Journal of Applied Horticulture, 9(2): 112-114, July-December, 2007

Influence of lysophosphatidylethanolamine application on fruit quality of Thompson Seedless grapes

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Abstract

The effect of foliar applications of lysophosphatidylethanolamine (LPE) on 'Thompson Seedless' (*Vitis vinifera* L.) was evaluated to determine the suitability of this plant amendment aid as a management tool in table grape production. LPE at 10 mg L^{-1} was sprayed on vines at two different stages of berry growth and development. Treatments were: 1) 4 weeks after fruit set; 2) 6 weeks after fruit set; and 3) 4 and 6 weeks after fruit set. Soluble solids content (SSC) of berries at all harvest dates was significantly higher for vines treated with LPE compared to the control. Titratable acidity (TA) gradually decreased during ripening, and by the third harvest, TA of berries from vines treated with LPE was lower than that of control. All the treatments resulted in higher fruit firmness when compared to control. However, there were no significant differences in firmness of berries from vines given LPE treatment at different stages of growth. LPE treatment increased berry size, although no significant difference in size between single and sequential applications of LPE was observed. These results indicate that LPE may play a role in plant hormone-associated regulation of berry growth and development.

Key words: Firmness, plant growth regulators, size, soluble solids content, titratable acidity

Introduction

Lipids are known to play important roles in membrane structure and energy reserves. It is now evident that lipids and their metabolites play important roles in other critical cellular functions particularly as mediators in signal transduction, cell activation, and cell proliferation (Cowan, 2006; Divecha and Irvine, 1995; Ryu *et al.*, 1997). Lysophospholipids are present in biological membranes in trace amounts but their concentration changes during exposure of plants to freezing (Welti *et al.*, 2002), in response to wounding (Lee *et al.*, 1997), and during cell expansion (Lee *et al.*, 2003; Scherer, 2002). Lysophosphatidylethanolamine (LPE) is a minor glycerolipid present in all extra-chloroplastic membranes and is formed from the parent phospholipid, phosphatidylethanolamine (PE) by the action of phospholipase A_2 (PLA_2).

Previous studies showed that LPE, a naturally occurring phospholipid, can retard senescence in attached and detached leaves and fruits of tomato (Farag and Palta, 1993a). LPE-treated tomatoes displayed a longer shelf life whether they were harvested at the breaker, pink, or red stages of maturity (Farag and Palta, 1993b). LPE treatment has also been found to reduce senescence of leaves, fruits and cut-flowers (Kaur and Palta, 1997; Ozgen *et al.*, 2005). It was observed that LPE increased marketable yield, stimulated ripening and extended shelf life of green pepper (Hong and Chung, 2006). Hong (2006) further reported that the influence of LPE on fruit tissue was dependent on the stage of ripening. Thus, in a mature fruit (ready to ripen), LPE stimulated ripening while in a ripened fruit, it inhibited ethylene production and maintained fruit firmness thereby prolonging shelf life.

As mentioned above, LPE has been shown to affect various physiological processes in plants and it was therefore of interest to study the effect of this lysophospholipid on fruit quality of table grapes. 'Thompson Seedless' is one of the most important table grape cultivars grown worldwide, which is marketed nearly year-round throughout the world. Fruit quality parameters are most important for growers and contribute directly to on-farm income and success of the business. Therefore, in the present study the effects of foliar applied LPE on quality parameters, including soluble solids content (SSC), titratable acidity (TA), firmness, and berry size of 'Thompson Seedless' table grapes were investigated. In preliminary small scale experiments, we observed an increase in SSC and firmness of grapes indicating that foliar application of LPE might be an ideal management tool to enhance berry quality of 'Thompson seedless' grapes.

Materials and methods

The study was performed on 8-years old vineyards cv. Thompson Seedless, located at Coltauco, Rancagua, Chile. The experimental design consisted of a randomized block with three replicates of five vines each. Two buffer vines were used between different experimental vines to limit drifting of spray material from adjacent treatments. For single application studies, vines were foliar-sprayed with 10 mg L^{-1} LPE either 4 or 6 weeks after fruit set (December 29, 2005 and January 11, 2006). For sequential treatment, foliar application with 10 mg L^{-1} LPE was carried out at 4 weeks after fruit set, followed by 10 mg L^{-1} LPE at 6 weeks after fruit-set.

Clusters for analysis of SSC and TA were harvested on three occasions and at weekly intervals. Berry firmness and size were measured only at the third harvest. The first sampling was on February 7, 2006. Three clusters were selected at random from each vine and ten berries were collected from each cluster.

For SSC and TA analyses, ten berries without peel were first homogenized in a Waring blender. A refractometer (PR-101, Ataog Co., Ltd., Japan) and an autotitrator (DL 50 Grphix, Mettler-Toledo GmbH, Switzerland) were used to estimate SSC and TA, respectively. TA was measured by titrating the samples to pH 8.2 using 0.1 mol L^{-1} NaOH. Acidity was expressed as an acid factor of 0.075 (tartaric acid).

Fruit firmness and size were determined for berries from the middle part of each cluster harvested at random. For each treatment, 180 berries were analyzed for firmness by digital Durometer (Durofel 25, Agro Technologie, Tarascon, France) and for fruit diameter by caliper without detachment from the vines.

Data were evaluated using GLM procedures in the SAS 6.12 statistical package (SAS Institute, Inc. Cary, N.C.). Differences between treatment means were determined using Fisher's least significant difference (LSD), $P < 0.05$.

Results and discussion

For the first and third harvests, SSC of berries at all harvest dates was significantly higher for vines treated with LPE when compared to control (Table 1). However, there were no significant differences in SSC among the LPE treatments. In the second harvest, SSC of berries was highest for vines sprayed with LPE 4 weeks after fruit set.

The TA for the first harvest did not differ significantly among treatments (Table 1). In the second harvest, TA of berries was lowest for vine sprayed with LPE at 4 weeks after fruit set. For the third harvest, all LPE treatments, regardless of spray timing and frequency, resulted in higher SSC, compared to control. As expected, TA was lower for each treatment in the third harvest compared to the first harvest.

The importance of harvesting grapes at the best stage of maturity is well recognized. Legal minimum standards for maturity based on SSC and TA of berries have been established, but these standards vary considerably for different varieties, locations, and whether the fruit is destined for export or domestic markets. In many countries such as Chile, USA, and Australia, the export regulations require that 'Thompson Seedless' table grape has a minimum of 18°Brix. In early varieties including 'Thompson Seedless' grape, there is a strong desire by growers to harvest as early as possible in the expectation of receiving higher prices for new season fruit. Therefore, it is not unreasonable to suggest that the LPE-induced increase in SSC could contribute to earlier harvests which would be of considerable economic benefit to the grape growers.

All LPE treatments increased berry firmness. There were, however, no significant difference in firmness of berries from vines given LPE treatments at the different stages of growth (Table 2). Fruit firmness is one of the most important commercial characteristics of grapes, especially where fruit is destined for exportation. A problem that sometimes arises with 'Thompson Seedless' table grapes is the occurrence of soft berries. Softer berries reduce the attractiveness of table fruit, and do not store well or as long as firmer berries. Hong and Chung (2006) reported that LPE increased the marketable yield, stimulated ripening, and extended shelf life by increasing firmness in green pepper. It has been found that in a ripened fruit, LPE inhibited ethylene production to prolong shelf life and maintain fruit firmness (Hong, 2006).

Table 1. Effect of foliar-applied LPE on soluble solids content (SSC) and titratable acidity (TA) of 'Thompson Seedless' grape berries at first, second, and third harvest

Treatment^z	SSC (°Brix)	TA (%)
First harvest (Feb. 7, 2006)		
T1	15.7 c^y	0.84 a
T2	16.2 a	0.79 ab
T3	15.9 abc	0.84 a
T4	16.0 ab	0.80 ab
Second harvest (Feb. 14, 2006)		
T1	16.2 d	0.73 a
T2	17.4 a	0.65 b
T3	17.0 b	0.69 ab
T4	16.8 bc	0.70 ab
Third harvest (Feb. 21, 2006)		
T1	16.8 b	0.58 a
T2	17.7 a	0.54 b
T3	17.9 a	0.53 bc
T4	18.0 a	0.55 b

^{z}Treatment
T1: Control
T2: LPE (10 mg L^{-1}) at 4 weeks after fruit set (December 29, 2005)
T3: LPE (10 mg L^{-1}) at 6 weeks after fruit set (January 11, 2006)
T4: LPE (10 mg L^{-1}) at 4 and 6 weeks after fruit set
^{y}Across harvest time, means within columns with different letters are significantly different at $P < 0.05$ (n=45) using Fisher's LSD.

Singh *et al.* (1978) reported that in Thompson Seedless grape, gibberellic acid (GA_3) applied at veraison resulted in higher firmness compared to control, while application at 4 weeks after fruit set had no effect on firmness. In the present study, LPE application at 4 or 6 weeks after fruit set significantly increased fruit firmness.

All LPE treatments increased berry size. However, unlike the situation reported for GA_3 there was no significant difference in size of berries from vines treated with either single or sequential applications of LPE (Table 2). In general, the more applications of GA_3 have resulted bigger berry size at harvest (Gowda *et al.*, 2006; Singh *et al.*, 1978).

In seedless grapes, particularly in cv. Thompson Seedless, GA_3 increased berry size (Ben-Tal, 1990) by enhancing cell division, or cell enlargement, or both (Sachs and Weaver, 1968) which results in increased sugar and water uptake by the berry. It has been reported that the timing of GA_3 application for increasing berry size coincided with that for invertase stimulation and berry size correlates positively with increased invertase activity, indicating

Table 2. Effect of foliar-applied lysophosphatidylethanolamine (LPE) on berry firmness and diameter of 'Thompson Seedless' grapes at third harvest (February 21, 2006)

Treatment^z	Firmness (Durofel Unit)	Diameter (mm)
T1	10.1 b^y	17.9 b
T2	11.1 a	18.3 ab
T3	10.8 a	18.5 a
T4	11.1 a	18.5 a

^{z}Treatment
T1: control
T2: LPE (10 mg L^{-1}) at 4 weeks after fruit set (December 29, 2005)
T3: LPE (10 mg L^{-1}) at 6 weeks after fruit set (January 11, 2006)
T4: LPE (10 mg L^{-1}) at 4 and 6 weeks after fruit set
^{y}Means within columns with different letters are significantly different at $P < 0.05$ (n=180) using Fisher's LSD.

that upregulation of activity and/or synthesis of this enzyme is associated with increased berry size (Perez and Gomes, 2000). We have found that exogenous LPE increased invertase activity in expanding cotyledons of radish and that LPE-induced senescence delay correlates with changes in activity of extracellular acid invertase (data not shown).

In conclusion, results from this study confirm that foliar applications of LPE to 'Thompson seedless' vines increase SSC, fruit firmness, and berry size of table grapes. These results, together with the recent demonstration of the growth regulating activity of LPE (Cowan *et al.*, 2006), suggest that it may play an important role in plant hormone-coordinated regulation of berry growth and development. However, the underlying mechanisms by which exogenous LPE is able to effect physiological change remains to be elucidated. We hope future studies will provide more insight on this important and yet unresolved question.

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