J. Trop. Agric. and Fd. Sc. 39(2)(2011): 239–244

Thresholds for faba bean (*Vicia faba* L.) leaf expansion and stomata conductance response to plant available water

[Nilai ambang pengembangan daun kacang faba (*Vicia faba* L.) dan gerak balas konduksian stomata terhadap kesediaan air tanaman]

A.G. Mohamad Zabawi* and M.D. Dennett**

Keywords: plant available water, *Vicia faba*, leaf expansion, stomata conductance, threshold

Abstract

Leaf expansion and stomata opening of faba bean (*Vicia faba* L.) are closely related to the amount of plant water availability (PAW). The study was conducted to determine the critical level of PAW for leaf expansion and stomata opening as affected by the length of soil drying cycle. Soil water content of control treatment was maintained at 100% field capacity (FC), while water stress plants were irrigated back to field capacity when the soil water content decreased to 80, 60, 40, 20 and 0% of field capacity. Daily water content was measured by weighing each pot and expressed as the fraction of plant available water (PAW). Leaf expansion was measured every four days and stomata conductance when the respective drying cycle was reached. Relationship between relative leaf expansion (RLA) and relative stomata conductance (RSC) was described by a logistic function. A 50% reduction (critical threshold level) in RLA and RSC occurred when PAW = 0.42 and 0.27 respectively. The PAW threshold values when each process is affected would be useful in developing criteria for scheduling irrigation.

Introduction

Water deficit is commonly known as a major constraint in the production of most crops worldwide. It can have substantial impact on growth and development (Lecoeur and Sinclair 1996). Two main processes that are particularly sensitive to water deficit are leaf expansion and stomata conductance. Leaf expansion is one of the plant processes that is most sensitive to water deficit (Hsiao et al. 1985). Meanwhile, stomata conductance is less responsive to water deficit compared to tissue expansion (Passioura 1988; Sadras et al. 1993a). Limitation by water deficit to these processes can result in substantial reduction in growth and production.

Several authors have explored the effect of soil moisture deficits on leaf expansion and stomata behaviour in relation to plant available water of grain legumes (Sinclair et al. 1987; Lecoeur and Sinclair 1996; Soltani et al. 2000) and other crops (Muchow and Sinclair 1991; Sadras et al. 1993a; Ray and Sinclair 1997). However, in faba bean, although water limitation has been shown to give reduced growth and yield (De Costa et al. 1997; Mwanamwenge et al. 1998), little information exists on the

*Strategic Resources Research Centre, MARDI Headquarters, Serdang, P.O. Box 12301, 50774 Kuala Lumpur, Malaysia
**School of Biological Sciences, University of Reading, Earley Gate, Reading, Berks, RG6 6FN, United Kingdom
Authors' full names: Mohamad Zabawi Abdul Ghani and Mike D. Dennett
E-mail: bawi@mardi.gov.my

relationship between leaf expansion and stomata conductance in response to water deficit in terms of critical water availability that will affect both processes.

This experiment under glasshouse conditions was designed to evaluate the response of leaf expansion and stomata conductance to different degrees of soil water content by means of drying cycle of different length.

Materials and methods

The experimental design was randomised complete block consisting of six water treatments with three replications. *Vicia faba* L. cv Maris Bead was planted in pots of dimension 18 cm diameter and 15 cm depth. Soil mixture (50% sand : 50% loam) was filled to approximately 3 kg per pot. Three seeds were sown in each pot. Approximately one week after sowing, the plants were thinned out to one plant per pot. The treatments were imposed on the plants at 30 days after sowing.

Before the treatments started, all pots were saturated with water and allowed to drain over night and then weighed to determine the pot weight at field capacity (FC). Afterward, pots were weighed every day to monitor the amount of water loss. In control pots (100% FC), plants were irrigated everyday to replace the water loss during the previous day. Plants in stress treatments were irrigated back to field capacity when the water content decreased to 80, 60, 40, 20 and 0% of field capacity.

Non-destructive leaf area was determined by measuring leaf length and maximum width of individual leaves and its product was multiplied by a factor of 0.749. This factor was established by Mohamad Zabawi (2006) through regression analysis between the product of length and width of 100 individual leaves with leaf area measured using leaf area meter. Stomata conductance was measured using a Porometer (Delta-T Devices, Cambridge) for each plant when the respective drying cycle was reached i.e. approximately 2–3 days.

Leaf area and stomata conductance which represent a rate of leaf expansion and transpiration were compared to the amount of plant available water (PAW). For the purpose of this comparison, both parameters for stressed plants were normalised relative to that of control plants. These were obtained by dividing the leaf area and stomata conductance of stressed plants to the mean value of well watered plants. Plant available water (PAW), determined as the amount of water remaining in the soil at each measurement, was calculated according to the method widely used by many researchers (Ritchie 1981; Sadras et al. 1993a) i.e.

$$\text{PAW} = \frac{\text{(Current pot weight – Pot weight at wilting point)}}{\text{(Pot weight at field capacity – Pot weight at wilting point)}}$$

Pot weight at wilting point was measured by allowing plant to wilt for 3 days at flowering before pots were weighed. Current pot weight is the weight of experimental pot on the day of re-watering.

Daily leaf expansion was calculated as the differences between current leaf area and the leaf area on the previous measurement. Daily leaf expansion and stomata conductance were expressed as the ratio between stressed plants and the mean of control plants in that respective replication. The relationship between relative leaf expansion, stomata conductance and plant available water were estimated using the logistic function on GENSTAT Ver 6.1 as the typical response model for both processes to plant available water (Muchow and Sinclair 1991; Lecoeur and Sinclair 1996; Ray and Sinclair 1997; Soltani et al. 2000) in the form of:

$$\text{RLA or RSC} = a + c/\ (1+\exp\ [-b\ (\text{PAW} - m)])$$

where, RLA is a relative leaf expansion, RSC is a relative stomata conductance, a is a lower asymptote, b is the curvature, c is the distance between lower and upper asymptotes and m is the PAW at the point of inflection. In this function, the inflection point is the critical value of plant available water for both processes which coincides with 50% reduction in that process.

Results and discussion

Response of leaf expansion and stomata closure to plant available water

The relationship between leaf area expansion and plant available water showed that the expansion of leaf was relatively unchanged until the soil dried to a PAW of 0.8 (*Figure 1*). Below PAW of 0.8, leaf area expansion decreased rapidly. The relationship between relative leaf expansion and PAW was fitted by the following logistic function:

$$RLA = 1.0046/(1+\exp(-8.84(PAW - 0.424))$$

s.e.: (0.038) (1.52) (0.017)

The established relationship shows that the critical plant available water for leaf expansion of *Vicia faba* is 0.42 ± 0.02. Meanwhile, the response pattern of relative stomata conductance was similar to that observed for relative leaf area expansion (*Figure 2*). The equation for the relationship is:

$$RSC = 0.015 + 1.003/(1 + \exp(-7.48[PAW - 0.2709])$$

s.e.: (0.144) (0.159) (0.142) (0.046)

Relative stomata conductance was unaffected by plant water availability until the value of plant availability water also reaches 0.8. Further reduction occurred with decreasing PAW, and the critical value occurred at 0.27 ± 0.05.

By comparing the critical inflection value between relative leaf area expansion and relative stomata conductance, it could be clearly shown that stomata conductance was less sensitive to a reduction in plant available water than leaf expansion, in which a 50% reduction did not occur until PAW value was 0.27 ± 0.05 while leaf expansion showed the response at 0.42 ± 0.02.

The function curves obtained in this study for both relative leaf expansion and relative stomata conductance were similar to the other grain legumes such as chickpea (Soltani et al. 2000), field pea (Lecouer and Sinclair 1996), black gram, pigeon pea, cowpea and soybean (Sinclair and Ludlow 1986) as well as maize (Muchow and Sinclair 1991).

The results of the experiment showed that both the relative leaf expansion and stomata conductance (ratio between water

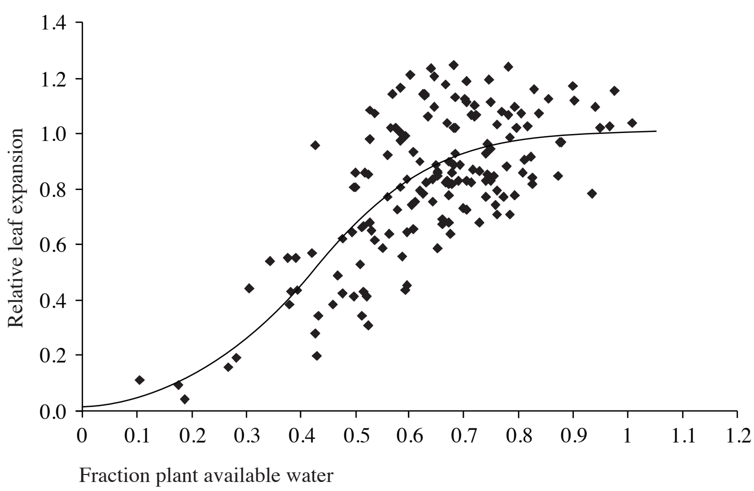

Figure 1. Relative leaf expansion as a function of plant available water

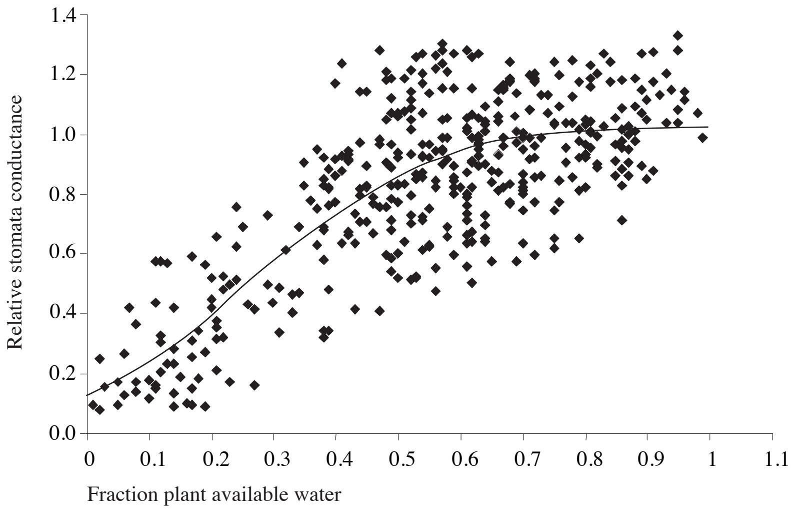

Figure 2. Relative stomata conductance as a function of plant available water

stress and well watered) begin to decrease when the plant available water (PAW) is 0.8. However, the critical value of plant available water (PAW) i.e. 50% reduction occurred at 0.42 and 0.27 respectively. It shows that leaf area expansion in Vicia faba exhibited high sensitivity compared to stomata conductance. Similar observations were found by other workers who concluded that stomata conductance is less responsive to water deficit compared to leaf expansion and other processes (Passioura 1988; Sadras et al. 1993a, 1993b). The early response of leaf expansion is mainly attributable to the fact that cell expansion is among the most sensitive process in fast growing tissues to water stress (Hsiao et al. 1985; Lawlor and Leach 1985).

Leaf expansion in faba bean was also more sensitive to a reduction in plant available water than other crops when compared on the basis of pot trial similar to that conducted in this experiment. In chickpea (Soltani et al. 2000), field pea (Lecoeur and Sinclair 1996), maize (Muchow and Sinclair 1991), and soybean (Sinclair and Ludlow 1986), a 50% reduction in leaf area expansion only occurred when plant available water was 0.23, 0.20, 0.20, 0.15 respectively, while 50% reduction in leaf expansion for faba bean was 0.42.

Similarly, relative stomata conductance of faba bean was also more sensitive compared to a number of other crops. In comparison, relative stomata conductance for faba bean fell to 50% when plant available water was 0.27, while in the cases of chickpea (Soltani et al. 2000), maize (Ray and Sinclair 1997) and field pea (Lecoeur and Sinclair 1996), they fell in the range of 0.1 to 0.25.

Conclusion

Leaf expansion and stomata opening in faba bean are sensitive to water stress. The response of leaf expansion is faster than the response of stomata conductance. The results of the study showed that 42% and 27% of plant available water are found to be critical to faba bean in terms of the response of leaf expansion and stomata closure. The knowledge of this critical value is important in irrigation planning.

The observation suggested that irrigation should be given when the plant available water reached approximately 42% since at this level there is a possibility of reduction in the rate of leaf expansion which is important for canopy development although the stomata conductance was not affected.

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Abstrak

Pengembangan daun dan pembukaan stomata kacang faba (*Vicia faba* L.) berkait rapat dengan kandungan air tersedia (PAW) yang boleh diserap oleh tanaman. Kajian ini menentukan aras kritikal PAW yang diperlukan oleh tanaman kacang faba (*Vicia faba* L.) bagi pengembangan daun dan pembukaan stomata yang dipengaruhi oleh jangka masa pusingan pengeringan tanah. Kandungan air tanah bagi rawatan kawalan dikekalkan pada aras 100% kapasiti ladang (FC) sementara tanaman yang mengalami tegasan air akan diairi apabila aras air pada kapasiti ladang menurun ke aras 80, 60, 40, 20 dan 0%. Kandungan air diukur secara menimbang setiap pasu dan berat ini dianggapkan sebagai kandungan air tersedia (PAW). Kadar pengembangan daun ditentukan setiap 4 hari sekali dan konduksian stomata diukur apabila aras pengeringan bagi setiap rawatan dicapai. Pertalian antara pengembangan daun relatif (RLA) dan konduksian stomata relatif (RSC) digambarkan melalui fungsi logistik. Pengurangan sebanyak 50% (aras ambang kritikal) bagi RLA dan RSC masing-masing berlaku apabila PAW =0.42 dan 0.27. Nilai ambang PAW bagi kedua-dua proses ini sangat berguna bagi membentuk kriteria membangunkan jadual pengairan.

Accepted for publication on 22 July 2011