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Effects of water stress on flowering, fruit drop and fruit size of 10-year-old mangosteen (*Garcinia mangostana* L.) trees

[Kesan tegasan air terhadap pembungaan, pengguguran buah dan saiz buah pada pokok manggis (*Garcinia mangostana* L.) berumur 10 tahun]

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Key words: water stress, flowering, fruit drop, fruit quality, mangosteen

Abstrak

Kesan aras air tanah yang berlainan terhadap pembungaan, hasil dan kualiti buah manggis (*Garcinia mangostana* L.) pada pokok berumur 10 tahun telah dikaji pada musim kemarau di Stesen MARDI Bukit Tangga, Kedah. Perlakuan pengairan terdiri daripada: T1 (1 pemancar/pokok), T2 (2 pemancar/pokok), T3 (3 pemancar/pokok) dan T4 (4 pemancar/pokok). Satu pemancar dianggarkan dapat mengeluarkan 50 liter air sejam pada tekanan 100 psi. Perlakuan dimulakan 8 minggu sebelum jangkaan pembungaan. Potensi air daun (Ψ_L) telah digunakan untuk mengukur status air pada setiap perlakuan.

Perlakuan T1 mengalami tegasan air yang teruk dengan Ψ_L jatuh ke aras –0.80 MPa mulai minggu ketiga. Pada minggu kelapan, Ψ_L bagi T1 jatuh sehingga –1.17 MPa, kekal selama seminggu dan kemudiannya berlaku pembungaan pada minggu ke-10. Pada tempoh yang sama, T4 mengandungi lebihan air dengan Ψ_L sekitar –0.65 MPa. Potensi air daun bagi T2 dan T3 dianggap sederhana iaitu antara –0.65 MPa hingga –0.80 MPa pada kebanyakan hari.

Turutan keamatan pembungaan ialah T2>T3>T4>T1. Ini menunjukkan ketiadaan air secara berterusan atau keadaan air yang berlebihan gagal menghasilkan bunga yang lebat. Perlakuan T2 dan T3 yang sederhana status airnya menghasilkan bunga yang terbanyak. Selepas minggu ke-10, perlakuan yang sama dilakukan terhadap pokok baru dengan bilangan bunga yang seragam. Didapati Ψ_L bagi T1 antara –1.10 hingga –1.47 MPa semenjak tarikh berbunga sehingga hujan lebat telah menamatkan kajian ini. Manakala nilai bagi perlakuan lain ialah –0.78 hingga –0.99 MPa (T2), –0.74 hingga –0.84 MPa (T3) dan –0.63 hingga –0.78 MPa (T4). Keadaan ini menunjukkan status air kekal sama sebelum dan selepas pembungaan.

Pokok yang mengalami kekurangan air yang teruk mengalami kadar pengguguran buah yang tinggi sehingga mencapai 77% (T1) 6 minggu selepas berbunga manakala pokok yang mendapat air berlebihan (T4) hanya mengalami 50% pengguguran buah. Pokok yang menerima bekalan air yang sederhana (T2 dan T3) mengalami 62–71% pengguguran buah. Tegasan air juga menyebabkan saiz buah yang kecil semasa pembentukan serta penuaian. Pengurusan air yang

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baik dengan bekalan air yang sederhana sebelum dan selepas pembungaan adalah penting bagi meningkatkan hasil tanaman manggis.

Abstract
The effects of imposing different soil moisture levels on flowering, fruit yield and fruit growth of mature mangosteen (*Garcinia mangostana* L.) trees were studied in drought months at MARDI Station, Bukit Tangga, Kedah. The treatments: T1 (1 emitter/tree), T2 (2 emitters/tree), T3 (3 emitters/tree) and T4 (4 emitters/tree), were imposed at 8 weeks prior to expected flowering. Each emitter was estimated to release water at a rate of about 50 litres an hour. After flowering, similar treatments were continued on a new set of trees for another 6 weeks after which the trial had to be terminated due to heavy rainfall. Leaf water potential (Ψ_L) was used to indicate plant water status.

T1 was the most severely stressed with Ψ_L dropping to values below –0.80 MPa from the third week. On the eighth week, the value dropped to –1.17 MPa, remained constant for another week before occurrence of flowering at the 10th week. Within the same period, T4 had excess water supply as indicated by Ψ_L values fluctuating around –0.65 MPa. However, the Ψ_L in T2 and T3 were moderately stressed with values ranging from –0.65 to –0.80 MPa on most days.

Flowering intensity was in descending order: T2>T3>T4>T1. This indicated that lack of water or too much of it failed to trigger profuse flowering. It was the moderately stressed water treatments (T2 and T3) that produced the highest number of flowers. From the 10th week onwards, similar treatments were imposed on a new set of trees bearing approximately equal number of flowers. The Ψ_L of T1 fluctuated between –1.10 and –1.47 MPa for 8 weeks from the commencement of flowering until sudden termination of the trial due to heavy rainfall. In contrast, the Ψ_L values within the same period for the other treatments were –0.78 to –0.99 MPa (T2), –0.74 to –0.84 MPa (T3) and –0.63 to –0.78 MPa (T4). These values indicated a similar trend of Ψ_L before and after flowering.

Plants under severe stressed (T1) had a very high percentage of fruit drop of up to 77% at 6 weeks after flowering while plant receiving excess water (T4) had only 50% fruit drop. The moderately stressed trees (T2 and T3) had 62–71% fruit drop. Water stress also significantly reduced initial fruit size and at harvest. Good management of irrigation water that resulted in trees exposed to moderately stressed conditions prior to and during flowering is important in ensuring higher fruit production of mangosteen.

Introduction

Under the new Third Agriculture Policy of Malaysia, special attention is given to mangosteen (*Garcinia mangostana* L.) identifying it as a potential fruit type to be developed progressively and aggressively for export purpose. However, commercial production of this crop has been hampered by many limiting factors. One of them is the lack of water resulting from serious drought. Although the total annual rainfall in Malaysia is more than 2 500 mm, its uneven distribution has caused serious drought that affects growth and production of many agricultural crops (Nieuwolt 1982).

Insufficient water has been a major factor limiting growth and production of fruit trees (Hanan 1972). Water stress affects a wide range of physiological processes such as stomatal behaviour, photosynthesis, transpiration, translocation and partitioning of assimilates (Jones et al. 1985). Mangosteen is believed to be one of the fruit crops most sensitive to water stress. However, studies on the effects of water stress on mangosteen were mainly confined to their seedling or vegetative growth stages. For example, Masri et al. (1999) found that stomatal conductance, photosynthesis and overall seedling growth are greatly affected by water stress.

Effects of water stress on reproductive growth are important on account of their direct relationship with yield. Flowering, fruit set, premature fruit drop, fruit growth and fruit quality are important aspects of yield component that are usually affected by water availability. These have been proven in the studies on papaya (Masri et al. 1990), starfruit (Masri 1995) and durian (Masri 1999). However, information on the roles of water in affecting reproductive parameters of mangosteen is still lacking. Hence, this study was undertaken to quantify the effects of water stress on flower initiation, fruit drop, fruit growth and fruit quality of mangosteen. This knowledge may provide information for the proper irrigation management to ensure higher yield of this important fruit type.

Materials and methods

Experimental plants

The 10-year-old trees that had fruited for several seasons were planted in 1989 at the MARDI Bukit Tangga Station, Kedah. The planting distance was 7 m x 7 m and the soil type was Dampar series (moderate, brownish-yellow fine sandy clay loam, friable to firm and moderately well-drained). Fertilization, irrigation and other agronomic practices prior to inception of treatments were applied as recommended by MARDI (Rukayah et al. 1993).

Treatments and experimental design

The experiment was conducted during the drought season of 1998. The trees were subjected to four treatments of differential moisture levels by placing different number of emitters per tree. The trial was purposely scheduled during the drought months so as to coincide with flowering and fruiting as well as to minimize errors that might arise from rainfall disturbances. Nevertheless, rainfall was unavoidable. Treatments were started about 8 weeks before the expected time of flowering and fruiting. After flowering, similar treatments were imposed on a new set of trees that had roughly equal number of flowers.

The treatments were designated as T1 (1 emitter/tree) as stressed, T2 (2 emitters/tree) and T3 (3 emitters/tree) as moderately stressed while T4 (4 emitters/tree) as well-watered trees. Emitters were of spray-jet type with a flow rate of about 50 L/h at 100 psi pressure. The plants were irrigated every morning for one hour giving an estimated water supply of 50, 100, 150 and 200 L/h per tree per day for T1, T2, T3 and T4, respectively. The locations of these emitters in relation to the tree trunk were similar to the earlier study by Masri (1999). Treatments were arranged in a randomized complete block design with three single tree replications. Data were analysed using ANOVA and the differences between treatment means were compared by the LSD method.

Measurements of parameters

Leaf water potential (Ψ_L) was used to indicate and differentiate the water status of each treatment. Midday Ψ_L was measured at weekly interval on fully mature pair of leaves located one or two stages below the most recent flush. Leaf petioles were cut with a sharp razor and immediately inserted through a small hole in the lid of a pressure chamber (Scholander et al. 1965). Chamber pressure was then increased slowly until the sap from the xylem started to ooze out. The pressure at this point (which is visible with the help of a hand lens) was assumed to be equal to the Ψ_L.

Number of flowers on the tree was manually counted with the help of hand counters. Fruitlets that dropped under the tree during this period were assumed to be the resultant effect of treatments and were manually counted daily. Percentage of fruit drop was calculated as the number of fruit drop compared to the initial number of flowers. A total of 15 healthy fruits per treatment were tagged immediately after flowering and their diameters were weekly measured using vernier calipers. Relative fruit diameter increment rate was calculated based on the formula for mean relative growth rate (Gardner et al. 1986).

Results

Effect on flowering

The treatments with different number of emitters per tree were successful in maintaining the required regimes of plant water status prior to flowering as indicated by the Ψ_L values (*Figure 1*). T1 trees were most severely stressed, with consistent fluctuation in Ψ_L values below –0.8 MPa for almost 6 weeks prior to flowering. These values were significantly lower than in other treatments. In contrast, trees under T4 treatments had excess water with Ψ_L values fluctuating around –0.6 MPa. Trees under T2 and T3 treatments were considered moderately stressed with Ψ_L values ranging from –0.6 to –0.8 MPa on most of the days.

Flowering in all trees occurred about 9 weeks after the inception of treatments. One week before flowering, the Ψ_L of T1 had dropped to below –1.17 MPa, T2 to –0.89 MPa and T3 to –0.74 MPa as compared to –0.63 in T4 trees. As such, the most severely stressed trees were those under T1, followed by T2 and T3 while T4 trees had plenty of water before flowering. Accordingly, plants under T1 produced the least flowers, followed by T2, T3 and T4 *(Table 1)*.

Effect on fruit drop

After flowering, the experiment was continued on a new set of trees with similar number of flowers for another 8 weeks after which they were terminated due to heavy rainfall. Nevertheless, this period was sufficient to monitor fruit drop as a result of water stress. The Ψ_L of T1 plants continued to drop from –1.11 MPa one week after flowering, reaching the lowest level of –1.40

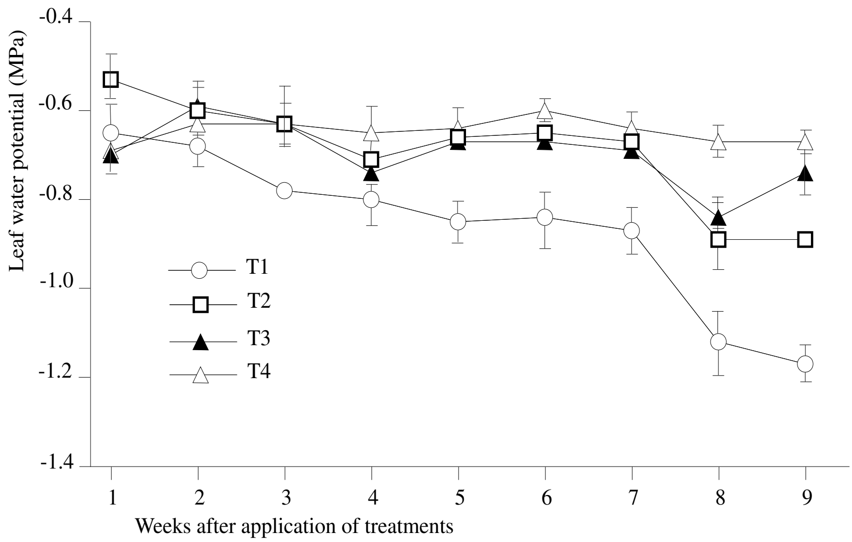

Figure 1. Changes in leaf water potential of the various treatments prior to flowering. Vertical bars represent the standard error of means

MPa 6 weeks later *(Figure 2)*. This suggests that they were under severe water stress for almost 6 weeks. Trees under T2 and T3 were moderately stressed with Ψ_L ranging from −0.80 to −1.27 MPa during the same period. The Ψ_L of T4 trees ranged from –0.54 to −0.76 MPa indicating that they were not under water stress after flowering.

Figure 3 showed the percentage of fruit drop for the various treatments during the first 6 weeks after flowering. Fruit drop were extremely high in stressed trees (T1) amounting to 77.6% while those with excess water showed only 50.9% fruit drop. Detailed observation on fruit drop pattern showed that the extensive fruit drop started from the fourth week after flower initiation regardless of the moisture status. About 67% (T1), 79% (T2), 63% (T3) and 53% (T4) of the total fruit drop occurred from the fourth to the sixth week after flower initiation.

Table 1. Effect of water stress on flower initiation of mangosteen

No. of emitters/tree	Treatments of water levels	Number of flowers/tree
1 (T1)	Stressed	46.7d
2 (T2)	Moderately stressed	402.0a
3 (T3)	Moderately stressed	263.7b
4 (T4)	Excess	101.0c

Mean values with the same letter are not significantly different at $p < 0.05$ using the LSD

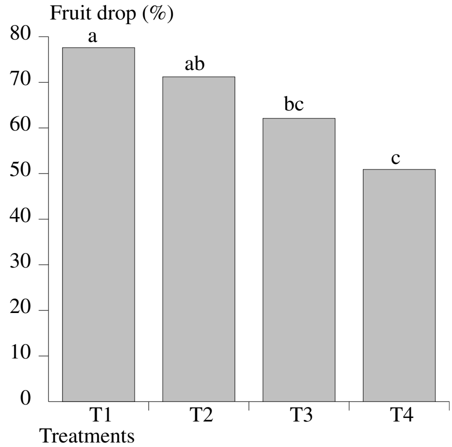

Figure 3. Percentage of premature fruit drop as affected by moisture stress. Means with the same letters are not significantly different at p <0.05 using the LSD

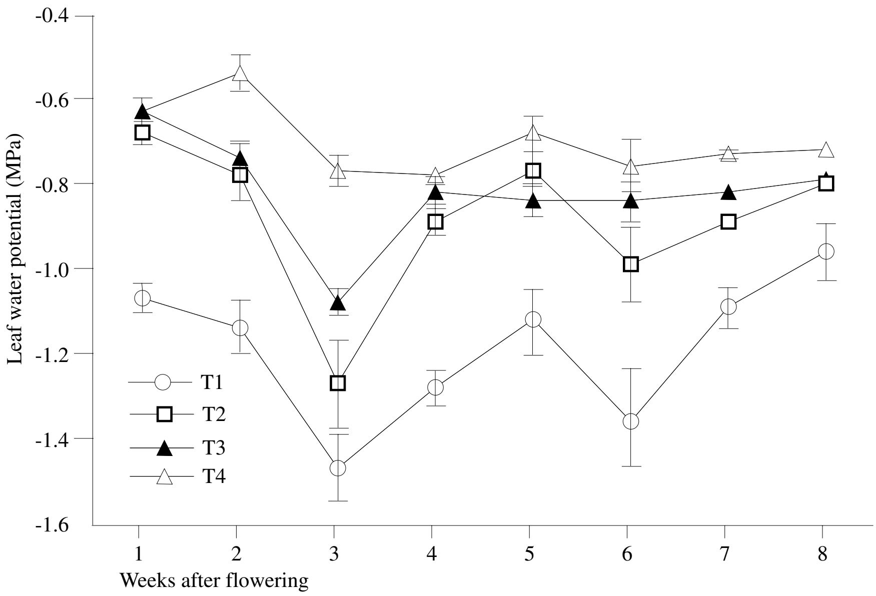

Figure 2. Changes in leaf water potential of the various treatments after flowering. Vertical bars represent the standard error of means

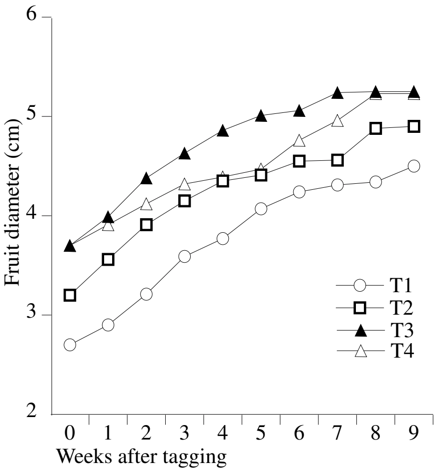

Figure 4. Effect of water stress on development of mangosteen fruit. Each data point is an average of 15 randomly selected fruits initially tagged at fruit setting stage

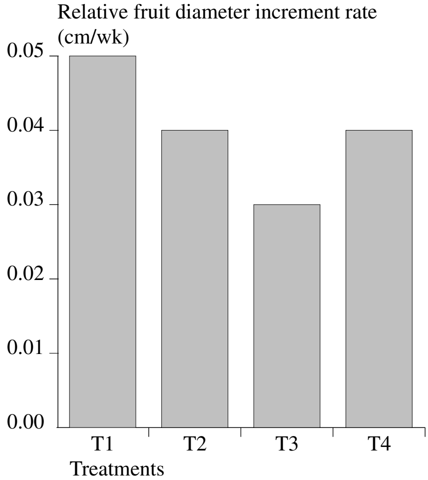

Figure 5. The calculated mean relative diameter increment rates of mangosteen fruits under different moisture levels. All means are not significantly different at p <0.05 using the LSD

Effect on fruit growth

The fruit size during setting was relatively small and this had reduced their fruit size potential at maturity. The fruit size at maturity was relatively small in stressed plants *(Figure 4)*. However, the relative fruit diameter increment rates for stressed trees (T1) were faster compared to other treatments *(Figure 5)*. The faster rate of fruit development was due to lesser fruit number per tree in stressed trees.

Discussion

Rainfall disturbances are the main limiting factor in determining the success of water relation studies in tropical condition. In this study, irrigating with different number of emitters per tree during the drought months was able to maintain different plant water status for more than 3 months. The different plant water status among treatments was depicted by significantly different leaf water potential values during most of the trial period. As such, meaningful measurements of flowering, fruit drop and fruit growth were made in relation to these moisture levels. Similar techniques were successfully used in earlier studies on papaya (Masri et al. 1990), starfruit (Masri 1995) and durian (Masri 1999).

In terms of moisture availability, results of this study indicated that moderately stressed plants (T2) flowered profusely, suggesting that mangosteen plants may not need very strong drought to trigger flowering. These results were similar with those obtained on other tropical fruits. Long period of water stress does not favour flower production in starfruit (Masri 1995), papaya (Masri et al. 1990) and durian (Masri 1999). On the other hand, treatment of continuously oversupply of water as depicted by T4 plants produced the least number of flowers. Similar observations were seen in some temperate fruits where moderate stress has increased flowering (Johnson et al. 1992; Elfving 1994).

Premature fruit drop was extremely excessive in mangosteen. At 6 weeks after flowering, almost 70% of the fruitlets from the best two treatments (T2 and T3), dropped prematurely. However, this is not surprising when compared with apple where about 90–95% of the potential fruit was lost in a series of fruit drop events that occurred during the first month after bloom (Elfving 1994). Fruit drop was even worse under water stress conditions (T1) where 77% of the fruits dropped prematurely. With excess water supply (T4), fruit drop decreased to about 50%. This suggests that with proper irrigation, a 20% improvement in fruit retention is expected. Factors other than water such as lack of carbohydrate reserves might be responsible for the high rate of fruit drop.

High percentage of small fruits is one of the major problems that occur during the early years of mangosteen production. In this study, fruit development was greatly reduced by water stress, leading to smaller fruits at maturity. Under normal condition, it was estimated that more than 70% of the fruits harvested were less than 80 g in weight. These fruits are considered below premium quality grades and sometimes are not marketable. From this study, it was shown that the problem of high percentage of non-marketable fruits would be highly exacerbated under water stress condition.

Conclusion

Moisture supply had tremendous effects on flower initiation, fruit drop and fruit growth of mangosteen trees. Subjecting the trees to moderate water stress conditions (Ψ_L values ranging from –0.60 to –0.80 MPa) prior to flowering has triggered them to produce more flowers compared to trees under severely stress condition or excess water supply. Although flowering was high in the moderately stressed trees, about 70% of these flowers dropped prematurely. Fruit drop was extremely high under stress condition amounting to 77%. This indicates that irrigation is crucial after flower initiation but not to the extent of over supply. It is suggested that trees be irrigated moderately before flowering and during fruit development. However, the roles of other plant internal factors such as carbohydrate and nutritional reserves in controlling fruit development should be looked into since sufficient water supply could only improve fruit retention by 20%.

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References

Elfving, D. (1994). Flower formation and fruit set in apple: a primer. *Good Fruit Grower December*: 69–71

Gardner, F.P., Pearce, R.B. and Mitchell, R.L. (1986). *Physiology of crop plants* p. 187–208. Ames: Iowa State University Press

Hanan, J.J. (1972). Repercussion from water stress. *HortSci. 7*: 108–12

Johnson, R.S., Handley, D.F. and DeJong, T.M. (1992). Long term response of early maturing peach trees to postharvest water deficits. *J. Amer. Soc. Hort. Sci.* ***117:*** 881–6

Jones, H.G., Lakso, A.N. and Syvertsen, J.P. (1985). Physiological control of water status in temperate and subtropical fruit trees. *Hort. Rev. 7:* 301–44

Masri, M. (1995). Effects of water stress on photosynthesis, flowering and fruiting of field-grown carambola (*Averrhoa carambola* L.). *MARDI Res. J.* ***23(2):*** 143–8

—— (1999). Flowering, fruit set and fruilet drop of durian (*Durio zibethinus* Murr.) under different soil moisture regimes. *J. Trop. Agric. and Fd. Sc.* ***27(1)***: 9–16

Masri, M., Abd. Razak, S. and Mohd. Zaki, G. (1990). Response of *Carica papaya* L. to limited soil moisture at reproductive stage. *MARDI Res. J.* ***18(2)***: 191–6

Masri, M., Azizah, H., Mohd Razi, I. and Mamat, A.S. (1999). Physiological responses of mycorrhizal and uninoculated seedlings of mangosteen (*Garcinia mangostana* L.) to water depletion and subsequent rewatering. *J. Trop. Agric. and Fd. Sc.* ***27(1)***: 17–26

Nieuwolt, S. (1982). *Climate and agricultural planning in Peninsular Malaysia* (special report) 139 p. Serdang: MARDI

Rukayah, A., Chong, S. T. and Masri, M. (1993). Pengurusan tanaman. In: *Penanaman manggis* (Mohd. Khalid, M.Z. and Rukayah, A., ed.) chap.2, p.10–18, Serdang: MARDI

Scholander, P.F., Hammel, H.T., Bradstreet, E.D. and Hemmingsen, E.A. (1965). Sap pressure in vascular plant. *Science* ***148***: 339–40