ISSN 2229-5518

Growth and chlorophyll levels of selected plants with varying photosynthetic pathways (C_3, C_4 and CAM)

Aparna Rathore, Yogesh.T.Jasrai

Abstract: Chlorophyll is the most prominent pigment in plants that participates in the process of photosynthesis. It is an important factor in determining the rate of photosynthesis. Based on the plastochron index, the chlorophyll concentration of the mature leaf was determined in selected plants (*Catharanthus roseus* (L) G. Don (C_3 plant)*, Andropogon citratus* DC (C_4 plant) and *Bryophyllum bipinnatum* (Lam) Oken (CAM plant). The plants were grown in earthen pots (diameter 23 cm) under natural conditions in a net-home. The chlorophyll concentration in *Catharanthus roseus* (L) G. Don (C_3 plants) was found to be more than in *Andropogon citratus* DC (C_4 plant) and *Bryophyllum bipinnatum* (Lam) Oken (CAM plant). Based on the plastochron index the growth rate of the C_3 plant was faster than the C_4 and CAM plants. This supports the fact that the C_3 plants are more efficient in growth in comparison to the C_4 and CAM plants.

Key words: C_3, C_4 and CAM plants, chlorophyll concentration, Arnon's method, Plastochron index, growth rate.

1 INTRODUCTION

The rate of photosynthesis is influenced by two factors: external factors including the light, temperature and carbon dioxide; and internal factors which include chlorophyll (Emerson, 1929). Chlorophyll is confined in the thylakoids of the chloroplast (Taiz and Zeiger, 1998). It is the most prominent pigment in the plants for photosynthesis. It is an important factor in plant determining the rate of photosynthesis (Taiz and Zeiger, 1998). More the concentration of chlorophyll more will be the rate of carbon dioxide capture as there will be more trapping centers and hence more will be the rate of growth. It has been experimentally proved that more is the chlorophyll content per unit volume of cells more will be the rate of photosynthesis and hence more the rate of growth (Emerson, 1929). But the chlorophyll composition alone cannot be taken up as criteria for designating a species to be efficient for carbon fixation and growth. There are other factors like the nature of the plant species. Some plant species are naturally more tolerant to the extremes of the climate conditions like drought/water stress and high temperature. C_4 and CAM plants are known to be of such forms and occur in abundance in hot, dry and arid climatic conditions, unlike C_3 plants.

Considering the climate change scenario with increasing temperature and CO_2 levels the responses of the C_3, C_4 and CAM plants can be compared and the most efficient and tolerant of them can be identified. The C_3 plants have Rubisco which functions as an oxygenase when the concentration of CO_2 is low and as carboxylase when the level of CO_2 is optimum. So, the increasing level of CO_2 will be beneficial as no photorespiration will occur and the net primary productivity of the plant will increase (Taiz and Zeiger, 1998). On the other hand the increasing temperature will cause the ratio of [CO_2] to [O_2] to decrease hence decreasing the ratio of carboxylation to oxygenation and leading to more photorespiration in comparison to photosynthesis. Photorespiration leads to release of CO_2, including consumption of O_2 and loss of carbon in the form of dry matter (Taiz and Zeiger, 1998).

The C_4 plants are more tolerant to high temperature and photorespiration as they have PEP carboxylase with a high affinity for substrate HCO_3^-. The stomatal aperture get reduced by the activity of PEP carboxylase hence water is conserved and also the concentration of CO_2 in the bundle sheath prevents photorespiration. Because of these reasons the C_4 plants are more abundant in dry and hot conditions (Taiz and Zeiger, 1998).

CAM plants are more efficient in water utilization as they lose only 50-100g of water for 1 gm of CO_2 gained in comparison to the 250-300 and 400-500 gm of water by the C_4 and C_3 plants respectively. They also have another feature, scotoactive stomata, which open only during night

- *Aparna Rathore is currently pursuing PhD degree program in Botany at Department of Botany, Gujarat University, Ahmedabad, Gujarat, India. E-mail: rathoreaparna@ymail.com*
- *Yogesh T Jasrai is currently Professor and Head, Department of Botany, Gujarat University, Ahmedabad, Gujarat, India. E-mail: yjasrai@gmail.com*

(cool) and close during day (warm). The CO_2 is also taken up only during the night time. As the CO_2 get concentrated in the leaf without escape, leading to reduced photorespiration (Taiz and Zeiger, 1998).

The objective of this study was to determine and compare the chlorophyll content of selected C_3 (*Catharanthus roseus* (L) G. Don), C_4 (*Andropogon citratus* DC) and CAM (*Bryophyllum bipinnatum* (Lam) Oken) plants by the Arnon's method. The study also correlates the chlorophyll content with growth rate (in terms of plastochron index).

2 MATERIAL AND METHOD

The saplings of *Catharanthus roseus* (L) G. Don*, Andropogon citratus* DC and *Bryophyllum bipinnatum* (Lam) Oken were planted in pots (diameter 23 cm) under natural conditions in net-home. Once established, the leaf plastochron index (LPI) of all the selected plants was determined (Dickson and Larson, 1981; Erickson and Michelini, 1957). The plastochron index was used to study the rate of plant growth.

Based on the LPI, mature leaf was used for chlorophyll quantification by Arnon's method (Arnon, 1949). The chlorophyll concentration of the mature leaf was also measured by non-destructive method using Apogee Opti-Sciences Chlorophyll Concentration Meter (CCM) 200.

The carbon dioxide concentration was also measured with the help of Carbon Dioxide Meter (Technovation Series 2005; range- 0-5%).

3 RESULT AND DISCUSSION

The chlorophyll concentration in *Catharanthus roseus* (L) G. Don was 0.373 mg/cm^2 (Table-1), in *Andropogon citratus* DC was 0.14 mg/cm^2 and in *Bryophyllum bipinnatum* (Lam) Oken was 0.043 mg/cm^2. This corroborates earlier reports on chlorophyll concentration in *Catharanthus roseus* (L) G. Don (Karthikeyan et al 2009; Cartmill et al 2008; Pandey et al 2007), *Andropogon citratus* DC (Karthikeyan et al 2009; Kassem et al 2006) and *Bryophyllum bipinnatum* (Lam) Oken (Laszlo et al 2007). Moreover, based on unit area the chlorophyll concentration as computed by CCM-200 was 34.42 ± 4.71, 14.82 ± 2.39 and 10.48 ± 0.41 mg/cm^2 in *Catharanthus roseus* (L) G. Don, *Andropogon citratus* DC and *Bryophyllum bipinnatum* (Lam) Oken respectively.

The chlorophyll levels in C_3 plant (*Catharanthus roseus* (L) G. Don) was found to be more (Table-1) than the C_4 plant (*Andropogon citratus* DC) followed by the CAM plant (*Bryophyllum bipinnatum* (Lam) Oken).This justifies the fact that the C_3 plants have more chlorophyll concentration in comparison to the C_4 and CAM plants.

However, chlorophyll concentration of C_4 plants (*Cynodon dactylon* (L) Pers, *Zea mays* L, *Amaranthus hybridus* L) was noted to be more than the C_3 plants (*Spinacea oleracea* L, *Triticum vulgare* L, *Phytolacca americana* L) (Black and Mayne 1970).

Studies on plastochron index revealed that the new apical leaf buds appeared after a week in case of *Catharanthus roseus* (L) G. Don and developed into a node after two weeks interval. The lateral buds and branches were first to come out in *Catharanthus roseus* (L) G. Don. The C_4 plant, *Andropogon citratus* DC took two weeks for the new leaf to appear and reached to maturity by four weeks. While for CAM plant, *Bryophyllum bipinnatum* (Lam) Oken the growth rate was the slowest and did not show any growth by the end of four weeks. The growth rate of selected C_3 plant was more than the C_4 and CAM plant (Table-2). Earlier, plant growth was studied in *Xanthium* (Erickson and Michelini, 1957), *Pisum sativum* (Ade-Ademilua, 2005), *Phaseolus vulgaris* (Shaik et al 1989), *Glycine max* (Snyder et al 1983).

The carbon dioxide concentration as measured with the CO_2 meter showed variation from 0.06% (in the morning, 6 am) to 0.03 % (after 9 am). The CO_2 concentration was recorded to increase as high as 0.07% (around 10 pm). Similar concentrations of CO_2 have been noted (Wei et al 2003; Ziska et al 2001; Sparling et al 1966).

4 CONCLUSION

The chlorophyll concentration in the C_3 plants was found to be more than the C_4 plants and the CAM plants. The growth rate of the C_3 plant was also more than the C_4 and CAM plants. Hence it indicates that the C_3 plants are more efficient in fixing CO_2 and grow faster in comparison to the C_4 and CAM plants. Doubling the current ambient CO_2 concentration was noted to stimulate the growth of C_4 plants to about 10–20% in contrast to C_3 plants by about 40–45% (Poorter, 1993; Reddy et al 2010) and CAM plants to about 12-16% (Nobel and Hartsock, 1986). This corroborates the fact that C_3 plants are more efficient in sequestering CO_2 as faster growth rate was noted for C_3 plants than the C_4 and CAM plant.

But keeping the climate change scenario into consideration the C_4 and CAM plants are more efficient as they can tolerate high temperature conditions, water stress, inhibit photorespiration and hence lead to the perfect functioning of the photosynthetic pathway. This would help them to survive better in the climate change scenario as they are already tolerant to the harsh climatic conditions while the C_3 plants will need to adapt to the changing climate.

REFERENCE

[1] Dickson, R. E. and Larson, P R. (1981) C_4 fixation metabolic labeling patterns and translocation

profiles during leaf development in *Populus deltoids*. *Planta*, 152: 461-470

[2] Erickson, R. O. and Michelini, F. J. (1957) The Plastochron Index. *American Journal of Botany*, 44: 297-304.

[3] Emerson, R. (1929) Chlorophyll content and rate of photosynthesis. *Proc. National Academy of Sciences*. 15: 281-284

[4] Taiz, L. and Zeiger, E. (1998a) Photosynthesis: The light reaction. In: *Plant Physiology*. Sinauer Associates Inc, Sunderland, Massachusetts pp: 155-250.

[5] Black, C. C. and Mayne, B. C. (1970) P_{700} activity and chlorophyll content of plants with different photosynthetic carbon dioxide fixation cycles. *Plant Physiology*, 45: 738-741.

[6] Arnon, D. I. (1949) Copper enzyme in isolated chloroplast. Polyphenoloxidase in *Beta vulgaris*. *Plant Physiology*. 24: 1-15

[7] Reddy, A. R., Rasineni, G. K., Raghvendra, A. S., (2010). The impact of global elevated CO_2 concentration on photosynthesis and plant productivity. *Current Science* 99: 46-57

[8] Poorter, H., (1993) Interspecific variation in the growth response of plants to an elevated ambient CO_2 concentration. *Vegetatio* 104/105: 77-97.

[9] Kassem, A M, El batawi, I E, Sidky, M A., (2006) Effect Of Solar Energy And Other Drying Methods On Quality Of Some Medicinal Plants. The 14th. Annual Conference of the Misr Society of Agricultural Engineering: 760-776

[10] Karthikeyan, B., Joel, M. M., Jaleel, C A., (2009) Response of Some Medicinal Plants to Vesicular Arbuscular Mycorrhizal Inoculations. *Journal of Scientific Research* 1: 381-386.

[11] Lazlo, B., Lazlo, F., (2007) Physiological Reactions of the Succulent CAM Plant *Bryophyllum daigremontianum* to Increased Salinity. *Contribuţii Botanice*: 47-55

[12] Cartmill, A. D., Valdez-Aguilar, L. A., Bryan, D L., Alarco, A., (2008). Arbuscular mycorrhizal fungi enhance tolerance of Vinca to high alkalinity in irrigation water. *Scientia Horticulturae* 115: 275–284

[13] Pandey, S., Gupta, K., Mukherjee, A. K., (2007). Impact of cadmium and lead on Catharanthus roseus - A phytoremediation study. *Journal of Environmental Biology* 28: 655-662.

[14] Ade-Ademilua OE, Botha CEJ (2005) A re-evaluation of plastochron index in peas - a case for using leaflet length. *South African Journal of Botany* 71: 76-80

[15] Shaik, M., Dickinson, T.A., Steadman, J.R., (1989). Variation in rust susceptibility in beans. Predicting lesion size from leaf developmental stage measured by leaf age, length and plastochron index. *Phytopathology* 79:1035-1042

[16] Synder, F. W., Bunce, J. A., (1983) Use of the Plastochron Index to Evaluate Effects of Light, Temperature and Nitrogen on Growth of Soya Bean (Glycine max L. Merr.) Annals of Botany 52: 895-903

[17] Wei, M., Xing, Y., Ma, H., (2003) Variation of CO_2 concentration in solar greenhouse in Northern China. *Ying Yong Sheng Tai Xue Bao*, 14: 354-358 accessed online http://www.ncbi.nlm.nih.gov/pubmed/12836540 on 5.7.2011

[18] Ziska, L. H., Ghannoum, O., Baker, J. T., Conroy, J., Bunce, J. A., Kobayashi, K., Okada, M., (2001) A global perspective of ground level, ambient carbon dioxide for assessing the response of plants to atmospheric CO_2. *Global Change Biology* 7: 789-796.

[19] Sparling, J H., Alt, M., (1966) The Establishment Of Carbon Dioxide Concentration Gradients In Ontario Woodlands. *Canadian Journal of Botany* 44: 321-329.

[20] Nobel, P. S., Hartsock, T. L., (1986) Short term and long term responses of crassulasean acid metabolism plants to elevated CO_2. *Plant Physiology* 82: 604-606.

TABLE 1

TOTAL CHLOROPHYLL CONCENTRATION IN SELECTED PLANTS

Plants	Chlorophyll concentration (mg/gm)	Chlorophyll concentration (mg/cm^2)
***Catharanthus roseus* (L) G. Don**	**1.263 ± 0.228**	**34.42 ± 4.71**
***Andropogon citratus* DC**	**1.063 ± 0.279**	**14.82 ± 2.39**
***Bryophyllum bipinnatum* (Lam) Oken**	**0.043 ± 0.006**	**10.48 ± 0.41**

TABLE 2

GROWTH RATE OF THE C_3, C_4 AND CAM PLANTS

Plants	**Growth period (week)**			
	1	**2**	**3**	**4**
Catharanthus roseus **(L) G. Don**	**Apical bud appearence**	**Distinct leaf node**	**Lateral buds appear along with new apical buds**	**New node appears**
Andropogon citratus **DC**	**-**	**-**	**-**	**New leaf appears**
Bryophyllum bipinatum **(Lam) Oken**	**-**	**-**	**-**	**No bud appears**