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BRIEF COMMUNICATION

Changes in chlorophyll content and photosynthetic rate of four cultivars of mango during reproductive phase

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Abstract

Total chlorophyll (Chl) content, leaf mass per area (LMA), and net photosynthetic rate (P_N) were studied in four cultivars of mango (*Mangifera indica* L.) from September to May. Maximum Chl contents were found in September and December, the period considered to be crucial for flowering in mango. P_N was maximum during October and maintained almost steady during the fruit growth period. However, LMA varied significantly in all cultivars. Mean Chl content, P_N, and LMA were lower in cv. Malaviyabhog than in other cultivars.

Additional key words: fruiting, *Mangifera indica*, seasonal course.

Crop productivity is a function of radiation interception, photosynthetic capacity, efficiency of conversion to dry matter, partitioning of dry matter among organs, and water content of these organs (Ho 1988). In young orchards, the productivity of fruit crops is improved by increasing tree density (Erez 1982, Layne and Tan 1984). As plants mature, shading becomes a problem due to profuse branching and an increase in foliage area. Penetration of photosynthetically active radiation (PAR) generally decreases in deciduous fruit trees as shoot extension continues throughout the season (Marini and Marini 1983). Shaded leaves have lower net photosynthetic rate (P_N) and leaf mass per area (LMA) (Marini and Sowers 1990) and these two parameters generally affect productivity. Chacko *et al.* (1982) reported the inability of thirty

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Abbreviations: Chl - chlorophyll; LMA - leaf mass per leaf area unit; P_N - net photosynthetic rate.

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leaves to support the growth of a single mango fruit to normal size. Chlorophyll (Chl) content and P_N are not always interrelated (Buttery and Buzzell 1977), however, a positive correlation was reported, *e.g.*, in olive (Proietti 1998) or sweet cherry prior to full leaf expansion (Teryl and Kennedy 1986). In apple, the LMA is positively correlated with P_N (Marini and Barden 1981) and this is why it has been used as a tool to determine photosynthetic potential in certain fruit crops (Barden 1975, 1977). Leaf expansion and CO_2 assimilation are important in determining the photosynthetic potential in mango (Tyagi *et al.* 1991). In mango cultivars, the characteristics of regular and irregular bearing are strongly influenced by the environment, but the pattern of changes in Chl content, P_N and LMA during reproductive phase has not yet been properly understood. This is why we studied them in leaves of regular and irregular bearing cultivars of mango during their reproductive phase.

Eight- to ten-year-old trees of four cultivars of mango (*Mangifera indica* L.), regular bearing Amrapalli (Dashehari × Neelum) and Malaviyabhog (polyembryonic, collected from N.E. hill regions of India), and irregular bearing Langra and Dashehari growing in the orchard of the Institute at Varanasi (25.2° N, 83.0° E) were used for experiments in 1994 and 1995. The 4th and 5th leaves of each twig (selected from all directions) of uniform size (20 - 25 cm diameter) and age (3 - 4 years) were used.

Chl was determined according to the Methods of Analysis of the Associations of Official Analytical Chemists (1975), leaf area was calculated following Šesták *et al.* (1971). The leaves were also dried at 110 °C for 1 h and then at 60 °C till constant mass. P_N was measured using a portable gas exchange system *Li-COR 6200* (Lincoln, USA). All measurements were made between 09:00 and 11:00 when photosynthetic photon flux (PPF) exceeded 500 μmol m^{-2} s^{-1}, which is above light saturation for P_N of mango tree. Air flow into the leaf chamber was at rate of 375 cm^3 min^{-1}, and air temperature varied between 25 and 30 °C. Readings were repeated on four leaves per twig or 16 leaves per plant.

Values were evaluated by analysis of variance (*ANOVA*) employing a factorial randomized block design (2-factor). Duncan's multiple range test was used to identify differences among means at $P < 0.05$.

Chl content on a fresh mass basis was maximum in cv. Dashehari during September and December, and similarly in cv. Langra in September, December, and January, while minimum was found in Langra in April (Table 1). However, on leaf area basis, the Chl content was maximum in Dashehari in December, and in Langra and Amrapalli in September, and minimum values were noted in March and May for Amrapalli. LMA was highest in Dashehari in April and October, and lowest in Malaviyabhog in February. Maximum P_N for Amrapalli was observed in October. In other three cultivars P_N did not show any significant differences during measured period (Table 1).

Year mean values (Table 2) showed that Chl content (on both the bases), P_N and LMA were lower in cv. Malaviyabhog than in other cultivars.

The differences in P_N might be in line with the fact that cvs. Dashehari and Amrapalli had thicker leaves than Malaviyabhog and Langra. Such differences in mango in relation to leaf thickness have also been reported by Taylor (1970). The P_N of thicker leaves is probably limited due to increased resistance to CO_2 transfer, and a

Table 1. Changes in chlorophyll content, leaf mass per area and photosynthetic rate in leaves of four cultivars of mango during growing season. Different letters in superscript following the values indicate statistically significant differences at $P < 0.05$.

Cultivar/parameter	September	October	November	December	January	February	March	April	May
Amrapalli									
Chl [g kg^{-1}(f.m.)]	2.72^{b-e}	2.79^{b-d}	2.15$^{?-i}$	2.72^{b-e}	1.91^{g-l}	2.75^{b-e}	1.86^{g-l}	1.56^{i-n}	1.50^{l-n}
Chl [g m^{-2}]	0.91^{ab}	0.86^{a-c}	0.64^{e-i}	0.80^{b-e}	0.55^{i-l}	0.77^{b-e}	0.31^{m}	0.51^{h-m}	0.31^{n}
LMA [g m^{-2}]	111.20^{a-d}	129.30^{a-c}	129.70^{a-c}	95.00^{b-i}	96.00^{b-h}	83.30^{d-i}	85.80^{d-i}	127.00^{a-c}	101.20^{b-h}
P_N [µmol(CO$_2$) m^{-2} s^{-1}]	6.52^{a}	6.86^{a}	4.58^{a}	4.49^{a}	5.45^{a}	6.48^{a}	6.17^{a}	6.34^{a}	5.56^{a}
Malaviyabhog									
Chl [g kg^{-1}(f.m.)]	2.25^{e-g}	2.18^{f-h}	1.83^{i-l}	2.25^{e-g}	1.71^{h-m}	2.33^{d-g}	1.50^{k-n}	1.30^{mn}	1.51^{k-n}
Chl [g m^{-2}]	0.50^{h-m}	0.52^{g-m}	0.45^{i-m}	0.43^{i-m}	0.38^{k-m}	0.50^{i-m}	0.59^{e-k}	0.35^{lm}	0.44^{i-m}
LMA [g m^{-2}]	81.80^{e-i}	103.70^{b-h}	100.80^{b-h}	70.50^{f-i}	69.80^{f-i}	56.80^{i}	65.40^{hi}	108.20^{a-f}	98.80^{b-h}
P_N [µmol(CO$_2$) m^{-2} s^{-1}]	5.79^{a}	5.50^{a}	4.29^{a}	4.41^{a}	4.48^{a}	4.75^{a}	4.99^{a}	5.50^{a}	4.46^{a}
Langra									
Chl [g kg^{-1}(f.m.)]	3.84^{a}	3.02^{b}	2.83^{b-d}	3.59^{a}	3.51^{a}	2.80^{b-d}	1.44^{l-n}	1.11^{n}	1.82^{i-l}
Chl [g m^{-2}]	0.94^{ab}	0.75^{b-f}	0.74^{b-g}	0.85^{b-d}	0.84^{b-d}	0.61^{e-j}	0.45^{i-m}	0.41^{j-m}	0.60^{e-l}
LMA [g m^{-2}]	100.00^{b-h}	103.00^{b-h}	78.00^{d-i}	76.50^{d-i}	71.80^{e-i}	78.80^{d-i}	98.00^{b-h}	113.50^{a-d}	110.50^{a-e}
P_N [µmol(CO$_2$) m^{-2} s^{-1}]	5.18^{a}	5.95^{a}	4.80^{a}	4.46^{a}	6.01^{a}	4.31^{a}	5.69^{a}	6.00^{a}	4.45^{a}
Dashehari									
Chl [g kg^{-1}(f.m.)]	3.99^{a}	2.89^{bc}	2.51^{c-f}	3.99^{a}	1.64^{j-m}	2.89^{bc}	2.09^{f-l}	1.67^{i-m}	2.01^{f-k}
Chl [g m^{-2}]	0.53^{f-m}	0.86^{a-d}	0.69^{c-h}	1.09^{a}	0.46^{i-m}	0.73^{b-g}	0.48^{h-m}	0.62^{e-i}	0.42^{i-m}
LMA [g m^{-2}]	102.00^{b-h}	133.80^{ab}	129.60^{a-c}	106.20^{a-g}	93.50^{c-i}	98.50^{b-h}	112.20^{a-d}	146.20^{a}	66.60^{g-i}
P_N [µmol(CO$_2$) m^{-2} s^{-1}]	6.03^{a}	6.00^{a}	5.75^{a}	5.17^{a}	4.39^{a}	4.77^{a}	6.78^{a}	6.19^{a}	5.24^{a}

decrease in radiation reaching inner leaf part (Gutschick 1984a,b). Minimum LMA of Malaviyabhog indicated its lower dry matter accumulation per unit leaf area than in other cultivars (Table 2). Similar results have also been reported by Tyagi and Medhabati (1988). This cultivar had also less Chl on both used bases than the other three cultivars.

Table 2. Differences in mean chlorophyll content, leaf mass per area (LMA) and net photosynthetic rate (P_N) in leaves of four cultivars of mango. Different letters in superscript indicate statistically different values in columns at $P < 0.05$.

Cultivar	Chlorophyll [g kg^{-1}(f.m.)]	[g m^{-2}]	LMA [g m^{-2}]	P_N [μmol(CO_2) m^{-2} s^{-1}]
Amrapalli	2.22^b	0.63^a	106.50^a	5.83^a
Malaviyabhog	1.88^c	0.46^b	84.00^b	4.91^b
Langra	2.66^a	0.69^a	92.20^b	5.21^{ab}
Dashehari	2.63^a	0.65^a	109.80^a	5.59^{ab}

In general, maximum Chl content was found during September and December, the period crucial for flower bud initiation in mango (Singh 1960). A second increase in Chl content was noticed during February which coincides with resumption of fruit setting to suffice the demand of developing sink. For fruit development the sink demand for photosynthates is a key factor determining the success of fruiting (Cannell 1985). The low P_N during winter months was replaced by steady rise in spring. Schaffer *et al.* (1986) found a variable influence of strawberry fruits on P_N. In apple tree no effect on P_N during periods of high fruit growth was recorded by Schechter *et al.* (1991). In pistachio trees, fruiting affected Chl content, stomatal conductance, P_N, and LMA from early season until mid June, the period which precedes the onset of bud abscission and fruit growth (Vemmos 1994). Similar trends were also reported in apple (Marini and Barden 1981) and strawberry (Chabot and Chabot 1977).

References

Association of Official Analytical Chemists. Official Methods of Analysis. 12th Ed. - Washington 1975.

Barden, J.A.: Specific leaf weight of apple as influenced by several factors. - HortScience **10**: 331, 1975.

Barden, J.A.: Apple tree growth, net photosynthesis, dark respiration and specific leaf weight as affected by continuous and intermittent shade. - J. amer. Soc. hort. Sci. **102**: 391-394, 1977.

Buttery, B.R., Buzzell, R.I.: The relationship between chlorophyll content and rate of photosynthesis in soybeans. - Can. J. Plant Sci. **57**: 1-5, 1977.

Cannell, M.G.R.: Dry matter partitioning in tree crops. - In: Cannell, M.G.R., Jackson, J.E. (ed.): Attributes of Trees as Crop Plants. Pp. 160-193. Institute of Terrestrial Ecology, Penicuik 1985.

Chabot, B.F., Chabot, J.F.: Effects of light and temperature on leaf anatomy and photosynthesis in *Fragaria vesca*. - Oecologia **26**: 363- 377, 1977.

Chacko, E.K., Reddy, Y.T.N., Ananthanarayanan, T.V.: Studies on the relationship between leaf number, area and fruit development in mango (*Mangifera indica* L.). - J. hort. Sci. **57**: 483-492, 1982.

Erez, A.: Peach meadow orchard: Two feasible systems. - HortScience **17**: 138-142, 1982.

Gutschick, V.P.: Photosynthesis model for C_3 leaves incorporating CO_2 transport, propagation of radiation, and biochemistry. 1. Kinetics and their parametrization. - Photosynthetica **18**: 549-568, 1984a.

Gutschick, V.P.: Photosynthesis model for C_3 leaves incorporating CO_2 transport, propagation of radiation propagation and biochemistry. 2. Ecological and agricultural utility. - Photosynthetica **18**: 569-595, 1984b.

Ho, L.C.: Metabolism and compartmentation of imported sugars in sink organs in relation to sink strength. - Annu. Rev. Plant Physiol. Plant mol. Biol. **39**: 355-378, 1988.

Layne, R.E.C., Tan, C.S.: Long term influence of irrigation and tree density on growth, survival and production of peach. - J. amer. Soc. hort. Sci. **109**: 795-799, 1984.

Marini, R.P., Barden, J.A.: Seasonal correlation of specific leaf weight to net photosynthesis and dark respiration of apple leaves. - Photosynth. Res. **2**: 251-258, 1981.

Marini, R.P., Marini, M.C.: Seasonal changes in specific leaf weight, net photosynthesis and chlorophyll content of peach leaves as affected by light penetration and canopy position. - J. amer. Soc. hort. Sci. **108**: 600-605, 1983.

Marini, R.P., Sowers, D.L.: Net photosynthesis, specific leaf weight and flowering of peach as influenced by shade. - HortScience **25**: 331-334, 1990.

Proietti, P.: Gas exchange in senescing leaves of *Olea europaea* L. - Photosynthetica **35**: 579-587, 1998.

Schaffer, B., Barden, J.A., Williams, J.M.: Net photosynthesis, dark respiration, stomatal conductance, specific leaf weight and chlorophyll content of strawberry plants as influenced by fruiting. - J. amer. Soc. hort. Sci. **111**: 82-86, 1986.

Schechter, I., Elfving, D.C., Proctor, J.T.A.: Apple tree canopy photosynthesis as affected by rootstock. - Can. J. Bot. **69**: 295-300, 1991.

Šesták, Z., Čatský, J., Jarvis, P.G. (ed.): Plant Photosynthetic Production. Manual of Methods. - Dr W. Junk, The Hague 1971.

Singh, L.B.: The Mango: Botany, Cultivation and Utilization. - Leonard Hill, London 1960.

Taylor, F.J.: Some aspects of the development of mango leaves. I. Leaf area, dry weight and water content. - New Phytol. **69**: 377-394, 1970.

Teryl, R.R., Kennedy, R.A.: Photosynthetic characteristics during leaf development in "Bing" sweet cherry. - J. amer. Soc. hort. Sci. **111**: 938-941, 1986.

Tyagi, D.N., Medhabati, T.: Physiology of mango (*Mangifera indica* L.) I. Preliminary studies on the physiological characteristics of leaf. - Indian J. Plant Physiol. **29**: 267-270, 1988.

Tyagi, D.N., Medhabati, T., Pandey, S.: Physiology of mango (*Mangifera indica* L.): physiological differences in leaf characteristics of the flowered and non-flowered shoots of mango. - In: Proceedings of International Conference on Plant Physiology. Pp. 43-48. Rajeshwari Publisher, Varanasi 1991.

Vemmos, S.N.: Net photosynthesis, stomatal conductance, chlorophyll content and specific leaf weight of pistachio trees (cv. Aegenes) as influenced by fruiting. - J. hort. Sci. **69**: 775-782, 1994.