The performance of durian clones under supplementary irrigation

(Prestasi klon durian yang diberi pengairan tambahan)

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Key words: performance, durian clones, supplementary irrigation, water stress

Abstrak

Maklumat khusus tentang tindak balas tanaman terhadap bekalan air diperlukan untuk merekabentuk sistem pengairan dan menguruskannya. Kajian dijalankan di dusun durian Stesen Penyelidikan MARDI, Seberang Perai (1992–1995) untuk menentukan kesan pengairan terhadap tanaman durian. Dalam kajian ini, pokok durian klon D24 dan D99 yang berumur 5 tahun dibekalkan tiga jumlah air dengan menggunakan sistem pengairan mikro. Kaedah imbangan air digunakan untuk menilai jumlah komponen air. Corak penggunaan air setiap perlakuan dikesan dengan menyukat lembapan tanah di zon akar pada jarak masa dan tempat yang ditetapkan. Parameter pertumbuhan asas seperti lilitan batang, garis pusat kanopi dan ketinggian pokok disukat.

Pengairan tambahan pada musim kemarau memberi kesan baik yang ketara terhadap pertumbuhan pokok sejajar dengan jumlah air yang dibekalkan. Secara asasnya, keperluan air tanaman durian bergantung pada permintaan atmosfera, simpanan air tanah di zon akar dan saiz kanopi pokok. Air di zon akar diserap mulai dari kawasan yang berdekatan dengan batang pokok. Pengambilan air kemudian menjankau keluar ke arah luar kanopi dan ke bawah sekurang-kurangnya 1.2 m dalam. Pada kebanyakan bulan, hujan memadai untuk keperluan tumbuhan. Walau bagaimanapun, kemarau daripada bulan Januari hingga Mac boleh mengakibatkan kekurangan air yang ketara di zon akar. Klon D24 lebih peka terhadap ketegasan air berbanding dengan D99. Bagi tanaman tanpa air tambahan, penambahan ketinggian pokok dan keluasan kanopi lebih kecil dan daun yang gugur pada musim kemarau lebih banyak daripada pokok yang diberi air tambahan. Kesan pengairan terhadap penghasilan buah dan bunga tidak dapat dikenal pasti tetapi D99 menghasilkan buah yang lebih banyak daripada D24.

Abstract

Specific data on crop response to water application are essential for irrigation design and management purposes. A field experiment was conducted in the durian orchard at MARDI Research Station in Seberang Perai (1992–1995) to determine the effect of irrigation on matured durian trees. Five-year-old durian (clone D24 and D99) trees were subjected to three levels of water regimes using micro-irrigation system. A water balance method approach was used to quantify the values of the water components. The water consumption patterns in each treatment were monitored by measuring the soil moisture changes in the root zone at discreet time and space intervals. Basic growth parameters such as trunk girth, canopy diameter and plant height were measured.

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Results indicate that supplementary irrigation during the drought period contributes to significant growth increments consistent with the amount of water supplied to meet the deficit. The crop water consumption basically depends on the atmospheric demand, soil water storage in the root zone and the individual plant canopy size. Water at root zone is preferentially removed from the area closest to the trunk. Water uptake then extends radially outwards to the end of canopy boundary and downwards to at least 1.2 m depth. In most months, rainfall is adequate to meet the plant water requirement. However, the drought from January to March can induce severe water deficit in the root zone. The D24 clone is more sensitive to water stress than D99. Non-irrigated plants have significantly lower plant height and canopy diameter increments, and a higher leaf drop during drought than the irrigated plants. The effect of irrigation on fruiting and flowering is not clear but D99 has significantly more fruit than D24.

Introduction

Durian (Durio zibethinus Murr.), the king of Malaysian fruits, is sensitive to water stress. In areas with pronounced drought, crop establishment without supplemental water application has a low success rate. As such, most of the recent durian orchards are irrigated. Cost of irrigation can be very high and depends directly on the amount of water applied. The durian tree water needs vary with the crop stage and the climatic demand. Besides these, the soil and clonal differences are also known to have mitigating effect on the durian water requirements. Field observations showed that the responses of durian trees to irrigation during crop establishment are encouraging. Masri (1991) reported that D24 seedlings are more prone to drought stress than D99 seedlings. This shows that different clones have different tolerance to water stress. Survival rate of D24 seedlings during the early crop establishment stage is as low as 50% compared to 90% for D99 seedlings (Zainal Abidin 1986).

Available information on the actual water requirement for field grown durian are doubtful while published reports on watering of durian in Malaysia are limited. Abdul Jamil and Ghani (1991) recommended 8–10 L/plant per application every 4–7 days during the first year of field establishment, and Zainal Abidin et al. (1992) recommended daily watering at 6–8 L/plant to reduce flower abortion. Nik Masdek (1993) reported that growers in Thailand irrigate their crop to balance the evapotranspiration (ET) demand, which is approximately 5 mm/day throughout the fruiting period. For clayey soil, irrigation is applied at 3-day intervals while on sandy soil, water is applied everyday. Presently, irrigation system is designed based on the estimated crop water requirement of evergreen trees as recommended by FAO's guideline on crop water requirements (Doorenbos and Pruitt 1977). For a matured durian tree planted at a normal spacing of 10 m x 10 m, the estimated maximum crop water requirement can reach as high as 360 L/day. A system design to meet full crop water requirement of this magnitude can be costly and prohibitive in many cases. Cost can be minimized if specific water requirement of durian crop is known and irrigation system is designed to meet the minimal critical requirement up to the early productive stage. Such values can only be justified under field observations.

A study was, therefore, conducted to determine the effect of water application on developing durian trees of two clones grown in a drought prone area where supplementary irrigation is mandatory. Quantitative evaluation of water requirement for irrigated durian orchard was carried out.

Soil depth (cm)	Saturated conductivity (mm/day)	Bulk density (g/cm ²)	Sand (%)	Silt (%)	Clay (%)	Available water holding capacity (mm)*	% by volume
0–15	3.0	1.36	59	12	29	14	9
15-30	5.6	1.44	53	10	37	21	14
30–45	2.7	1.44	44	12	44	20	13

Table 1. Physical properties of soil in the experimental site

*soil moisture contents determined @ 10 kPa and 1 500 kPa

Materials and methods Irrigation treatments

The experiment was conducted in the durian orchard at MARDI Research Station in Seberang Perai located in agro-ecological zone 4 in northwest Peninsular Malaysia from 1992 to 1995. Zone 4 experiences 3 months of drought and 1 month of excessive rain as classified by Nieuwolt et al. (1982). The soil is a well drained sandy clay loam over yellowish-brown gravelly sandy clay of Hollyrood series, Oxic Dystropept (Wong 1981) and was previously planted with rubber. The soil physical properties are indicated in Table 1. The durian trees of clones D24 and D99 were planted in July 1987 at a spacing of 10 m x 10 m on flat land adjacent to an undulating terrain. Standard agronomic practices were followed (Zainal Abidin et al. 1992). During the dry period, the trees were individually irrigated with water from a deep tube well by microirrigation system.

Twelve durian trees of uniform size were selected from each clone from the same field and subjected to three levels of water regimes (W1, W2 and W3) by controlling the irrigation application rate during the irrigation period. Plants in treatment W1 received no irrigation but depended on rainfall only, while those in W2 and W3 were irrigated at approximately 75 and 100 L/day respectively during the drought period except during period prior to flowering and on weekends. The water was delivered through micro-sprayers and the volumes emitted were measured during the irrigation period. Irrigation was discontinued during the rainy days. The crop performance

data, viz. girth size at 50 cm from the soil surface, average canopy diameter, plant height, number of flowers and fruit, were collected. Leaf drop from each tree was also collected during the dry period of 1993.

The soil moisture status and depletion pattern of the root zone were monitored by a neutron probe (model CPN 503 DR Hydroprobe, CPN Corp., California, USA). Readings were taken at 0.15 m intervals from 0.15–1.50 m depth at 1.0, 2.5, 3.0, and 3.5 m from the trunks. For the top 75 mm, soil moisture status was monitored by gravimetric method. Weather data, rainfall and Epan were taken from a weather station about 400 m away from the plot.

Statistical analysis

Randomized block design (RBD) was used in the experiment. Means of the crop parameters were separated using Duncan Multiple Range Test at the 5% level. ANOVA were determined using SAS statistical packages. The statistical design assumed soil in this field is homogenous.

Theoretical consideration

Quantitatively, water available for a tree crop may be monitored by a water balance technique using the conventional formula: $\Theta_i = \Theta_{i-1} + Q_p + Q_I - Q_r + Q_d + Et_c$ Eqn. 1 Where Θ_i = soil water on the day or week in the profile

 Θ_{i-1} = soil water on previous day or week

- Θ_p = precipitation
- Q_I^P = irrigation
- $\vec{Q_r}$ = runoff
- Q_d = drainage
- $E\tilde{t}_{c}$ = actual crop evapotranspiration

During the dry period, the component Q_r and Q_d are negligible and may be ignored. The root zone soil water depletion $(\Theta_i - \Theta_{i-1})$ can be represented by: $\Theta_i - \Theta_{i-1} = Q_p + Q_1 - Et_c$ Eqn. 2

All components of equation 2 can be measured independently except Et_c which is essentially equivalent to actual water consumption by the tree, and can be solved from this equation. Alternatively, Et_c can also be estimated by:

 $Et_c = k_c ET_o$ Eqn. 3 Where ET_o = potential evapotranspiration (mm/day)

> k_c = crop coefficient indicating the crop capacity to meet the ET_o demand

Under non-restricting water condition, k_c can be expected to be about 1 or greater, and under restricted plant available water, k_c can be reduced.

An independent measurement of ET_o , in this case by Epan method, is then used to derive the expected k_c value for the crop at the particular average moisture condition in the root zone. Details of this theoretical consideration may be referred to Jensen (1980) and Doorenbos et. al (1979).

Results and discussion Rainfall and plant growth

The rainfall pattern for 1992–1994 and the 10-year average monthly pan evaporation at MARDI Research Station, Seberang Perai are presented in Figure 1. The moisture deficit duration (rainfall less evaporation) is normally 5 months in each year, consistently during December to February and occasionally in either March, June or July and September. Even though there is no water deficit on the yearly basis, the monthly deficit is obvious and can be detrimental to the durian plants. This is especially so during the development stage when the root zone is shallow and the total plant available water in the root zone is critical. Based on the atmospheric demand, the total moisture deficit for the 5 drought months during the 3-year period averaged 343 mm/year and amounted to about 23% of the 10-year average annual evaporation.

Growth of perennial crops in this environment can, therefore, be expected to be reduced corresponding to this moisture



Figure 1. Rainfall pattern for MARDI Research Station at Seberang Perai during 1992–1994 compared to the 10-year average annual evaporation

Treatment	Trunk girth increment (cm)	Canopy diameter increment (m)	Plant height increment (m)	Leaf drop (g) 1993
Water level				
W1 (0 L/day)	18.5	1.23a (100)	1.18a (100)	2 831a
W2 (75 L/day)	22.6	1.99b (162)	1.73ab (147)	662b
W3 (100 L/day)	22.8	2.21b (180)	2.04b (173)	612b
Clone				
D24	23.3	1.98	1.65	2 142a
D99	19.9	1.63	1.65	596b

Table 2. Effect of water level and clone on the growth performance of maturing durian trees at Seberang Perai, Dec. 1991–Dec. 1993

Mean values in each column with different letter differ significantly at p < 0.05 Values in brackets indicate percentage compared to W1

deficit. Similarly, if water deficit could be augmented by supplementary irrigation, corresponding growth difference could be anticipated. There is no simple correlation of water-growth relationship. However, over a few years, the cumulative differences due to water stress may be expressed in plant growth performance. As shown in Table 2, the values of some growth parameters for the irrigated trees can be higher than those of non-irrigated trees by more than 50%. The cumulative growth difference over 40 months indicated 20% and 16% growth advantage for canopy diameter and plant height respectively. These observations implied that the additional water application did bring about the anticipated differences in the crop performance. Daily water application at 75-100 L/tree as a supplement to rainfall registered a tangible growth difference indicative of the benefit of water. The amount of water was predetermined based on the canopy size, the expected growth during this period and the prevailing atmospheric demand.

Effect of water treatment

Water treatments influenced the growth and performance of the maturing durian trees. Significant growth differences were found between the irrigated and non-irrigated trees in terms of canopy diameter, plant height and leaf drop (*Table 2*). There was no significant difference between clones in vegetative growth except for trunk girth

Table 3. Effect of water level and clone on the growth performance of durian trees after the fourth year (Dec. 1992–July 1995)

Treatment	Trunk girth (m)	Canopy diameter (m)	Plant height (m)
Water level			
W1	0.79	6.1a (100)	6.24a (100)
W2	0.92	6.4ab (105)	6.60ab (106)
W3	0.88	7.4b (121)	7.22b (116)
Clone			
D24	0.93a	6.71	6.70
D99	0.78b	6.54	6.67

Mean values in each column with different letter differ significantly at p < 0.05 Values in brackets indicate percentage compared to W1

which was only apparent after the third year *(Table 3)*. The water treatment seemed to have no effect on fruiting at this age *(Table 4)*. However, D99 as expected had more fruit than D24 because it normally fruits earlier and more abundant than D24.

The canopy diameter and leaf drop are the most commonly used growth parameters for indicating water-growth relationship, irrigation design and management purposes. Leaf drop is an indicator of stress severity. The dry periods would induce the physiological system of durian tree to shed its leaves to minimize water loss. Leaf shedding can lead to slow growth as indicated in the amount of leaf drop, and the corresponding reduction in canopy diameter and plant height for non-irrigated (W1)

Treatment	No. flowers/tree		No. fruit/tree	
	1993	1995	1994	1995
Water level				
W1	10.5	72	10.3	25
W2	8.0	83	1.0	35
W3	7.8	72	5.5	37
Clone				
D24	5.8	58	0.8a	4a
D99	11.7	94	10.3b	61b

Table 4. Effects of water level and clone onflowering and fruiting pattern, 1993–1995

Mean values in the same column with different letter differ significantly at p < 0.05

plants (*Table 3*). D99 is more droughttolerant than D24, as indicated by lesser leaf drop during the same drought (*Table 2*).

The sensitive response of the canopy diameter of durian trees to water treatment is not surprising. It confirmed that irrigation design for durian trees can then be emulated based on the established principle of estimating tree crop water requirement (CWR) in litres per day given by: $CWR = ET_o \times CS$ Eqn. 4

Where $ET_o =$ potential evapotranspiration (mm/day) CS = area of canopy shade (m²)

By employing this simple formula, the CWR for short periods of 5-10 days can be estimated quite accurately. As an example, CWRs during the drought of 91/92 and 93/94 were calculated. The 5-day average daily Epan during the drought period ranges from 4 to 7 mm/day with an average of 5.6 mm/day. This value is equivalent to ET_{o} of 4.8 mm/day. The average canopy diameter of the crop were 4.4 m and 6.2 m measured in December 91 and December 93 respectively. Based on the canopy diameter and ET_{o} , and applying equation 4, the daily consumption during the drought periods (January to March) of 1992 was at least approximately 73 L/tree, while for the1993 drought, it was 145 L/tree.

Application of 75 and 100 L/day is equivalent to meeting the tree requirement at

 k_c value of approximately 0.7 and 1.0. It was about the right amount to meet the daily requirement during the 1992 period, and was not too excessive as indicated in the water content of the soil profile of the irrigated trees. The depletion level was higher in the non-irrigated trees compared to irrigated trees, indicating a greater accumulation of soil water deficit in the root zone. Progressively, the water requirement of the crop increased as the canopy developed. Generally, rainfall would supplement the crop water demand. Deficit in soil water will manifest if supply cannot meet the demand. Irrigation water requirement should be met to ensure detrimental soil water deficit does not occur. The exact amount of soil water required varies with different soil type, clone and age of tree. To trigger flowering, a slight soil water deficit is required. For our experiment, we allowed the stress to last about one month after the last rainfall prior to the drought period.

Soil water in the root zone

During periods of limited rainfall, available soil water in the root zone will determine the supply. The quantity available depends on the volume of root zone and its soil water storage capacity. For our plot, the soil moisture stored in the 1.2 m profile as measured by a neutron probe indicated that the maximum water content amounted to 280 mm during the wet period and a minimum of 170 mm during the dry period. Assuming maximum depletion occurred during these drought periods, then the profile available soil water for plant uptake is at least 120 mm. This amount is sufficient to support CWR for at least 4 weeks of normal transpiration. Under reduced transpiration due to leaf drop, curling and other physiological adaptation, this amount of soil water can support the crop through the normal dry period albeit under restricted growth. However, root zone of young durian plants is shallow and available soil water is correspondingly less. Masri (1990) reported the root distribution of durian is of inverted

cone in shape, with most of the root (60% of RLD) concentrated within 60 cm from the crown and 0–30 cm from the soil surface. Similarly, soil water depletion due to plant uptake would be expected to be consistent with root distribution. Observations on the soil water contents in root zone over a period of time indicated a similar pattern.

The mean of 43 readings (on different days) of total water content up to 1.2 m depth at 1.0 m from the trunk is smaller than the values at 2.5, 3.0 and 3.5 m from the trunk. The daily depletion calculated based on individual tree at a particular event (time periods of known moisture contents) indicated that durian trees preferentially remove the soil moisture from the upper soil layer and nearer the trunks. Soil moisture removal then extends radially outwards and downwards. There were differences in soil water contents between the non-irrigated trees and the irrigated trees (Figure 2). The soil water contents were lowest near the trunk. There were also differences in depletion levels under irrigated and nonirrigated condition (Figure 3). The depletion was greater nearer the trunk when antecedent soil water was wet. However, for the non-irrigated trees, the pattern of depletion had shifted to the wetter area away from the trunk by the end of February, since the soil water nearer the trunk had already been depleted earlier and subsequent depletion was minimal.

The non-irrigated trees have a higher depletion level but at a decreasing rate to as low as 18 L/day as observed during the 11-day rainless period in January for trees with 3 m canopy radius. The depletion after wet days can be as high as 195 L/day corresponding to k_c value of slightly greater than one. The durian tree root zone can store a substantial amount of soil water. However, prolonged drought can reduce the root zone's soil water content and irrigation is warranted to meet the crop water requirement for normal growth. Fluctuation of the soil water content in the upper layers and nearer the trunk is greater compared to



Figure 2. Soil water contents in the 1.2 m profile at four distances from the trunk of non-irrigated and irrigated durian trees on 10 Feb. 1993



Figure 3. Depletion pattern within the root zones of non-irrigated and irrigated durian trees during 10–28 Feb. 1993

those of the deeper layers and further away from the trunks.

Conclusion

Irrigation system is a necessity for a successful durian orchard in the drought prone areas of Malaysia. The responses of crop growth parameters to supplemental water were at least equivalent to the percentage of water deficit on the yearly basis. The durian tree preferentially takes up the soil water from the upper layer and nearer the trunk. Water uptake then extends radially and downwards towards the wetter area. The standard design procedure of using the average ET demand and canopy size of the tree to determine the daily requirement of each tree may be employed. However, the irrigation water requirement during various stages varies with canopy size and daily ET demand. Irrigation at 75-100 L/day per tree to meet partial water requirement, at approximately equivalent to k_a values of 0.5–1.0 during peak drought at the early productive years, was vegetatively beneficial. Variety D99 is more tolerant to drought and is more productive than D24 though its growth is slower during the early establishment.

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