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Hill Reaction, Photosynthesis and Chlorophyll Content in Non-Sugar-Producing (Turnip, *Brassica rapa* L.) and Sugar-Producing (Sugar beet, *Beta vulgaris* L.) Root Crop Plants

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Abstract: A pot experiment was conducted at the Botany Department, A.M.U., Aligarh, on 2 root crop plants, viz. turnip (*Brassica rapa* L.), non-sugar-producing and sugar beet (*Beta vulgaris* L.), sugar-producing, to compare their physiological activity (Hill activity, photosynthesis and chlorophyll content). The seeds of each plant were sown in 20 pots (80% soil + 20% FYM) separately. Two samplings were done at 125 and 140 days (after sowing). Hill activity was measured spectrophotometrically using DCPIP indicator and photosynthesis was assayed by LICOR-6200 Photosynthesis System. Sugar beet gave the maximum leaf-area, Chl *a/b* ratio, stomatal conductance and photosynthesis rate and Hill activity at 125 days. However, the total chlorophyll was higher in turnip at both stages than sugar beet. The stomatal resistance was maximum in turnip at 140 days and minimum in sugar beet at 125 days. The data show that chlorophyll contents are not related to the photosynthesis rate. The latter was most profound in sugar beet at both stages as considerable amounts of photosynthates are transformed into sucrose and therefore sugar beet contains over 20% sugar by weight.

Key Words: Hill activity, photosynthesis, turnip, sugar beet

Introduction

The sun's radiant energy is captured and stored by organisms, viz. plants, algae, and a few species of bacteria, which all have specialised pigments. These organisms have the ability to manufacture carbohydrate in the presence of light through the process of photosynthesis. The photosynthetic efficiency of plants is also considerably diversified. C_3 plants, C_4 plants and CAM plants are very common. In C_3 plants, due to photorespiration the previously fixed carbon is lost by oxidation of RuBP to PGA and CO_2 without the formation of ATP (1,2). CAM plants have developed a system that allows them to photosynthesise while conserving water in their arid environment. C_4 plants have evolved a mechanism that enables them not to merely conserve water, but also to photosynthesise rapidly at high light intensities and high temperature conditions (3,4). Sucrose plays a central role in plant growth and development. It is a major end product of photosynthesis and functions as a primary transport sugar and in some cases as a direct or indirect regulator of gene expression (5).

Even in C_3 plants, the photosynthesis efficiency varies greatly. For example, of the 2 C_3 plants turnip and sugar beet, the latter has more than 20% sucrose and is the major source of sucrose. The turnip does not synthesise sucrose efficiently. The present work examines how the photosynthetic characteristics in relation to leaf area, chlorophyll *a* and *b* contents and their ratio, stomatal conductance, stomatal resistance, photosynthesis rate and Hill activity differ in the non-sugar-producing turnip (*Brassica rapa* L. var. Snowball - family Cruciferae) and the sugar-producing sugar beet (*Beta vulgaris* L. var. Dark Red – Family Chenopodiaceae).

Materials and Methods

This experiment was conducted in a net house of the Botany Department A.M.U., Aligarh, on 2 root crop plants, turnip (*Brassica rapa* L.) and sugar beet (*Beta vulgaris* L.). Forty earthen pots of equal size (25 cm in height and 25 cm in diameter) were cleaned, washed and then completely dried. Before filling the pots with soil, the inner wall of the pot was covered with washed, dried and porous polythene sleeves and the lower part of the polythene was passed through the hole in the bottom of the pot to ensure drainage and aeration. A 5 kg 20% farmyard soil was put in each pot. The soil was analyzed at the Soil Testing Laboratory, Kuarsi Farm, Aligarh (Soil texture: Sandy loam, Nitrogen (N): 225 kg/ha, Phosphorus (P): 15 kg/ha, Potassium (K) 440 kg/ha, pH 7.6). The pots, 20 each for turnip and sugar beet, were arranged in appropriate distance. These (20) pots were kept in the net house in 4 rows, with 5 in each row. The healthy turnip variety Snowball and sugar beet variety Dark Red (obtained from Suttons Seed Company, Kolkata) were selected for the experiment. The seeds were sterilised using ethyl alcohol (95%) and were sown at the depth of 2 cm in soil and left to grow. Hoeing and weeding were done from time to time. Irrigation was done as and when needed but normally at an interval of 2 days. The other cultural practices recommended for these plants were adopted. Assays of chlorophyll content and Hill activity in leaves were done at 125 and 140 days after sowing. Chlorophyll *a* and *b* contents were estimated in fresh leaf pieces by the method described by Lichtenthaler and Buschmann (6). Hill activity in the fresh leaves of the plants was assayed according to Meidner (7) using 2, 6-dichlorophenol-indophenol (DCPIP) dye. For the light source, a 35 mm slide projector with an electrical lamp of 150 W was used. The photosynthesis rate, stomatal conductance and stomatal resistance were analysed by LICOR-6200 Portable Photosynthetic System (USA). The data (with 5 replicates) were statistically analysed (8) and their means and standard errors are given in the Table.

Results and Discussion

The data were collected at 2 stages of growth, viz. 125 and 140 days (after sowing). Sugar beet gave the maximum leaf area at 125 days, while turnip showed the minimum leaf area. C*hl a* content was highest in turnip at 140 days, in which *Chl b* content was also highest. *Chl a/b* ratio was maximum in sugar beet at 125 days and minimum in turnip at 140 days. The total chlorophyll content was maximum in turnip at 140 days and minimum in sugar beet at 140 days. The stomatal conductance was maximum in sugar beet at 125 days and minimum in turnip at 140 days. The stomatal resistance was maximum in turnip at 140 days and minimum in sugar beet at 125 days. As far as the photosynthesis rate was concerned, it was maximum in sugar beet and minimum in turnip at 125 and 140 days. The Hill activity was maximum in sugar beet and minimum in turnip.

Sugar beet has a greater leaf-area and this led to a higher rate of photosynthesis. This fact is also confirmed by the data of photosynthesis, as the sugar beet exhibited higher rate of photosynthesis than turnip, which showed maximum *Chl a, Chl b* and total chlorophyll contents in comparison with sugar beet (Table), revealing that the chlorophyll contents are not related to the photosynthesis rate. Pulkrabek (9) reported similar changes in chlorophyll content throughout the growing season in sugar beet. However, the *Chl a/b* ratio was maximum in turnip at both growth stages, showing that there is a positive relationship between *Chl a/b* ratio and photosynthesis. This is also in accordance with the results

Table. Different photosynthetic characteristics of turnip (*Brassica rapa* L. var. Snowball) and sugar beet (*Beta vulgaris* L. var Dark Red) at 2 stages of maturity, viz. 125 and 140 days (after sowing).*

Parameters	125 days		140 days	
	Turnip	Sugar beet	Turnip	Sugar beet
1. Average leaf area (sq cm)	31.58 ± 12.97	39.88 ± 17.67	34.35 ± 13.58	38.50 ± 11.78
2. Chlorophyll a content (mg ml^{-1})	11.23 ± 0.98	11.12 ± 1.41	11.77 ± 0.53	10.51 ± 1.24
3. Chlorophyll b content (mg ml^{-1})	8.73 ± 0.70	6.94 ± 1.30	9.36 ± 0.43	7.40 ± 1.33
4. Chl a/ Chl b ratio	1.29 ± 0.03	1.60 ± 0.22	1.26 ± 0.11	1.42 ± 0.09
5. Total chlorophyll content (mg ml^{-1})	19.78 ± 1.36	18.06 ± 2.45	21.13 ± 0.18	17.91 ± 2.53
6. Stomatal conductance (mol m^{-2} s^{-1})	0.788 ± 0.041	1.127 ± 0.064	0.763 ± 0.050	1.112 ± 0.061
7. Stomatal resistance (s cm^{-1})	1.882 ± 0.075	1.695 ± 0.075	1.925 ± 0.095	1.740 ± 0.098
8. Photosynthesis rate [μ mol (CO_2) m^{-2} s^{-1}]	26.26 ± 1.41	34.12 ± 1.92	25.75 ± 1.56	33.45 ± 2.00
9. Hill activity (μ mol DCPIP reduced min^{-1} mg^{-1} chlorophyll)	0.612 ± 0.047	0.883 ± 0.84	0.525 ± 0.047	0.773 ± 0.060

*Mean of 5 replicates ± shows the standard error of the data reported by Dinelli et al. (10). Stomatal conductance was higher in sugar beet than in turnip. In contrast, the stomatal resistance showed a reverse trend. Although both parameters are inverse to each other, why both plants reflected this trend is not clear. Photosynthesis rate was most profound in sugar beet at both stages. However, the turnip showed a lower rate of photosynthesis. This fact is not surprising, as in sugar beet considerable amounts of photosynthates are transformed into sucrose. Jerome et al. (11) reported that in sugar beet the mass transfer rate of translocation under conditions of sufficient sink demand is limited by the net photosynthesis rate or more specifically by sucrose synthesis. It is noteworthy here that sugar beet contains over 20% sugars by weight. This is corroborated by the work of Das et al. (12), which also showed that there was an affirmative correlation between photosynthesis rate and sugar content in 72 germplasm accessions of mulberry.

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