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Short Communication

Changes in sugars in organs of *Phalaenopsis* florets during different flowering stages of intact plant inflorescences

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ABSTRACT

Phalaenopsis flowers possess extraordinary longevity. However, the changes of sugars, including glucose, fructose and sucrose, in organs of floret during different flowering stages of inflorescences attached to a plant have not been reported. To accomplish this, the sugars level in different floret organs were studied at 4 different stages (1. half open, 2. bloom 1 month, 3. bloom 2 months, and 4. wilting). Glucose and fructose were the major soluble sugars in the sepal, petal, labellum, pedicel, and remainder (including the column, anther cap, pollinia, and stigma) of a floret, but their levels decreased from stages 1 to 4. However, the amount of sucrose increased significantly at stage 4 in the sepal, petal, pedicel, and remainder, with the exception that the labellum remained constant throughout all stages. These results demonstrate that glucose and fructose are the major solutes that contribute to floret opening and blooming, and sucrose is salvaged and exported before floret senescence for opening other florets on the same inflorescence. Meanwhile, labellum possesses different sugar metabolism from other organs of *Phalaenopsis* floret.

Keywords : Floret, flowering stages, *Phalaenopsis*, sugars

INTRODUCTION

Phalaenopsis flowers are popular worldwide as they feature a variety of shapes, sizes, colors, and have a long life, reaching up to 3 months (Halevy et al., 1996). Flowers require energy and turgor pressure for opening and blooming. Sugars are the primary energy source in plants (Gibson, 2004). Sugars also act as osmoticum to reduce water potential and provide turgor pressure for flower opening and blooming (Shu et al., 2010). To date, few studies have examined the changes in endogenous sugars in the *Phalaenopsis* flower during different flowering stages.

Among the soluble sugars, sucrose is the most frequently used carbon source in cut flowers, such as *Gerbera jamesonil* (Wani et al., 2012), *Dendrobium* (Ratchanee et al., 2013), and *Lilium* (Majidian et al., 2014). In cut *Dendrobium* inflorescences, sucrose feeding had no effect on the sugar concentrations in the tepals of open flowers, whereas it increased the sugar concentrations in the column and labellum (Ratchanee et al., 2013). These results imply that flower organs differ in terms of their sucrose metabolism. Trivellini et al. (2011) indicated that sugar concentrations in *Hibiscus rosa-sinensis* L. flowers, an ephemeral flower that opens and wilts within 1 day, exhibit a multifarious spatiotemporal partition during development and senescence.

The *Phalaenopsis* floret structure consists of a sepal, petal, labellum, column, anther cap, pollinia, stigma, and pedicle, which connects the floret to the flower stalk (O'Neill et al., 1993). Because the column, anther cap, pollinia, and stigma cannot be easily and quickly dissected, they were collected and denominated as the "remainder" in this study. Moreover, the floret phenotype development was divided into the following stages: (1) half open, (2) bloom 1 month, (3) bloom 2 months, and (4) wilting (Fig. 1). This study offers insights as to how the transitional changes of sugars within the various organs of a floret during different flowering stages on the inflorescences of intact plants.

Fig. 1 : *Phalaenopsis aphrodite* flower developmental stages
Stage 1, half open (A); stage 2, bloom 1 month (B); stage 3, bloom 2 months (C); stage 4, wilting (D). Bar = 1 cm.

Glucose, fructose, and sucrose were the major free soluble sugars in the floral organs of *Phalaenopsis*. The highest glucose content found for the sepal, petal, labellum, remainder, and pedicel were 9.90, 10.82, 10.36, 9.88, and 6.11 mg g^{-1} fresh weight (FW), respectively (Fig. 2A). These high values all appeared at stage 1 and proceeded to exhibit a decreasing trend until stage 4. Similarly, the highest fructose content of the sepal, petal, labellum, remainder, and pedicel (observed at stage 1) were 6.39, 6.93, 5.89, 5.90, and 4.01 mg g^{-1} FW, respectively (Fig. 2B). These too exhibited a decreasing trend until stage 4. Meanwhile, the amount of glucose was always higher than that of fructose in these organs at all four stages.

Conversely, the sucrose content exhibited a decreasing trend until stage 3, then increased in stage 4, at which the highest sucrose contents were 3.45, 3.28, 5.63, and 4.28 mg g^{-1} FW, respectively, in the sepal, petal, remainder, and pedicel (Fig. 2C). However, the sucrose content of the labellum remained constant at each stage. Moreover, at stage 4, sucrose accounted for 68%, 70%, 62%, 46%, and 60% of the total sugar

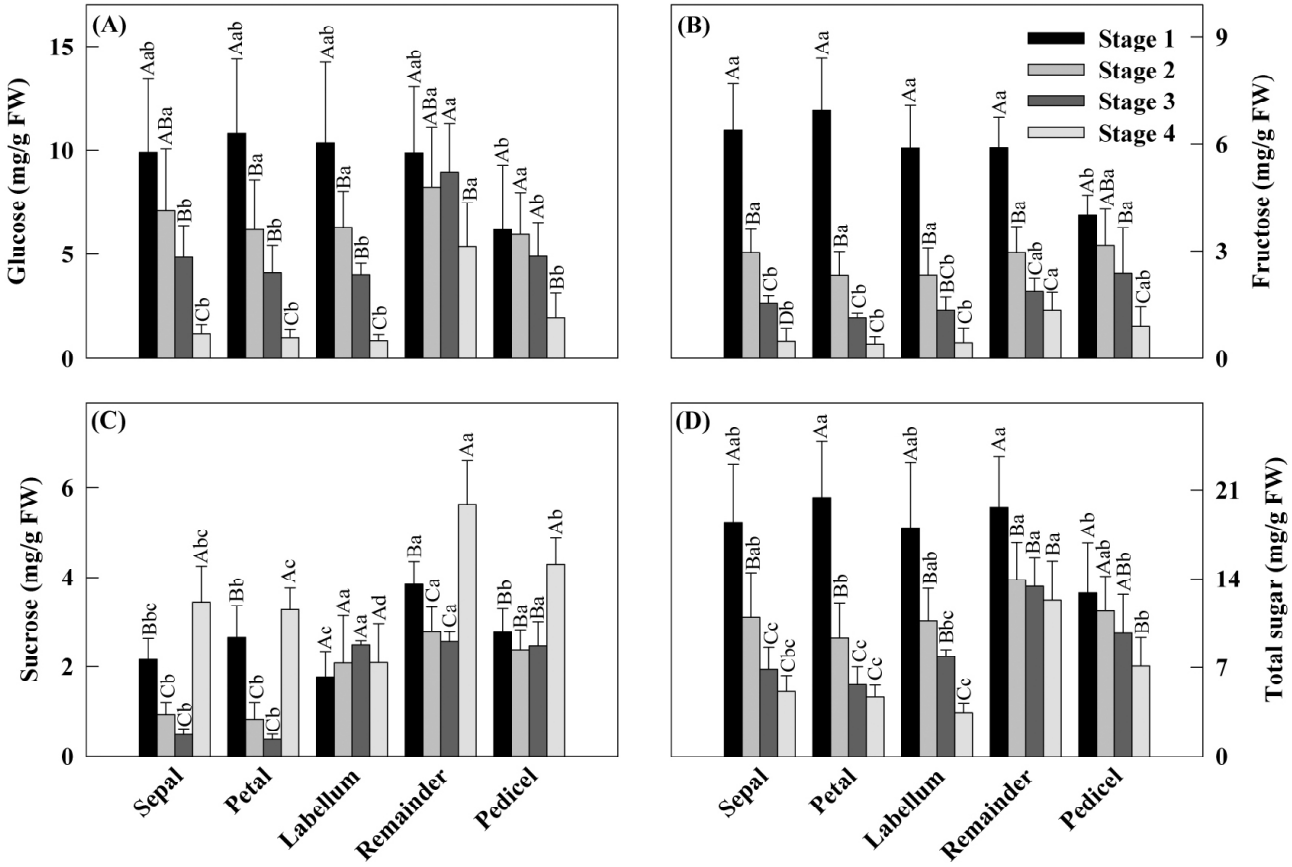

Fig. 2 : Changes in free sugars (mg/g FW) in various organs of Phalaenopsis aphrodite florets during different flowering stages of intact plant inflorescences.

content (the sum of glucose, fructose, and sucrose) in the sepal, petal, labellum, remainder, and pedicel, respectively. Note that sucrose contributed less than 60% only in the remainder.

Fig. 2D shows the total sugar content in different organs declined gradually from stage 1 to stage 4, however, the decline rates in the sepal, petal, and labellum differed from those in the remainder and pedicel. In particular, compared with the total sugar content at stage 1, those at stages 2, 3, and 4 were 59%, 37%, and 26% in the sepal; 46%, 27%, and 23% in the petal; 59%, 44%, and 19% in the labellum; 71%, 68%, and 63% in the remainder; and 89%, 75%, and 55% in the pedicel, respectively. Thus, the decreasing trends of total sugar in the remainder and pedicel were less significant than those in the other organs.

All values are presented as the means ± SE of six individual florets. The different capital letters show statistically significant differences according to least significant difference (LSD) test ($P \leq 0.05$) between the different stages of the same organ. The different lowercase letters show statistically significant differences according to LSD test ($P \leq 0.05$) between the different organs in the same stage.

Although a dramatic decrease in sugar concentration during flower senescence is a universal phenomenon, various species, including cultivars, undergo different changes. In the senescence flower of *Dianthus*, there is a reducing sugar decline in *D. chinensis*; however, reducing sugars remained almost constant from flower opening to senescence in *D. barbatus* (Dar et al., 2015). In the corolla of *Digitalis purpurea*, the glucose content declines more rapidly than the fructose content, resulting in fructose being the major reducing sugar during senescence; meanwhile, sucrose cannot be detected in the flowers (Stead & Moore, 1977). Conversely, in cut flowers of *Lilium*, nearly identical amounts of fructose and glucose are present within the lily tepals during flower bud development (Majidian et al., 2014). Figure 2 shows the glucose, fructose, and total sugar contents all decreased from stage 1 to stage 4, and the average level of glucose was always higher than that of fructose in various floral organs of *Phalaenopsis*.

In contrast to hexoses, the sucrose content significantly increased 7.3-, 8.9-, 2.6-, and 1.7-fold from stage 3 to stage 4 in the sepal, petal, remainder, and pedicel, respectively. However, the content remained constant in the labellum at all four stages. Moreover, at stage 4, sucrose was the major sugar in all organs, accounting for > 60% of the total sugar content, except in the remainder, wherein accounted only for 46%. Based on these results, labellum and remainder possess discrepant sucrose metabolisms, and the increase in sucrose contents in the sepal and petal may act as a crucial indicator in the floret senescence of *Phalaenopsis*. In fact, sucrose content also significantly increases in the wilting petals of *H. rosa-sinensis* (Trivellini et al., 2011). Bieleski (1995) demonstrated that sucrose synthesis occurs during senescence in the daylily petal, and sucrose is the principal sugar in phloem exudate. In *gladiolus* (Yamane et al., 1993) and *Dendrobium* (Ketsa & Wongs-aree, 1995) inflorescence, the wilting floret remobilizes carbohydrates to younger buds on the same inflorescence. The structure of the *Phalaenopsis* floret is the basis of contact between the sepal, petal, and labellum with the remainder, which directly connects to the pedicel. Therefore, it is reasonable to infer that the sucrose in the sepal and petal during the wilting stage is transported through the remainder into the pedicel to salvage the carbon source before floret senescence, thereby opening other florets on the same inflorescence.

In conclusion, the present study is the first to report the spatiotemporal changes in sugars in various organs of *Phalaenopsis* florets from the half-open to wilting stages of intact plant inflorescence. Glucose and fructose contribute to floret opening; however, sucrose may be transported to the pedicel before floret senescence to salvage for opening the other florets on the same inflorescence. More detailed assessments of the distinct mechanisms of sucrose metabolism on various floral organs would offer better insights into the biochemical aspects used to control the senescence of florets that are attached to *Phalaenopsis* inflorescence.

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