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Response of papaya (*Carica papaya* L.) to limited soil moisture at reproductive stage

[Tindak balas betik (*Carica papaya* L.) terhadap kandungan air tanah yang terhad pada peringkat reproduktif]

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Key words: soil moisture deficit, stress, growth, papaya

Abstrak
Kajian terhadap kesan pengurangan air tanah pada peringkat reproduktif betik (*Carica papaya* L.) varieti Eksotika telah dijalankan. Perlakuan terdiri daripada tegasan, tadahan hujan dan pengairan . Didapati bahawa kadar penambahan tinggi dan garis pusat batang bagi perlakuan tegasan ialah masing-masing 52% dan 36% lebih rendah berbanding dengan perlakuan pengairan. Bilangan pelepah hidup sepokok pula 50% lebih rendah. Pengurangan kandungan air tanah pada perlakuan tegasan juga telah mengurangkan bilangan bunga dan buah masing-masing sebanyak 86% dan 58% berbanding dengan perlakuan pengairan. Tegasan air juga didapati merencatkan pertumbuhan dan pembesaran buah betik.

Abstract
The effects of depleting soil moisture at the reproductive stage on papaya (*Carica papaya* L.), Eksotika variety, were studied under field conditions. Treatments consisted of stress (not irrigated and sheltered), rainfed (not irrigated but exposed to rainfall) and irrigated. In the stress treatment, height and trunk diameter increments were 52% and 36% respectively less than those of irrigated plants. Consequently, plant under stress treatment had 50% fewer attached leaves per tree. Water deficit significantly reduced number of flowers and fruit by 86% and 58% respectively. Water stress also retarded growth and development of papaya fruit.

Introduction

Considerable attention is currently given to the soil moisture level as a factor that can affect fruit production in Malaysia. This is due to the varying rainfall duration and distribution in this country. The diurnal, seasonal and annual distributions of rainfall vary widely from region to region and from year to year (Nieuwolt 1982). These variations could lead to drought of varying intensities during the cropping season.

The effects of drought on crop growth and development are a consequence of morphological and physiological alterations of plant growth. Therefore, the overall response of plants to water stress is the

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Plate 1. Rainfall was excluded from treated plots using plastic covers installed along the tree rows

result of complex interactions of many physiological processes.

Studies on the effects of water stress on growth and development of papaya under Malaysian conditions are relatively limited. Chan and Tee (1975) reported that dry spells caused abortions of floral and fruit structures, leading to sterile phases and fruiting skips along the stem. In another study, Ong and Chan (1983) found that high temperature interacted with dry spell resulted in fluctuations of fruit yield of three types of papaya. Constant availability of soil moisture was associated with continuous growth of papaya which resulted in the regular production of flowers and fruit (Anon. 1982).

In this study, the effects of depleting the soil moisture at the reproductive stage on growth, flowering and fruit set of Eksotika papaya were evaluated under field conditions.

Materials and methods

Seeds of papaya variety Eksotika were sown in 15 cm x 23 cm polyethylene bags and were raised in the nursery with a 50% shade level. At 6 weeks after sowing, the seedlings were transplanted to field plots arranged in a randomised complete block design with four replications. The planting distance was 1.8 m x 3 m and each replicated plot consisted of four sample trees with adequate border rows. All plots were drip irrigated to ensure uniform and vigorous crop growth before the various treatments were imposed.

Three treatments namely, stress (not irrigated and sheltered), rainfed (not irrigated but exposed to rainfall) and irrigated, were established at the fourth month after transplanting. Soil moisture deficit in the stress treatment was induced by withholding irrigation as well as excluding rain water using transparent plastic sheet covers. These sheets were supported by wooden frames installed 1-m high along the tree rows. Such structures permitted free air movement under the covers *(Plate 1)*. Trenches of 1-m wide and 1-m deep were constructed to prevent interference of soil moisture among plots.

Soil moisture in the top 30 cm soil depth was monitored every 2 days by using the neutron scattering method (Hydroprobe Model ELE-503 DR). The average readings

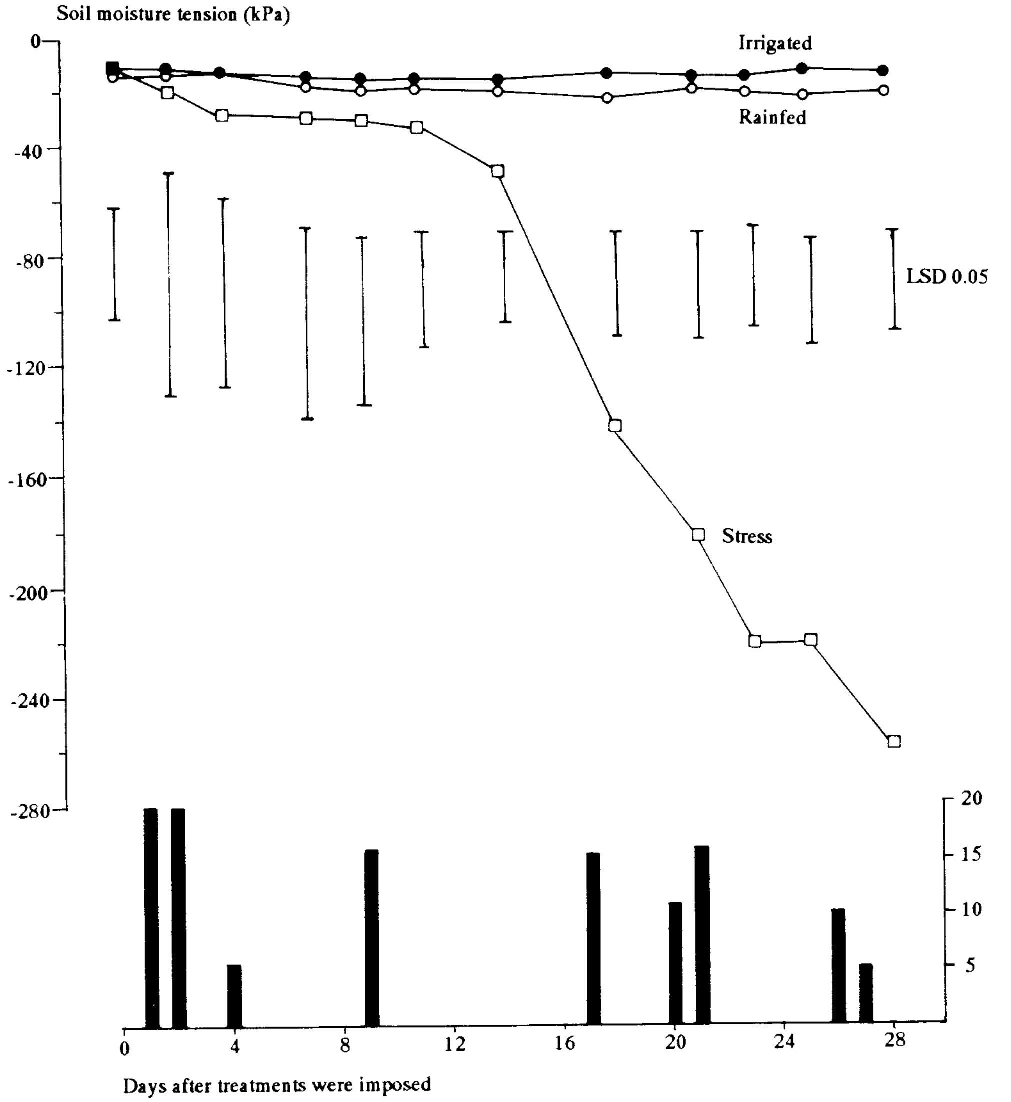

Figure 1. Changes in soil moisture tension in the top 0-30 cm soil depth as affected by the treatments and rainfall

from two access tubes installed in each plot were considered as one replication. Data on the volumetric soil moisture were transformed into soil moisture tension (Ψs) using the soil moisture characteristic curve developed by Wong (1981).

Weekly recordings of vegetative growth parameters such as plant height, stem diameter and number of attached leaves started immediately after the treatments were imposed. Plant height was measured from the collar at the base of the trunk to the tip of the youngest shoot. Stem diameter was determined at 15 cm above the collar using vernier calipers. Ten healthy fruit per treatment separated as hermaphrodite and female were tagged 1 day after anthesis and their lengths and circumferences were monitored so as to quantify the effects of stress on fruit growth and development. Treatments of differential moisture levels were terminated 30 days after they were

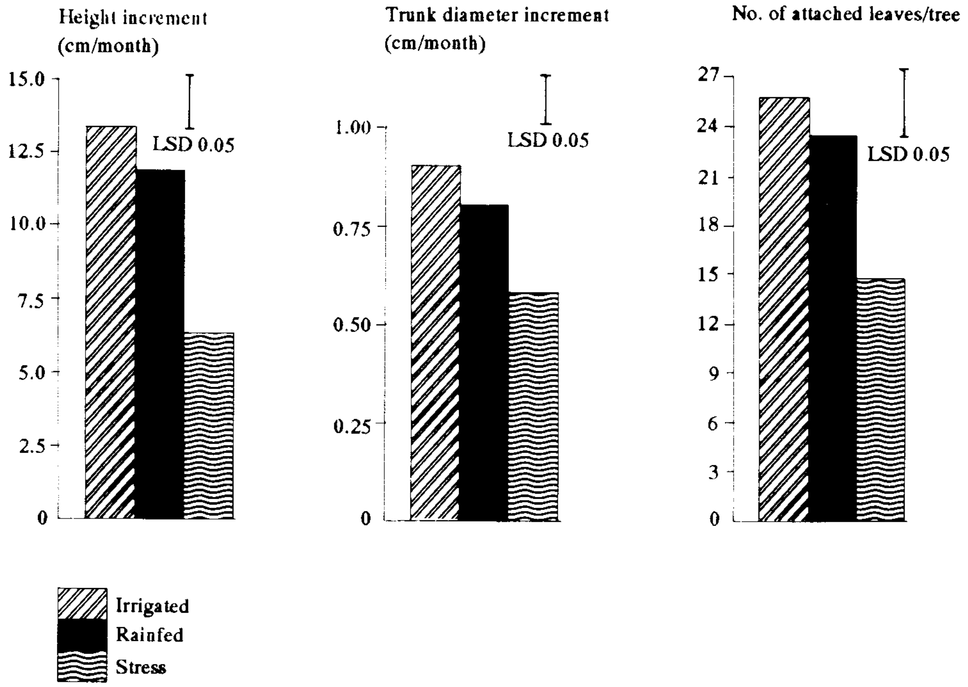

Figure 2. Effects of soil moisture deficit on vegetative growth of papaya

imposed and reproductive parameters such as number of flowers and fruit were recorded.

Results and discussion

Poor water availability in the soil and high transpiration result in a negative water balance. Plants suffer moisture stress when the loss of water by plants is greater than its uptake. In this experiment, moisture stress was defined as a function of soil moisture tension (Ψs). For most crop species, optimum Ψs are in the range of -20 to -50 kPa (Mengel and Kirkby 1982).

In the irrigated and rainfed treatments, the Ψs fluctuated between -12 and -18 kPa *(Figure 1),* indicating that the plants did not suffer any moisture deficit. By contrast, the Ψs in the stress treatment gradually increased and were significantly (p = 0.05) higher (-65 kPa) than the Ψs in the rainfed (-20 kPa) and irrigated plots (-16 kPa) 14 days after the treatments were imposed. After the 14th day of withholding water, the Ψs in the stress treatment increased tremendously from -65 kPa to -260 kPa. This suggested that the plants in the stress treatment experienced moisture deficit. Visual symptoms of wilting were first noticed in these plants on the 14th day after withholding water. The wilting or drooping of leaves in mid-afternoon is a sign of plants beginning to experience moisture deficit (Masri and Boote 1987).

Plant height and trunk size were used to characterise vegetative growth of papaya trees. The height and trunk diameter increments of plants under stress treatment were 52% and 36% respectively, which are significantly lower (p = 0.05) than those in the irrigated treatment *(Figure 2)*. This suggested that the growth of papaya trees was retarded under moisture stress conditions. The lower height and trunk diameter increments in stress plants corresponded closely to the higher Ψs values

(Figure 1). In comparison, height and trunk diameter increments of plants under rainfed treatment did not differ significantly ($p = 0.05$) from that of the irrigated plants and this also corresponded closely to their respective Ψs values.

Limited soil moisture caused significant ($p = 0.05$) reduction in leaf number *(Figure 2).* Plants under moisture stress had 50% fewer attached leaves per tree than that of the irrigated plants. The fewer leaves in the stress treatment were due to premature senescence. Fewer leaves per tree will mean a loss of photosynthetic surface for the plant. Increased leaf senescence under water stress was also reported in corn (*Zea mays* L.) (Sharp and Davies 1985), and in corn and soybean (*Glycine max* L.) by Masri and Boote (1988).

As for the reproductive parameters, plants under rainfed and stress treatments had significantly fewer flowers per tree compared with irrigated plants *(Figure 3).* Moisture stress caused 35% and 86% reduction in flower number in the rainfed and stress treatments respectively as compared with the irrigated treatment. Similarly, fruit number in the stress and rainfed treatments were 58% and 45% respectively fewer compared with the irrigated plants *(Figure 3).* The reduction in the number of flowers and fruit may be attributed to the excessive abortion. It has been reported that dry spells cause abortion of floral and fruit structures of papaya (Chan and Tee 1975).

Moderate water deficit as depicted by the rainfed treatment did not significantly retard vegetative growth during the reproductive stage. These were manifested by the non-significant differences ($p = 0.05$) in height and trunk size increments as well as leaf number per tree between the rainfed and irrigated treatments. However, the effects were significant ($p = 0.05$) for reproductive parameters (number of flowers and fruit). It appears that reproductive parameters were

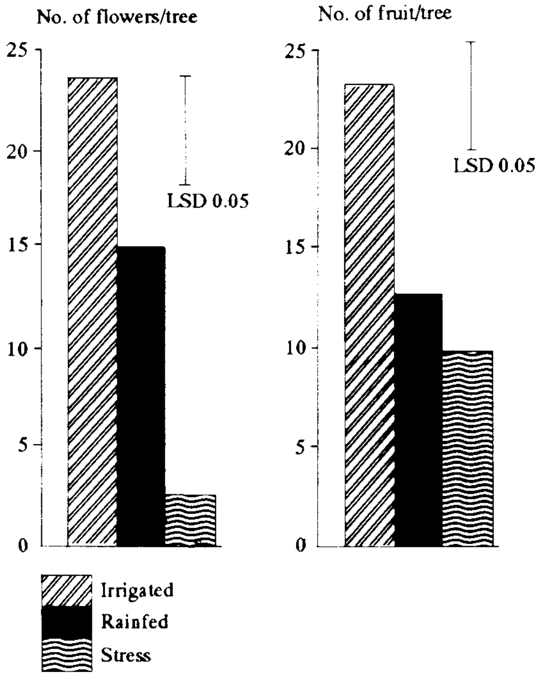

Figure 3. Effects of soil moisture deficit on number of flowers and fruit of papaya

more sensitive to water stress compared with vegetative parameters during this stage of crop growth (4-5 months after transplanting).

Data on the weekly increment in fruit length and circumference of each treatment are shown in *Figure 4.* The rates of length and circumference increment in the rainfed and stress treatments are slower than those of the irrigated. This indicated that the rates of fruit growth and development were slower under water stress conditions. The slower rate of fruit growth was true for both female and hermaphrodite fruits.

Conclusion

The induced soil moisture stress conditions during the reproductive growth stage had caused significant reduction in vegetative and reproductive growth of papaya. Plant height and trunk diameter increments were significantly reduced and premature leaf senescence was excessive. Flower production and fruit set were

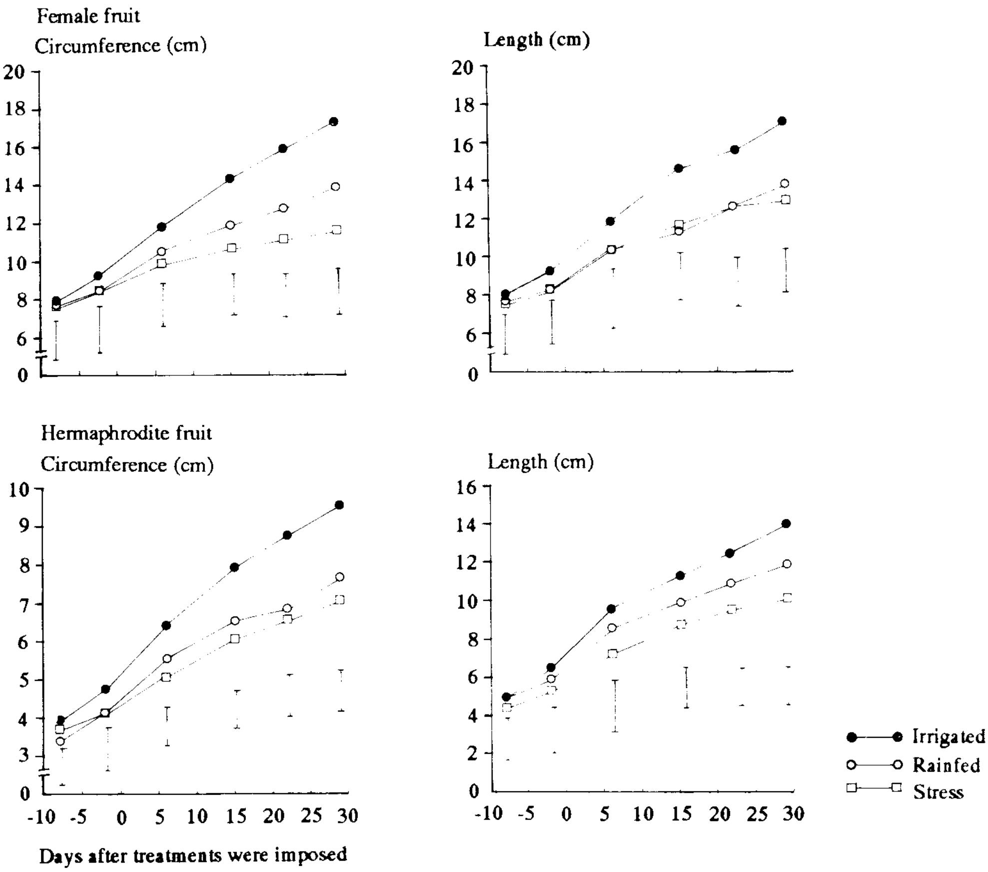

Figure 4. Fruit growth and development as affected by different soil moisture levels

greatly suppressed while fruit growth and development were retarded.

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