ORIGINAL ARTICLE

Regulating irrigation during pre-harvest to avoid the incidence of translucent flesh disorder and gamboge disorder of mangosteen fruits

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Abstract

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Regulating irrigation during pre-harvest to avoid the incidence of translucent flesh disorder and gamboge disorder of mangosteen fruits
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In humid tropical areas, excess water during pre-harvest usually causes the occurrence of translucent flesh disorder (TFD) and gamboge disorder (GD) in mangosteen. To evaluate options for avoiding these incidences, an experiment was conducted with different water management regimes during pre-harvest. Twelve 14-year-old trees were grown under transparent plastic cover with three irrigation regimes: 1) Control (rainfed condition), 2) 7-d interval watering, 3) 4-d interval watering and 4) daily watering. A further four trees were arranged as the control (rainfed) treatment, but these were grown without the plastic roof cover. The treatments were started at 9 weeks after bloom. The results showed that diurnal changes of leaf water potential and stomatal conductance were lowest in the control, because intermittent drying occurred during the study period. The highest fruit diameter, fruit weight, flesh firmness and flesh and rind water contents were found in the daily watering treatment. However, all of these values were lowest in the control trees. The amount of TFD was also lowest in the control (3.7%), and it was significantly different from the treatment where trees were watered at 4-d intervals (18.0%) and where trees were watered daily (28.9%). There was

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no significant difference of TFD between the control and the 7-d interval watering treatments. In contrast, GD was not significantly different among the treatments. It is suggested that the risk of TFD and GD incidence could be avoided by maintaining mild soil water deficit around -70 kPa during pre-harvest.

Key words : mangosteen fruits, irrigation regimes, leaf water potential, translucent flesh disorder, fruit-quality

บทคัดย่อ

สายัณห์ สดุดี และ ระวี เจียรวิภา

การจัดการน้ำก่อนการเก็บเกี่ยวเพื่อหลีกเลี่ยงการเกิดอาการเนื้อแก้วและยางไหลของผลมังคุด

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มังคุดจัดเป็นไม้ผลในเขตร้อนที่ประสบปัญหาการได้รับน้ำในปริมาณมากจนเป็นสาเหตุทำให้เกิดอาการเนื้อแก้วและยางไหลในผล เพื่อหลีกเลี่ยงอาการผิดปกติของผลดังกล่าวจึงทำการศึกษาการให้น้ำในช่วงก่อนการเก็บเกี่ยวในต้นมังคุดอายุ 14 ปี ซึ่งอยู่ในโรงเรือนหลังคาพลาสติกใส จำนวน 12 ต้น และภายนอกโรงเรือนจำนวน 4 ต้น แบ่งระดับการได้รับน้ำ 4 วิธีการทดลองคือ 1) ควบคุม (ได้รับน้ำตามธรรมชาติ) 2) ได้รับน้ำทุก 7 วัน 3) ได้รับน้ำทุก 4 วัน และ 4) ได้รับน้ำทุกวัน โดยเริ่มการทดลองเมื่อผลอายุ 9 สัปดาห์หลังดอกบาน ผลการทดลองพบว่า ค่าศักย์ของน้ำในใบและค่าการชักนำปากใบในรอบวันมีค่าต่ำสุดในต้นมังคุดควบคุม ส่วนค่าเส้นผ่านศูนย์กลางผล น้ำหนักผล ความแน่นเนื้อ เปอร์เซ็นต์น้ำในเปลือก และเปอร์เซ็นต์น้ำในผล มีค่ามากที่สุดในต้นมังคุดที่ได้รับน้ำทุกวัน แต่มีค่าน้อยที่สุดในต้นมังคุดควบคุม เช่นเดียวกับอาการเนื้อแก้วซึ่งพบน้อยที่สุดในต้นมังคุดควบคุม (3.7%) ซึ่งมีความแตกต่างทางสถิติอย่างมีนัยสำคัญกับต้นมังคุดที่ได้นับน้ำทุก 4 วัน (18%) และทุกวัน (28.9%) แต่ไม่มีความแตกต่างทางสถิติระหว่างต้นมังคุดควบคุมและได้รับน้ำทุก 7 วัน ขณะที่อาการยางไหล พบว่าไม่มีความแตกต่างทางสถิติในทุกวิธีการทดลอง ดังนั้นเพื่อหลีกเลี่ยงการเกิดอาการเนื้อแก้วและยางไหลในผล จึงควรควบคุมความชื้นในดินในช่วงก่อนการเก็บเกี่ยว ให้อยู่ประมาณ -70 kPa

ภาควิชาพืชศาสตร์ คณะทรัพยากรธรรมชาติ มหาวิทยาลัยสงขลานครินทร์ อำเภอหาดใหญ่ จังหวัดสงขลา 90112

Translucent flesh disorder (TFD) and gamboge disorder (GD) are physiological disorders of mangosteen (*Garcinia mangostana* L.) fruits caused by excess water or heavy rainfall prior to pre-harvest (Sdoodee and Limpun-Udom, 2002). The incidence of TFD and GD are both major problems of mangosteen production in the humid tropics (Yaacob and Tindall, 1995), because these disorders cause hard flesh with poor flavour. Flesh translucency of mangosteen fruit shows as a water soaking of the flesh, whereas GD is evidenced by a yellow colour in the rind or in the flesh (Pankasemsuk *et al*., 1996; Chutinunthakun, 2001). Luckanatinvong (1996) reported that the incidence of TFD was caused by excess water during the pre-harvest stage of fruit development, where water-uptake was driven by the difference in osmotic potential between that of rain water and that of the affected fruits. Chutinunthakun (2001) found that the threshold of TFD and GD incidence of mangosteen fruits subjected to excess water is around 9 weeks after bloom. Recently, there have been reports of the impacts of excess water causing splitting of pecan fruit (Wood and Reilly, 1999), and fruit cracking of both sweet cherry (Lane *et al*., 2000) and of tomato (Peet and Willits, 1995). Sdoodee and Limpun-Udom (2002) reported that when the mangosteen tree was subjected to a -100 kPa soil moisture and then it was rewatered suddenly, this led to the incidence of GD. Sekse (1995) also found that a sudden change of soil water content may cause cuticular fracturing in fruits of sweet cherry. The impacts of excess water on the occurrence of fruit disorder symptoms needs to be alleviated to ensure the production of high quality fruit in field production. Therefore, the objective of this investigation was to study whether the incidence of TFD and GD could be avoided by irrigation management during the pre-harvest.

Materials and Methods

Experimental site and layout

The experiment was conducted at an experimental orchard in Songkhla province (latitude: 6º 17′ N and longitude: 100º 07′ E), southern Thailand. Fourteen-year-old mangosteen trees (3.0±0.3 m height) grown at a spacing of 4 x 4 m were used. The experiment was designed to provide four different regimes of irrigation: 1) Control including rainfed conditions, 2) 7-d interval watering, 3) 4-d interval watering, and 4) daily watering. The control trees were grown in the open area whereas each of the trees within the irrigation treatments were grown under a transparent plastic cover during the experimental period. Each treatment was imposed across four single tree replicates, therefore 16 trees were used. The experiment was arranged as randomized complete block design. The treatments were started at 9 weeks after bloom, and the trees were rewatered to 80% field capacity using mini-sprinkling.

Weather and soil water potential conditions

The weather conditions were recorded at an adjacent meteorological station (about 1 km from the experimental site) at the Rubber Research Station, Songkhla province. Soil water potential was monitored with tensiometers (model 2725, U.S.A.) installed at a 30 cm depth, and about 1 m from each tree trunk.

Photosynthetic photon flux, leaf water potential and stomatal conductance measurements

Photosynthetic photon flux (PPF) above the tree in each treatment was measured using an LI-250 light meter with an LI-190SA quantum sensor (LI-COR Inc., USA). Diurnal changes of leaf water potentials and stomatal conductances were determined using a pressure chamber and an AP4 porometer (Delta-T Device, UK), respectively. Young fully-expanded leaves (four replicates) were used for these measurements.

Determination of fruit diameter expansion

Fifteen tagged fruits per tree were measured weekly with a digital caliper (Mitutoyo, Japan) for the 13 weeks following bloom.

Fruit characteristics and incidence of fruit disorders

Fruit-samples were harvested from each treatment approximately 14 weeks after bloom. The proportion (%) of normal flesh, TFD and GD were calculated from 100 fruits in each treatment. Flesh juice acidity or titratable acid concentration (TA) was determined by titration with 0.1 N NaOH. The Brix value presented as TSS was determined by hand refractometer (Atago N1). Rind thickness was measured using a digital caliper. Individual fruit diameter, fresh weight and dry weight (following drying at 80ºC for 96 hours) were also measured. Flesh firmness was measured using a firmness tester (Effegi, Italy) that was pushed twice into the fruit in the equatorial region. Each fruit was separated into rind and flesh.

Results

Weather conditions

Weather conditions during the experimental period were recorded from January to August 2001 (Figure 1). A dry period occurred between February to early March. Flowering was preceded by dry conditions. There was moderate rainfall during fruit development with decreasing rain at harvest.

Soil moisture conditions

Soil moisture was measured from weeks 9-14 after bloom (Figure 2). In the control, soil water potential was low and dropped to about -90 kPa (30 cm depth), except for the week 10-11 after bloom when rainfall markedly reduced the water deficit. In contrast, in the daily watering treatment,

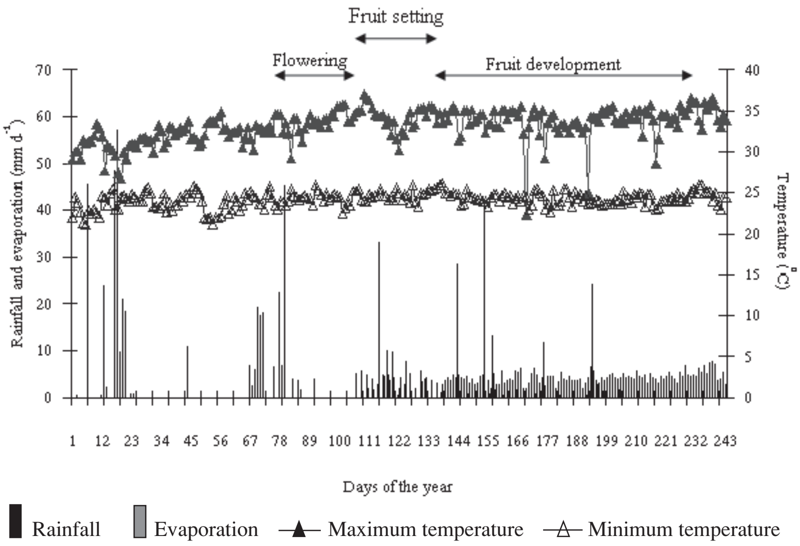

Figure 1. Weather conditions (daily rainfall and evaporation, maximum temperature and minimum temperature) during January-August 2001.

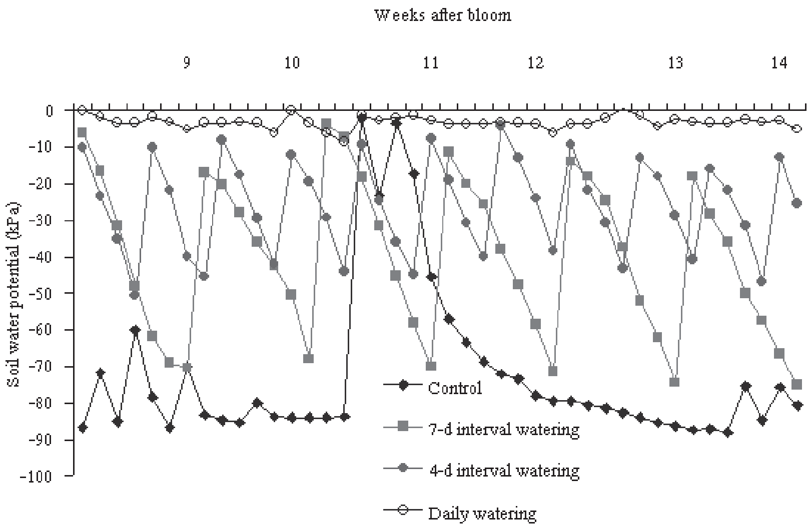

Figure 2. Changes of soil water potential (kPa) at 30 cm soil depth in the 4 treatments.

it remained nearly constant at -5 kPa (30 cm depth).

Diurnal changes of leaf water potential and stomatal conductance

The diurnal changes in PPF, leaf water potential and stomatal conductance were measured at 12 weeks after bloom on day 198 (17th July 2001) and at 14 weeks after bloom on day 212 (31st July 2001) (Figure 3). PPF on days 198 and 212 was highest in the control (Figure 3A and 3B) because it was outside the transparent plastic roof that provided the shelter from rain. The roof reduced PPF by about 30%. Diurnal leaf water potential values on both day 198 and on day 212 (Figure 3C and 3D) were lowest in the control treatment compared with those of the irrigated treatments.

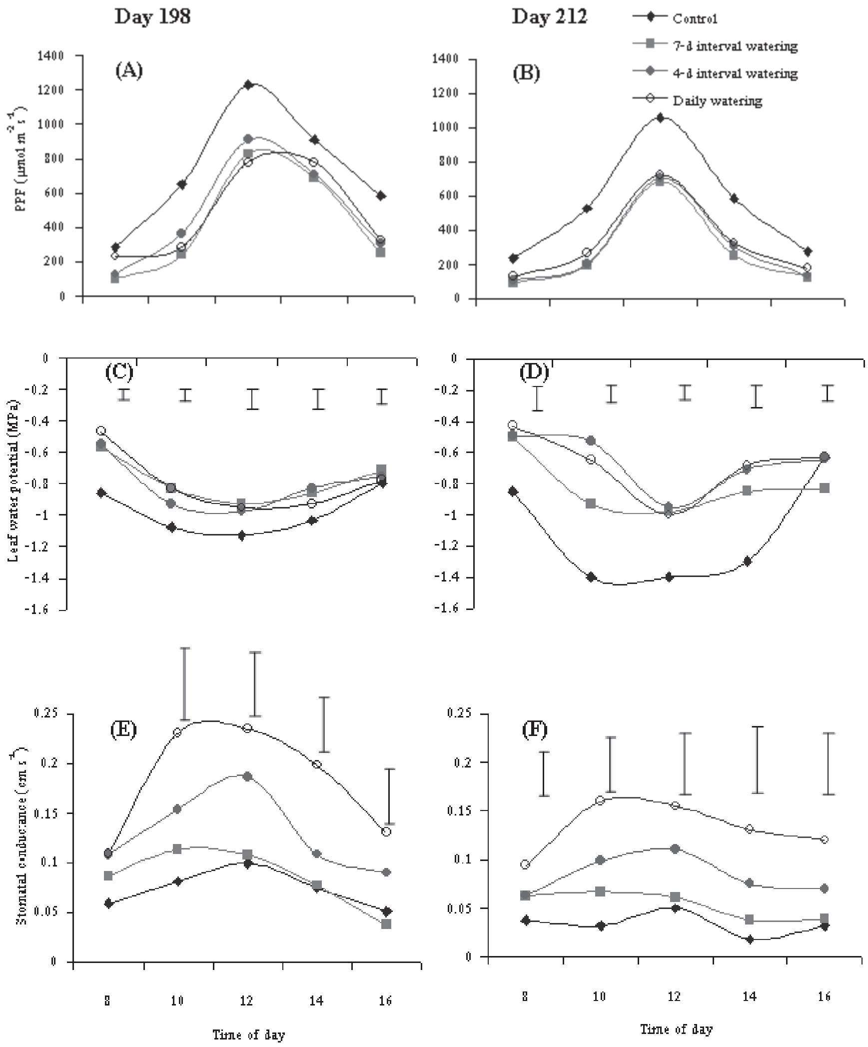

Figure 3. Diurnal changes of PPE above the mangosteen canopy (A, B), leaf water potential (C, D) and stomatal conductance (E, F) of the mangosteen trees in the 4 treatments on day 198 (17th July 2001) and day 212 (31st July 2001). Data are the means of 4 leaves per tree. (Vertical bars indicate LSD ($P \leq 0.05$)).

Likewise, diurnal values of stomatal conductances were lowest in the control trees, but highest in the treatment receiving daily irrigation (Figure 3E and 3F). These results indicated that intermittent water stress conditions occurred within the control treatment during the experimental period. At these times, leaf water potentials were reduced with concurrent decreases in stomatal conductances.

Fruit growth

Fruit diameter increased steadily from 1 week to 13 weeks after bloom (Figure 4A), and showed the lowest fruit diameter increase in the control. Differences among other treatments were non significant. It tended to decrease from week 9 to week 13 after bloom that it was evident in the marked decrease in fruit growth rate (Figure 4B).

Table 1. Fruit characteristics of mangosteen fruits at harvest in the 4 treatments.

Fruit characteristics	Control	7-d interval watering	4-d interval watering	Daily watering	C.V. (%)
Fruit diameter (mm)	48.59^{c}	53.19^{b}	53.91^{b}	56.97^{a}	2.56
Fruit weight (g)	56.23^{c}	78.08^{b}	79.33^{b}	89.16^{a}	7.50
Rind thickness (cm)	0.57^{c}	0.67^{a}	0.62^{b}	0.64^{b}	3.42
Flesh firmness (N)	3.82^{d}	4.51^{c}	5.85^{b}	6.68^{a}	17.51
TSS (ºBrix)	18.83^{a}	18.21^{b}	17.68^{c}	17.80^{c}	1.93
TA (%)	0.61^{b}	0.63^{ab}	0.64^{a}	0.62^{ab}	5.49
Flesh water content (%)	75.60^{b}	79.89^{a}	80.03^{a}	80.68^{a}	3.00
Rind water content (%)	61.49^{c}	64.75^{b}	65.64^{ab}	66.75^{a}	2.84

Means with the same superscript in each row are not significantly different by DMRT ($P \leq 0.05$).

Table 2. Percentage of normal flesh, TFD, GD and TFD+GD of mangosteen fruits in the 4 treatments.

Treatments	Normal	TFD	GD	TFD+GD
Control	91.14a	3.71c	5.15ns	0b
7-d interval watering	80.58b	9.52c	4.77	5.12b
4-d interval watering	70.27c	17.99b	3.50	5.02b
Daily watering	54.22d	28.93a	3.07	13.78a
C.V. (%)	6.72	24.57	35.94	42.94

Means with the same superscript in each column are not significantly different by DMRT ($P \leq 0.05$).
ns = no significant difference.

Compared with the other treatments, fruit diameter was reduced in the control treatment around 10% at harvest.

Fruit disorders

Fruit diameter, fruit weight, flesh firmness, and percentage of flesh and rind water were highest in the treatment where trees were watered daily. However, TSS of the fruit in the control treatment was highest and lowest in the daily and 4-d watering treatments (Table 1).

The amount of TFD was significantly highest in the daily watering treatment (28.9%), but was only 3.7% in the control, while it was not significantly different from the treatment in which trees received 7-d interval watering (9.5%) (Table 2). Overall GD percentage was low, but the disorder symptoms tended to be higher in the control than in the treatments where trees were frequently irrigated.

Discussion

Drought promoted flowering during February to early March. Chutinunthakun (2001) reported that mangosteen trees need a drying period to induce flowering. There were intermittent periods of drought during the fruit development stage (Figure 1).

As soil dried, root water-uptake was also limited, and leaf water potentials also decreased as is evident in vineyard (Michaelsen *et al*., 1999). In the control treatment, the soil water potential approached -90 kPa (Figure 2), and decreases of

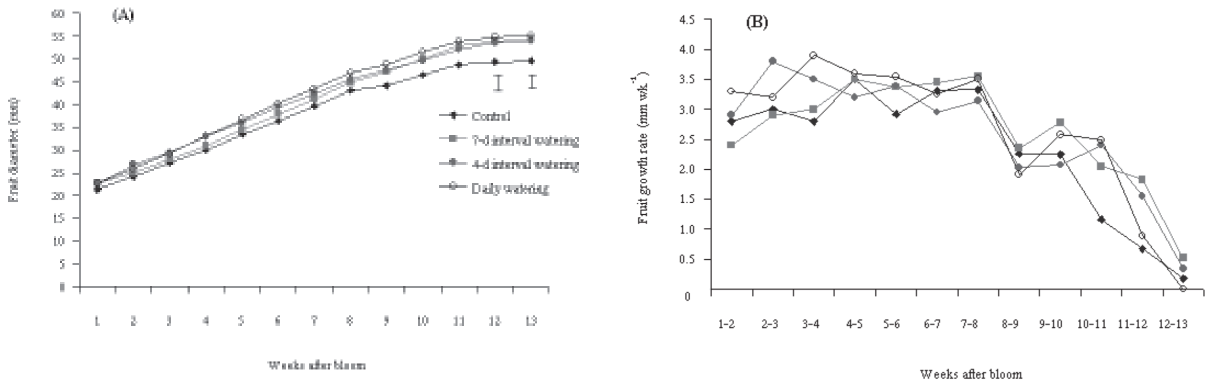

Figure 4. Changes of fruit diameter (A) and fruit growth rate (B) of mangosteen fruits in the 4 treatments between 1-13 weeks after bloom. (Vertical bars indicate LSD (P$\leq$0.05)).

leaf water potential and stomatal conductance were apparent (Figure 3). This is an adaptation of fruit trees to maintain water-uptake by increasing the water potential gradient between the plant and the soil. The partial opening of stomata, as evident through a decrease in stomatal conductance, is an adaptation to reduce water loss from the leaf during periods of stress (Batten *et al*., 1994; Ehlers and Goss, 2003; Sdoodee and Singhabumrung, 1996; Willmer and Fricker, 1996).

Low rainfall during the pre-harvest period resulted in a decrease in soil moisture potential in the control treatment. With the consequent limitation in water-uptake, this led to the reductions observed for fruit diameter, fruit weight, rind thickness and fruit water content (Table 1). Naor (2001) suggested that fruit expansion is interrupted by plant water deficit resulting from low soil moisture status. George and Nissen (2002) also found that drought reduced fruit size by 11% in custard apple; this was due to effects on cell division in the fruit 4-6 weeks after fruit set or on net carbon assimilation. Therefore, the fruits in control treatment were smaller than those of the irrigation treatments. It has been previously shown in water-stressed fruit that the fruit accumulate water by supply from the phloem and not by supply from the xylem (Nerd and Nobel, 2000). This resulted in low water content and a higher concentration of sugars in water-stressed fruit compared with non-stressed fruit in this study.

The magnitude of the incidence of TFD was different among the irrigation regimes. In the daily watering treatment, the fruits showed the highest incidence of TFD (28.9%) and TFD+GD (13.8%), and TFD percentage was lowest in the control (3.7%). In the control treatment, no fruit had both TFD and GD (Table 2). In the mangosteen fruit, excess water supply by either rain or by irrigation during pre-harvest has been shown to cause TFD incidence (Laywisadkul, 1994; Chutinunthakun, 2001; Sdoodee and Limpun-Udom, 2002). When water content in fruit is high, this leads to a breakdown of apoplast or symplast compartmentation which is exhibited as the occurrence of TFD (Luckanatinvong, 1996). Consequently, this is likely to be the reason why the saturated soil in the daily rewatering treatment was a major cause of TFD in this study. Excess water during pre-harvest was not a main factor in the incidence of GD. However, in other studies, the incidence of GD was shown to be due to large difference in water potential between the soil and the plant, and particularly when there is rapid movement of water and solutes into the fruit after sudden rewatering (Sdoodee and Limpun-Udom, 2002). These results overall, therefore, support the proposition that water is a major factor in the incidence and severity of both TFD and GD.

On the basis of the results, it is recommended that a mild soil water deficit of approximately -70 kPa should be maintained during pre-harvest. However, some balance will be needed as any abrupt changes in such soil water potential values, as a result of rainfall, are likely to lead to a high occurrence of GD. Consequently, some irrigation is desirable to avoid such abrupt changes and the rate of reduction in soil water potential may be able to be delayed until as close as possible to the time of harvest to minimize the impact on fruit size while still achieving the goal of minimizing the incidence of TFD.

Conclusions

The incidence of both TFD and GD in mangosteen can be avoided by the management of soil moisture during pre-harvest with soil water potential maintained at -70 kPa (30 cm soil depth). However, it should be noted that, although TFD incidence decreases under low soil moisture during pre-harvest, water deficit may be detrimental to fruit size.

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