Growth, photosynthetic pigment content and oil yield of *Pogostemon cablin* grown under sun and shade conditions

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Abstract

Patchouli (*Pogostemon cablin* Benth.) plants grown under shade (LI) showed an increased height due to internodal elongation, leaf area, leaf area index, and chlorophyll (Chl) *b*, Chl (*a* + *b*) and carotenoid (Car) contents compared to the plants grown in sunlight (HI). The number of branches and green leaves decreased under LI treatment, with a marginal variation in the patchouli oil yield. A comparison between the relative contents of photosynthetic pigments indicated that Chl *b* and Car accumuled preferentially over Chl *a* in the LI grown plants.

Key words: carotenoids, chlorophyll, irradiance, leaf area, patchouli

Introduction

Patchouli (*Pogostemon cablin* Benth. syn. *P. patchouli* Hook F.) plant is commercially important for its oil, which is used in aromatic industry, and in textile industries for insecticidal activities (Demeters *et al.* 1992, Hasegawa *et al.* 1992, Sharma *et al.* 1992). Patchouli plant is grown mainly in Indonesia, Malayasia, China and to a lesser extent in Madagaskar, Reunions and Seychelles (Maheswari *et al.* 1993). The plant is now domesticated in the planes of India and is grown for industrial production of the essential oil from the shade dried foliage. So far there is hardly any study on the adaptive response of this aromatic crop to various environmental conditions like irradiance, temperature, soil moisture and mineral element content. The adaptive modulation allow the plants to survive and guarantee

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Abbreviations: Chl - chlorophyll; HI - high irradiance (sun light); LAI - leaf area index, LHCP - light harvesting chlorophyll-protein complexes; LI - low irradiance (shade); PS 1 - photosystem 1; PS 2 - photosystem 2.

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the greatest possible efficiency of radiant energy utilization (Masarovičová and Štefančík 1990, Morales *et al.* 1991, Pospíšilová *et al.* 1991). The low irradiance (Singh *et al.* 1988) as well as high irradiance (Barber and Andersson 1992) may be a stress for the plants. These responses vary from one plant species to the other. Plants growing under varying irradiances exhibit phenotypic responses depending upon their genotypic adaptibility to the environment (Björkman 1981, Larcher 1983).

In the present study, the growth, photosynthetic pigment contents and oil yield of patchouli plants grown under LI and HI in the tropics is reported.

Materials and methods

Plants: Patchouli (*Pogostemon cablin* Beth. cv. Johor) was collected from the Indian Institute of Horticultural Research, Bangalore. Stem cuttings (10 cm long) with 6 leaves were treated with 0.2 g dm^{-3} indole butyric acid by quick dip method for rooting in sterile sand in the laboratory. The rooted cuttings were transplanted after 2 weeks of rooting to the pots containing a mixture of sand, soil and manure in proportion of 2:1:1, respectively. The plants were grown for 2 months for the field establishment. Ten pots containing uniform plants were selected for experiments. One set of pots were kept in sunlight (HI) and another set was kept under shade (LI) of a tree canopy (LI = 43 % HI). The experiment was conducted in a randomized block design with 10 replications in each treatment.

Growth measurements: Plant growth was measured after 65 d of stem cutting. The apical buds of the treated plants were tagged. The foliage developing from these buds during 90 d treatment period occupying the third basipetal nodal position from the apex was taken as the experimental sample for pigment analysis. Leaf area was calculated by the equation: length × breadth × 0.76.

Pigment extraction and estimation: Fresh leaves were collected from the field and the pigments were treated with chilled acetone. Chl (*a* and *b*) content was estimated by the method of Arnon (1949) and carotenoid content as described by Liaaen-Jensen and Jensen (1971).

Extraction and estimation of patchouli oil: The yellowing leaves giving aroma were collected and shade dried. Patchouli oil was extracted by steam distillation of the dried leaves and the total oil yield was expressed as the percentage of the shade dried leaf mass. Oven drying or drying under direct sunlight affected the oil yield.

Results

Lowering the irradiance accelerated main shoot elongation by 18 % over the HI plants (Table 1). This elongation was accompanied with a 15 % increase in nodal length. The number of branches in LI plants decreased by 39 % of the HI plants and the number of green leaves decreased from 41 in HI to 22 in LI (Table 1). The number of harvestable yellow leaves was same for both the treatments. To the contrary, the leaf area and leaf area index (LAI) increased under LI by 30 % of that of HI.

The contents of Chl *a*, Chl *b*, Chl *a*+*b* and Car expressed per fresh matter unit increased in LI grown plants by 39, 128, 68 and 95 % over that in HI grown plants, respectively (Table 2). The Chl *a*/*b* and Chl (*a* + *b*)/Car ratios decreased in LI plants compared to the HI plants, suggesting relatively faster accumulation of Chl *b* and Car under LI (Table 2). The pigment distribution pattern per unit area of the foliage was quite different. The Chl *a* content decreased in LI grown plants by 10 % which suggested a 'dilution effect' for Chl *a* as the leaves expanded (Table 2) under shade. It is unlikely that there was any rapid catabolism of Chl *a* which might lead to this dilution effect. The Chl *b*, Chl (*a* + *b*) and Car contents in LI plants were higher than in HI plants.

The patchouli oil yield of LI plants was 2.25 ± 0.05 % compare to 2.4 ± 0.2 % in HI plants. The oil yield was decreased by only 6 % of HI by LI.

Table 1. Changes in morphological parameters and content of pigments of patchouli grown under full sunlight (HI) and in shade (LI). The data are means ± S.E. of 10 (growth characteristics) or 5 pigment content) separate experimental pots. The relative increase (+) or decrease (-) in growth characteristics of LI grown plants over HI grown plants are also shown.

	HI	LI	Change [%]
Plant height [cm]	38.6 ± 2.8	45.4 ± 3.7	+ 18
Nodes per plant	8.1 ± 0.6	8.3 ± 0.5	
Internodal length [cm]	4.8 ± 0.5	5.5 ± 0.4	+ 15
Branches per plant	4.6 ± 0.2	2.8 ± 0.2	- 39
Green leaves per plant	41.0 ± 3.0	22.0 ± 2.0	- 46
Yelow leaves per plant	4.0	4.0	
Leaf area [dm^2 $plant^{-1}$]	14.4 ± 1.6	18.9 ± 1.3	+ 51
Leaf area index	1.6 ± 0.2	2.1 ± 0.2	
Chl *a* [mg g^{-1}(f.m.)]	0.51± 0.05	0.71± 0.05	+ 39
Chl *b* [mg g^{-1}(f.m.)]	0.25± 0.04	0.57± 0.05	+128
Chl *a*+*b* [mg g^{-1}(f.m.)]	0.76± 0.08	1.28± 0.09	+ 68
Car [mg g^{-1}(f.m.)]	0.22± 0.04	0.43± 0.06	+ 95
Chl *a* [mg m^{-2}]	146 ± 10	123 ± 11	- 10
Chl *b* [mg m^{-2}]	71 ± 5	106 ± 8	+ 49
Chl *a*+*b* [mg m^{-2}]	217 ± 19	238 ± 20	+ 10
Car [mg m^{-2}]	62 ± 4	81 ± 6	+ 29
Chl *a*/*b* ratio	2.1± 0.2	1.3± 0.2	
Chl/Car ratio	3.4± 0.4	3.0± 0.2	

Discussion

The increase in plant height and the decrease in the number of branches and leaves in the LI grown patchouli plants suggests the suppression of the development of the shoot and leaf buds by apical dominance (Phillips 1969). These data corroborate with the reports of Nilsen and Bao (1987) on the appearance of leaves in *Rhododendron maximum*.

Generally leaf area and leaf pigment contents increase with decreasing irradiance (Nilsen and Bao 1987, Singh *et al.* 1988, Morales *et al.* 1991). The increase in Chl *a* and decrease in Chl *a/b* ratio may be taken as selection criteria for efficient photosynthesis in LI grown rice plants (Liu *et al.* 1984). In contrast to this hypothesis, Chl *a* content decreased per unit area basis in patchouli; 'pigment dilution' effect (Table 2) suggested that the pigment synthesis could not cope up with the area expansion in LI plants (Misra and Misra 1992).

HI plants have about 40 - 60 % of their Chl in photosystem 2 (PS 2) distal antenna, 10 - 15 % in other sub-units of PS 2 and 30 % in PS 1 complex (Barber 1983). The Chl *b* is present only in the distal antenna whereas Chl *a* is present throughout the pigment-protein complexes (Barber 1987, Hansson and Wydrzynsky 1990). The Chl *b* content of LI leaves increased significantly by 128 % of HI on fresh mass basis and by 49 % on leaf area basis. Because Chl *b* is a pigment of the light-harvesting Chl-protein complexes (LHCP 2), shade treatment could affect the distal antenna of PS 2 responsible for the harvest of solar radiation, rather than the reaction center. Anderson *et al.* (1988) reported that the LHCP 2 content of PS 2 β-centers did not change during adaptation of plants to growth irradiances, but the antenna size of α-centers in appressed thylakoid regions. The inner pool of LHCP 2 appeared to remain stable. However, during long-term adaptation of plants to LI, the distal antenna size increased and *vice versa* (Anderson *et al.* 1988). The increase in the leaf area index along with the enhancement in the distal antenna size could increase solar radiation interception in LI grown patchouli plants.

The variations in the patchouli oil yield, which is an end product of the photosynthetic energy conservation in the green foliage, along with an increase in the leaf area and leaf pigment contents suggests the energy economy of patchouli plant growth and productivity. The adaptive features to HI and LI confer patchouli cultivation as a monocrop under sunlight or in a mixed cropping system where these plants can be grown under the canopy shade of other plants without affecting the oil yield.

References

Anderson, J.M., Chow, W.S., Goodchild, D.J.: Thylakoid membrane organisation in sun/shade acclimation. - Aust. J. Plant Physiol. **15**: 11-16, 1988.

Arnon, D.I.: Copper enzymes in isolated chloroplast. Polyphenoloxidase in *Beta vulgaris*. - Plant Physiol. **24**: 1-5, 1949.

Barber, J.: Photosynthetic reaction centers: A common link. - TIBS **12**: 321-326, 1987.

Barber, J.: Photosynthetic membrane transport in relation to thylakoid membrane composition and organisation. - Plant Cell Environ. **6**: 311-322, 1983.

Barber, J., Andersson, B.: Too much of a good thing: Light can be bad for photosynthesis. - TIBS **17**: 161-166, 1992.

Björkman, O.: Responses to different quantum flux densities. - In: Lange, O.L, Nobel, P.S., Osmond, C.B., Ziegler, H. (ed.): Physiological Plant Ecology. Vol. I. Pp. 57-107. Springer-Verlag, Berlin - Heidelberg - New York 1981.

Demeters, H.B., Wohlgemuth, R., Scheider, E.: On the effect of sweet clover leaves and granular patchouli oil on the webbing clothes moths *Tineola bisselliella* Hum. (Lepidoptera: Tineidae). - Anz. Schädlingskunde Pflanzenschutz Unweltschutz **65**: 81-88, 1992.

Hansson, O., Wydrzynski, T.: Current perception of photosystem II. - Photosynth. Res. **23**: 131-162, 1990.

Hasegawa, Y., Tajima, K., Toi, N., Sugimura, Y.: An additional constituent occurring in the oil from patchouli cultivar. - Flavour Fragrance J. 7: 333-335, 1992.

Larcher, W.: Physiological Plant Ecology. 2nd Ed. - Springer-Verlag, Berlin - Heidelberg - New York 1983.

Liaaen-Jensen, S., Jensen, A.: Quantitative determination of carotenoids in photosynthetic tissues. - In: Colowick, S.P., Kaplan, N.O. (ed.): Methods in Enzymology. Vol. 23. Pp. 586-602. Academic Press, London - New York 1971.

Liu, X.Q., Liu, Z.Y., Ma, D.P., Zeng, S.F.: A study of relationship between chlorophyll content and photosynthetic rate in rice. - Acta agron. sin. **10**: 57-62, 1984.

Maheswari, M.L., Vasant Kumar, T., Sharma, N., Chandel, K.P.S.: Patchouli - an Indian perspective. - Indian Perfumer **37**: 9- 11, 1993.

Masarovičová, E., Štefančík, L.: Some ecophysiological features in sun and shade leaves of tall beach trees. - Biol. Plant. **32**: 374-387, 1990.

Misra, M., Misra, A.N.: Leaf water potential and photosynthetic pigment development of greening leaves from GA_3 treated barley seedlings. - Proc. nat. Acad. Sci. India B **62**: 129-133, 1992.

Morales, D., Jimenez, M.S., Coballero, M.: Morphological and gas exchange of *Canarina canariensis* (L.) Vatke to sun and shade. - Photosynthetica **25**: 481-487, 1991.

Nilsen, E.T., Bao, Y.: The influence of leaf age, season and microclimate on the photosynthetic apparatus of *Rhododendron maximum* I. Chlorophylls. - Photosynthetica **21**: 535-542, 1987.

Phillips, I.D.J.: Apical dominance in plants. - In: Wilkins, M.B.W. (ed.): The Physiology of Plant Growth and Development. Pp. 165-204. McGraw Hill, London 1969.

Pospíšilová, J., Solárová, J., Šrámek, F., Peisker, M.: Long-term effects of irradiance on growth, water relations and epidermal conductance of cyclamen cultivars. - Biol. Plant. **32**: 163-167, 1991.

Sharma, R.N., Gupta, A.S., Patwardhan, S.A., Hebbalkar, D.S., Tare, V.: Bioactivity of laminaceae plants against insects. - Indian J. exp. Biol. **30**: 244-246, 1992.

Singh, V.P., Dube, S.K., Murty, K.S.: Effects of low and high light stress on growth and yield of rice. - Indian J. Plant Physiol. **31**: 84-91, 1988.