원예과학기술지 16(2):233-235. 1998

Characteristics of Leaves, Roots, and Fruit as Influenced by Energized-Functional Water Supply in Fuji Apple Trees

Kim, Wol Soo* · Chung, Soon Ju
Dept. of Horticulture, Chonnam National University, Kwangju 500-757 Korea
* corresponding author

ABSTRACT Energized-functional water (EFW) and powder (EFP) were manufactured by Kyungwon Institute of Life Science, Seoul, through a series of processes; tap water ultra-purification energy imprinting with catalysts in platinum columns mixing energy-imprinted water + activated zeolites + photosynthetic bacteria fermenting at 25℃ filtering EFW and/or EFP. A single application of EFP to soil under tree canopy before bud burst, combined with three EFW applications to soil during growth of 'Fuji' apples (*Malus domestica* Borkh.) resulted in a higher Ca concentrations in fruit skins and flesh, and lower Ca and N concentrations in leaves and shoot-bark tissues. EFW also stimulated the net photosynthesis of leaves and root activity. Soluble solid concentrations (SSC) and anthocyanin levels of fruits were also significantly increased at harvest, producing greater firmness and less core browning during storage at 0℃. However, there was no significant difference in titratable acidity of fruit juice between the EFW treatment and the controls.

Additional key words: *Malus domestica*, energy imprinting, mineral nutrient, Ca, fruit quality, root activity

Introduction

The productivity and quality of fruit are determined mainly by three factors of variety, climatic condition, and agro-techniques in commercial orchards. Although there has been great development in production of new varieties and agricultural techniques for the last two or three decades, soil, water and air have suffered from global industrialization. Agricultural environ- ments may have become unsatisfactory; the weather being too cold or hot, too wet or dry. Soils are in poor physical condition, and have improper pH or saline levels. Man-made activities cause such problems such as high levels of pest- icides, inorganic fertilizers and herb- icides during cropping seasons (Bennett, 1993).

In recent years, some revolutionary research projects have been conducted to address environmental problems, and to improve yield and quality by using new materials and ultra-functional substances in agriculture. These efforts have led to the introduction of several commercial products such as Effective Microorganisms (EM) in Japan (Matsmoto, 1994), the mineral complex Spray-N-Grow in the USA (Nightingale, 1994), pi(π) water in Japan (Makino, 1994), Open-All in the USA (CMH Environmental Group, 1993), and energized-functional water (EFW) treated polyethylene film in Korea (Bahng et al., 1996). The purpose of the present investigation is to determine the effects of EFW on the growth and development of Fuji apples.

Materials and Methods

Manufacturing process and components of EFW. The Kyungwon Enterprise Co. manufactured EFW through a series of processes: i) ultra-purification of tap water by multiple-filtering systems, ii) specified quantum-energy-imprinting with several catalysts in platinum columns, iii) activating zeolites on an iron belt, iv) fermenting mixtures of energy-imprinted water + activated zeolites + photosynthetic bacteria at 25℃ for 15 days in stainless steel fermenter, and v) separation of EFW and energized-functional powder (EFP) by press-filteration. In an analysis of EFW using ion chromatography (Dionex- 500, Dionex Corp., Calif.) the water was found to contain 8.7 $mg.L^{-1}$ NH_4^+-N, 340.0 $mg.L^{-1}$ NO_3N, 17.5 $mg.L^{-1}$ K, 109.6 $mg.L^{-1}$ Ca, 10.0 $mg.L^{-1}$ Mg, 9.6 $mg.L^{-1}$ Na, 33.3 $mg.L^{-1}$ SO_4, and 33.6 $mg.L^{-1}$ Cl. In addition, EFW had a pH of 8.15 and an EC of 0.94 $mS \cdot cm^{-1}$.

Plant materials and · treatments. Ten-year-old Fuji apple trees (*Malus domestica* Borkh.) grafted on M26 were used in this experiment. Trees were trained to a vertical axis system at a spacing of 3.5m×6.0m (470 trees · ha^{-1}) in the experimental orchard at the Horticultural Research Institute, in Suwon, Korea. After supply 3 kg · $tree^{-1}$ EFP and plowing it to a 30 cm depth on March 20, 1994, five liters of EFW were applied under the tree canopy three times at the time of full-bloom, April 29; just after the June-drop, June 20; and at the fruit enlarging stage, July 20, 1994. Control trees received 5 liters of tap water at the same three times as the EFW treatment. In order to measure the orchard soil pH and mineral composition, five soil samples per plot were taken on March 5 (before treatment of EFP and EFW) and on August 5, 1994.

Analysis of macro-nutrient elements. Samples were comprised of 30 leaves and the bark from 10 shoots collected from the mid-third portions of current shoots at July 15 to August 5, 1994. Fruit samples were harvested on October 21, 1994, and 20 fruits were then peeled by hand. Samples of leaves, shoot-bark and fruits were oven-dried at 75C and ground in a stainless steel mill. A 250 mg sub-sample was digested on a block digester at 350C for 0.75 hrs with H_2SO_4 solution containing K_2SO_4 and HgO. Nitrogen concentration in the digest was determined after the formation of a phosphomolybdenum complex (Technicon Autoanalyzer II, Industrial Method No. 334-74A/A; Technicon, Elmsford, NY). One gram of the sample was dry-ashed at 475℃ and dissolved in 0.5 M HCl before determination of K, Ca and Mg by atomic absorption spectrophotometry (Perkin-Elmer, 2380).

Net photosynthesis and root activity. Net photosynthesis was measured with a portable closed photosynthesis system (LI-COR, Lincoln, Neb.) between 1:00 PM and 3:00 PM on August 15, 1994 with the leaves located outside and/or inside tree canopy. Photosynthetic photon flux (PPF, 400-700 nm), air and leaf temperature, and relative humidity (RH) inside the leaf chamber were measured concurrently with gas (CO_2) exchange. Root activity was measured by triphenyltetrazorium chloride (TTC) testing (Lee and Lee, 1991), with one-year-old root samples on August 15, 1994.

Fruit evaluation. A sample of approximately 200 fruits, consisting of all the fruits harvested from the middle portion of each tree on October 21, 1994, was taken to assess fruit quality. Sub-samples of 15 fruits from each plot were assessed for average fruit weight, flesh firmness, SSC, and titratable acidity (TA). Flesh firmness was determined on peeled fruit using a multi-rheometer (Art, Hujiwara, DKK Corp., Tokyo); data were recorded in kilograms and then converted to Newtons. SSC was determined with a hand-held refractometer (0-32%; Atago N1, Tokyo). Anthocyanin in fruit skin tissues was measured by a modified method from Fuleki and Francis (1968). The extract was 95% ethanol and 1.5 N HCl (85:15, v/v). Three grams of fruit skin tissues and 40 mL extractant were macerated in a blender, washed twice with 10mL solvent and centrifuged twice at 4,500 g for 25 min. The supernatant was used to measure absorbance at 532 nm and converted to anthocyanin by standard curve. Additional samples of 65 fruits were placed in a storage room at 0℃ and 93% RH for 80 days. Upon removal from cold storage, 15 fruit were assessed for flesh firmness, while the remaining 50 fruit were kept at 20℃ for 7 days to evaluate physiological disorders.

Statistical analysis. The statistical design was completely randomized with treatment replicated 10 times with single tree plots. Data were analyzed using the SAS analysis of variance procedure (release 6.09; SAS Inst., Cary, N.C.).

Table 1. Effect of EFW treatment on macronutrient elements in fruit skin, flesh, leaf and one-year-old shoot-bark tissues of Fuji apple trees.

Treatment	N (%)	K (%)	Ca (%)	Mg (%)
		Fruit skin		
EFW	0.27	0.64	0.032	0.060
Control	0.34	0.62	0.023	0.062
Significance	*	NS	**	NS
		Fruit flesh		
EFW	0.21	0.67	0.015	0.019
Control	0.25	0.74	0.013	0.020
Significance	*	NS	*	NS
		Leaf		
EFW	2.09	1.33	1.69	0.35
Control	2.32	1.48	1.84	0.32
Significance	*	NS	*	NS
		Shoot-bark		
EFW	1.33	0.64	0.56	0.24
Control	1.54	0.67	0.62	0.19
Significance	*	NS	*	NS

NS,*, ** Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Table 2. Effect of EFW treatment on net photosynthesis of leaves and root activity of Fuji apple trees.

Treatment	Net photosynthesis (μmolm-2sec-1)		Root activity
	Outside[z]	Inside[z]	(formazan μgg-1h-1)
EFW	14.77	7.24	336
Control	11.62	5.35	189
Significance	*	*	**

[z]Sampling position of leaves in tree canopy.
*,**Significant at $P \leq 0.05$ or 0.01, respectively.

Table 3. Effect of EFW treatment on fruit qualities of Fuji apples at harvest and cold storage.

Treatment	Fruite wt. (g)	Soluble solid concn (%)	Titratable acidity	Fruit firmness (N)	Anthocyanin (mg · cm^{-2})	Core browning[z]
			At harvest			
EFW	325	16.0	0.41	75.8	12.8	1.2
Control	310	14.9	0.42	72.0	10.3	3.5
Significance	NS	**	NS	*	*	*
			At 80 days after cold storage			
EFW	318	14.6	0.32	67.4	11.6	3.7
Control	307	13.5	0.35	54.8	9.5	6.7
Significance	NS	**	NS	**	*	**

[z]0=none, 1=trace, 3=slight, 5=moderate, 7=severe, 9=extreme.
NS,*,**Nonsignificant or significant at P=0.05 or 0.01, respectively.

Results and Discussion

The supply of EFW and EFP to orchard soil under the tree canopy resulted in lower N, and higher Ca concentrations in the fruit skins of Fuji apple (Table 1). In fruit flesh tissues, Ca levels dropped dramatically in comparison to fruit skins, but remained higher than in the control. In contrast N and Ca concentrations in leaf and shoot-bark tissues were significantly decreased after EFW treatment. However, there were no significant differences in K and Mg concentrations in either the fruit, leaf or shoot-bark tissues between EFW and control.

EFW supply stimulated net photosynthesis in leaves of the outer and inner canopies of the,Fuji apple trees (Table 2). Root activity was increased by as much as 78 % with the EFW treatment compared with the control.

SSC of fruit juice and anthocyanin level in fruit skin were significantly increased by EFW treatment. Little core browning was observed in control fruits after harvest, but further less in EFW treated fruits. After 80 days of cold storage, the EFW treated fruits showed higher SSC, fruit firmness, and lower core browning (Table 3).

Several functional waters and substances have been produced by ultra-sonic irradiation (Koda and Nomura, 1994), oxidative electrolyzation (Masayo, 1994), and energy-imprinting (Bahng et al., 1996; Kim and Chung, 1997) and they have been used to improve the productivity and quality of crop plants. Using 'Open-All', a soil conditioner manufactured by the CMH Environmental Group (1993), SSC, berry set, and yields of grapes were increased in California vineyards. Many researchers have also reported that a higher Ca in plant tissues reduced *Gloesporium perennans* in apples (Sharpless and Johnson, 1977), *Rhizoctonia solani* in beans (Bateman and Lumsden, 1965), *Botrytis cinera* in lettuces (Krauss, 1971), and *Fusarium* wilt in tomatoes

(Corden, 1965). Furthermore, Makino (1994) found that energized pi (π) water stimulated seed germination, and resulted in higher yields of corn, radish and potato. Ita (1995) reported that SSC and fruit weight in melons and fruit weight in cucumbers were increased by spraying with oxidative electrolytic water, while powdery mildew of the plants could also be controlled without fungicides in plastic film houses. In a previous study it was reported that EFW could function as a neutralizing agent for acid soils, increasing Ca and Mg in farm lands, activating nutrient metabolism in plants, and improving disease resistance (Kim and Chung, 1997). In this experiment the supply of EFW to Fuji apple orchard significantly influenced the increased pH of the soils from 5.6 to 6.3 and the Ca contents of the fruit, although there was no difference in Mg concentrations between the EFW treatment and control. A higher SSC in the fruits may be related to the increased root activity and net photo- synthesis in EFW-treated trees. Yoo (1996) has also reported that cherry tomatoes treated with EFW increased the yield and SSC compared to the controls. Lower levels of exchangeable Ca in fruit tissues has been related to more bitter pits in apples (Yamazaki et al., 1968; Kim, 1991; Ferguson and Watkins, 1983). It was quite remarkable that higher Ca and/or lower N in fruits showed a lower bitter rot incidence during the preharvest stages, but a lower bitter pit, a decreased respiration, and decreased ethylene evolution during postharvest storage. In the present study, EFW supply resulted in several orchard soil conditioning effects, increasing pH, Ca and Mg contents, and increasing the SSC and Ca contents of Fuji apple fruit, as well as stimulating root activity and the net photosynthetic rate of the leaves. Core browning and other physiological disorders during cold storage were remarkably reduced after EFW supply.

In conclusion, EFW seemed to be effective on the growth and quality of apples. More understanding of functional water and its relationship with the growth and development of apple trees and fruit is important for effective orchard management.

Literature Cited

Bahng, G.W., H.J. Kim, W.S. Kim, and Y.S. Kim. 1996. Making and characterization of polyethylene film for greenhouse utilizing energized water. Research Report. KRISS- 96- 097-IR. Ministry of Science and Technology. Seoul.

Bateman, D.F. and R.D. Lumsden. 1965. Relation between calcium content and nature of the pectic substances in bean hypocotyls of different ages to susceptibility to an isolate of *Rhizoctonia solani*. Phytopathology 55:734-738.

Bennett, W.F. 1993. Nutrient deficiencies and toxicities in crop plants. The American Phytopathological Society. APS Press. Minn.

CMH Environmental Group. 1993. The nature tank : The Open-All, family of soil and water conditioners. Calif.

Corden, M.E. 1965. Influence of calcium nutrition on *Fusarium* wilt of tomato and polygalacturonase activity. Phytopathology 55:222-224.

Ferguson, I.B. and C.B. Watkins. 1983. Cation distribution and balance in apple fruit in relation to calcium treatments for bitter pit. Scientia Hort. 19:301-310.

Fuleki, T. and F. J. Francis. 1968. Quantitative methods for anthocyanins. I. Extraction and determination for total anthocyain in cranberries. J. Food Sci. 33:72-77

Ita, S.K. 1995. Studies on use and its effect of the oxidative electrolytic water in agriculture. The Research Report of Miyajaki Univ., Miyajaki.

Kim, M.S. 1991. Relation of the bitter pit development with mineral nutrients, cultivate and rootstocks in apple (*Malus domestica* Borkh.). Ph.D. Thesis. Seoul National Univ., Seoul.

Kim, W.S. and S.J. Chung. 1997. Bio-Green functional water supply influences mineral uptake and fruit quality in Tsugaru apples. J. Korean Soc. Biol. Product. Facilities & Environment Control 6:71-79.

Koda, S. and H.Y. Nomura. 1994. Ultrasonic irradiation effect on water. p. 103-109. In : Symposium of functional water. Tokyo.

Krauss, A. 1971. Einfluss der Ernahrung des Salats mit Massennahrstoffen auf den Befall mit *Botrytis cinera* Pers. Z. Pflanzenernaehr. Bodenkd 128:12- 23.

Lee, D.K. and J.C. Lee. 1994. Studies on flooding resistance in fruit trees. 2. Physiological changes according to flooding. J. Kor. Soc. Hort. Sci. 32:97-101.

Makino, S.J. 1994. Marvelous pi (π) water ; water revolution securing for the earth and human. I.B.E. Co., Aichi.

Masayo, H. 1994. Washing of endoscopy by functional water and application of functional water for diseases of digestive organ. In : Symposium of functional water. Tokyo.

Matsmoto, K.S. 1994. Natural cultivation of agricultural crops by effective microorganisms (EM). International Research and Development Center for Natural Agrocultivation. Tokyo.

Nightingale, A.E. 1994. Commercial growers have high success rate with Spray-N-Grow. Grower News. Texas.

Sharpless, R.O. and D.S. Johnson. 1977. The influence of calcium on senescence changes in apple. Ann. Appl. Biol. 85:450-453.

Sinsno, W.S. 1994. The use of oxidative electrolytic water in crops. The Research Report of Miyajaki Univ., Miyajaki.

Yamazaki, T., T. Niizuma and T. Taguchi. 1968. Studies on the soil fertility of apple orchard. II. Relation to the occurrence of bitter pit and the soil cations. J. Jpn. Soc. Hort. Sci. 37:185-191.

Yoo, S.H. 1996. Tomato cultivation by the application of energized water in plastic film house. Education Center. National Agricultural Cooperative Federation. Ansung, Korea.

Energized 기능수 처리에 따른 후지사과의 잎, 뿌리 및 과실특성

김월수 · 정순주
전남대학교 원예학과

초 록

Energized 기능수는 미약 에너지 발생 신소재로서 다음과 같은 공정을 거쳐서 경원생명과학연구소에서 제조되었다: 지하수 순수화 처리촉매제 첨가 에너지 imprinting in platinum column 재료혼합 energized water + 특수처리된 zeolite + 광합성 세균균주 발효 (25C) 여과 최종산물 energized 기능수 (여과액) + energized powder (잔유물) .

후지사과 나무가 발아하기 전에 주당 3kg의 energized power를 수관하부에 살포하여 토양과 혼합하고 energized 기능수를 생육기 동안 3회에 걸쳐 토양관주한 결과 수확된 과실의 과피와 과육에 Ca 함량이 증가된 반면 잎과 신초 수피조직중의 Ca 및 N함량은 감소되었다.

Energized 기능수 처리는 사과나무 잎의 순광합성율과 뿌리활성을 촉진시켰다. 또한 과실특성에 있어서 가용성 고형물과 안토시아닌 함량이 현저히 증가되었고, 과실의 저온저장중 과실경도가 높게 유지되었으며 과심부 갈변현상이 감소되었다. 과실의 유기산 함량은 처리간에 차이가 없었다.

추가 주요어: 사과, 에너지 imprinting, 무기물, 칼슘, 과실특성, 뿌리활력