

## Water stress and leaf necrosis symptom of rambutan seedlings (*Nephelium lappaceum* Linn.)

[Tegasan air dan simptom nekrosis daun pada anak rambutan (*Nephelium lappaceum* Linn.)]

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Key words: leaf scorching, soil moisture content, moisture stress, rambutan seedlings

### Abstrak

Anak pokok rambutan (*Nephelium lappaceum* Linn.) khasnya di kawasan-kawasan yang mengalami musim kering yang ketara mengalami daun lecu di dahan-dahan bawah. Ujikaji telah dijalankan di dalam rumah kaca untuk mengenal pasti punca masalah ini. Beberapa perlakuan pengairan telah diuji dengan menggunakan anak pokok rambutan dan kaedah rekabentuk lengkap terawak (CRD).

Apabila lembapan dikurangkan secara berperingkat-peringkat sehingga tahap kurang daripada 20%, tanda-tanda lecu didapati pada anak pokok rambutan dalam tempoh 3 minggu. Pada minggu keenam apabila lembapan dikurangkan lagi sehingga kurang daripada 15%, daun menjadi lecu dengan ketara. Pada tahap lembapan kurang daripada 14% pada minggu ke-10, lecu yang sangat ketara dapat dilihat. Luasnya daun lecu didapati berkait rapat dengan kandungan lembapan tanah. Di samping itu, kesan ketegasan lembapan juga menyebabkan hujung pucuk anak pokok rambutan terbantut dan tiada pucuk baru terbentuk.

Ketegasan lembapan didapati menyebabkan nekrosis pada daun anak pokok rambutan. Hal ini disahkan apabila anak pokok rambutan pulih dengan cepatnya setelah disiram dengan air yang secukupnya. Seterusnya, tiada lagi daun yang lecu. Pucuk dan daun baru tumbuh seperti biasa.

### Abstract

Rambutan trees (*Nephelium lappaceum* Linn.) experience leaf scorches on the lower branches, particularly in areas with a distinct dry season. Glasshouse experiments were conducted to investigate the causes of this scorching phenomenon. The experiments were conducted using a completely random design with varying watering regimes as treatments on rambutan seedlings.

When soil moisture content was reduced gradually to below 20.0% by weight, signs of leaf scorching were observed on these seedlings within 3 weeks. By the sixth week when the soil moisture content was further decreased to less than 15.0%, severe leaf scorches developed. At the 10th week, leaf scorches were very prominent when soil moisture content was below 14.0%.

The leaf area affected by scorching was significantly correlated with the soil moisture content. In addition, the affected rambutan seedlings exhibited apical small leaf characteristics and that no new shoot emerged.

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Moisture stress had been shown to cause leaf necrosis in rambutan seedlings. This was confirmed when necrotic seedlings recovered rapidly upon rewatering. Subsequently, no further leaf scorching was observed. New shoots and leaves emerged which proceeded to develop normally.

## Introduction

Rambutan trees (*Nephelium lappaceum* Linn.) are often observed to exhibit severe scorplings of the old leaves on the lower branches. Leaf necrosis appears first in the leaf tip and then along the leaf margin which subsequently spreads toward the mid-vein. In severe cases, defoliations of the affected leaves occur. In mature plant, such occurrences rarely prove fatal although it may seriously affect plant vigour and fruit production. In young seedlings, leaf necroses often result in severe leaf fall and sometimes plant death.

The development of similar leaf necrosis has been ascribed to various causes. It has the classic symptom of K deficiency, i.e. necrosis on leaf tip and margin of old leaves (Bidwell 1979; Mengel and Kirkby 1982). Similar necrotic symptoms in rambutan leaves were attributed to K deficiency by Kanopathy (1976). Certain vascular diseases in herbaceous plants had induced similar leaf symptoms (Talboys 1968) however, the positions of the affected leaves differed. Ling and Mainstone (1981) observed necroses of leaf tips and margins of old cocoa leaves on fully expanded terminal flushes. They attributed this observation to P deficiency.

Water deficit in leaves might cause plants to develop leaf necrosis similar to nutrient deficiency symptoms (Naylor 1972). When water deficit occurred, there was a slowing down of growth rate and often a loss in chlorophyll accompanied by yellowing, first in the lower leaves and progressively moving upwards to the upper leaves. Observations in the field (MARDI Research Station, Bertam) where leaf necrosis was most severe in 3 to 4-year-old rambutan trees revealed that the most seriously affected plants were located in low

lying areas where soil structure was poor. The leaves of the affected plants were generally smaller than those of the healthy plants. In addition, leaf necrosis was more marked during the dry season. Applications of K fertilizers failed to correct the leaf condition. This led to a strong suspicion that moisture stress was the main cause of the observed leaf necrosis in the rambutan trees.

This investigation sought to induce similar leaf necrosis symptoms in rambutan seedlings by subjecting them to different water regime treatments in a pot trial under glasshouse condition.

## Materials and methods

Rambutan seedlings, several months old and 45–60 cm in height were planted in 12 large pots, each contained one plant. They were subjected to four levels of watering regime treatments. Each treatment was replicated three times. The pots were arranged in a completely random design on benches inside a glasshouse. The pots had drainage holes at the bottom and were filled with soil of sandy clay loam material. No fertilizers were added to the pots.

When the pots were filled with soils, 3.5 L of water was added to each pot which was then allowed to drain freely for a week before planting. The rooting zones within the pots were marked for soil sampling purpose.

The watering regime treatments (*Table 1*) consisted of 250, 500 and 1 000 mL of watering on alternate days, and another treatment consisted of keeping the rooting zones within the capillary fringe. This was achieved by introducing water through a perforated plastic tube inserted into the pots where the level of water within the pots could be measured. The drainage holes of these pots were plugged. Water was

Table 1. Watering regime treatments on rambutan seedlings

Treatment	Initial run (mL)	Reverse watering* (mL)
1	250	2 000
2	500	1 000
3	1 000	500
4	Capillary fringe	250

\*Before reverse treatment began, severely scorched leaves were removed and the scorched parts of the less severely damaged leaves were cut off.

added until it was about 15 cm from the marked rooting zone.

After 10 weeks, the watering regimes were reversed, i.e the previous watering rates of 250, 500 and 1 000 mL, once every 2 days and keeping rooting zones within the capillary fringe were altered to 2 000, 1 000, 500 and 250 mL respectively. Watering was also changed to daily application to prevent excessive soil drying particularly in pots receiving 250 and 500 mL. These treatments were continued for 11 weeks.

Soil materials from the marked (on the pots) rooting zone were taken for moisture determinations once a week on the last day of the week before watering. The soil materials were extracted from the pots using a thick-walled glass tube inserted into the marked zone. The extracted soil samples, weighing 20–30 g each, were replaced immediately by putting back similar soil materials into the pots. The soil moisture content was determined gravimetrically on oven dried basis.

The effects of watering regimes on the rambutan seedlings were recorded periodically. These included the progressive development of leaf necrosis, observations on new shoot development and leaf size characteristics. When marked leaf necrosis was observed, treatments were terminated. The percentage area of necrotic tissues was determined using an area grid point counting procedure.

## Results

### *Soil moisture content*

The mean soil moisture contents of the different watering regimes are depicted in *Figure 1*. During the initial treatment run, soil moisture content in the 250 mL and 500 mL watering regimes decreased continuously for 4–5 weeks before stabilizing. This was mainly due to a combination of excessive water loss via continued drainage of moist soil and evapotranspiration relative to water input. Added water only began to reflect in the rooting zone after the third (250 mL) and fifth (500 mL) week. Subsequent to this, fluctuations in soil moisture content reflected variability due to watering and sampling difficulties. For pots receiving higher volume of water treatments (1 000 mL and capillary zone), there was an initial increase in moisture content in the first 2 weeks subsequent to which fluctuations in soil moisture content again reflected variability introduced mainly by soil samplings. However, on reversed treatment run, pots that were previously receiving 250 mL and 500 mL of water picked up moisture rapidly after getting larger volumes of water. By the second or third week, soil moisture contents began to stabilize. Similarly, the fall in soil moisture contents for those pots receiving 500 mL and 250 mL was dramatic, particularly in the treatment where the rooting zone was kept within the capillary fringe during the initial treatment run. Mean soil moisture content for this treatment decreased from 26.6% to 8.8% by the third week on reversed watering treatment.

At the end of the initial treatment run, pots receiving 250 mL and 500 mL of waterings had mean soil moisture contents of 9.8% and 14.3% respectively. The mean soil moisture content of the 1 000 mL treatment was 21.9% while mean soil moisture content at the capillary zone was 26.5%. When watering regime treatments were reversed, similar trend in soil moisture content was obtained. Higher watering rate

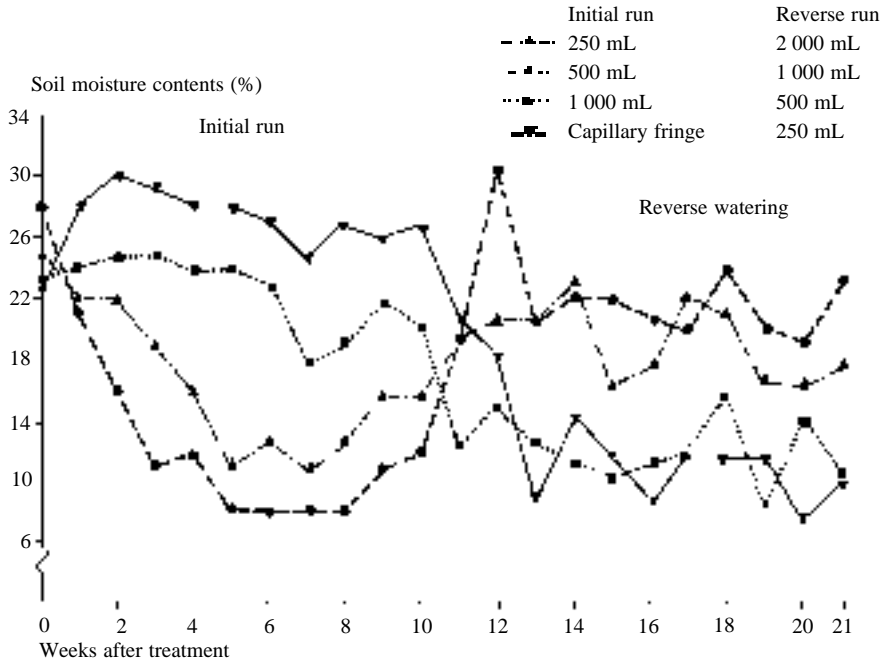


Figure 1. Mean weekly soil moisture content during treatment runs

produced higher soil moisture content. The mean soil moisture contents (Table 2) resulting from the various water regime treatments were significantly different ( $p < 0.05$ ).

**Effects of soil moisture content on leaf scorching**

The effects of soil moisture content on leaf scorching are illustrated in Figure 2.

All initial soil moisture contents exceeded 20.0%. However, by the third week, signs of leaf scorching were already observed on those plants on soils having moisture content of less than 20.0%. The tips of lower leaves turned brown. At the sixth week, the effects of low soil moisture content on leaf scorching became very clear. The browning of leaf tips had progressed to the leaf margins and some had 25.0% of the leaf area affected by scorching. Leaf scorplings were very pronounced on those plants on soil having moisture content reduced to below 15.0%. No new shoots developed in these rambutan seedlings. Two seedlings on soil having moisture content of

about 23.0% did develop slight browning of leaf tips. New shoots, however, developed in these plants. For plants on soil with a moisture content exceeding 26.0%, no leaf scorching was observed and new shoots developed normally. At the eighth week, plants developed severe leaf scorching when soil moisture contents were reduced to less than 14.0%, while those plants on soil with moisture contents of 15.0–22.0% developed slight to moderate leaf scorplings. Those plants on soil with moisture content maintained at more than 23.0% did not develop any sign of leaf scorching.

By the 10th week, the effects of soil moisture content on leaf scorching were very prominent. All leaves of plants grown on soil having moisture content of less than 14% were severely affected. Some of the lower leaves had abscised. Plants on soil having moisture content of 19.0–21.0% developed severe leaf scorplings on the lower leaves only. Leaves of the new shoots were stunted. Plants grown on soil having maintained moisture content exceeding 25.0% did not develop any leaf scorching symptom.

Table 2. Effects of water treatments on soil moisture content

Treatment	Initial run moisture content (% by wt.)			Reverse watering moisture content (% by wt.)		
	Mean	SD	C.V.	Mean	SD	C.V.
1	9.8a	0.7	5.9	21.7a	1.5	13.3
2	14.3b	0.8	7.7	19.7a	0.9	7.0
3	21.9c	1.6	7.5	12.6b	1.1	5.5
4	26.5d	2.6	9.8	11.2b	1.6	7.5

Mean values in the same column with the same letters are not significantly different at  $p < 0.05$  using the New DMRT. The Test was conducted after having satisfied that the error variances are homogenous by  $\chi^2$  Test.

$X^2 = 3.24$  (df = 3),  $p > 0.5$  for initial run.

$X^2 = 0.73$  (df = 3),  $p > 0.5$  for reverse run.

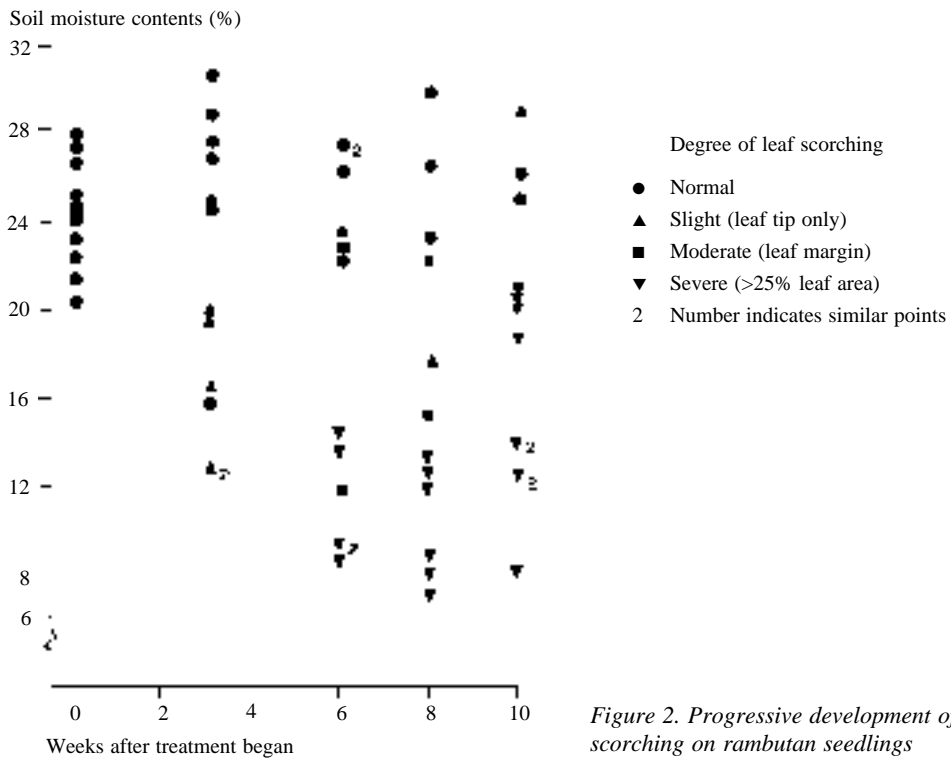


Figure 2. Progressive development of leaf scorching on rambutan seedlings

The degree of leaf scorching in relation to soil moisture content is significantly correlated (Figure 3).

The sensitivity of rambutan seedlings towards soil moisture stress is indicated by the regression. For every 1.0% increase in soil moisture content, there was a reduction of 3.11% leaf area affected by scorching. When soil moisture content reached 27.3%, no scorching symptom would appear. At

low soil moisture content of about 8–10%, most of the leaves had desiccated to such an extent that abscission took place.

**Effects of reversed watering regime treatments on leaf developments**

During the initial treatment lasting 10 weeks, rambutan seedlings previously receiving 250 mL of water every other day suffered severe scorplings in all the leaves.

Subsequently, when the watering was increased to 2 000 mL daily for 11 weeks, young shoots emerged and the lower leaves did not develop scorching symptom (*Table 3*). The young leaves on the new shoots expanded fully. The mean soil moisture content of the last 8 weeks for this treatment was 21.7%. Similar leaf development characteristics were observed in plants formerly receiving 500 mL of water which were now receiving 1 000 mL of watering daily. The mean soil moisture content (the last 8 weeks) for this treatment was 19.7%. On the other hand, plants with roots growing within the zone of capillary rise which did not develop leaf scorching in the first 10 weeks, suffered severe leaf scorings of all the leaves when waterings were reduced to 250 mL daily in the subsequent 11 weeks. Some of the lower leaves were defoliated and no new shoots were observed. The upper leaves failed to develop fully resulting in small stunted leaves. The mean soil moisture content in these pots in which the plants were grown was 11.2%. Plants formerly receiving 1 000 mL of watering suffered severe scorings on the lower

leaves only when the watering regime was reduced to 500 mL daily. No new shoots developed and the upper leaves again failed to develop fully. The mean soil moisture content in these pots was 12.6%.

Therefore, the reversed watering regime treatments confirmed the results obtained during the initial treatment run that low soil moisture content did induce leaf necrosis in rambutan seedlings.

## Discussion

### *Leaf scorching*

The common occurrences of necroses in the lower leaves of rambutan trees are readily understood when the soil moisture content at which leaf scorching became pronounced is compared with the soil field capacity (*Table 3*). Rambutan seedlings on soil having a mean moisture content of 12.6% which was equivalent to 81.3% field capacity developed severe scorings in the lower tier leaves. The upper leaves though unaffected failed to expand to their normal sizes. At 11.2% soil moisture content equivalent to 75.2% field capacity, all the leaves in the rambutan seedlings developed severe leaf necrosis.

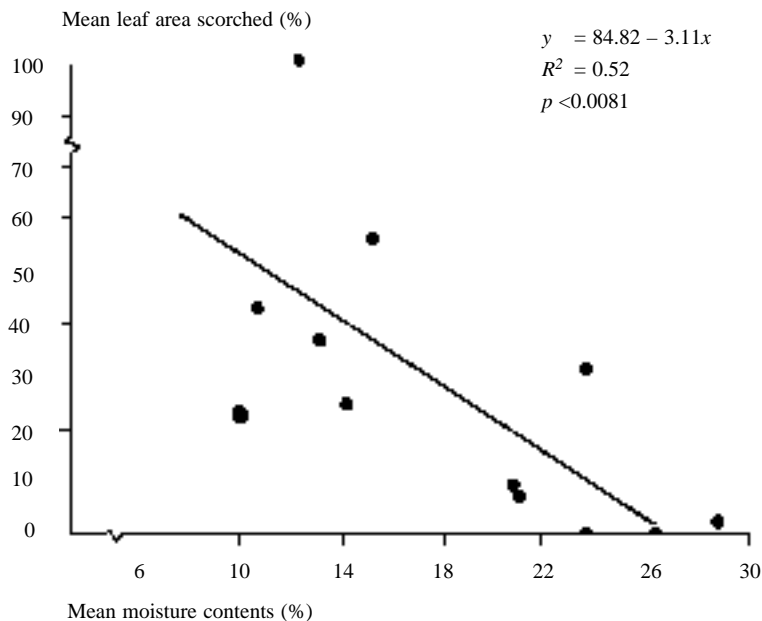


Figure 3. Effects of soil moisture on rambutan leaf scorching

Table 3. Effects of reversed watering treatments on leaf developments of rambutan seedlings

Treatment (mL)	Means (%)						
	Moisture content	Moisture content at 33.3Kpa	% of field capacity	Leaf area scorched	% leaf affected	Shoot development	Leaf size
2 000	21.7	15.3	100.5	0	0	New	Normal
1 000	19.7	17.5	112.6	0	0	New	Normal
500	12.6	15.5	81.3	28.8	66	None	Small upper leaves
250	11.2	14.9	75.2	*	100	None	Small upper leaves

\*Cannot be determined due to leaf fall

The lower leaves were dehydrated to such an extent that abscission occurred. This indicates that rambutan seedlings are very sensitive to moisture stress.

Very often, soil moisture content falls below field capacity, particularly in areas having pronounced seasonality in rainfall. Rambutan trees are most likely to develop severe leaf scorchings in these areas. Even in areas without pronounced seasonality in rainfall, due to the sensitivity of the rambutan plants to moisture stress, it is common to observe leaf scorchings on the lower branches. This condition is further accentuated if rambutan trees are grown on poorly structured soils such as skeletal soils.

#### ***Leaf characteristics relating to moisture stress***

Failures to initiate new shoot, development of relatively smaller upper leaves, leaf margin necrosis and defoliations of older leaves are common symptoms of plants under slow subacute moisture deficit condition (Talboys 1968). Non-lethal water stress leads to reduction in leaf size, shoot extension and stem growth. In actively transpiring plants when soil water is non-limiting, there is a continuous flow of soil water from the root to liquid-gas interface in the leaves (Baker 1985). A negative gradient exists within the xylem system between transpiring sites and the roots. When soil

water becomes limiting, the plants react by reducing synthetic activities through stomatal closures, decreasing enzymic activity and CO<sub>2</sub> intake (Craft 1968). In moisture-stressed plants, meristemic activities are restricted which in turn affect shoot elongation and leaf enlargement (Kramer 1969; Boyer 1976). These processes are likely to account for the absence of shoot development and the failures of the upper leaves of the rambutan seedlings to expand fully under gradually developing subacute moisture stress condition. Similar phenomena were also observed in cocoa plant (Balasimha 1987).

#### ***Sequential development of leaf scorching***

The experiment had demonstrated the sequential development of leaf necrosis under gradually developing subacute moisture stress conditions. The leaf tips turned brown first followed by the outer leaf margin and the necrosis subsequently developed inwards at the direction of the mid-vein. In slowly developing subacute moisture stress condition where new shoots appeared, only the older leaves were affected by scorchings. In prolonged non-lethal moisture stress condition, all the leaves were similarly affected and no new shoots developed. As the slow progressive dehydration process continued, the lower leaves suffered progressive tissue break

down which eventually led to tissue death. Slatyer (1967) had described similar sequential effects of water deficits on plant growth.

When plants are under water stress, nutrients and moisture in the lower mature leaves are being drawn to supply the demand of the younger actively transpiring leaves (Kramer 1969). When mineral salts are moving out of leaves, export of mineral salts from the young actively growing leaves are almost non-existent (Delvin 1966). Therefore, when the rambutan seedlings were subjected to gradual progressive moisture stress, minerals and water were exported out of the lower mature leaves to supply the sink demand of the younger leaves. When the continued transport of minerals and water out of the older leaves reached a critical point, tissue deaths occurred in the lower older leaves preferentially in the outer extremities. Boyer (1976) observed that in maize under low leaf water potential, the lower leaves senesced first. If the water stress conditions persisted, tissue death occurred in the older leaves which subsequently led to defoliations.

When the subacute moisture stress condition was relieved as shown in the reversed watering regime treatments, the dormancy in meristemic activities was broken. This led to the development of new shoots and leaves. Cell activities recovered and the leaves expanded fully to their normal sizes. Gates (1968) attributed the effects of moisture stress on primordial initiation to be superficial similar to that of dormancy. Primordial development could resume once the stress condition was removed as long as the stress condition was not too severe or protracted. The recovery from non-lethal moisture stress upon removal of the stress condition was also discussed by Kramer (1969) although complete recovery of former condition might not be attained.

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