

Effect of irrigation on intensity of respiration and study of sugar and organic acids content in different development stages of *Lonicera kamtschatica* and *Lonicera edulis* berries

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ABSTRACT: This article investigates the effect of irrigation on the intensity of respiration of *Lonicera kamtschatica* and *Lonicera edulis* during different stages of fruit development in the conditions of Nitra in 2002 and 2003. Changes in organic acids and sugar content during fruit ripening process were also monitored within non-irrigated variant of *Lonicera kamtschatica* and *Lonicera edulis* in 2002. The intensity of respiration can be divided into 4 stages corresponding with intensive cell division of fruit (stage I), enlargement of fruit pericarp and fruit colouring (stage II) and fruit softening (stage III). In the early stages of fruit development the intensity of respiration increased (stage I), then declined (stage II), and then increased again to the “climacteric peak” (stage III). In this stage fruit achieved the best quality for direct consumption; it was characterized by the highest sugar content (9.5% in *Lonicera kamtschatica* and 7.7% in *Lonicera edulis*) and the lowest organic acids content (3.61% in *Lonicera kamtschatica* and 3.32% in *Lonicera edulis*). After this stage, fruit became overripe and its quality declined (stage IV). During the two-year observation, there were no statistically significant differences in respiration intensity of fruits of *Lonicera kamtschatica* and *Lonicera edulis* grown with or without irrigation.

Keywords: intensity of respiration; content of sugar and organic acids; irrigation; *Lonicera kamtschatica* (Sevast.) Pojark.; *Lonicera edulis* Turcz. ex Freyn

The intensity of respiration reflects the intensity of metabolism (MARENČÍK 1999). Fruit can be categorized as climacteric (e.g. bananas, pears) and non-climacteric (e.g. strawberries and oranges), depending on whether or not they have a respiratory peak during the process of ripening (BUCHANAN et al. 2000). Internal factors affecting respiration are the type of fruit and the stage of maturity. Respiration rates of climacteric fruit are high early in the development and decline until they rise again as fruits ripen (FONSECA et al. 2002).

Edible honeysuckle originates in Russia and represents a lesser known fruit species in Slovakia. The intensity of respiration and the changes in

organic acids and sugar content during different developmental stages of the fruit have not been investigated. Also, the influence of irrigation on the intensity of respiration has not been studied. *Lonicera kamtschatica* and *Lonicera edulis* fruits contain exceptionally high content of ascorbic acid ranging from 28.56 to 86.96 mg/100 g, potassium 1,017.5 to 1,476.4 mg/100 g and anthocyanins from juice 8.72 to 17.36 g/kg and saft 0.61 to 9.68 g/l (JURÍKOVÁ, MATUŠKOVIČ 2007). PLEKHANOVA (1990) reported on the duration of phenological phases: from the appearance of typical fruit colour to fully ripened fruit it lasts 5–10 days and from flowering to fully ripened fruit it lasts 30–42 days. The effect

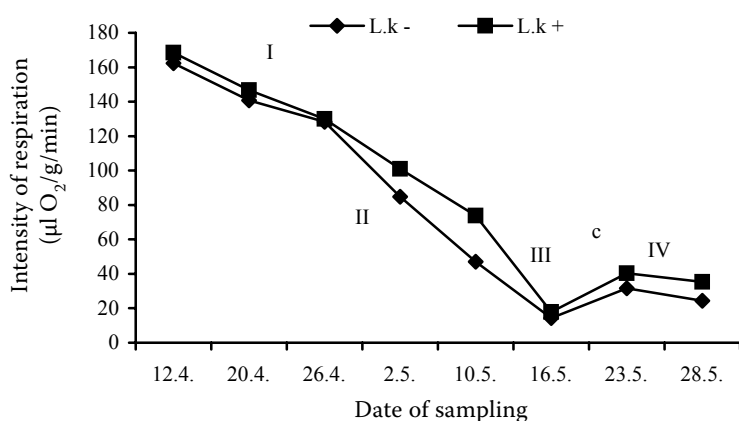


Fig. 1. Study of respiration intensity of *Lonicera kamtschatica* berries in 2002
L.k.- *Lonicera kamtschatica* without irrigation, L.e.- *Lonicera edulis* without irrigation, L.k.+ *Lonicera kamtschatica* with irrigation, L.e.+ *Lonicera edulis* with irrigation, I – IV – intensity of respiration in different development stages of berries, c – climacteric peak of respiration

of temperature and water on fruit development and ripening was studied by PLEKHANOVA (1998); she emphasized that temperature is the most important factor influencing nutrient content, growth, maturation, and storage of edible honeysuckle fruits.

MATERIAL AND METHODS

A trial plot with edible honeysuckle was established in Nitra in autumn 1994. Two-year-old plants of two species, *Lonicera kamtschatica* (Sevast.) Pojark., cultivar Gerda/25, and *Lonicera edulis* Turcz. ex Freyn, were planted at the spacing of 2.0 × 1.5 m. The experimental area was covered with black polyethylene mulch. The soil and climatic conditions of the site were as follows: open level, 130 m above sea level, corn processing area, clay-loam – drift, pH 6.4, mould content of 3.5%, precrop black fallow, average rainfall of 564 mm per year, the temperature in vegetation period of 16.3°C.

Both irrigated and non-irrigated plots were established in order to examine the influence of drip irrigation on the intensity of respiration. Fruit samples were collected at one-week intervals and seven to eight stages of fruit development were examined in

2002 and 2003. These comprised four maturity stages based on skin colour and fruit softening; immature, mid-ripe, ripe, and overripe fruit. Immature fruit had green skin and rapid cell division, mid-ripe had 50% blue and 50% pale green skin and were undergoing cell enlargement, and ripe fruit had the typical skin colour i.e., uniformly blue with waxy coating, and had softened. Overripe fruit was characterized by shrinkage due to water loss. The first berry samples were taken after flowering and were of green pea size. The intensity of respiration was examined as oxygen depletion by the Warburg method under constant laboratory conditions (HOJČUŠ et al. 1981). The intensity of respiration was calculated as µl of O₂ progressed by 1 g of fruit per minute (µl O₂/g/min). The fact that compositional changes during the first stage of maturity have not been previously reported is probably because the compounds produced are of less interest from a sensory standpoint. During the process of fruit maturation, berries were examined for the content of organic acids (by the titration method) and sugar (by the method of Somogyi) within non-irrigated variants of *Lonicera kamtschatica* and *Lonicera edulis* in 2002. A low yield made it impossible to provide the same analyses in 2003.

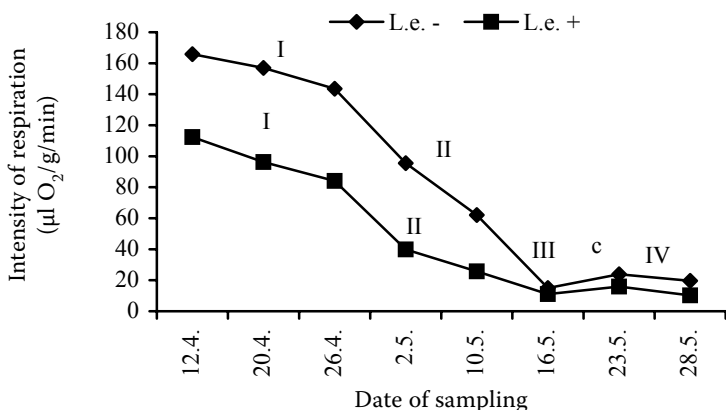


Fig. 2. Study of respiration intensity of *Lonicera edulis* berries in 2002

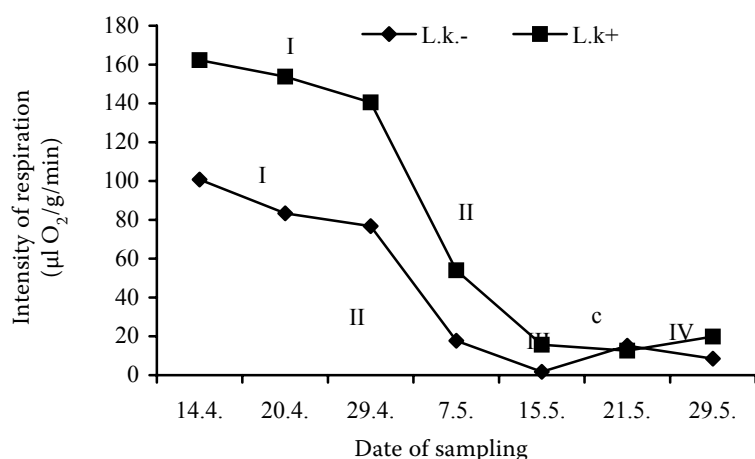


Fig. 3. Study of respiration intensity of *Lonicera kamtschatica* berries in 2003
L.k.- *Lonicera kamtschatica* without irrigation, L.e.- *Lonicera edulis* without irrigation, L.k.+ *Lonicera kamtschatica* with irrigation, L.e.+ *Lonicera edulis* with irrigation, I – IV – intensity of respiration in different development stages of berries, c – climacteric peak of respiration

A randomly chosen sample (10 berries) was kept aside for further characterization as described below. Statistical evaluation was provided by ANOVA (two factorial analysis of variation, Statistica program). The influence of irrigation and year are taken into account as probable sources of variability. They were expressed graphically by unweighted means in the Statistica program. Vertical bars denote 0.95 confidence interval.

RESULTS AND DISCUSSION

The respiration intensity of berries of *Lonicera kamtschatica* and *Lonicera edulis* under irrigation and non-irrigation during 2002–2003 is given in Figs. 1–4.

The intensity of respiration can be divided into 4 stages according to fruit development stages (Figs. 1–4). High intensity of respiration, caused by intensive cell division in the early developmental stage (stage I), was typical for green, immature berries. In stage II when cell enlargement occurs and fruit

colour develops, the respiration curve rapidly declined until May 16 in 2002 and May 15 in 2003. This decrease of 98.3% was the most evident in non-irrigated *Lonicera kamtschatica* in 2003 (Fig. 3). In stage III, when berries softened, a new rise in respiration intensity occurred on May 23 in 2002 and on May 21 in 2003 in all trials except *Lonicera kamtschatica* with irrigation in 2003. This increase in oxygen depletion in stage III is termed the “climacteric” rise in respiration. The highest climacteric peaks were recorded in both irrigated *Lonicera kamtschatica* (88.8%) and *Lonicera edulis* (81.2%) and in non-irrigated *Lonicera edulis* (81.6%) in 2003. The lowest peak occurred in irrigated *Lonicera edulis* (30.8%) in 2002. After the climacteric peak in stage III, fruits became overripe (stage IV).

The same climacteric type of respiration was reported by FONSECA et al. (2002). The respiration increase at the end of the ripening process is in agreement with the results of DOLGAEVA et al. (1987) who studied black currant and MONTERO et al. (1996) who carried out experiments with strawberry.

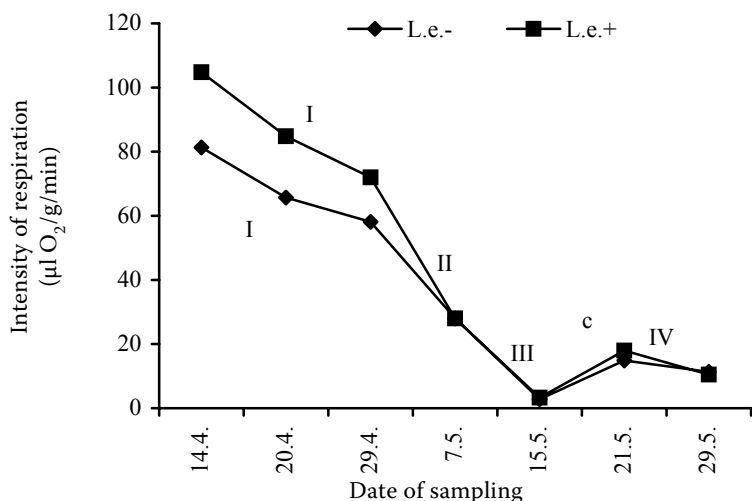


Fig. 4. Study of respiration intensity of *Lonicera edulis* berries in 2003

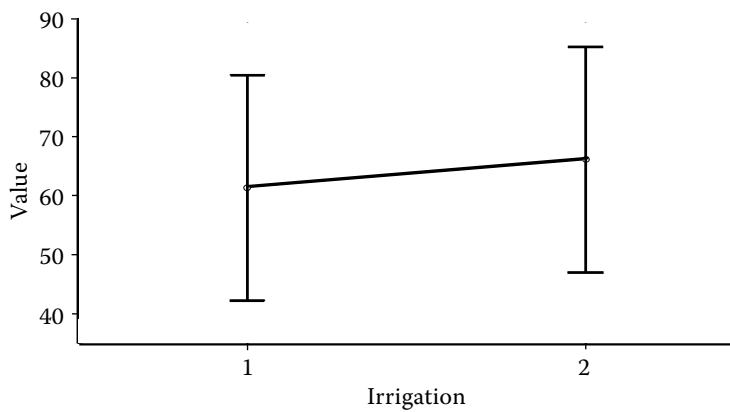


Fig. 5. Statistical evaluation of irrigation effect by unweighted means
1 – non-irrigated variants; 2 – irrigated variants

Comparing irrigated and non-irrigated *Lonicera kamtschatica* and *Lonicera edulis*, we found a higher intensity of respiration in irrigated variants, except for *Lonicera edulis* in 2002 when there was a higher intensity of respiration in non-irrigated (165.9 to 19.6 $\mu\text{l O}_2/\text{g}/\text{min}$) in comparison with irrigated (112.4–10.2 $\mu\text{l O}_2/\text{g}/\text{min}$). However, these differences between irrigated and non-irrigated variants were not statistically significant ($P = 0.72657$) on the probability level ($\alpha = 0.05$) (Fig. 5).

We found a higher respiration intensity in 2002 than in 2003, these differences were, however, not statistically significant ($P = 0.7948$) on the probability level ($\alpha = 0.05$) (Fig. 6), either.

PLEKHANOVA (1998) reported differences in fruit ripening of different species of the edible honeysuckle. On the contrary, we found a similar respiration curve and duration of individual development stages in all variants. We found a comparable respiration intensity in berries of *Lonicera kamtschatica* in both years (in 2002, 168.4–24.3 $\mu\text{l O}_2/\text{g}/\text{min}$ and in 2003, 162.3–8.5 $\mu\text{l O}_2/\text{g}/\text{min}$) and in *Lonicera edulis* only in 2002 (165.9–10.2 $\mu\text{l O}_2/\text{g}/\text{min}$). In 2003, the intensity in *Lonicera edulis* berries was considerably lower (104.8–10.5 $\mu\text{l O}_2/\text{g}/\text{min}$).

The conclusion of this experiment is following: softening of fruit was associated with a climacteric

rise of respiration; increased respiration at the climacteric peak indicated full maturity of fruit. The designation of *Lonicera's* fruit as “climacteric” is important as it affects its handling and storage.

From the appearance of the typical colour to fully ripened fruit it was 5 days. From flowering to fruit ripening it was 41 days in 2002 and 37 days in 2003 which is in accordance with PLEKHANOVA (1990) who reported 30–42 days. BÖHM et al. (1988) reported that fruit of pears initially grow very slowly, with the stage of cell division lasting 3 weeks. On the contrary, we found that this stage lasted 15 to 17 days in fruits of *Lonicera kamtschatica* and *Lonicera edulis*. This same author also reported that cherries achieve fully ripened stage 8 to 12 weeks after fertilization, whereas we determined only 5 to 6 weeks for fruit development. Clearly, fruit of edible honeysuckle belongs to early ripening fruit species (2 weeks before strawberry) as reported by many authors (BURMISTROV 1985; PETROVA 1987; RJABOVA 1990). This fruit is important because it represents the first valuable source of vitamins after winter.

Changes in organic acid and sugar content were examined during the fruit ripening process within non-irrigated variants of *Lonicera kamtschatica* and *Lonicera edulis* in May 2002. Stages II and III, as identified by the studies of respiration intensity, were

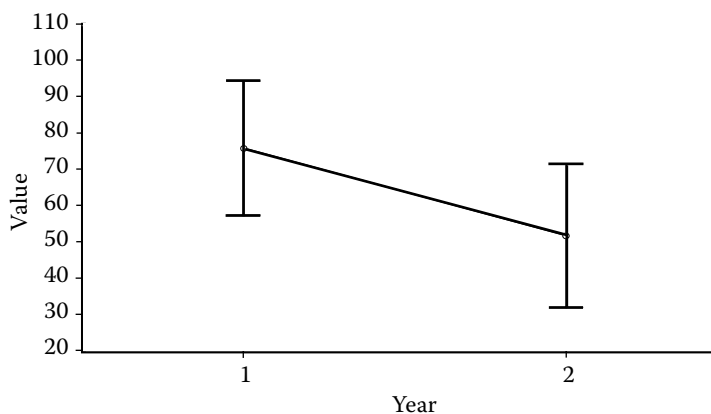


Fig. 6. Statistical evaluation of year effect by unweighted means
1 – 2002; 2 – 2003

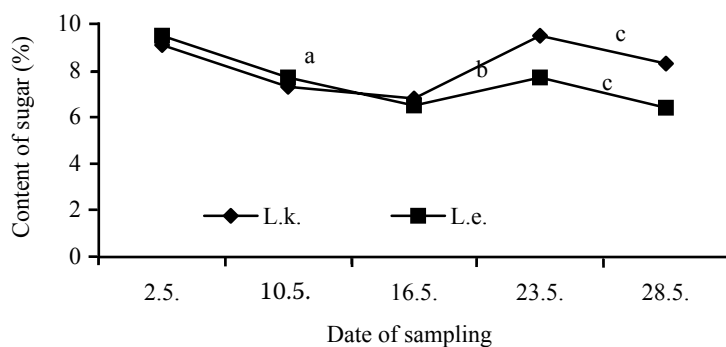


Fig. 7. Evolution of changes in sugar content during fruit ripening in 2002
 a,b,c – accumulation of sugar and organic acids in 3 stages of fruit ripening
 L.k. – *Lonicera kamtschatica* without irrigation
 L.e. – *Lonicera edulis* without irrigation

considered. We found an increase in organic acids content at the beginning of ripening (May 2 to 10) (stage a). When berries enlarged and began to colour the content of organic acids declined to May 23 (stage b) as fruit softened. Finally, as fruits became overripe, it increased again (stage c) (Fig. 8). Sugar content also accumulated in 3 stages (Fig. 7). In the first stage a (May 2 to 16) the tendency of sugar content to decline is associated with a rise of organic acids. In stage b (May 16 to 23), the concentration of sugars increased, it reached the maximum level at the “climacteric peak”, and declined again in stage c. This evolution of organic acids followed a pattern similar to that reported for grape (ESTEBAN et al. 1999). On the contrary, a marked decline in organic acids concentration during the ripening process was reported for sea buckthorn (RAFFO et al. 2004) and for blueberry (AYAZ et al. 2001). According to RUBINSKIENE et al. (2006), in black currant fruits titratable acidity increased at the beginning of ripening and as the ripening process proceeded, it decreased as the content of anthocyanins increased. The initial stages in the evolution of organic acids were confirmed in our experiment but we found an increase in organic acids as fruits became overripe. KANNELIS et al. (1993) reported that the onset of colouring and softening of grape is linked to rapid accumulation

of glucose and fructose and a decrease in organic acids content. In the case of *Lonicera kamtschatica* and *Lonicera edulis*, similarly to grape, the stage of berry softening (23.5) corresponds to rapid sugar accumulation and decline in organic acids. Decomposition of organic acids was evident when berries softened. This was associated with an increase in respiration of all examined samples and was expressed as the “climacteric peak”. These results are in accordance with those reported by RUBINSKIENE et al. (2006).

On the basis of changes in sugar and organic acids content with developmental stages, we conclude that the berries of *Lonicera kamtschatica* and *Lonicera edulis* achieved the best quality for direct consumption in the stage when they are regularly coloured and soften. This stage is characterized by an increase in sugar content and decrease in organic acids and is associated with the “climacteric peak”. Thus, the study of respiration intensity along with the examination of nutrients during the process of ripening can help to determine the optimum date for fruit harvest in order to achieve the best quality for direct consumption.

This study presents the first data for sugar and organic acids content at different maturity stages and their changes in relation to intensity of respiration in *Lonicera* species.

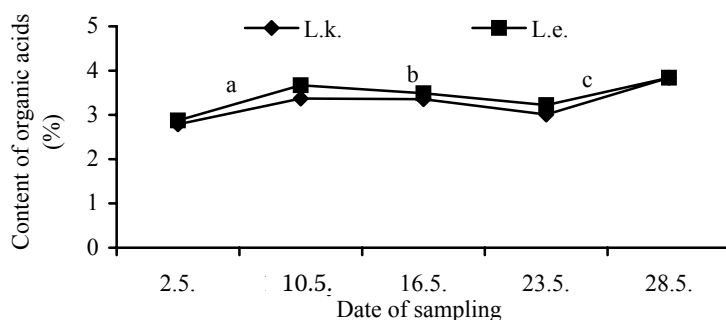


Fig. 8. Evolution of changes in organic acids content during fruit ripening in 2002

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Received for publication September 16, 2008

Accepted after corrections November 25, 2008

Efekt zavlažovania na intenzitu respirácie a štúdium obsahu sacharidov a organických kyselín v rôznych vývinových štádiách bobúľ *Lonicera kamtschatica* a *Lonicera edulis*

ABSTRAKT: Článok sa zaoberá stanovením vplyvu zavlažovania na intenzitu respirácie plodov *Lonicera kamtschatica* and *Lonicera edulis* v rôznych štádiách vývinu v podmienkach Nitra v rokoch 2002 a 2003. Taktiež boli sledované zmeny v obsahu organických kyselín a sacharidov počas procesu dozrievania plodov pri nezavlažovaných variantoch *Lonicera kamtschatica* a *Lonicera edulis* v roku 2002. Štúdiom intenzity respirácie bolo preukázané, že respiračná krivka môže byť rozdelená na štyri štádia zodpovedajúce intenzívnemu deleniu buniek plodu (štádium I), zväčšovaniu buniek oplodia spojeným s vyfarbovaním plodov (štádium II) a napokon mäknutiu plodov (štádium III). V raných štádiách vývinu plodov intenzita respirácie narastá (štádium I) a potom klesá (štádium II) až po dosiahnutie klimakterického vrcholu (štádium III). V tomto štádiu plody dosahujú najlepšiu kvalitu pre priamu konzumáciu charakterizovanú najvyšším obsahom sacharidov (9,5 % u *Lonicera kamtschatica* a 7,7 % u *Lonicera edulis*) a najnižším obsahom organických kyselín (3,61 % u *Lonicera kamtschatica* a 3,32 % u *Lonicera edulis*). Po

dosiahnutí tohto štádia začínajú plody prezrievať a ich kvalita sa zhoršuje. V dvoch rokoch pozorovania neboli zistené štatisticky preukazné rozdiely v intenzite respirácie plodov *Lonicera kamtschatica* a *Lonicera edulis* pestovaných so zavlažovaním a bez zavlažovania.

Kľúčové slová: intenzita respirácie; obsah sacharidov a organických kyselín; závlaha; *Lonicera kamtschatica* (Sevast.) Pojark.; *Lonicera edulis* Turcz. ex Freyn

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