxidant content in the organic apple orchard, the postharvest behaviors varied widely between organic and conventional fruit and within organic fruit(1-3). Also, the post behavior research on organic or integrated fruits has concentrated in the Northwestern Region of the U.S.A and Canada or Europe which are arid places and well controlled for disease problems(3-4) with little or no research in the warm and humid area of Korea.

Organic fertilizers, such as rice bran, coffee bran, and chitin compost, increase chemical, physical, and biological properties in soil(5), which result in improving tree growth and development. Lee’s previous research(6) showed that the induced high fruit skin color and sugar contents by organic fertilizers have possibly shortened fruit’s maturation time. Also, increased fruit Ca concentration seemed to have contributed to reduce fruit stone cells in Asian pears grown on organic compost in conventional orchards.

The organically grown fruit had a higher total polyphenol compounds compared to conventional fruit(4,7) resulting in

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increasing polyphenoloxidase(PPO) and antioxidant activity. Polymerization of polyphenol compounds mediated by polyphenoloxidase(PPO) improved plant defense mechanism of the stressed plant surface, and the other antioxidant activities, such as superoxide, dismutase, catalase, and glutatione peroxidase, were observed curing the damaged areas(4). The phenol compounds in apples would be decreased by application of synthetic chemical fertilizer, insecticide, and herbicide at conventional apple orchards. Research suggests that some natural substance in fruit and vegetable can suppress free radicals that could contribute to some diseases in plants(8). The study was conducted to investigate the effects of organic fertilizers, such as rice bran, coffee bran compost, and chitin incubated compost, on fruit qualities and antioxidant activities of 'Niitaka' pear trees in a conventional orchard.

Materials and methods

Application of fertilizer

The study was conducted with an eight-year-old 'Nitaka' pear cultivar grown in a conventionally managed orchard at a Main Agricultural Experiment and Extension Center, Chonnam National University, NaJu, Chonnam, Korea in 2005. The study was a randomized complete design with ten replications of each treatment. Trees were scattered with one of five different treatments at the end of March before trees were blooming: 1) control(60 g of chemical fertilizer per tree(16N-11P-12K); 2) rice bran(RB, 10 kg per tree); 3) coffee bran compost(CBC, 10 kg per tree); 4) chitin incubated compost(CIC, 10 kg per tree); 5) RCC(RB+CBC+CIC, 30 kg per tree). Coffee bran compost was mainly made by coffee bran and rice bran. Chitin compost(Jikimi®) was composed of 25% of crab shell, 10% of rice hulls, 40% of rice straw, 1% of Bacillus Cereus, and 1% of mineralized N-P-K.

Fruit characteristics and fruit decay

Trees were harvested at early October. The fruit skin color was graded by fruit hunter value with high grade spectrum color sensor(CR 301 Minolta, Japan), and more positive values of L, a, and b stand for more lightness, redness, and yellowness, respectively. The thirty fruit samples per treatment were approximately harvested at the size of 650 g per fruit. The fruit was peed out, and fruit firmness was observed with hand-held penetrometer with 5 mm diameter plunger(Japan). For the soluble solids analysis, the fruit juice was squeezed and measured by hand-held refractometer(N1 Atago, Japan), and titrate acidity(%) was reported by titrating a 10 mL juice aliquot with 0.1 N NaOH. The subsamples of fruit were divided and placed in room temperature for 6 and 12 days for investigating fruit decay.

Stone cells

The ten g of pear fresh was used for the stone cell analysis, and the analysis was followed by Lee's method(9) that the final dry weight of the sediment was determined for the value of stone cells.

Fruit P, K, Ca, and Mg

After fruit characteristics were measured, the fruit samples were dried at 70℃ for 3 days and ground to pass a 2 mm mesh screen. The 0.5 g ground fruit sample was extracted by miro-kjeldahl techniques in the flow hood until its color turned from green to white. The final digested aqueous was measured at 470 nm on UV-visible spectrometer(Shimadzu UV-1601, Japan) for fruit phosphorous(P) concentration. Also, the diluted final digested aqueous was measured by inductively coupled plasma atomic emission spectrometer (Pye-unicam PU 9000, England) for the analyses of calcium(Ca), magnesium(Mg), and potassium(K) concentrations at the cooperative laboratory of College of Agriculture in Chonnam National University.

Total phenolic contents

After the final extracted aqueous was obtained with 10 g in the fresh and peel tissues, the total phenol compound was determined with modified Folin-Ciocalteu reagent method(10). Electron donating ability(%) by 1,1, diphenyl-2-picryl hydrazyl(DPPH) radical scavenging method in fruit was measured with reducing ability of the samples to the DPPH by Kang et al.'s method(11). The 0.1 ml of final extraction of the peel and fresh tissues with 3.9 ml of DPPH was measured in 10 and 20 minutes respectively at 515 nm on UV-visible spectrometer(Shimadzu UV-1601, Japan). The electron donating ability(%) was determined as;

$$\text{Electron donating ability} = \{(\text{absorbance with the aqueous}/\text{absorbance without the aqueous}) \times 100\}$$

Statistical analysis

The study was randomized completely design with 10 replications. Statistical analysis was conducted with Duncan's multiple ranged test level of 0.05(SPSS Institute). The thirty fruit samples per tree were randomly chosen for the variable analyses.

Results and discussion

Fruit characteristics

There were no significant differences for the brightness and redness of the fruit skin grown on all the treated trees(Table 1 and Fig. 1). The more yellow fruits was produced by trees treated with the coffee bran compost(CBC) and with combined fertilizer(RCC) composed of rice bran(RB), coffee bran compost(CBC), and chitin incubated compost(CIC) treated trees, which agrees with the previous result that compost treatment increased fruit skin color(6).

Table 1. Fruit skin color measured by hunter value as affected by organic fertilizers of ’Niitaka’ pear orchard in NaJu, Chonnam, 2005

Treatment[1)]	Hunter value		
	L	a	b
Control	62.9 a[2)]	6.6 ab	39.1 a
RB	62.9 a	6.6 ab	39.1 a
CBC	62.4 a	7.1 a	38.9 a
CIC	62.4 a	5.4 b	38.7 a
RCC	62.2 a	7.5 a	38.6 a

[1)]RB = Rice bran; CBC = Coffee bran compost; CIC = Chitin incubated compost; RCC = RB+CBC+ CIC.
[2)]Means separation within columns by Duncan’s multiple range test at p = 0.05. n = 30.

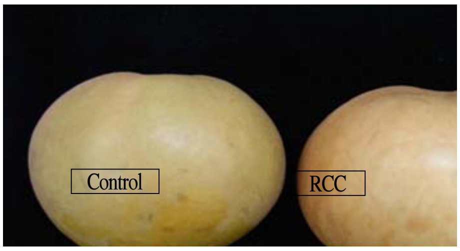

Fig. 1. Comparison of fruit skin color as affected by RCC fertilizer and control of a ‘Niitaka’ pear tree in NaJu, Chonnam, 2005.

RCC = Rice bran + coffee bran compost + chitin incubated compost.

There were no significant differences for the fruit weight and hardness, but the organically fertilized trees showed lighter and firmer fruits than those of the control(Table 2). Although the soluble solids content(SSC) was higher on the organically treated fruits compared to the control, the sweetness, defined as a soluble solids to titratable acid(TA) ratio, was not high on the organically fertilized trees due to high acid contents of the fruits(Table 2). This was a similar to Peck’s study(3) that conventional fruit had high SSC to TA ratio compared to the organically grown ‘Gala’ apple.

Table 2. Fruit characteristics as affected by organic fertilizers of ’Niitaka’ pear orchard in NaJu, Chonnam, 2005

Treatment[1)]	Fruit characteristics				
	Fresh wt.	Hardiness	Soluble solids (SS)	Acidity (A)	SS/A
Control	660 a[2)]	1.27 a	12.1 a	0.63 a	19.3
RB	678 a	1.32 a	12.2 a	0.78 a	15.6
CBC	682 a	1.31 a	12.3 a	0.72 a	17.0
CIC	667 a	1.28 a	11.6 a	0.70 a	16.6
RCC	685 a	1.31 a	13.0 a	0.79 a	16.4

[1)]RB = Rice bran; CBC = Coffee bran compost; CIC = Chitin incubated compost; RCC = RB+CBC+ CIC.
[2)]Means separation within columns by Duncan’s multiple range test at p = 0.05. n = 30.

Stone cell

Fruit inedibility, defined as the amount of stone cell, was low on all the organic fertilized trees, especially on the RB and CBC-treated trees(Fig. 2 and 3). During water stressed

Fig. 2. Photograph of fruit stone cell segments as affected by RCC fertilizer and control of a ‘Niitaka’ pear tree in NaJu, Chonnam, 2005.

RCC = Rice bran + coffee bran compost + chitin incubated compost.

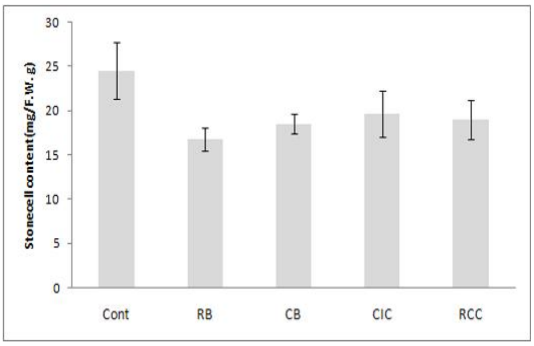

Fig. 3. Fruit stone cell segments as affected by organic fertilizers of a ‘Niitaka’ pear tree in NaJu, Chonnam, 2005.

RB = Rice bran; CBC = Coffee bran compost; CIC = Chitin incubated compost; RCC = RB+CBC+ CIC.
Vertical bars represent ±SD of the mean. n = 30

periods in the fresh part of the fruit, fruit and leaf competed for the water uptake which led in turn to cause cork, lignin, and stone cell contents in fruit to develop(12). Stone cells are formed in the early fruit development(13), and strategy for preventing the stone cells should be performed before the tree's flowering in orchard. Ground cover system showed increased organic matter and effective conservations of soil moisture because the elevated soil organic matter prevented soil evaporation and maintained high relative humidity(14). Therefore, applying compost or ground cover system would be beneficial for improving fruit quality by reducing water stress and stone cells in the fresh tissue.

Fruit P, K, Ca, and Mg concentrations

All organically fertilized trees had higher fruit Ca concentrations than those of the control trees, and no differences were found within the organic treatments for the nutrient(Table 3). The fruit K and P concentrations showed high on the control trees, which may be because the high fruit K and P concentrations would prevent Ca ion movement into the fruit and cause negative relationship between those nutrients in the fruit(15).

Table 3. Fruit nutrient concentrations as affected by organic fertilizers of 'Niitaka' pear orchard in NaJu, Chonnam, 2005.

Treatment[1]	Mineral concentration (mg/kg, dw)			
	Ca	K	Mg	P
Control	107 b[2]	8.38 a	117 a	103 a
RB	127 a	6.56 b	119 a	72 b
CBC	129 a	6.52 b	92 a	66 b
CIC	116 a	7.02 ab	113 a	98 a
RCC	125 a	6.93 ab	114 a	76 a

[1]RB = Rice bran; CBC = Coffee bran compost; CIC = Chitin incubated compost; RCC = RB+CBC+ CIC.
[2]Means separation within columns by Duncan's multiple range test at p = 0.05. n = 30.

The fruit Ca is mostly found in the cell wall as a Ca-pectate that is responsible for the cell wall strength and cell membrane permeability, which makes less ethylene development in the tissue and delays fruit ripening(16,17). Figure 4 compares the fruit decay grown on the RC and control treatments after 6 and 12 days of divided fruits. Control fruits showed very dark and sunken appearances in most of the fresh part after twelve days of the divided fruits, which would have been caused by stimulating high ethylene gas and shortening fruit decay due to the lower fruit Ca concentration on the control trees(Table. 3).

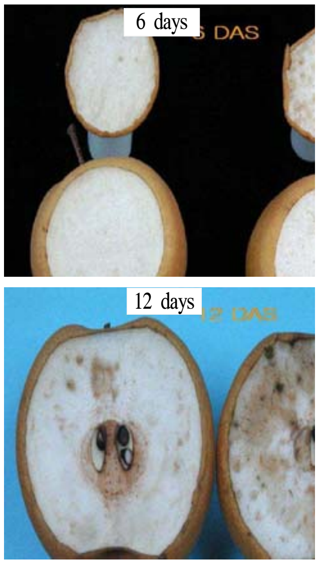

Fig. 4. Comparison of fresh color change in room temperature on 6 and 12 days after divided fruit as affected by RCC fertilizer and control of a 'Niitaka' pear tree in NaJu, Chonnam, 2005.

RCC = Rice bran + coffee bran compost + chitin incubated compost.

Total phenolic contents

The naturally formed phytochemicals or functional substances in fruit potentially prevent human illness such as cancer, heart disease, and hypertension(4). The phytochemicals include polyphenol compounds, flavonoids, carotinoids, and tocopherols, which eliminate free radicals of superoxide ion

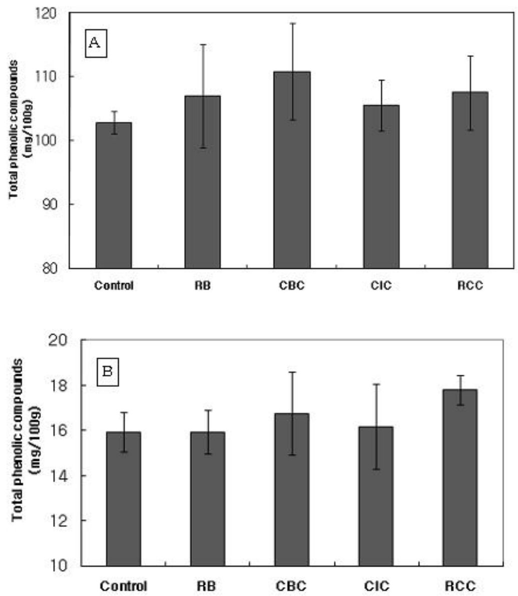

Fig. 5. Phenolic compounds in the peel (A) and flesh (B) as affected by organic fertilizers of a 'Niitaka' pear tree in NaJu, Chonnam, 2005.

RB = Rice bran; CBC = Coffee bran compost; CIC = Chitin incubated compost; RCC = RB+CBC+ CIC.
Vertical bars represent ±SD of the mean. n = 30.

and lipid peroxil radicals as well as prevent lipoxigenase and cyclo-oxygenase(18). In our experiment, all the organic fertilized fruits showed high concentrations of polyphenol compound compared to the control fruit(Fig. 5), which is a similar result shown by pear and peach fruits in organic orchards(4). Generally, the fruit skin had about five times higher phenol compounds than the fresh fruit part on all the treatments(Fig. 5).

Antioxidant activity

The antioxidant activity was investigated by 1,1, diphenyl-2-picryl hydrazyl(DPPH) scavenging method. Overall, electron donating ability in the fruit peel was faster and higher compared to the fruit fresh(Fig. 6). All the organically fertilized fruits showed higher antioxidant levels than those of the control, although the difference within the organic fertilizers was not significant. This pattern was similar to the result that the total phenolic compound in fruit skin were ranked by the treatments(Fig. 5); CBC was the greatest followed by RCC, RB, CIC, and control. The polyphenol is the major antioxidant compound(4), and increased polyphenol compound would contribute to the antioxidant activity.

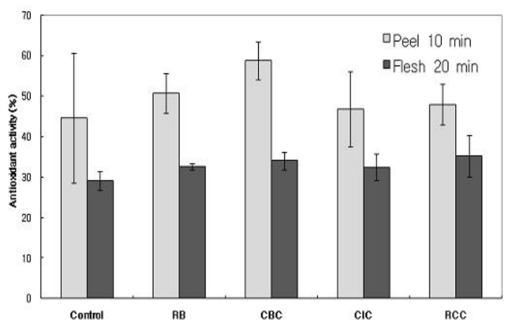

Fig. 6. Antioxidant activity with DPPH scavenging method in the peel and flesh as affected by organic fertilizers of a 'Niitaka' pear tree in NaJu, Chonnam, 2005.

RB = Rice bran; CBC = Coffee bran compost; CIC = Chitin incubated compost; RCC = RB+CBC+ CIC.
Vertical bars represent ±SD of the mean. n = 30.

Conclusion

Some of the fruit qualities, such as skin brightness, fresh hardness, and fresh sweetness, were not significantly different among the treatments. However, the organically fertilized fruits showed lower stone cell segments and longer fruit storage, which would allow shortening the fruit maturation time and keeping longer shelf life in fresh fruit market. Also, the organically fertilized fruits showed increased fruit phenolic compounds and antioxidant levels in a conventional orchard, which could contribute less human health risk that may come from fruit produced by a conventional orchard. Overall, RCC, the three mixed organic fertilizer, did not have significant difference for the fruit quality and antioxidant level compared to the other organic fertilizers.

요 약

관행재배 과원의 토양에 여러 유기질 퇴비를 시비하였을 경우 배 과실의 품질특성의 차이를 구명하고자 실시하였다. 8년생 신고배에 쌀겨퇴비, 커피박퇴비, 키친퇴비(미생물지킴이®) 및 위의 3종 유기질 비료 복합 처리구를 배치하고 주당 10 kg 을 시비하였고, 대조구는 화학비료를 주당 60 g 시비하였다. 과실당도나 경도, 산도에서는 복합처리구에서 대조구보다 높았고 석세포 함량은 모든 유기질 비료 처리구에서 대조구보다 낮았다. 과피와 과육에서의 DPPH 라디컬 소거활성은 모든 처리구에서 대조구보다 높아지는 경향을 나타냈고, 페놀화합물 함량도 과피와 과육에서 대조구보다 높은 경향을 나타냈다. 과피의 페놀화합물 함량은 처리구에 상관없이 과육보다 6배 정도 높은 경향을 나타냈다.

이상의 결과로 보아, 화학비료를 대체한 유기질 비료의 시용으로 배 과실내 석세포 감소와 품질 특성의 향상과 총 페놀함량 증가 및 DPPH 라디컬 소거활성이 증가하였다.

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References

1. DeEll, J.R. and Prange, R.K. (1992) Postharvest quality and sensory attributes of organically and conventionally grown apples. HortScience, 27, 1096-1099
2. DeEll, J.R. and Prange, R.K. (1993) Postharvest physiological disorders, diseases and mineral concentrations of organically and conventionally grown McIntosh and Cortland apples. Can. J. Plant Sci., 73, 223-230
3. Peck, G.M., Andrews, P.K., Reganold, J.P., and Fellman, J. K. (2006) Apple orchard productivity and fruit quality under organic, conventional, and integrated management. HortScience, 41, 99-107

4. Carbonaro, M., Mattera, M., Nicoli, S., Bergamo, P., and Cappelloni, M. (2002) Modulation of antioxidant compounds in organic vs conventional fruit (peach, *Prunus persica* L., and pear, *Pyrus communis* L.). J. Agric. Food Chem., 50, 5458-5462
5. Mắder, P., Bach, F.A., Dubois, D., Gunst, L., Fried, P., and Niggli, U. (2002) Soil fertility and biodiversity in organic farming. Science, 296, 1694-1697
6. Lee, S.H., Kim, W.S., Kim, K.Y., Kim, T.W., Whuangbo, H., Jung, W.J., and Jung, S.J. (2003) Effect of chitin compost incorporated with chitinolytic bacteria and rice bran on chemical properties and microbial community in pear orchard soil. J. Kor. Soc. Hort. Sci., 44, 201-206
7. Weibel, F.P., Bickel, R., Leuthold, S., and Alfoldi, T. (2000) Are organically grown apples taster and healthier? A comparative field study using conventional and alternative methods to measure fruit quality. Acta. Hort., 517, 417-426
8. Opoku, A.R., Maseko, N.F., Terblanche, S.E. (2002) The in vitro antioxidative activity of some traditional Zulu medicinal plants. Phyto. Res., 1, 51-56
9. Lee, J.E. and Kim, W.S. (2001) Morphological characters of stone cells on the effect on fruit quality of pears. J. Kor. Soc. Hort. Sci., 42, 449-452
10. AOAC. (1985) Official method of analysis. 16th ed. Association of official chemists, Washington D.C.
11. Kang, Y.H., Park, Y.K., and Lee, G.D. (1996) The nitrite scavenging and electron donating ability of phenolic compounds. J. Kor. Food Sci. Technol., 28, 232-239
12. Torikata, H.T. (1976) Physiological disorder and counter-measure of fruit tree. Seimongtoushinkai Pub. Co., p. 236-241
13. Choi, J.H., Suh, H.S., Choi, J.J., Park, H.S., Kim, W.S., and Lee, S.H. (2003) Anatomical observation on stone cell formation in fruit flesh of Asian pear 'Niitaka'. J. Kor. Soc. Hort. Sci. 44, 885-888
14. Packer, I.J. and Hamilton, G.J. (1993) Soil physical and chemical changes due to tillage and their implications for erosion and productivity. Soil Tillage Res., 27, 327-339
15. Kim, W.S., Chung, S.J., Kim, K.Y., DeJong, T., and Choi, H.S. (2002) Relationships between Ca, K, and Mg concentration and browning of blossom end part of 'Fuyu' sweet persimmon during MA storage. Adv. Hort. Sci., 16, 95-100
16. Ferguson, I.B. (1984) Ca^{2+} in plant senescence and fruit ripening. Plant Cell Env., 7, 477-489.
17. Watkins, C.B., Harman, J.E., Ferguson, I.B., and Reid, M.S. (1982) The action of lecithin and calcium dips in the control of bitter pit in apple fruit. J. Am. Soc. Hort. Sci., 107, 262-267
18. Laughton, M. J., Evans, P. J., Moroney, M. A., Hoult, J. R. S. and Halliwell, B. (1991) Inhibition of mammalian 5-lipoxygenase and cyclo-oxygenase by flavonoids and phenolic dietary additives: Relationship to antioxidant activity and to iron ion reduction ability. Biochem. Pharmacol., 42, 1673-1681

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