Foliar Absorption of ^{45}Ca Radioisotope Containing Fertilizers on Different Fruit Trees

M.B. Hossain[1], K.S. Ryu[2,*], J.S. Park[2] and G.T. Kim[2]

[1]Soil Science Division, Bangladesh Institute of Nuclear Agriculture (BINA), P.O. Box-4, Mymensingh 2200, Bangladesh.
[2]Department of Food and Bioenvironmental Science, College of Life & Environment Sciences, Daegu University, Kyongsan, Kyongbuk, Korea 712-714, Republic of Korea

**Corresponding author. Email: ryuks@daegu.ac.kr*

Abstract

Foliar experiments were conducted to identify the absorption efficiency of ^{45}Ca enriched incalgyun and monocalcium phosphate fertilizers at different duration on pear, apple and peach. Factorial experiment was laid out in a randomized block design with three replications. Pear, apple and peach were the test crops. The absorption capacity was analyzed by using bio-imaging analyzer and liquid scintillation counter. The different type and intensity of colours from the bio-imaging results showed the comparable and representative quantities of calcium absorption in leaf tissue at different duration with different fertilizers. In this regard, bio-imaging findings concluded that pear, apple and peach leaves are efficient organs for absorption of calcium nutrient. The maximum calcium absorption was found 0.859, 1.150 and 0.532 µCi g^{-1} dry weight of leaf using incalgyun fertilizer on pear, apple and peach, respectively whereas the lowest calcium absorption was obtained from monocalcium phosphate fertilizer. Incalgyun absorption was higher than the monocalcium phosphate treated fertilizer. It means that absorption was differently influenced on the nature of the tested fertilizers. The highest and lowest absorption capacity was found in 48 and 6 hrs after application of fertilizers. The absorption capacity was increased with the increase of time and absorption efficiencies in tested trees were found apple>pear>peach. From the interaction results, we may conclude that lower leaf surface along with incalgyun fertilizer could be an effective factor as foliar applied substance. Regression analysis revealed that fertilizer versus different duration showed the positive correlation on pear, apple and peach. For rapid and complete uptake of foliar incalgyun fertilizer is necessary to spray both lower and upper surface as evenly as possible to get optimum yield and improve the quality of fruit.

Keywords: fruit trees, Ca nutrient, foliar absorption, tracer technique

Introduction

Fruit mineral composition plays a key role in their quality (Marcelle, 1995). It is believed that calcium is one of the most critical nutrients determining the fruit quality (Fallahi et al., 1997). Calcium has been reported to enhance color development as well as to promote firmness that keeping quality in a large variety of apple and peach. A large number of calcium related disorders in fruit are well recognized. These are bitter pit of apple and corking in pear and apple. Judicious application of calcium containing fertilizers can prevent or control these disorders. Soil calcium is not successful in enhancing calcium in fruit tissues (Sadowski and Swiderska, 1977). On the other hand, plant leaves readily absorb mineral nutrients and foliar application has been widely used as a method of fertilization (Swietlik and Faust, 1984). So, the practicability using of calcium as a foliar program may offer an immediate short term improvement.

Leaf surface composition is an important factor for the absorption of foliar nutrients because nutrients can penetrate either the cuticle or through the stomata. Whereas the processes governing cuticular uptake have been studied extensively, only little is known about stomatal uptake. In fruit tree leaves stomata are usually more abundant or confined to the lower leaf surface. Some researchers claimed that different plants/species have different capacity to absorb foliar nutrients (Volk and McAuliffe, 1954; Cook and Boynton, 1952) according to their leaf surface structure. Numerous reports have been shown about the leaf surface absorption efficiency in different plants and nutrients especially nitrogenous fertilizer (Rodney, 1952; Totten and McCarty, 2004). However, little is known about the absorption efficiency through lower surface of leaf by foliar applied calcium containing fertilizers on pear, apple and peach. In this situation it is essential to need to determine the absorption efficiency of calcium containing incalgyun and monocalcium phosphate fertilizers on lower leaf surface of pear, apple and peach. Foliar absorption efficiency of calcium can be precisely evaluated by tracer technique method. Therefore, the aim of this study was to examine the absorption efficiency of ^{45}Ca enriched incalgyun and mono-calcium phosphate fertilizers with different duration on pear, apple and peach.

Materials and Methods

Plant Materials and Fertilizers Application

Pear (*Pyrus calleryana*), apple (*Malus domestica*) and peach (*Prunus persica*) experiments were conducted at Daegu University experimental farm in Republic of Korea. Treatments comprised of ^{45}Ca enriched incalgyun and monocalcium phosphate fertilizers in combination with 6, 12, 24 and 48 h duration. Factorial experiment was laid out in a randomized design with three replications. Isotope sample ($^{45}CaCl_2$ was 1 mCi mL^{-1} solution) collected from NEN, USA. Isotopic fertilizers were prepared with an activity of 5 μCi mL^{-1} solution using incalgyun and mono-calcium phosphate fertilizers. Mono-calcium phosphate is a calcium di-hydrogen phosphate [$Ca(H_2PO_4)_2$ $2H_2O$] and incalgyun is a fermented of mono-calcium phosphate using yeast. Fertilizers were applied in the evening on dorsal part of pear, apple and peach leaves in 6, 12, 24 and 48 h duration by the same method as described by Dong et al. (2002).

Leaf Analysis

Bioimaging and liquid scintillation counting were done by Bio-imaging analyzer (Model BAS-1500, Fuji film Tokyo, Japan) and Liquid scintillation counter (Model 6500, Beckman) as outlined by Chung (2001), respectively. Specific activity of radio active calcium calculated as described (IAEA, 1976).

Statistical Analysis

All the collected data were analyzed for ANOVA and Duncan's Multiple Range Test to indicate statistically significant and treatment differences. Regression analysis used to determine the response between fertilizer and different duration in respect of nutrient absorption.

Results and Discussion

Bio-imaging

In Figure 1, the relative utilization of foliar applied radioactive calcium on pear, apple and peach with the progression of time from 6 to 48 h is illustrated. From left to right, the bio-imaging results represented at 6, 12, 24 and 48 h duration using incalgyun and monocalcium phosphate fertilizers. Incalgyun treated leaf colour intensity was higher than the monocalcium phosphate treated leaf. So, incalgyun treated leaf showed higher absorption capacity than monocalcium phosphate fertilizer. The lowest absorption was indicated by light blue colour and the yellow colour produced higher absorption of radio active calcium than blue colour. The absence of the above mentioned colours in leaf failed to absorb calcium after application of fertilizer. The highest and lowest image results observed after 48 and 6 h of fertilizers application. According to color intensity we may conclude that nutrient absorption capacity increased with the increase of time. The different type and intensity of colours from bio-imaging results showed the comparable and representative quantities of radioactive calcium absorption in leaf

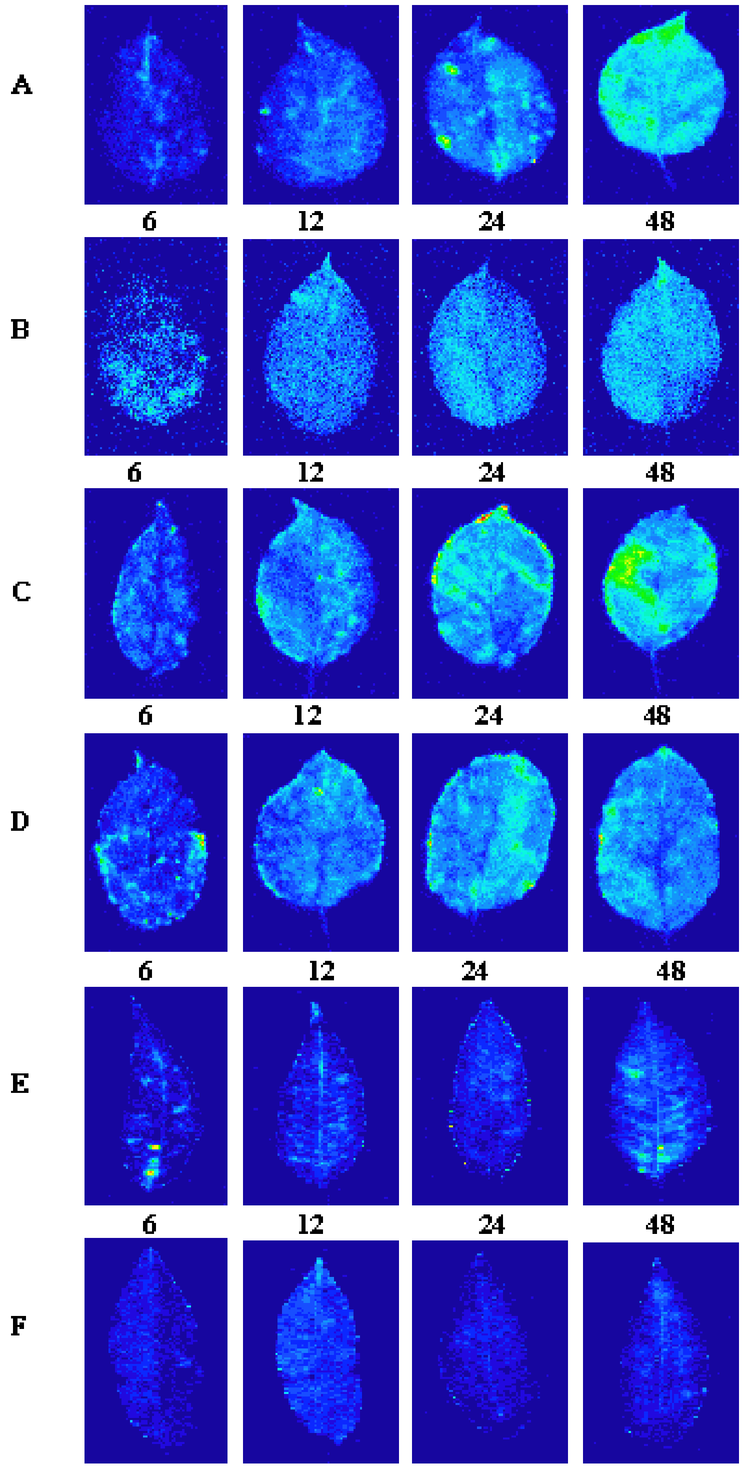

Figure 1 Foliar absorption of ^{45}Ca labeled incalgyun and monocalcium phosphate fertilizers applied to dorsal part of leaves on pear, apple and peach in 6, 12, 24 and 48 h duration after application of fertilizers (A & B: pear; C & D: apple and E & F: peach).

tissue. In this regard, bio-imaging findings concluded that pear, apple and peach leaves are efficient organs for absorption of calcium nutrient. Similar trends were observed as previously mentioned (Wittwer and Lundahl, 1951).

Specific Activity

Specific activity of ^{45}Ca results was presented (Table 1). Absorption capacity was significantly influenced by different factors such as fertilizer and duration. The highest absorption was found 0.859,

Table 1 Effect of ^{45}Ca enriched incalgyun and monocalcium phosphate fertilizers on pear, apple and peach leaves.

Treatment	Fruit tree[1/]		
	Pear	Apple	Peach
	Specific activity ($\mu Ci\ g^{-1}$ dry weight of leaf)		
Fertilizer (F)			
Incalgyun (F_1)	0.859a	1.150a	0.532a
Monocalcium phosphate (F_2)	0.510b	1.041b	0.437b
Duration (D)			
6 hours (D_6)	0.173d	0.373d	0.304d
12 hours (D_{12})	0.607c	0.682c	0.441c
24 hours (D_{24})	0.688b	1.383b	0.546b
48 hours (D_{48})	1.271a	1.942a	0.646a
Interaction (F*D)			
F_1*D_6	0.208e	0.388	0.344
F_1*D_{12}	0.762c	0.734	0.512
F_1*D_{24}	0.908b	1.493	0.551
F_1*D_{48}	1.558a	1.983	0.719
F_2*D_6	0.138e	0.358	0.264
F_2*D_{12}	0.452d	0.630	0.369
F_2*D_{24}	0.468d	1.274	0.541
F_2*D_{48}	0.984b	1.901	0.573
CV(%)	8.48	9.73	11.12

[1/] Mean in the same column having different letters differ significantly at 5% ($p<0.05$) level of significance.

1.150 and 0.532 $\mu Ci\ g^{-1}$ dry weight of pear, apple and peach leaf. Among the fruit trees apple showed the highest absorption capacity (1.150 μCi) using incalgyun fertilizer. Monocalcium phosphate fertilizer showed the lower absorption capacity than incalgyun fertilizer in each tree. There was a significant difference showed between incalgyun and monocalcium phosphate fertilizers on pear, apple and peach. The highest (0.532 μCi) and lowest (0.437 μCi) absorption were found both incalgyun and monocalcium phosphate fertilizers in peach leaf. The absorption efficiency of calcium containing fertilizers in fruit trees showed apple>pear>peach. Because incalgyun is a fermented material after using yeast. Yeast is contributed to produce accelerators to increase the rate of diffusion of molecules as well as to hold sufficient moisture between leaf surface and applied materials which can decrease the surface tension with the resulting decrease in contact angle of the spray droplets on the leaf surface. As a result, incalgyun appeared to be absorbed in greater amount than monocalcium phosphate fertilizer. Some researchers found that rising of the relative humidity, or the presence of a hygroscopic agent might be expected to delay this break of foliar absorption. In that sense monocalcium phosphate fertilizer failed to absorption flow due to rapid drying of the spray to the point of crystallization. Similar findings as previously reported (Buchholz and Schonherr, 2000; Cook & Boynton 1952).

Absorption capacity was significantly influenced by different duration of fertilizer application which was presented in Table 1. The highest and lowest absorption capacity was found after 48 and 6 h duration of fertilizer application. The highest

Table 2 Correlation regression between fertilizer and different duration of fruit trees (n=8).

Parameter	Regression equation	Coefficient value (r)[1/]
^{45}Ca incalgyun Vs duration of pear	y= 0.0287x + 2.1430	0.959**
^{45}Ca monocalcium phosphate Vs duration of pear	y= 0.0181x + 0.1024	0.962**
^{45}Ca incalgyun Vs duration of apple	y= 0.0374x + 0.3083	0.961**
^{45}Ca monocalcium phosphate Vs duration of apple	y= 0.0356x + 0.2654	0.983**
^{45}Ca incalgyun Vs duration of peach	y= 0.0093x + 0.2868	0.985**
^{45}Ca monocalcium phosphate Vs duration of peach	y= 0.0055x + 0.3488	0.723**

[1/] Significant at 1% (**p<0.01) level.

absorption results 1.271, 1.942 and 0.646 µCi calcium g^{-1} dry weight of pear, apple and peach leaves and the lowest results were observed 6 h after application of fertilizers. From these results we may conclude that absorption capacity was increased with the increase of time because the absorbed nutrient utilized by metabolism processes gradually begin to catch up in the leaf for subsequent translocation to other parts of the plant. In that situation the time being studies through dorsal part of leaf observed considerable amount of absorption increased with the increase of time. These findings are in close agreement with the findings described (Cook and Boynton, 1952; Bukovac and Wittwer , 1957). Interaction effect between fertilizer and duration on nutrient absorption was not statistically significant (Table 1) except pear. The highest results were observed using incalgyun plus 48 h duration which followed by monocalcium phosphate fertilizer with 48 h durations for each crop. The lowest absorption results were found both incalgyun and monocalcium phosphate fertilizers including 6 h duration. Lower leaf surface of fruit contain higher number of stomata than the upper surface. From these results, appreciable amount of calcium nutrient absorbed through lower leaf surface of pear, apple and peach. So, it may be conclude that stomata can play a major role in foliar nutrition. These results strongly supported (Eichert et al., 2001; Eichert and Burkhardt, 2001; Schlegel and Schonherr 2002; Totten and McCarty, 2004). So, it is concluded that lower leaf surface along with incalgyun fertilizer could be an effective factor for efficient use of foliar applied substance.

Correlation Regression

Correlation coefficient results regarding incalgyun and monocalcium phosphate fertilizers with different duration on pear, apple and peach leaves were shown (Table 2). Correlation coefficient results showed positively correlated and statistically significant at 1% ($^{**}p<0.01$) level of significance. Correlation coefficient values of incalgyun versus duration and monocalcium phosphate versus duration showed on pear (0.959^{**} & 0.962^{**}), apple (0.961^{**} & 0.983^{**}) and peach (0.985^{**} & 0.723^{**}), respectively. Fertilizer absorption variability increased with the increase of time.

Conclusions

It is concluded that lower leaf surface along with incalgyun fertilizer could be an effective factor for efficient use of foliar applied substance. For rapid and complete uptake of foliar incalgyun fertilizer is necessary to spray both lower and upper surface as evenly as possible to get optimum yield and improve the quality of fruit.

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