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Changes in the rate of photosynthesis and respiration in leaves and berries of Vitis vinifera grapevines at various stages of berry development

by

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Veränderungen der Photosynthese- und Respirationsintensität bei Blättern und Beeren von Reben (Vitis vinifera) während verschiedener Entwicklungsphasen der Beeren

Zusammenfassung. — Bei den Blättern und Beeren der Rebensorten Pusa Seedless und Tas (kernhaltig) wurden mit Hilfe der Warburg-Technik die Photosynthese- und Respirationsintensität zur Zeit des ersten raschen Beerenwachstums (Phase I), des verlangsamten Wachstums (II) und des erneut beschleunigten Beerenwachstums (III) bestimmt. Für weiterführende Untersuchungen erwies sich das 4. Blatt, gegenüber der Traube, als optimal geeignet, da es im Vergleich zu den verschiedenen anders inserierten Blättern die höchste Photosyntheseintensität besitzt.

Bis zur 4. Woche der Beerenentwicklung wurde bei beiden Sorten ein Anstieg, danach bis zur Ernte eine Abnahme der Photosynthese im Blatt gefunden. Die Respiration der Blätter zeigte bei beiden Sorten während des Versuchszeitraumes fast keine Veränderungen.

Bei der Photosynthese der Beeren wurde in der 4. Woche ihrer Entwicklung ein Maximum, in den folgenden Wochen ein allmählicher Rückgang festgestellt. Die Beeren beider Sorten zeigten, vor allem in der ersten Wachstumsphase, einen stetigen Rückgang ihrer Respirationsintensität.

Aus den Untersuchungen kann gefolgert werden, daß die in den grünen Beeren selbst gebildeten Photosynthate keinen nennenswerten Beitrag zum Beerenwachstum leisten und daß ferner durch das Vorhandensein oder Fehlen von Samen die Photosynthese- und Respirationsaktivität von Beeren und Blättern nicht beeinflußt wird.

Introduction

In contrast to western countries, grapes in India are mostly consumed as dessert fruit. Therefore, a good quality and an early maturing of grape cultivars are needed, particularly in North India, where due to early monsoon a lot of spoilage of berries occurs. Two cultivars, namely Pusa Seedless (medium) and Tas (late), which are extensively cultivated in North India, generally suffer from this problem. Therefore, it is necessary to study the various physiological factors, which govern the different phases of berry growth. In a previous paper (3) we have demonstrated that various growth regulators are involved in controlling the berry growth in grapes. The present paper extends the information regarding the changes in the rate of photosynthesis and respiration in leaves and also in berries of these two cultivars, as it was thought that the seed might quantitatively and/or qualitatively affect these two parameters. An attempt has also been made to find out as to how far photosynthates synthesized by leaves and berries contribute to the growth of the berries during different phases of their life cycle.

The developing Pusa Seedless and Tas (seeded) berries take approximately 63 and 77 days respectively after anthesis to reach maturity (2). The growth of the berries follows a biphasic pattern, having two distinct periods of active growth (stage I and stage III). The development prior to the 'colour change' (veraison) is referred to as the first growth period, while subsequent growth up to maturity is referred to as the second growth period. The lag phase (stage II) separates these two growth periods. The first rapid growth lasts up to the 4th week after anthesis in both the cultivars and the second (stage III) between 6—9 weeks in Pusa Seedless and 7—11 weeks in Tas. The lag phase (stage II) is confined to the 5th and 6th weeks in Pusa Seedless and to the 5th, 6th and 7th weeks in Tas (2).

Materials and methods

The experimental material was drawn from fourteen-year-old, four-arm kniffin-trained vines of Pusa Seedless and Tas (seeded) cultivars of *Vitis vinifera* L., grown in the vineyard of the Division of Horticulture and Fruit Technology, Indian Agricultural Research Institute, New Delhi.

Leaf sampling technique was standardized before taking the samples for determining the photosynthetic activity of the vine leaves. For this purpose, eight fully expanded leaves were picked from the nodes 1—8 (from basal to the apical portion of the shoot) in triplicate from three vines of both the cultivars during the first week of the berry development. Ten punches of 5 mm diameter were cut out from the middle portion of each leaf (leaving veins) with the help of a cork borer. Out of these, two were selected randomly, weighed and further used for the determination of the rate of photosynthesis.

A standard Warburg technique was used for measuring the CO_2 and O_2 flux of excised leaves and berries held at 27 ± 1 °C (15). For measuring the photosynthetic activity of excised leaves and berries, Warburg vessels were illuminated by special 40 Watt bulbs mounted underneath the water bath of the apparatus. In case of photosynthesis two leaf discs and about 100—150 mg of excised berry slices (taken from median sized berries) of 1 mm thickness were weighed and floated on 1 ml of 0.1 M $Na_2CO_3/NaHCO_3$ buffer (pH 9.32), whereas for measuring the rate of respiration, four leaf discs and 300—500 mg of berry slices of 1 mm thickness were floated on 1 ml of 0.1 M citrate-phosphate buffer (pH 6.5) in the flask, with 20% KOH (0.2 ml) in the centre well of the flask. A circular filter paper was also kept about 0.5 cm above the well. The apparatus was allowed to run for 10 min. The degree of stability in CO_2 and O_2 flux over that period was found to be approximately 98.5%. All the Warburg measurements were performed in triplicate. The rate of photosynthesis and respiration was determined for two consecutive years (1974 and 1975) and the values presented are the averages of two years' data.

Results

1. Standardization of leaf sampling

The photosynthetic activity of different leaves at various positions of the current year's shoot is shown in Fig. 1. As evident from this figure, the 4th leaf (opposite to the bunch) attained the highest photosynthetic activity as compared to other leaves in both the cultivars. In Tas the increase in the rate of photosynthesis

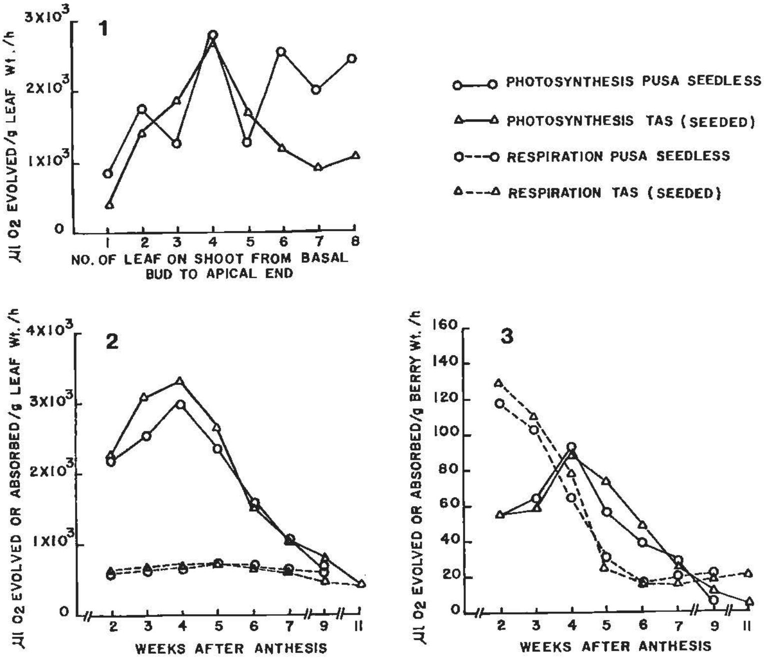

Fig. 1: Photosynthetic activity of leaves at various positions of the shoot.

Fig. 2: Photosynthetic and respiratory activity of leaves opposite to the bunches at various stages of berry development.

Fig. 3: Photosynthetic and respiratory activity of berries at various stages of their development.

Abb. 1: Die Photosyntheseaktivität verschieden inserierter Blätter.

Abb. 2: Die Photosynthese- und Respirationsaktivität der den Trauben opponierten Blätter während verschiedener Phasen der Beerenentwicklung.

Abb. 3: Die Photosynthese- und Respirationsaktivität der Beeren während verschiedener Phasen ihrer Entwicklung.

was linear from 1—4 leaves, which declined gradually up to the 7th leaf with a slight increase in the 8th leaf. However, Pusa Seedless leaves showed a somewhat erratic behaviour.

2. Changes in the photosynthetic and respiratory activity of leaves at various stages of berry development

The photosynthetic activity of leaves was found to increase up to the 4th week (pre-lag phase) of berry development in both the cultivars (Fig. 2). The photosynthetic activity of leaves obtained at the 4th week of berry development was 3000 µl O_2 evolved/g fresh wt./h in Pusa Seedless and 3297 µl O_2 evolved/g fresh wt./h in Tas. After the 4th week there was a continuous decrease in the rate of photosynthesis till harvest in both the cultivars. Tas vine leaves showed a slightly higher rate of photosynthesis as compared to Pusa Seedless leaves in the beginning of the lag phase, thereafter a decrease was noticed during the later part of the lag phase.

The rate of respiration followed almost the similar trend as that of photosynthesis in both the cultivars. It remained almost parallel throughout the experiment, except in Tas vine leaves where a more rapid fall after the 7th week (post-lag phase) was observed and it continued till harvest (Fig. 2). At harvest the rate of respiration of leaves was more or less identical in magnitude to that of photosynthesis in both the cultivars.

3. Changes in photosynthetic and respiratory activity of berries at various stages of their development

Like that of leaves, the peak photosynthetic activity of berries was recorded at the 4th week (pre-lag phase) of berry development in both the cultivars (Fig. 3). Thereafter, a gradual reduction was noticed in the subsequent weeks. At harvest the photosynthetic activity was negligible in both the cultivars (6 μl O_2 evolved/g fresh wt./h).

Berries of both the cultivars showed a decline in their rate of O_2 uptake, expressed on a fresh weight basis, during their development. The decline was greater during the first growth period. Irrespective of the presence or absence of seeds, the initial level of respiration was 118—130 μl O_2/g fresh wt./h and this rate fell to 17 μl O_2/g fresh wt./h towards maturity.

Discussion

In common with other grape cultivars (4, 7), foliage opposite to the bunch showed maximum photosynthetic activity in both the cultivars of grapes under the present investigation. Therefore, the leaf opposite to the bunch was selected as an ideal experimental material for determining the rate of photosynthesis and respiration in both seeded and seedless cultivars of grapes.

Like leaves of many other higher plants (9, 13, 14) the *V. vinifera* leaves achieved the maximum photosynthetic activity at the 4th week after anthesis when they became fully expanded. In Pusa Seedless and Tas cultivars this period can very well be related to the first growth cycle (pre-lag phase) when berries' expansion took place to the magnitude of 35% and 44% respectively (2). After pre-lag phase a steady decline in the rate of photosynthesis was noticed till harvest in both the cultivars. This gradual decrease in the photosynthetic activity of leaves may be due to the entrance of foliage into the stage of senescence, which became more apparent with the bronze colour of leaves. Senescent leaves have reduced capacity to synthesize assimilates (7, 9). The respiration rate of leaves in the two cultivars remained almost similar throughout the berry development, showing thereby no effect of stage of berry development and seed.

Like in leaves, the rate of photosynthesis of berries increased up to the 4th week of berry development (stage I) due to their green colour. It declined rapidly during the lag phase (stage II) accompanied by loss of green colour. In the post-lag phase (stage III) the rate of photosynthesis of berries decreased remarkably as they were approaching the ripening time. A continuous decrease in photosynthetic activity has also been shown in Sultana grape berries during the subsequent weeks of their development (8). In both the cultivars, the photosynthetic activity of berries was negligible as compared to leaves, showing thereby hardly any contribution of the berries for their growth during the various phases of their life cycle.

A very slight uptake of CO_2 by photosynthesis in the skin of detached fruits as compared to the simultaneous uptake of CO_2 by the leaves might have been the reason for the substantial difference between leaf and berry tissue photosynthetic capacity as reported in apple (5). Growth of the berries was mainly associated with the translocation of photosynthates (2), nutrients (12) and also with the influx of sugar and osmotic attraction of water (1) from the leaves to the berries.

The rate of respiration of berries remained very high during the pre-lag phase in both the cultivars. This may be due to the fact that during the beginning of the pre-lag phase berries underwent continuous cell division, which resulted in an increased amount of protein per unit fresh weight. This, in turn, increased the rate of respiration. During the lag phase the rate of respiration greatly fell, particularly at "veraison", with a slight resurgence of the activity during the post-lag phase (stage III) of the berry development in both the cultivars. This slight increase in the respiratory activity of the berries might be due to a change in respiratory substrates, as berries during this period undergo a considerable biochemical differentiation, especially after the lag phase, when they accumulate a wide range of compounds (8, 10, 11). However, no consistent differences in respiration occurred between seeded and seedless cultivars. It would appear that the influence of seed development on respiratory activity is small. Similar results have also been reported earlier (6).

Summary

The photosynthetic and respiratory activity of leaves and berries was measured in Pusa Seedless and Tas (seeded) cultivars with WARBURG technique at pre-lag, lag and post-lag phases of berry development. The fourth leaf opposite to the bunch was found to be the ideal material for further study by virtue of having the highest photosynthetic rate as compared to other leaves at different positions.

The rate of the leaf photosynthesis was found to increase up to the 4th week of berry development, thereafter a decline was noticed till harvest in both the cultivars. The rate of leaf respiration remained almost parallel throughout the experiment in both the cultivars.

The peak photosynthetic activity of berries was recorded at the 4th week of berry development with a gradual reduction in the subsequent weeks in both the cultivars. Berries of both the cultivars showed a decline in their respiratory activity, which was greater during the first growth period.

The main conclusions which can be drawn from the present investigation are that, firstly, photosynthates synthesized by green berries hardly make any contribution to the growth of the berries. Secondly, presence or absence of seeds do not have any effect on the photosynthetic and respiratory activity of berries and leaves.

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