

Meteorological Conditions of Mangosteen Orchard in West Java, Indonesia and Seasonal Changes in C–N Ratio of Their Leaves as Affected by Sector (Position in Canopy) and Tree Age

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(Course of Applied Plant Science)

Productivity and quality of mangosteen fruit is markedly affected by tree age and sector (position in canopy). The objective of this study was to make clear seasonal changes in meteorological conditions of mangosteen orchard, and C–N ratio of leaves in relation to tree age and sector. The experiment was conducted using mangosteen trees grown in commercial orchard in Bogor, Indonesia during May to October 2010. Mangosteen trees of 3 different ages, young (20-year-old), middle (35-year-old), and old (50-year-old), each of five trees, were selected for study, and the canopy of each tree was divided into 9 sectors based on height (bottom, middle, top) and width (inner, center, outer). The light intensity on sunny days was higher in Sector 9, it was 8.1, 7.5, and 7.7 $\mu\text{mol}\cdot\text{M}^{-2}\cdot\text{s}^{-1}$ in young, middle-aged and old trees, respectively, whereas in Sector 1 it was low, resulting 0.5, 0.4, and 0.5 $\mu\text{mol}\cdot\text{M}^{-2}\cdot\text{s}^{-1}$ in young, middle-aged and old trees, respectively. Regardless of tree age, light intensity in outer position in canopy was higher than in the inner, and also it was higher in taller than in lower positions in canopy. In 2010, the phenological aspects of mangosteen orchard markedly changed because of irregular rainfall. In spite of tree age, SPAD value of leaves in upper parts such as Sectors 5–9 was high comparing with lower ones such as Sectors 1–4. In young trees, carbohydrate content of leaves was higher in top positions such as Sectors 7–9 than in bottom ones such as Sectors 1–3, whereas in middle-aged and old trees, no significant difference of carbohydrate content was observed among sectors. Regardless of month and tree age measured, nitrogen content of leaves was higher in lower positions in canopy such as Sectors 1–4 than in upper ones such as Sectors 5–9. Consequently, the C–N ratio of leaves was higher in the upper part of canopy compared to the lower. Based on the results, the relationships between meteorological status and C–N ratio of leaves and fruit productivity and quality of mangosteen are discussed in relation to position in canopy and tree age.

Key words : chlorophyll, C–N ratio, meteorological conditions, sector (position in canopy), tree age

Introduction

Mangosteen (*Garcinia mangostana* L.) is a tropical evergreen tree, believed to have originated in the Sunda Islands and the Moluccas, growing in humid and shaded environmental conditions and does not occur outside the countries of the region^{9,13,26}. Mangosteen, a slow-growing tree, is adapted to 20–50% of shade and regarded as a shade tolerant tree, while shading is essential especially for the first 2 to 4 years of growing^{11,24}. Mangosteen orchards in Indonesia are generally found in villages and contain several fruit species. In general, growing of mangosteen (in mixed stand) together with durian, rambutan, longkong and so on is a common practice in Thailand, because growers experienced that the young plants require nurse trees or artificial shade to encourage their growth^{1,17}.

Mangosteen starts flowering as early as four to five years after planting of seedlings if adequate fertilizers and water are given, but fruit size and yields are rather

small while young. It is well known that carbohydrate level of the fruit tree closely relates with induction of flower bud²⁵. Inconsistency in the flowering and fruiting in mangosteen is a common problem; its production always remains unstable from the immature to the mature tree stage, when the production can vary from tree to tree and from one season to another⁸. Assimilate accumulation and partitioning among sinks in mangosteen tree depends on seasonal growth patterns of vegetative and reproductive sinks²⁵.

In Indonesia, fruit productivity and quality of mangosteen are still low¹⁶. Low productivity is mainly caused by poor flower bud differentiation and fruit set. Beside long juvenile period, lack of profuse flowering and irregular fruiting during the early stage of tree

Received October 3, 2011

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maturity are also considered as major problems¹²⁾. Also, fruit quality varies largely among orchards, because mangosteen are managed by traditional ways and their production system depends on Nature⁴⁾. Most important factor lowering fruit quality is yellow latex, a physiological disorder⁴⁾. It has been reported that quality of mangosteen fruit varies greatly among sectors. Specific information on the effects of fertilizers on mangosteen is lacking, and many existing recommendations are based on empirical trials and traditional practices²⁷⁾. Leaf analysis has been a guide in diagnosing nutritional problems and a basis for fertilizer recommendation for mangosteen trees. The objective of this study is to clarify the meteorological conditions for commercial mangosteen orchards and also the seasonal changes in nitrogen and carbohydrate contents, and C-N ratio of leaves as affected by sectors and tree ages.

Materials and Methods

Plant materials and treatments

Mangosteen trees of 3 different ages, young (20-year-old), middle (35-year-old), and old (50-year-old), five of each, were selected for study at a commercial orchard in Bogor, Indonesia in May of 2010. Based on tree height and width, the canopy of each tree was divided into 9 sectors, i.e. Sector 1 (inner bottom), Sector 2 (center bottom), Sector 3 (outer bottom), Sector 4 (inner middle), Sector 5 (center middle), Sector 6 (outer middle), Sector 7 (inner top), Sector 8 (center top), and Sector 9 (outer top) (Fig. 1).

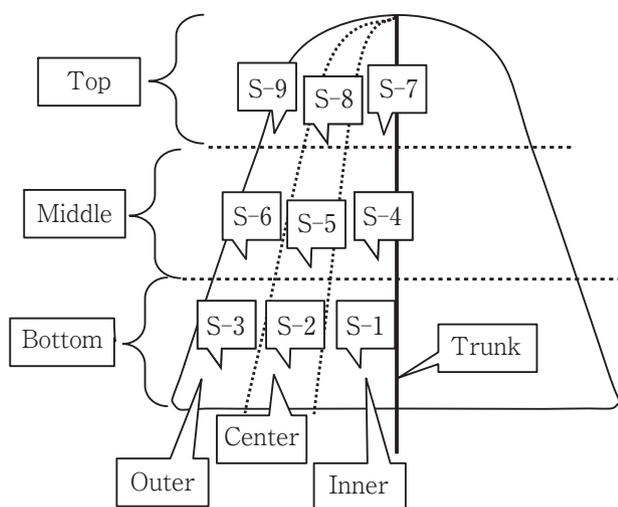


Fig. 1 Illustration of sector (position in canopy) of mangosteen tree.

Meteorological status

Light intensity in mangosteen orchard was measured by light meter (LI-250A, LI-COR) on sunny and cloudy days in each sector in August of 2010. The monthly rainfall data in 2009 and 2010 was collected from Bogor Meteorological Station.

Chlorophyll content and C-N ratio of leaves

Six leaves of similar age were selected in each sector in August and their SPAD value was determined by chlorophyll-meter (SPAD-502, Konica Minolta). The leaves were collected, then chlorophyll was extracted by 85% acetone and the content was determined by spectrophotometer (UV-VIS 1800, Shimadzu).

Six more leaves were collected from each sector at monthly intervals from May to September 2010. Another six leaves were also collected in August from branches of three types showing different growth aspects, A: branches with fruit, dormant bud, and vegetative shoots, B: branches with fruit and dormant bud, C: branches with dormant bud and vegetative shoots. Leaf samples were washed, dried in an oven, and ground into powder with a mill. Carbohydrate and nitrogen contents of leaves were determined by CN analyzer (MT700MC, Yanaco).

Statistical analysis

An analysis of variance was conducted to test the differences between sector (fruiting position) and tree age. Data were subjected to analysis of variance (ANOVA) using SPSS statistical software version 16.0 (SPSS Inc., IBM). A completely randomized design with five replicates was used. Where applicable, means were separated by DMRT with a level of significance $P < 0.05$.

Results and Discussion

Meteorological status

Light intensity in mangosteen orchard increased rapidly with respect to time of day and reached a maximum at 2:00 p.m., then gradually decreased (Fig. 2A). Light intensity was significantly different among sectors, but no significant difference was observed among tree ages. As shown in Fig. 3A, the highest light intensity on cloudy days was observed in Sector 9, resulting $0.3 \mu\text{mol}\cdot\text{M}^{-2}\cdot\text{s}^{-1}$ for all tree ages, followed by Sectors 8, 6, and 3, whereas in Sector 1 it was the lowest ranging from 0.02 to $0.03 \mu\text{mol}\cdot\text{M}^{-2}\cdot\text{s}^{-1}$. Regardless of tree age, the highest light intensity on sunny days was found in Sector 9, and it was 8.07, 7.53, and $7.74 \mu\text{mol}\cdot\text{M}^{-2}\cdot\text{s}^{-1}$ for young, middle-aged,

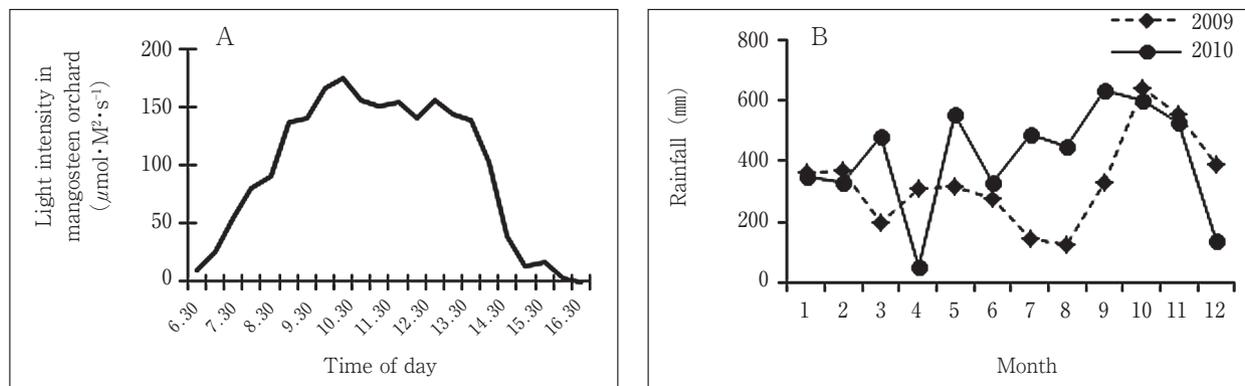


Fig. 2 Diurnal changes of light intensity during a sunny day (A) and monthly rainfall (B) in mangosteen orchard.

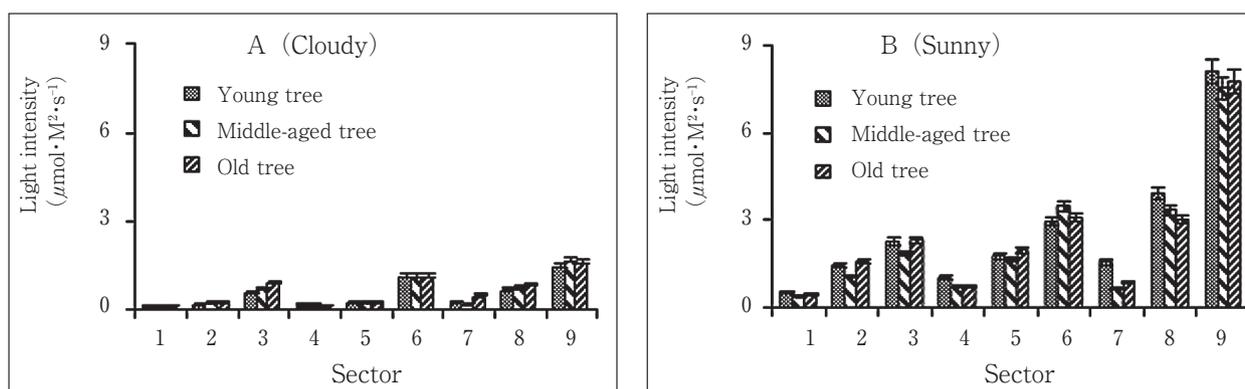


Fig. 3 Light intensity of cloudy (A) and sunny (B) days in mangosteen orchard as affected by sector and tree age. Light intensity was measured in August 2010. Vertical bars indicate \pm SE ($n=5$).

and old trees, respectively (Fig. 3B). In contrast, the lowest was found in Sector 1, and it was 0.53, 0.42, and 0.49 $\mu\text{mol}\cdot\text{M}^{-2}\cdot\text{s}^{-1}$ for young, middle-aged, and old trees, respectively. Light intensity in outer positions in canopy such as in Sector 3, 6 and 9 was higher than in inner ones such as Sectors 1, 4, and 7. Light intensity was also higher in taller than in lower positions in canopy. Increasing light intensity results in increased photosynthesis until $700 \mu\text{E}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ when light saturation is achieved¹⁴. It has been reported that in both shaded and unshaded plants, the index of chlorophyll increased with increasing NH_4 ratio in nutrient solution²³. Higher dry weights were attained when plants were grown under 50% shade^{5, 11}. An excessive crop load caused adverse effect on fruit size of mangosteen, and this led to a marked decrease yield of large size fruit²⁰. The bagging of mangosteen fruits has potential to improve fruit quality and added benefits on visual appearance¹⁵.

Throughout growth or development of fruit, water stress greatly affects the final yield². Mangosteen trees need a drying period to induce flowering¹⁹. Mangosteen

production in southern and eastern Thailand increases as the drought period before flowering increases². The irrigation strategies after attaining a threshold water stress condition could be to stimulate flowering of mangosteen in Thailand¹⁸. In usual years such as 2009, mangosteen trees in West Java regularly face a drought period from July to August, followed by a flowering period from September to October. In 2010, however, the phenological pattern of mangosteen tree changed markedly owing to irregular rainfall. Climate in 2010 was anomalous, and a drought occurred in April inducing flowering of mangosteen in May (Fig. 2B). A change of phenological pattern in mangosteen affected by irregular rainfall distribution was also reported in Thailand in 1999¹⁹. Climate change has a major impact on the hydrological cycle and consequently on available water resources, flood and drought potentials and agricultural productivity².

SPAD value and chlorophyll content of leaves

For all sectors the SPAD value of leaves ranged from 67.5 to 79.1 (Fig. 4). SPAD value in both young and

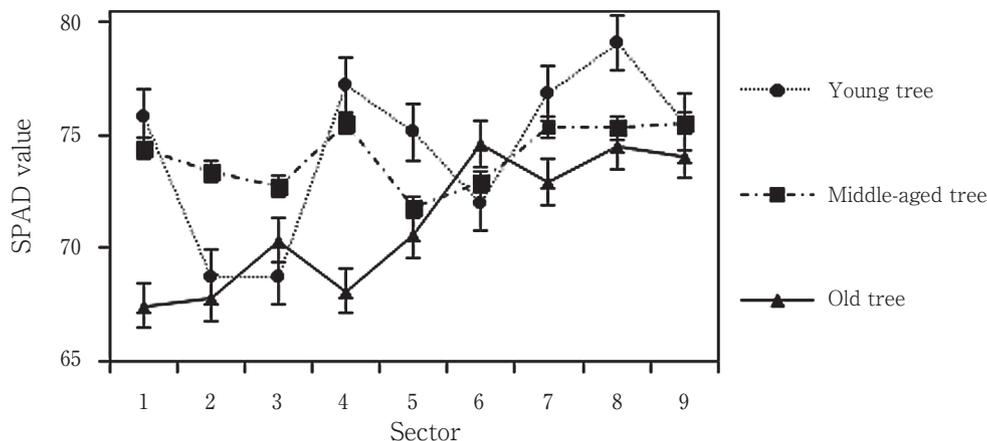


Fig. 4 SPAD value of mangosteen leaves as affected by sector and tree age. Vertical bars indicate \pm SE (n=5).

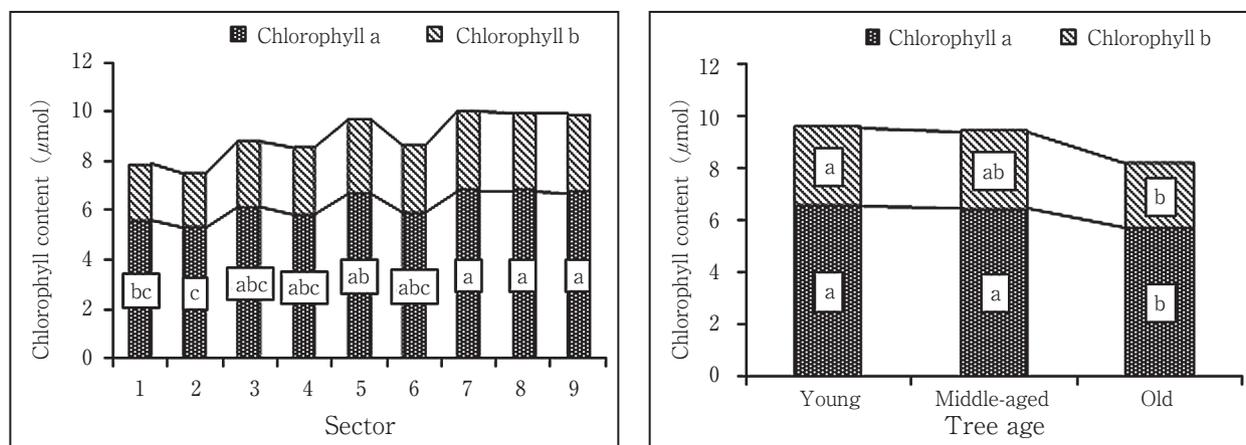


Fig. 5 Content of chlorophyll a and b in mangosteen leaves as affected by sector (A) and tree age (B). Different letters indicate significant difference at $P < 0.05$ by Duncan's multiple range test.

middle-aged trees was higher in inner positions in canopy such as Sectors 1, 4, and 7 than in outer ones such as Sector 3, 6, and 9, while in old trees, it was higher in outer sectors than inner ones. In spite of tree age, SPAD value of leaves in upper parts such as Sectors 5-9 was high compared to lower ones such as Sectors 1-4. SPAD value had a positive correlation with leaf N concentration in pummelo⁷.

The contents of chlorophyll a was significantly different among sectors and tree ages. Fig. 5A showed chlorophyll a of leaves was higher in top positions in canopy such as Sectors 7-9 than in bottom ones such as Sectors 1-3. On the other hand, content of chlorophyll b was not significantly different among sectors. Both chlorophyll a and b contents of leaves was higher in young and middle-aged trees compared to old ones (Fig. 5B). It has been reported that both chlorophyll a

and b contents per fresh weight of mangosteen leaves were low at full sun condition and increased gradually with an increase in light shading⁶. In this study chlorophyll a/b ratio increased gradually with age; it was 2.20, 2.25, and 2.95 in young, middle-aged, and old trees, respectively. Chlorophyll a/b ratio in seedlings was low with an average of 0.808⁶. Increase in tree age results in increase of height and width of canopy. The large size of canopy affects the transmission of sunlight into the inner and bottom parts of canopy⁶.

Seasonal changes in carbohydrate and nitrogen contents, and C-N ratio of leaves

Carbohydrate content of leaves varied largely among sectors and tree ages. The highest value was observed in July for middle and old trees, but it was June for young trees (Fig. 6). In young trees, carbohydrate content of leaves was higher in top positions such as

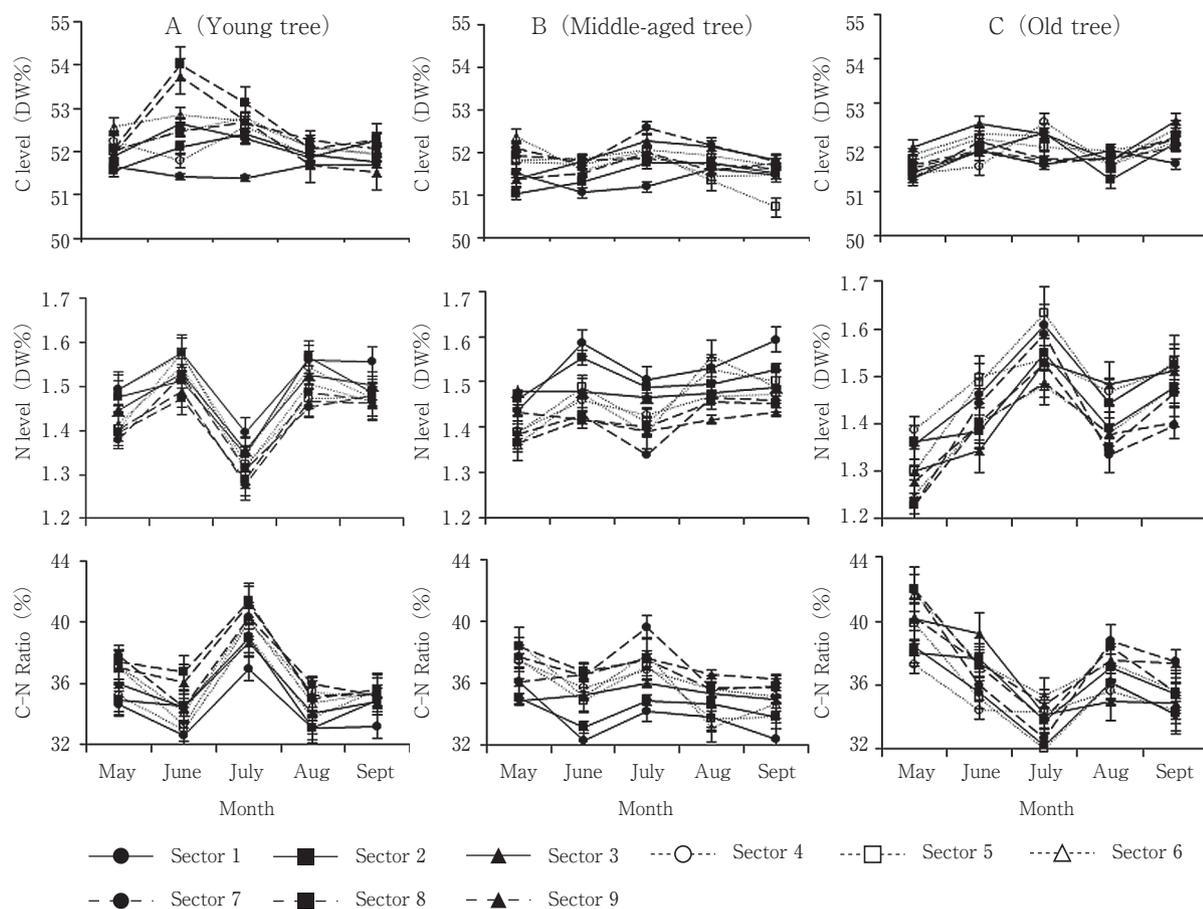


Fig. 6 Seasonal changes in carbohydrate and nitrogen contents, and C-N ratio of mangosteen leaves as affected by sector in young (A, left series), middle-aged (B, central series), and old trees (C, right series). Vertical bars indicate \pm SE (n=5).

Sectors 7-9 than in bottom ones such as Sectors 1-3, whereas in middle-aged and old trees it ranged from 50.7 to 53.0% and 51.3 to 52.6%, respectively. Regardless of month and tree age measured, nitrogen content of leaves was higher in lower positions in canopy such as Sectors 1-4 than in upper ones such as Sectors 5-9. The value in young, middle-aged, and old trees was around 1.3-1.6%, 1.3-1.6%, and 1.2-1.6%, respectively. The C-N ratio of leaves was higher in upper parts of the canopy compared to lower parts. There was no significant difference in C-N ratio of leaves among tree ages; it was 32.6 to 41.4% for young, 32.2 to 39.6% for middle-aged, and 32.2 to 42.0% for old trees. In young and middle-aged trees, C-N ratio of leaves was the highest in July, whereas in old ones the highest value was observed in May. Mangosteen leaves are believed to survive for many years on the tree²¹. Nitrogen concentration decreases slightly during the growing season in all orchards in Thailand²². Carbohydrate content of grapevine signifi-

cantly fluctuates throughout the year; it increases during the growing season, then decreases when the grapevine sprouts in spring¹⁰.

Carbohydrate and nitrogen contents, and C-N ratio of leaves as affected by three types of branch

Fruit production of mangosteen varies markedly from tree to tree and branch to branch, because trees are composed from branches with 3 different types, 1) branches with fruit, dormant bud, and vegetative shoots, 2) branches with fruit and dormant bud, and 3) branches with dormant bud and vegetative shoots (Fig. 7). Carbohydrate content of leaves was highest in branches with fruit, followed in branches with dormant bud, and branches with vegetative shoots; its value was around 52.4, 52.0, and 51.4%, respectively (Fig 7A). High nitrogen content of leaves was observed in branches with vegetative shoots, whereas in branches with fruit and branches with dormant bud it was the lowest. There was significant difference in nitrogen content of leaves on branches of different types; the

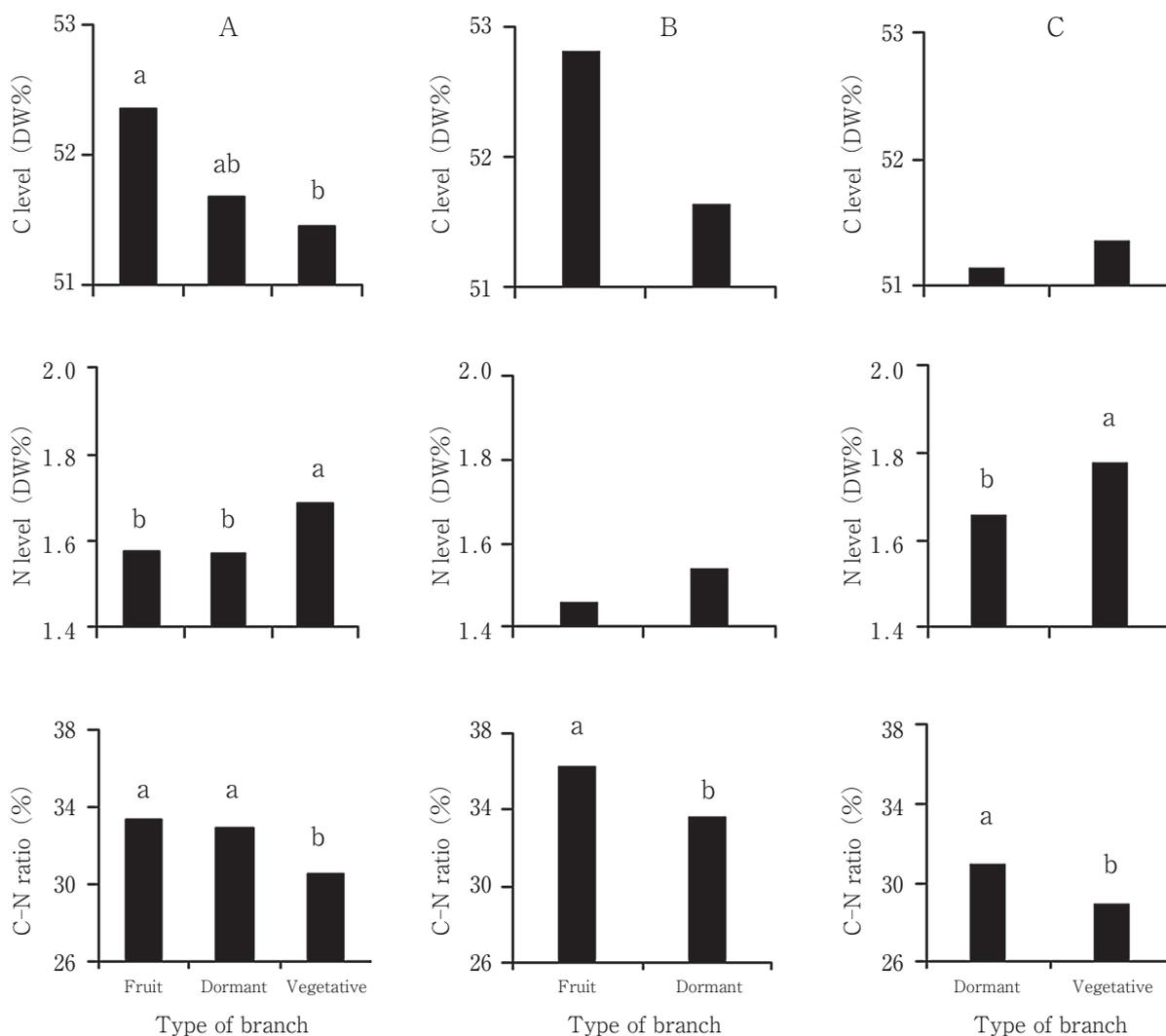


Fig. 7 Carbohydrate, nitrogen, and C-N ratio of mangosteen leaves in three types of branch with differing growth aspects. A : branches with fruit, dormant bud, and vegetative shoots, B : branches with fruit and dormant bud, C : branches with dormant bud and vegetative shoots. Different letters on column indicate significant difference at $P < 0.05$ by Duncan's multiple range test.

value was 1.6, 1.5, and 1.7%, in branches with fruit, branches with dormant bud, and branches with vegetative shoots, respectively. The C-N ratio of leaves was higher in branches with fruit and dormant bud, compared to vegetative shoots. The C-N ratio of mangosteen leaves was 33.3% for branches with fruit, 33.8% for dormant bud, and 30.7% for vegetative shoots.

Carbohydrate content of mangosteen leaves was higher in branches with fruit than in branches with dormant bud (Fig. 7B). No significant difference was observed in the nitrogen content of leaves between branches with fruit and branches with dormant bud, although it was higher in the latter. Consequently the

C-N ratio of leaves was 36.3, and 33.7% in branches with fruit and in branches with dormant bud, respectively.

Fig. 7C shows that carbohydrate content of mangosteen leaves in branches with dormant bud and vegetative shoots was lower, the value being around 51.1 to 51.4%. Nitrogen content of leaves in branches with vegetative shoots was higher compared to branches with dormant bud, being 1.8 and 1.7%, respectively. The C-N ratio of leaves was 30.9 and 28.9% for branches with dormant bud and vegetative shoots, respectively. Nitrogen content of leaves in branches with dormant bud and vegetative shoots (Fig. 7C) was higher compared to branches with fruit, dormant bud,

and vegetative shoots (Fig. 7A) and branches with fruit and dormant bud (Fig. 7B).

For young trees the nitrogen level was lowest in July (Fig. 6A). This may suggest that nitrogen compound was required for growth of new vegetative shoots. In Malaysia, it has been reported that flushing starts in July and August when nitrogen content decrease to the lowest level of 1.18%⁸⁾. Nitrogen remained high from August to September, because there were no vegetative shoots in young trees. In May, when flowering began in old trees, the concentrations of nitrogen remained lowest from 1.2 to 1.4% (Fig. 6C). In old trees, drought conditions caused high C-N ratio in May, and this fact may promote flower bud differentiation. The monitoring in 2004 had shown that during flushing, nitrogen was low but reversed during flowering, implying that nitrogen was heavily used for vegetative shoot development⁸⁾. Mangosteen trees need 21-30 days of dry conditions, and then watering before the flowering period for flower bud differentiation. Though blooming is not uniform, the average flowering period is about 40 days³⁾.

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インドネシア、西ジャワのマンゴスチン園における気象環境と葉の C-N 率の樹冠部位および樹齢による違い

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(応用植物科学コース)

マンゴスチンの果実生産性や果実品質が樹冠部位や樹齢によって異なる点について、インドネシア西ジャワの商業的マンゴスチン園で照度と降雨量を調査するとともに、20、35および50年生樹を5個体ずつ選び、各個体樹冠の高さと幅から9つのセクター（樹冠部位）に分け、葉の葉色値（SPAD 値）、クロロフィル含量、炭水化物含量、窒素含量および C-N 率を比較した。晴天日の照度は、樹齢による差は小さくセクター 9（各樹齢 $7.5\sim 8.1 \mu\text{mol}\cdot\text{M}^{-2}\cdot\text{S}^{-1}$ ）が最も高く、一方セクター 1（各樹齢 $0.4\sim 0.5 \mu\text{mol}\cdot\text{M}^{-2}\cdot\text{S}^{-1}$ ）で最も低かった。樹冠外部の照度はいずれの樹齢も樹冠内部よりも高く、またセクター 1、2、3 のような下部よりも 7、8、9 のような上部で高かった。調査を行った2010年は雨季の開始が例年よりも2～3か月早く、このため樹体の生育相が例年とは大きく異なった。葉色値は樹齢に関係なくセクター 1～4 のような下部の葉よりもセクター 5～9 のような上部の葉で高かった。葉の炭水化物含量は、20年生樹ではセクター 1～3 の下部よりも 7～9 の上部で高かったが、35年生と50年生樹ではそれぞれ50.7～53.0%と51.3～52.6%で大差なかった。一方、葉の窒素含量は樹齢や測定時期に関係なくセクター 5～9 の上部よりもセクター 1～4 の下部で高かった。このため、葉の C-N 率は樹冠の下部よりも上部で高かった。この結果をもとにマンゴスチンの果実生産性と品質および樹冠部位と樹齢との関係を考察した。

Received October 3, 2011

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