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The effect of fruit position and bagging treatment on Gamboge disorder in mangosteen (*Garcinia mangostana* L.)

Ajmir AKMAL [1, 2], Edi SANTOSA [3], Roedhy POERWANTO [4], Elvira Sari DEWI [5]

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Abstract: Gamboge disorder has a detrimental effect on mangosteen. The leakage of the gamboge may result from water availability. Thus, modifying the transpiration of the fruit by bagging might minimize the inappropriate leak of the gamboge produced by the fruit. The study's objective was to understand the relationship between different fruit positions and bagging treatment on the gamboge disorder in mangosteen. The experiment was conducted on 10-years old trees by tagging young fruits, five replicates with two fruit positions (inside and outside), and bagging treatment (no bagging, transparent and black plastic bagging). The result showed that bagging the fruits inside the canopy does not affect fruit mass. However, bagging with transparent and black plastic of the fruits inside the canopy decreases fruit size. The fruit quality improves by black bagging on the inside canopy fruits. These findings demonstrate that bagging fruits outside the canopy lowers their quality. Black bags used to package fruits inside the canopy improve fruit quality. However, the treatment also causes more fruit to fall from the tree and decreases the nutrient content.

Key words: canopy architecture; fruit position in canopy; gamboge; fruit characteristics; mangosteen; nutrients

Učinek položaja plodov in ovijanja z vrečkami na pojav fiziološke bolezni gamboge pri mangostinu (*Garcinia mangostana* L.)

Izvleček: Fiziološka bolezen "gamboge"ima škodljiv učinek na kakovost plodov mangostina. Iztekanje grenkih smol (bolezen gamboge) je lahko posledica pomanjkanja vode, zato bi s spreminjanjem transpiracije plodov z ovijanjem z vrečkami lahko zmanjšali neprimerno iztekanje smol iz plodov mangostina. V raziskavi je bilo preučevano razmerje med različnimi položaji plodov v krošnji, njihovim ovijanjem z vrečkami in pojavom motnje gamboge na plodovih mangostina. Poskus je potekal na desetletnih drevesih z označevanjem in ovijanjem mladih plodov v petih ponovitvah dveh položajev v krošnji (znotraj in na obodu krošnje) in načini ovijanja (brez ovoja, prozoren in črn plastični ovoj). Rezultati so pokazali, da ovijanje plodov znotraj krošnje ne vpliva na maso plodov, vendar pa ovijanje s prozornimi in črnimi plastičnimi vrečkami znotraj krošnje zmanjša velikost plodov. Ovijanje plodov s črnimi plastičnimi vrečkami znotraj krošnje izboljša njihovo kakovost, a povzroča tudi njihovo odpadanje in upad nekaterih hranil. Ovijanje plodov na obodu krošnje zmanjšuje njihovo kakovost.

Ključne besede: arhitektura krošnje; položaj plodov v krošnji; lastnosti plodov; mangostin; hranila

1 Universitas Al Muslim, Agriculture Faculty, Agricultural Industrial Technology Department, Bireuen, Indonesia
2 Corresponding author, e-mail: ajmir.akmal@gmail.com
3 IPB University, Agriculture Faculty, Agronomy and Horticulture Department, Bogor, Indonesia
4 IPB University, Center for Tropical Horticulture Studies, Bogor, Indonesia
5 Universitas Malikussaleh, Department of Agroecotechnology, Faculty of Agriculture, Aceh Utara, Indonesia

1 INTRODUCTION

Mangosteen (*Garcinia mangostana* L.) is distributed widely in India, Indonesia and Thailand (Mansyah et al., 2013; Parthasarathy and Nandakishore, 2014; Makhonpas et al., 2015); and becomes important source of antioxidant in the tropic (Tjahjani et al., 2014). However, the presence of gamboge or yellow latex disorder in mangosteen fruit becomes a barrier for global promotion (Sdoodee and Limpun-Udom, 2002; Affandi et al., 2008; Qosim, 2013; Rai et al., 2014).

The incident of gamboge disorder has been reported widely across places, seasons, culture practices and tree segments (Setiawan, 2005; Primilestari, 2011; Apiratikorn et al., 2012; Mansyah et al., 2013; Kurniadinata et al., 2016). For example, gamboged-fruits in Java-Indonesia was 30–83 % (Primilestari, 2011; Kurniadinata et al., 2016), in Sumatra-Indonesia 17–53 % (Mansyah et al., 2013; Kurniadinata et al., 2016), while in Songkhla-Thailand 3–5 % (Sdoodee and Chiarawipa, 2005).

There are two forms of gamboge disorder in mangosteen fruits, i.e., in fruit peel and fruit aril. Gamboge spot on the fruit peel is easily removed during post-harvest handling, but the spot on the aril is almost undetectable without open the fruit. Aril with gamboge is less palate because it taste bitter by consumers; although the gamboge contains α-mangosteen and γ-mangosteen a kind of xanthone as anti-inflammatory effects (Sukatta et al., 2013). A device for selecting gamboged-aril using near infra-red detector has been developed (Novita et al., 2011), however the accuracy is still low. Therefore, study to reduce gamboge is important.

Gamboge is common in Gutiferaceae family (Richards, 1990; Te-chato, 2007). The gamboge disorder arises when the latex duct leakages due to fluctuation of water, calcium (Ca) deficiency, disease infection and physical impacts (Asano et al., 1995; Sdoodee and Chiarawipa, 2005; Affandi et al., 2008; Dorly et al., 2008; Poerwanto et al., 2010; Diczbalis, 2011; Irianto et al., 2013; Purnama, 2014; Kurniadinata et al., 2016; Kurniawan et al., 2016). Among potential causes, status of Ca is one of the most tributal among scientists (Dorly, 2008; Poerwanto et al., 2010; Primilestari, 2011; Kurniawan, 2016); because application of Ca has inconsistent effect on the gamboge reduction.

Setiawan (2005) has revealed that Ca status on the mangosteen fruit varies among tree canopy segments as well as among gamboged-fruits. It is well known that uptake of Ca in a plant is driven by transpiration power (Bangerth, 1979); and the transpiration rate through leaf stomata depends on environment conditions (Tjondronegoro et al., 1999; Setiawan et al., 2015). It is probable that different fruit position at canopy has different transpiration rate. Hence, in present experiment, transpiration rate was manipulated through bagging with impermeable plastic to maintain high air relative humidity around mangosteen fruit. We hypothesis that restriction transpiration leads low uptake of Ca, consequently the fruit severe gamboge disorder. Although Bangerth (1979) and White and Broadley (2003) have stated that Ca ions translocation to the fruit could be small because immobile characteristic of Ca ions through the phloem. Objective of present study was to evaluate gamboge disorder and nutrient status in mangosteen from different fruit position and bagging materials.

2 MATERIALS AND METHODS

2.1 STUDY SITE

Research was conducted at Pasir Kuda Experimental Station of Center for Tropical Horticulture Studies (PKHT), Bogor Agricultural University, Bogor, Indonesia from Mar 2016–May 2017. Soil is podzolic type and has water table about three meters below soil surface. Monthly rainfall during experiment ranged from 240–375 mm, temperature ranged from 27–37 °C (average 28.3 °C), and relative humidity ranged from 65–82 % (average 71 %). Wind speed ranged from 0.25 –2.03 m s^{-1} at daytime and sunny condition about 3–6 hour per day.

2.2 PLANT MATERIAL

Experiment used mangosteen trees about 10-year-old derived from seedling at which the previous fruits exhibited variation on gamboge incident. Individual tree were fertilized before flowering (Mar–Apr 2016) with nitrogen, phosphorus, potassium and dolomite at rate 0.5 kg, 0.5 kg, 0.5 kg and 2 kg, respectively. The experiment consisted of two factors, i.e., fruit position at canopy (inside and outside canopies) and bagging (control without bagging, bagging using transparent and black plastic), totaled six treatment combinations. We performed five replications and, in each replication, used one tree.

Initially, we tagged five replications of mangosteen flowers at anthesis to obtain uniform fruit age on 31 May 2016. On 20 Jun 2016 (20 days after anthesis), the young fruits approximately 3–4 cm in diameter, were bagged according to the treatment. Time to bagging followed Pludbuntong and Poovarodom (2013) to coop with critical time of nutrient uptake. At six weeks after anthesis, we determined the final fruits position and classified as outside and inside canopy. We selected healthy 5 fruits for each treatment combination. Outside-canopy (OC) fruit received direct sunshine or visible from horizontal observation, in contrast the sunshine to fruit was blocked by leaves for inside canopy (IC) (Fig. 1)

Water vapor around bagged fruits was theoretically in saturated condition during fruit development until harvest; thus, transpiration rate from the fruit (if any) was theoretically zero. Control unbagged fruits were exposed freely to ambient condition. The bag covered fruit loosely to ensure no restriction on the fruit growth (Fig. 1B–C).

Fruit drop was observed weekly for those of the treatment and non-treatment of a particular tree. The fruit was harvested at 3.5 months after anthesis at stage maturity for consumption indicating by red-purplish peel. Fruit size, color, specific gravity, aril mass and total soluble solid were measured immediately after fruit harvest. Gamboge disorder on peel was scored 1–5 according to Kartika (2004), i.e., 1-as free gamboge, 2-as smooth skin had 1–5 gamboge spots, 3-as smooth skin had 6–10 gamboge spots, 4-as skin dirty had many gamboge spot and present gamboge lines, and 5-as skin dull had severe gamboge spot and lines. Gamboge in aril was scored 1–5 according to Kartika (2004), i.e., 1-as free gamboge, 2-as one aril had gamboge, 3-as two arils had gamboge, 4-as three arils had gamboge, and 5-as more than three arils had gamboge. Levels of Ca, Mg, P and K in fruit peel were determined using AAS (Shimadzu AA 6400, Japan). Nitrogen content of same part was evaluated using Kjedahl method. Specific gravity was measured with Platform Scale method by divide the mass of material in the air by the mass of water displaced multiplied by the specific gravity of water.

Statistical analysis: Data was analyzed using Statistical Tool for Agricultural Research (STAR). We performed ANOVA to determine significant different between the treatment, further evaluation was performed using Duncan Multiple Range test (DMRT) at probability level 5 %.

3 RESULTS AND DISCUSSIONS

3.1 ANALYSIS OF VARIANT

Analysis of variant showed that bagging significantly affected fruit mass, gamboge incident on peel and aril, total soluble solid (°Brix), calcium, and phosphorus levels (Table 1). Characteristics of fruit size (diameter, mass, and specific gravity), gamboge disorder and aril mass varied among trees. We found interactions between fruit position and bagging on fruit mass and height, specific gravity, peel mass and gamboge spot on aril.

All the variables exhibited low coefficient of variant, except peel thickness and nitrogen level that had coef-

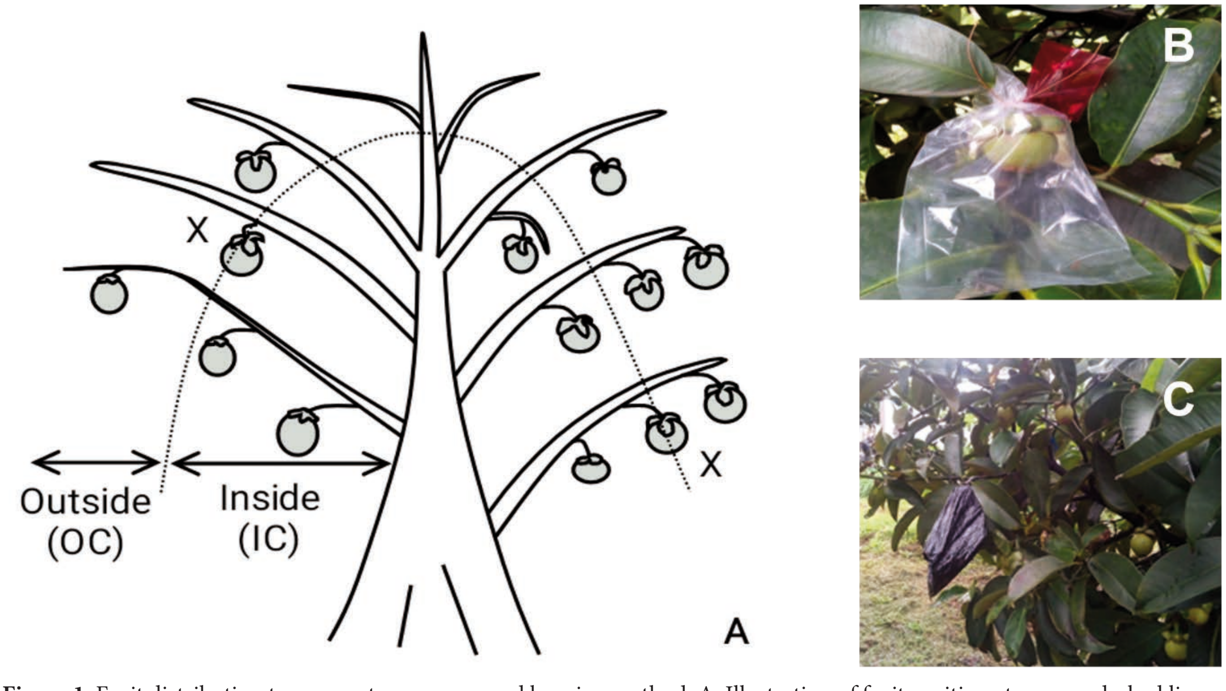

Figure 1: Fruit distribution to mangosteen canopy and bagging method. A, Illustration of fruit position at canopy, dashed line denotes penetration border of direct sunshine on canopy. B, Outside-canopy (OC) fruit is bagged with transparent plastic. C, OC fruit is bagged with black plastic

Table 1: Mean square of fruit characters of *Garcinia mangostana* L. based on ANOVA from repetition, bagging and fruit position at tree canopy, and its interaction

	Mean square				
Variable	Tree (repetition)	Bagging (B)	Fruit position (F)	B × F	cv (%)
Fruit drop	0.4908	0.2190	0.7933	0.1313	26.08
Fruit diameter (horizontal)	0.0010**	0.5532	0.5077	0.3868	3.86
Fruit height (vertical)	0.0197*	0.2535	0.2638	0.0409*	4.33
Fruit mass	0.0109*	0.5428*	0.5310	0.0945*	11.18
Fruit specific gravity	0.0341*	0.7680	0.5496	0.0651**	9.93
Peel mass	0.2007	0.2460	0.7246	0.0270**	11.06
Peel thickness	0.4065	0.3935	0.2842	0.3941	42.14
Peel color index	0.2826	0.4725	0.4870	0.3258	6.59
Gamboge spot on peel	0.0159*	0.0287*	0.3607	0.4966	28.80
Gamboge spot on aril	0.0004**	0.3787**	0.4673	0.0311*	28.01
Aril mass	0.0239*	0.8481	0.1971	0.1871	17.56
Sweet level (°Brix)	0.1362	0.0085**	0.7243	0.7043	1.22
Calcium level (Ca)	0.0756	0.0805*	0.2213	0.5844	22.11
Nitrogen level (N)	0.3956	0.1599	0.6579	0.6828	37.01
Phosphorus level (P)	0.2495	0.0028**	0.0101*	0.6806	9.45
Potassium level (K)	0.0916	0.3640	0.3297	0.4723	20.63
Magnesium level (Mg)	0.0844	0.9695	0.1889	0.9695	25.61

Significant at level of 5 %; ** significant at level of 1 %; cv-coefficient of variant

ficient of variant larger than 30 %. It indicates that the characters of peel thickness and nitrogen level were highly dependent on the characteristic of the mangosteen tree. According to Mansyah et al. (2013) and Sobir et al. (2013), genetic variation among seedlings is apparent in apomicts *Garcinia mangostana*. In present experiment, plants are originally from seeds, thus, high variation among trees was due to different genetic background. We had tried to observe subsequence fruiting period in Apr–May 2017, however, most trees failed to flower due to a lot of rain during period of Jun–Oct 2016. According to Sdoodee and Sakdiseata (2013), mangosteen expresses alternate bearing with index 0.25–0.57, indicates strong effect of climatic condition especially rain fall on the fruiting.

High coefficient of variance among trees could relate to the mangosteen physiology. Wiebel et al. (1993) states that mangosteen is shade-tolerant, however, the highest carbon gain is obtained for leaves grown in 50 % shade than 20 % or 80 % shade treatments. We observed different canopy shaped such as spherical, columnar, and irregular in the experiment, which might cause different shading level on leaves among the trees leads to different source capacity. Sdoodee and Phonrong (2006) concluded that a set of 17–18 leaves is required to support one mangosteen fruit to get optimum marketable size.

3.2 FRUIT DROP

Fruit drop was pronounced in all trees, in both treated-and untreated-fruits. A tree with a larger number of fruits tended to abort more fruits than smaller one.

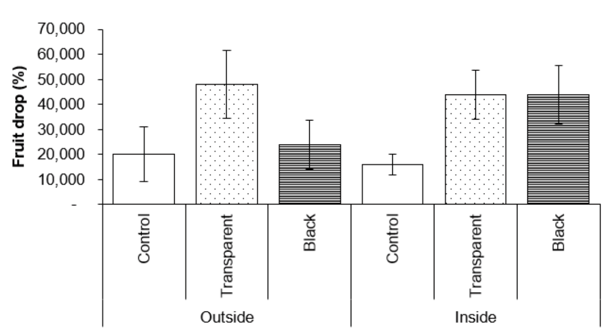

Figure 2: Total number of fruits drop in Garcinia mangostana L. as affected by bagging treatments. Bar ± S.E

On average, a tree aborted 4–7 fruits weekly from one month after anthesis until harvest. Fruit started to mature at 3.5 months after anthesis. Within bagged fruits, there was significant different on the drop rate among the treatments (Fig. 2). In OC, the drop rate of control fruits was statistically similar to the fruit bagged with black plastic. On the other hand, bagged-IC-fruit aborted by about three times larger than control, irrespective of bagging material. This finding implies that drop of IC fruit is more sensitive than OC fruits.

Fruit drop in mangosteen is still poorly studied. In mango, Hofman et al. (1999) stated that bagging increase fruit drop. Setiawan (2012) stated that fruit drop in mangosteen depends on canopy sector, i.e., at rate 44–50 % from outer canopy and 40–41 % from inner canopy. In present experiment, both young and mature fruits aborted in bagging treatments. Interestingly, all aborted fruits from control treatment were at the young age 5–10 weeks after anthesis. It is likely that bagging treatment stimulates fruit drop at later stage of fruit development.

There is a correlation between fruit drop and gamboge disorder. Aborted fruits from transparent plastic were higher than 90 %, irrespective the fruit position at canopy, severed from gamboge disorder on peel. At control, by less than 25 % of aborted fruits expressed gamboge spot. However, the number of aborted fruits with gamboge spot from control IC tended to be larger than those from control OC, although statistically similar (Fig. 2). Unexpectedly, bagging with black plastic increased aborted-young fruit noticed with gamboge disorder on peel. It is still unclear, why gamboge incident was high in aborted-fruits and why application of black plastic reduced drop in OC fruit.

3.3 FRUIT SIZE

Interaction between bagging treatment and fruit position on specific gravity, fruit and peel mass, and fruit diameter presented in Table 2. The maximum value of specific gravity was found in black plastic bagging in IC and in control in OC. in IC fruit bagging with black plastic increased specific gravity by 10.7 % contrary to IC that reduced by 11.2 %. Different fruit size of mangosteen among canopy sectors has been reported by Setiawan (2012).

In both canopy positions, the largest fruit mass was obtained in control bagging. Furthermore, the peel from the black plastic bagging was heavier than the peel from the OC. Fruit diameter was similar among treatments, irrespective of the position at canopy and bagging. It has been studied that fruit quality depends on fruit load (Sdoodee and Phonrong, 2006; Sdoodee et al., 2008) and fruiting seasons (Apiratikorn et al., 2012).

We speculated that different microclimate around IC and OC may affect the fruit size. At daytime, OC fruits received much direct sunshine causing fruit heating. Bagging with black plastic presumably increased air temperature around the OC fruit markedly caused high respiration. As a result, OC fruits had lower fruit mass. In Satsuma Mandarin, Daito et al. (1981) reported that respiratory rate varies among the fruiting locations within the canopy. In storage experiment, Castro et al. (2012) notified that mass loss of mangosteen fruit is accounted 34.4 % higher in 25 °C than 13 °C. In our simulation, temperature inside bag was 3-6 °C higher than ambient temperature. On the other hand, IC fruits received limited direct sunshine by about 10–25 % from full sunshine. Average temperature inside canopy recorded 0.5–11.6 °C lower than outside canopy. As consequences of increasing heat inside bagged-IC fruits, the fruits temperature was approximately similar to the temperature of control OC fruits that received direct sunshine. Therefore, specific gravity and peel mass of black plastic treatments of IC fruits are like control of OC fruits (Table 2).

3.4 FRUIT QUALITY

Fruit position and bagging treatments did not affect sweet level of aril (Table 3). This data is in line with previous finding (Apiratikorn et al., 2012; Pludbuntong

Table 2: Specific gravity, fruit and peel weight, and fruit diameter of mangosteen from bagging treatment and fruit position at tree canopy

	Specific gravity (g)		Fruit mass (g)		Peel mass (g)		Fruit diameter (cm)	
Bagging	IC	OC	IC	OC	IC	OC	IC	OC
Control	56.97b	61.97a	56.10b	61.15a	35.58b	41.29a	4.52ab	4.36b
Transparent	58.06ab	57.22ab	56.38b	55.07b	35.31b	36.47b	4.20b	4.59ab
Black plastic	63.06a	55.01b	54.30b	54.30b	41.52a	36.27b	4.42ab	4.75ab

Values in each column of parameter followed by different alphabet are significantly different based on DMRT at α 5 %; IC-inside canopy, OC-outside canopy and Poovarodom, 2013). Apiratikorn et al. (2012) stated that total soluble solid (TSS) and total acid (TA) of mangosteen fruits are stable among seasons. Peel color index was similar statistically among fruit position at canopy and bagging treatment (Table 1 and 3). Interestingly, fruits treated with black bag had bright red-brownish color while dull red brownish from control and transparent treatment, irrespective of the fruit position. Saengnil et al. (2005) has recommended to cover mangosteen fruit with bag to increase visual attrackness. This indicates that pigmentation in mangosteen peel is sensitive to bagging. In apple, Saure (1990) noted that temperature and light determine fruit pigmentation. Fruit bagging is common to maintain high quality fruit (Fallahi et al., 2001; Saengnil et al., 2005; Candra et al., 2013; Pludbuntong and Poovarodom, 2013).

3.5 GAMBOGE DISORDER

Gamboge disorder on peel and aril was marked in all fruits irrespective of fruit position at canopy and bagging treatment (Fig. 3). Irrespective of gamboge severity, number of fruits with gamboge-peel on control IC was approximately 0–60 % (average 36 %), while it was approximately 60–100 % (average 80 %) on control OC. Fruit with gamboge-aril was 0–40 % (average 28 %) and 40–80 % (average 64 %) in control OC and IC, respectively. It is contrary to persimmon fruit disorder that the least is in the middle canopy (George et al. 1996). Number of gamboge-fruit in present experiment is larger than that has been reported by Setiawan (2005). According to Apiratikorn et al. (2012) gamboge disorder in mangosteen depends on the fruiting season. In present experiment, however, the gamboge disorder seems unlikely due to different fruit position at canopy solely, as indicated by insignificant effect (Table 1).

Number of fruits with gamboge-aril was insignificantly different in OC fruit treated with transparent plastic, but significantly increased by about 57 % in black plastic than control. The gamboge-aril on IC fruit, on the other hand, decreased up to 44 % and 24 % in transparent and black plastic treatments, respectively. In peel, number of gamboge-IC fruit increased by 77.8 % from control when treated with black plastic. Interestingly, bagging with transparent plastic tended to reduce gamboge-peel in IC fruits, although statistically insignificant at level of 5 % to control. In OC fruit, bagging irrespective of the material decreased number of fruits with gamboge-peel, i.e., 35–45 %.

Here, we present manipulation of transpiration highly affects gamboge disorder in mangosteen fruit. The effect of blocking transpiration was more pronounce in IC than OC fruits in the incident of gamboge-aril; conversely, it is more pronounced in OC fruits in the presence of gamboge-peel. It is likely that mechanism that promote gamboge disorder on peel and aril could be different. We observed inconsistent relationship of gamboge-aril of OC fruit with by bagging treatment (Fig. 3B), unlike the gamboge-peel (Fig. 3A). On peel, gamboge severity increased by bagging treatment irrespective of fruit position; and IC fruits was more sensitive to bagging treatment. It seems that high gamboge disorder on peel is common on mangosteen fruit from outer canopy.

Individual tree produced different level of gamboge disorder in both peel and aril (Table 1). This matter could arise as consequences of different microclimate due to different canopy shape of each tree. Inside canopy had relative air humidity 1.98–2.71 times higher and wind speed 0.1–0.3 m s^{-1} lower than the outside canopy. Thus, microclimate inside canopy facilitates fruit to have lower transpiration rate, in absence of bagging treatment.

3.6 NUTRIENT STATUS

Calcium and phosphorus levels varied among different fruit position and bagging treatments, while potassium and magnesium levels were stable among treatments (Table 4). Nitrogen tended to decrease in bagged fruit than control, irrespective of the fruit position at canopy although statistically similar at 5 % level of con-

Table 3: Sweetness level (°Brix) and peel color index of mangosteen at harvest from bagging treatment and fruit position at tree canopy

	(°Brix)		Peel color index	
Bagging	IC	OC	IC	OC
Control	18.30a	18.22a	1.692a	2.044a
Transparent	17.80a	18.02a	1.740a	2.530a
Black plastic	17.96a	17.99a	2.560a	1.890a

Values in column followed by different alphabeth are significantly different based on DMRT at α 5 %; IC-inside canopy, OC-outside canopy

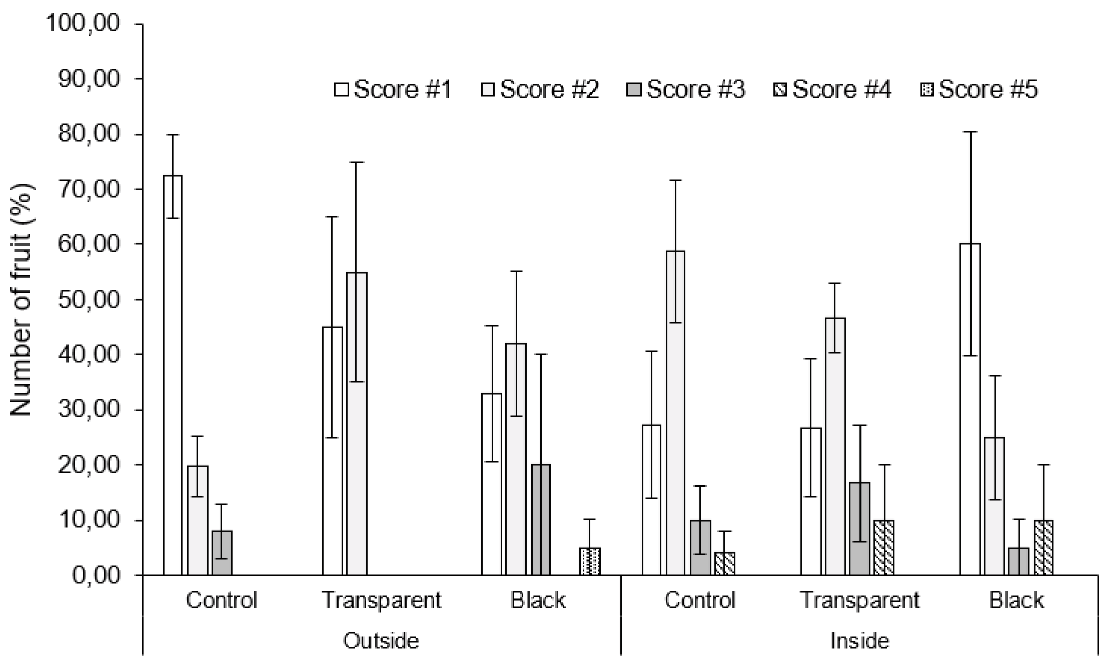

Figure 3: Percentage of fruit according to score of gamboge incident on peel (A) and on aril (B). Score #1, healthy fruit without gamboge while score #5 is very severe of gamboge. Bar ± S.E

fident of DMRT test. Bagging with black plastic consistently lowered Ca and P levels on mangosteen peel of OC fruits. In IC fruits, there was no marked different on Ca and P levels among bagging treatments. In control fruits, Ca level was significantly higher in OC than IC fruits, but the level of other nutrients was similar among OC and IC fruits. Consequently, transpiration manipulation in IC fruits reduce Ca level by 16.67 %. The reduction of Ca level was more marked in OC fruits; depends on bag color, i.e., 34.78 % in black plastic and 26.09 % in transparent plastic. This is in line with Pludbuntong and Poovarodom (2013) where blocking transpiration reduces Ca level on mangosteen fruit.

There were correlations between Ca level and gamboge disorder on aril ($R^2 = 0.135$; $p < 0.000$). These findings supported hypotheses that Ca plays important role on gamboge disorder. Limited transpiration and high fruit temperature in bagged treatment as the effect of high exposure to sunshine may increase the incident of gamboge-aril. It implies that increasing transpiration rate and maintaining fruit temperature could be important aspect in gamboge management, because according Setiawan (2012) 86–94 % mangosteen fruit is located inside canopy. Sdoodee and Hadloh (2007) have evaluated a pruning trial of mangosteen tree, reveals that topping at 3-meter height increases light transmission, photosynthetic rate by 48.55 % and root growth, and maintains continuation of fruit bearing.

4 CONCLUSIONS

Fruit position and bagging treatment in mangosteen trees influence the fruits' characteristics, quality, and

Table 4: Nutrient level of fruit peel of mangosteen from different bagging treatment and fruit position at tree canopy

	Ca (%)		N (%)		P (%)		K (%)		Mg (%)	
Bagging treatment	IC	OC	IC	OC	IC	OC	IC	OC	IC	OC
Control	0.18b	0.23a	0.64a	0.51a	0.09a	0.09a	1.65a	2.17a	0.05a	0.05a
Transparent	0.15c	0.17bc	0.43a	0.43a	0.08b	0.07bc	2.04a	1.99a	0.05a	0.04a
Black plastic	0.15c	0.15c	0.36a	0.39a	0.08b	0.06c	1.69a	1.60a	0.05a	0.04a

Values in each column of parameter followed by different alphabet are significantly different based on DMRT at α 5 %; IC-inside canopy, OC-outside canopy nutritional content. Fruits inside the canopy with black bagging improved quality by reducing the percentage of gamboge disorder on the peel and fruit aril compared to transparent bagging. However, both bagging treatments increased the number of fruit falls and reduced nutrient content. Outside canopy fruits with black bagging had a lower percentage of fruit health, size, and quality than transparent bagging. Therefore, there may be better options than bagging the fruits outside the canopy.

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