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Effects of water stress on photosynthesis, flowering and fruit-set of field-grown carambola (*Averrhoa carambola* L.)

[Kesan tegasan air terhadap fotosintesis, pembungaan dan pembentukan putik buah belimbing (*Averrhoa carambola* L.) di ladang]

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Key words: water stress, photosynthesis, flowering, fruit-set, carambola

Abstrak

Kesan kemarau terhadap fotosintesis, pembungaan dan pembentukan putik dua klon belimbing komersil telah dikaji di ladang Pusat Penyelidikan Buah-Buahan, MARDI Bukit Tangga, Kedah. Pokok belimbing telah didedahkan pada dua tahap air yang berbeza iaitu diairi setiap hari sehingga tahap kapasiti ladang dan tanpa pengairan selama 21 hari pada musim kemarau Januari 1992. Perubahan kandungan air tanah dan kadar fotosintesis serta kesan terhadap pembungaan dan pembentukan putik telah diukur sepanjang tempoh kajian. Hasil daripada kajian menunjukkan bahawa fotosintesis, ketumpatan bunga dan buah serta pembentukan putik telah berkurangan secara ketara akibat tegasan air. Kadar fotosintesis maksimum kedua-dua klon didapati pada PAR 700 μmol/m^2 setiap saat dengan B17 mempunyai kadar yang lebih tinggi iaitu 11.1 μmol/m^2 setiap saat berbanding dengan 8.1 μmol/m^2 setiap saat bagi B10. Bagaimanapun, kadar ini berkurangan kepada 6.7 (B17) dan 6.4 (B10) μmol/m^2 setiap saat semasa tegasan air. Tegasan air juga mengurangkan ketumpatan bunga daripada 29.8 kepada 19.5 (B10) dan daripada 38.8 kepada 17.3 (B17) bunga/cm^2 BCSA, sementara ketumpatan buah berkurangan daripada 24 kepada 18 (B10) dan daripada 17 kepada 10 (B17) buah/cm^2 BCSA. Ketumpatan buah yang kurang semasa tegasan air ialah akibat kadar pembentukan putik yang rendah yang telah berkurangan daripada 83% kepada 38% (B10) dan daripada 90% kepada 25% (B17). Pengurangan yang lebih teruk pada B17 dalam semua parameter menandakan bahawa B17 lebih peka kepada tegasan air berbanding dengan klon B10.

Abstract

The effects of drought on photosynthesis, flowering and fruit-set of two commercially grown carambola clones were studied under field conditions at the Fruit Research Centre, MARDI Bukit Tangga, Kedah. The plants were subjected to two moisture levels, namely ‘irrigated’ (daily irrigation at field capacity) and ‘drought’ (no irrigation for a 21-day period), during the drought season of January 1992. Changes in the soil moisture, photosynthetic rate as well as the effects on flowering and fruit-set were monitored during the experimental period. Results showed that photosynthesis, flower density, fruit density and fruit-set were significantly reduced by water stress. Maximum photosynthetic rates were observed at PAR 700 μmol/m^2 per second in both clones with higher rate of 11.1

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μmol/m^2 per second for B17 as compared with 8.1 μmol/m^2 per second for B10. However, under water stress conditions, these rates were decreased to 6.7 (B17) and 6.4 μmol/m^2 per second (B10). Water stress also reduced flower density from 29.8 to 19.5 (B10) and from 38.8 to 17.3 (B17) flowers/cm^2 BCSA while fruit density from 24 to 18 (B10) and from 17 to 10 (B17) fruit/cm^2 BCSA. Lower fruit density was accounted for by the low fruit-set observed in the non-irrigated plants where fruit-set was reduced tremendously from 83% to 38% (B10) and from 90% to 25% (B17) by water stress. It was also shown that the magnitude of reduction by water stress in all parameters measured was more severe in B17 suggesting that this clone is more sensitive to water stress than B10.

Introduction

Carambola (*Averrhoa carambola* L.) or commonly known as starfruit is an important fruit type grown commercially in Malaysia. In terms of moisture supply, the wet tropical climate of Malaysia with total annual rainfall of more than 2 500 mm is considered excellent for carambola production. However, the uneven distribution of rainfall may cause serious problems such as water stress. Nieuwolt (1982) reported that the diurnal, seasonal and annual distributions of rainfall in Malaysia varied from region to region and from year to year. These variations could lead to drought of varying intensities during the cropping season, which could limit carambola production due to problems of water stress.

Insufficient water has been a major limiting factor in the growth and production of fruit trees (Hanan 1972; Jones et al. 1985). Consequently, the effects of water stress on photosynthesis, flowering and fruiting are important since crop yield ultimately depends on the rate and efficiency of these processes. In a glasshouse study, Mohd. Razi et al.(1992) found that photosynthesis, respiration, stomatal conductance and chlorophyll content of carambola seedlings were significantly reduced by water stress. They also found that leaf, stem and root growth of the seedlings was also reduced by water stress. Campbell et al. (1985) reported that carambola growth and production in Florida were adversely affected by drought.

To fully understand the effects of water stress on carambola production, it is important to ascertain the effects under field conditions. Although it is possible to obtain results from pot experiments in controlled environments, the behaviour of plants tends to differ in their response to water stress under field conditions. Thus, this study was conducted to evaluate the effects of water stress on photosynthesis, flowering and fruit-set of field-grown carambola. It was also intended to quantify any differential response among carambola clones to water stress in the field.

Materials and methods

Cultural practices

The plants used for the experiment, consisting of B10 and B17 clones, were planted in 1989 at the Fruit Research Centre, MARDI Bukit Tangga, Kedah. The planting distance was 6 m x 6 m, and the soil type was sandy clay loam. Fertilization, irrigation and other agronomic practices were applied as recommended by Izham et al. (1992). Pollinizer clone of B2 was planted in rows, one row for every four rows of B10 or B17.

Treatments and experimental design

During the drought season of 1992, the plants were subjected to two moisture levels, namely irrigated (daily irrigation to field capacity) and drought (no irrigation beginning 18 January 1992 until 21 days later). The moisture content in the irrigated plots was maintained at field capacity by monitoring gravimetrically the moisture values higher than 0.03 MPa of the moisture curve. The treatment plots were arranged factorially in randomized complete block design (RCBD) with four replications. During the 21-day dry period, growth parameters were monitored. Data were analysed using Analysis of Variance (ANOVA) and differences between treatment means were compared by the Least Significant Difference (LSD) method.

Measurements of parameters

Soil moisture content was used to indicate moisture status in irrigated and drought plots. The moisture levels in the irrigated and drought plots were monitored weekly by the gravimetric method. Soil samples at 60 cm deep were taken at four equidistant points from each of the two selected trees in each replicate using soil cores. The difference between fresh and oven-dried (90 °C for 48 h) weights was used as moisture content percentage. Data on the volumetric soil moisture were then transformed into soil moisture potential using the soil moisture characteristic curves developed for this particular soil type.

The photosynthetic rate of leaflet pair number 3–5 of the most recent flush on a selected branch was measured using the LCA3 Portable Photosynthesis System (ADC-Hoddesdon, UK). The branches selected were mostly located in the middle of the canopy. The photosynthetic rate measurements, 8–10 measurements on each tree, were made on the 20th day after the treatments were imposed. Since the measurements were made from 0900 h to 1400 h, the photosynthetic rates at photosynthetic active radiation (PAR) ranging from 100 to 900 μmol/m^2 per second were obtained. The relative humidity and temperature during these measurements were 62.1–70.3% and 28.7–32.9 °C.

The magnitudes of flowering and fruiting as affected by water stress were expressed as flower and fruit densities. Branches, mostly secondary, were selected and tagged. Their diameter, initial number of inflorescences and fruit were recorded. At the end of the study, the number of flowers and fruit were again counted and the calculated flower and fruit densities were expressed on the basis of per unit branch cross sectional area (BCSA) as suggested by Lombart et al. (1988).

Results and discussion

Soil water potential

Plants normally suffer moisture stress when the loss of water is greater than the uptake resulting in a negative water balance. In this experiment, moisture stress is defined as a function of soil moisture potential (ψs). For most crop species, the optimum ψs are in the range of –0.2 to –0.5 MPa (Mengel and Kirkby 1982). The changes in ψs for both irrigated and drought treatments are shown in *Figure 1*. In the irrigated plots, the ψs remained at –0.03 MPa indicating that the plants did not suffer any moisture stress. By contrast, the ψs in the non-irrigated plots decreased tremendously and were significantly lower (–0.81 and –0.56 MPa for B10 and B17 plots respectively) on the 14th day after treatments were imposed. From the 14th day onward, the ψs remained significantly lower in the non-irrigated plots as compared with controls although slight rainfall was experienced on the 20th day.

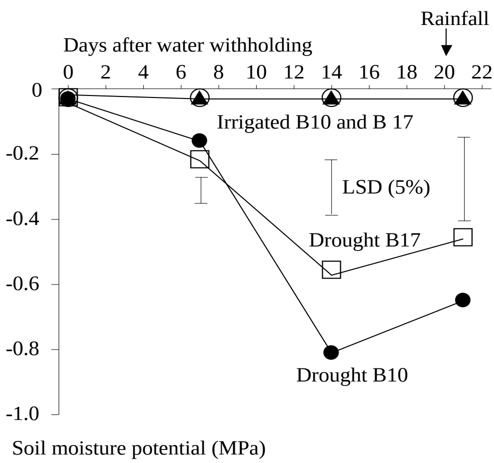

Figure 1. Changes in soil moisture potential as affected by treatments

The lower values of ψs indicated that plants in the non-irrigated plots experienced moisture stress. As pointed out by Mengel and Kirkby (1982) that generally the optimum ψs for soils are in the range of –0.20 to –0.50 MPa, the ψs in the drought treatments were well below –0.50 MPa for both B10 and B17 plots. Visual symptoms of mid-day leaf wilt were observed on both clones on the 10th day after water was withheld. The wilting and drooping of leaves in mid-afternoon is a sign of plants experiencing moisture deficit (Masri and Boote 1987).

Effects of drought on photosynthesis

As shown in *Figure 2*, under non-stress conditions, photosynthetic rates of both clones increased as PAR increased achieving maximum rates at PAR of about 700 µmol/ m^2 per second. At PAR greater than 300 µmol/m^2 per second, the photosynthetic rate of B17 was higher than B10 and at PAR higher than 500 µmol/m^2 per second these rates were significantly different ($p = 0.05$) suggesting that B17 is more efficient in converting light for photosynthetic processes. It was also observed that in both clones, photosynthetic rates declined at PAR greater than 700 µmol/m^2 per second which may indicate photosynthetic saturation at PAR 700 µmol/m^2 per second in carambola.

When comparing plants from the drought and irrigated plots, the photosynthetic rates of both B10 and B17 were relatively unaffected by water stress at PAR less than 400 µmol/m^2 per second *(Figure 3).* This non-significant reduction in both clones might not be related to moisture status but more to insufficient light that limits photosynthetic activities. However, at PAR greater than 500 µmol/m^2 per second, the rates of photosynthesis of both clones were significantly reduced by water stress as compared with their respective control plants. Similar reduction in photosynthesis and overall plant growth of carambola under water stress was also reported by Mohd. Razi et al. (1992).

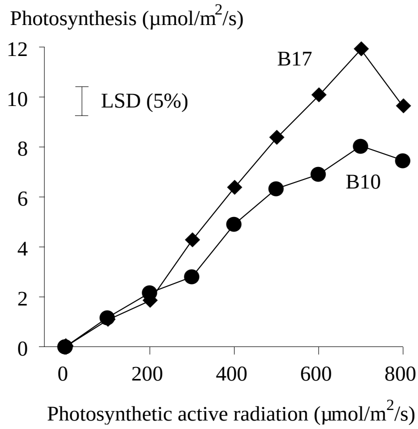

Figure 2. Photosynthetic rate of B10 and B17 under non-stress conditions

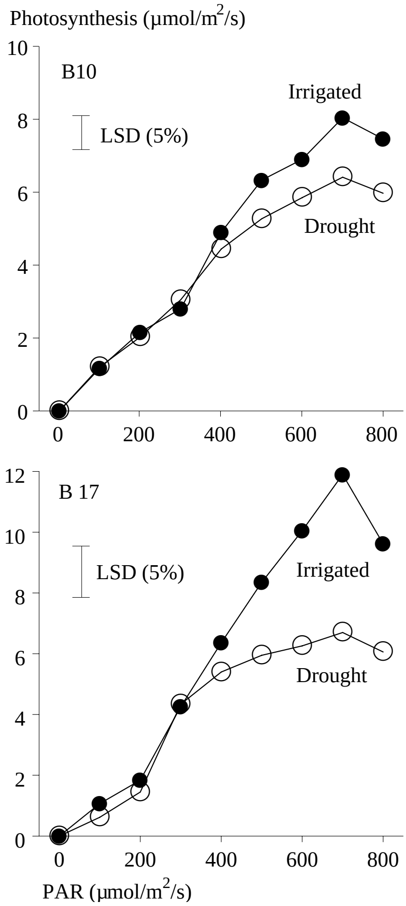

Figure 3. Photosynthetic rates of B10 amd B17 under irrigated and drought conditions

The response of the two clones to water stress was also based on the calculated percentage of reduction in photosynthesis by each clone as compared with their respective controls at the same PAR levels. This was due to the differences in the photosynthetic rates of the two clones at any PAR levels *(Figure 2)*. It was found that at PAR greater than 400 μmol/m^2 per second the photosynthetic reduction in both clones was less than 10% and photosynthesis seemed not significantly reduced by water stress. However, as PAR increased from 500 to 700 μmol/m^2 per second, the photosynthetic rates of both clones were significantly reduced by water stress, where the reduction in photosynthesis was always higher in B17 than in B10. A maximum reduction of 50% was observed in B17, whereas the maximum reduction in photosynthesis of B10 was only about 20%. Severe reduction in photosynthesis of B17 clone indicated that B17 is more sensitive to water stress than B10.

Effects of drought on flower density

The ability of carambola plants to produce flowers is important in determining fruit yield. Besides reducing vegetative growth (Mohd. Razi et al. 1992), water stress also affects flower production of carambola *(Figure 4)*. Flower densities of B10 and B17 were relatively similar, about 30 flowers/cm^2 BCSA under irrigated conditions. Water stress was found to reduce flower density of B17(43.9%) and B10 (34.5%) as compared with their respective controls. These results may indicate that water stress did not favour flower production in carambola. For papaya, Masri et al. (1990) reported similar results of reduced flower production up to 86% under water stress conditions. They attributed this severe reduction to excessive flower abortion. However, in the case of carambola, a lower fruit density was observed due to lesser initiation of new flower buds during the water stress period and not due to flower abortion. These results were in agreement with Menzel et al. (1986) who found virtually no floral bud initiation in passionfruit *(Passiflora edulis)* subjected to water stress. They also concluded that water stress reduced flower size but did not lead to premature abscission of flowers.

Effects of drought on fruit density and fruit-set

Under non-stress conditions, B10 had higher fruit density (24 fruit/cm^2 BCSA) than B17 (17 fruit/cm^2 BCSA) as shown in *Figure 5*. This indicates that B10 is a more prolific clone. However, under water stress conditions, fruit densities of both clones were reduced significantly. In comparing the magnitude of reduction, it was observed that fruit density of B17 was more severely affected (41% reduction) as compared with 25% reduction in B10.

The reduction in fruit density might be due to lower fruit-set in non-irrigated plants as depicted in *Figure 6*. Fruit-set was 83% (B10) and 90% (B17) under irrigated

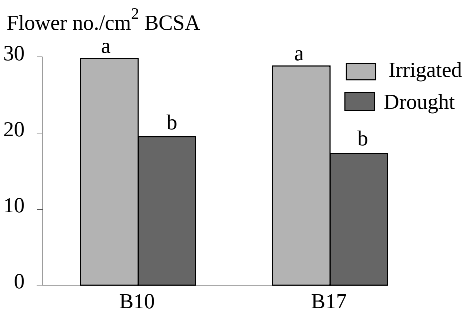

Figure 4. Flower densities of B10 and B17 under irrigated and drought conditions

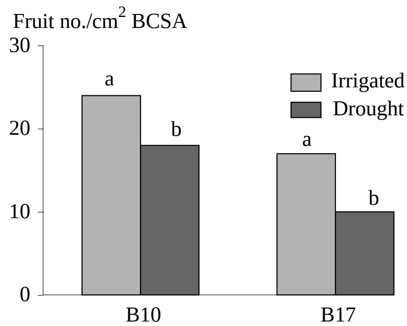

Figure 5. Fruit densities of B10 and B17 under irrigated and drought conditions

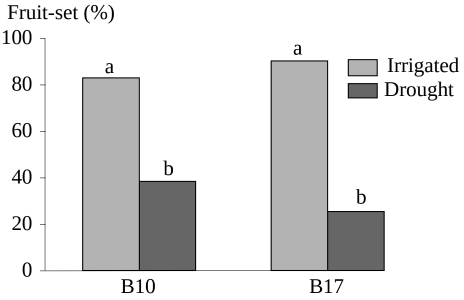

Figure 6. Fruit-set of B10 and B17 under irrigated and drought conditions

conditions. However, water stress had significantly reduced fruit-set to 38.4% and 25.4% in B10 and B17 respectively. These results indicated that fruit-set in carambola was very sensitive to moisture stress. Reduction in fruit-set due to water stress was tremendous, 75% (B17) and 42% (B10). These results suggested that reduction in fruit density of carambola under water stress conditions was mainly due to reduced fruit-set. Similar results were also obtained in passionfruit (Menzel et al. 1986). In terms of magnitude of reduction of fruit-set due to water stress, it was again found that the reduction was more severe in B17 than B10.

Conclusion

Photosynthetic rate, flower and fruit densities as well as fruit-set of field-grown carambola were significantly reduced by water stress. However, it was found that there was differential sensitivity of carambola clones to water stress conditions. Reductions by water stress on all parameters measured were more severe in B17 as compared with B10, suggesting that B17 is more sensitive to water stress than B10. These findings have practical implication on the need to irrigate during periods of drought to prevent reduction in yield of carambola.

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