How Plant Water Status Affects the Structure of Proleptic Shoots of Almond Trees

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Abstract

Proleptic shoots have different vegetative and reproductive characteristics that can be affected by water availability; however the potential effects on shoot structure have been difficult to quantify. The aim of this study was to investigate how plant water status affects the structure or patterns of axillary meristem fates and flowering along proleptic shoots of almond trees. Hidden semi-Markov models were built for shoots growing on trees under two irrigation rate treatments. The shoot structures in each treatment were modeled with 7-state models corresponding to seven distinctive zones along the shoots. The transition probabilities between zones as well as the probability of axillary meristem fates and of the number of flower buds per node were not affected by irrigation treatments. Only one intermediate zone (fourth zone) along the shoots developed fewer nodes with the low irrigation rate. The central zones of shoots appear to be the most affected by factors such as mild water stress that reduce the growth or vigour of shoots.

INTRODUCTION

Water availability plays an important role in shoot growth (Berman and DeJong, 1997) reproductive bud differentiation (Goldhamer and Viveros, 2000), as well as on branching density, indicating that irrigation can influence axillary meristem fate and flowering patterns (Hipps et al., 1995). In this study these patterns are referred to as the structure of the shoots.

The structure of proleptic shoots has been studied using hidden semi-Markov models (HSMMs) in trees growing under homogeneous horticultural practices (Costes and Guédon, 1997; Fournier et al., 1998; Renton et al., 2006). The objective of this work was to compare the structures of proleptic shoots growing on trees with different water status.

MATERIALS AND METHODS

Three irrigation treatments were on applied on 16 almond 'Nonpareil' trees per treatment using two different sprinkler nozzles and line pressures during 2010. In this paper, results only for the high irrigation treatment (31.8 L h^{-1}) and the low irrigation treatment (16.3 L h^{-1}) are discussed. Midday stem water potential (MSWP) in each sample tree and the number of new leaves on 36 proleptic shoots per irrigation treatment were evaluated throughout the growing season.

At the end of season, every metamer of the sample shoots was described starting from the base to the tip of the shoots using two variables: the fate of the axillary meristem (blind node (axillary meristem fails to develop a bud), vegetative bud, sylleptic shoot, or central flower bud) and the number of flower buds per node (from 0 to 3). Data were analyzed using V-Plants software, the successor of AMAPmod (Godin et al., 1997). Empirical intensity distributions that indicated the probability of each observation for

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each node rank were extracted. Based on these distributions, HSMMs were built to describe differences between irrigation treatments.

RESULTS AND DISCUSSION

The MSWPs of the high and low irrigation treatments were close to each other from the beginning of the season to mid-May. Later in the season there were significant differences in MSWPs between treatments, except on June 10 (Fig. 1).

The intensity distributions of the shoot structure showed distinctive zones along the shoots with one main observation within a zone in the case of axillary meristem fate (Fig. 2). The irrigation rates mainly modified the probabilities of vegetative buds subsequent to a zone with sylleptic shoots. The shoot structures in each treatment were modeled with 7-state HSMMs that described each zone along the shoots (Fig. 3).

The observation distributions of each zone were similar between irrigation treatments (Fig. 3). The zone at the base of the shoots corresponded to blind nodes. The second zone had vegetative buds and almost 50% of them had 1 or 2 lateral flower buds. The third zone had mainly sylleptic shoots and 3 or more flower buds. The fourth zone had mainly vegetative buds and 75% of them had 1 or 2 lateral flower buds. The fifth zone mainly had vegetative buds without lateral flowers buds. The last zone before the terminal bud had mainly blind nodes or nodes with central flower buds. The initial and transition probabilities between zones were also consistent between treatments and all the zones had a high probability of being present in most shoots (Fig. 3). The main differences in shoot structure were observed in the fourth zone. This zone had fewer nodes in the low irrigation treatment (Fig. 3).

The number of new nodes developed in shoots in both irrigation treatments was similar until late in the growing season on July 22nd (78.2 nodes in the high irrigation treatment and 73.4 nodes in the low irrigation treatment). After that, the rate of node development was distinctly lower in the low irrigation treatment. Shoots in the low irrigation treatment developed a mean of 76.8 nodes by the end of the season and shoots in the high irrigation treatment had a mean of 88.7 nodes.

Since applied irrigation treatments induced small differences in the tree water status until mid-May when shoots had developed about 40 nodes and these nodes included the first three zones of the shoots, the irrigation treatments had small effects on the structure of the basal part of the shoots. The main structural difference between shoots was that there were fewer nodes of the fourth zone. The time that the nodes that developed in this zone were formed coincided with when differences in the tree water status between treatments started to be observed, but at that time there were no differences in the number of nodes per shoot between the two treatments. Therefore, the fewer nodes of this zone were probably not related to the effect of tree water status on the development of the nodes, but the node number of this zone may have been determined by node developmental events that occurred after the shoot growth was completed. The characteristics of the fifth and sixth zones were similar between treatments even though there were differences in tree water status when the nodes of these zones were developing. Therefore, these zones were apparently less affected by external factors than the central zone of the shoots. The fourth zone mainly differed from the fifth zone in the number of flower buds per node. Thus the number of nodes of the fourth zone may have been determined by the number of nodes of the apical zones which appeared to be independent of water deficit as well as determined by the total nodes of the shoots and the flower bud formation of the fourth zone which could have been affected by water deficit.

Other studies have reported that the central zones in shoots also had fewer nodes or were absent along with the reduction of shoot length in peach and apple and with increasing tree age in apple (Fournier et al., 1998; Renton et al., 2006). Results of this study are consistent with those reports. Structurally, the central zones of shoots appear to be the most affected by factors that reduce the growth or vigour of shoots.

Literature Cited

Costes, E. and Guédon, Y. 1997. Modeling the sylleptic branching on one-year-old trunks of apple cultivars. J. Amer. Soc. Hort. Sci. 122:53-62.

Berman, M.E. and DeJong, T.M. 1997. Diurnal patterns of stem extension growth in peach (*Prunus persica*): Temperature and fluctuations in water status determine growth rate. Physiol. Plant. 100:361-370.

Fournier, D., Costes, E. and Guédon, Y. 1998. A comparison of different fruiting shoot of peach tree. Acta Hort. 465:557-566.

Godin, C., Guédon, Y., Costes, E. and Caraglio, Y. 1997. Measuring and analyzing plants with the AMAPmod software. p.63-94. In: M.T. Michalewicz (ed.), Plants to Ecosystems: Advances in Computational Life Sciences. CSIRO, Melbourne.

Goldhamer, D.A. and Viveros, M. 2000. Effects of preharvest irrigation cutoff durations and postharvest water deprivation on almond tree performance. Irrig. Sci. 19:125-131.

Hipps, N.A., Pagès, L., Huguet, J.G. and Serra, V. 1995. Influence of controlled water supply on shoot and root development of young peach trees. Tree Physiol. 15:95-103.

Renton, M., Guédon, Y., Godin, C. and Costes, E. 2006. Similarities and gradients in growth unit branching patterns during ontogeny in 'Fuji' apple trees: a stochastic approach. J. Exp. Bot. 57:3131-3143.

Figures

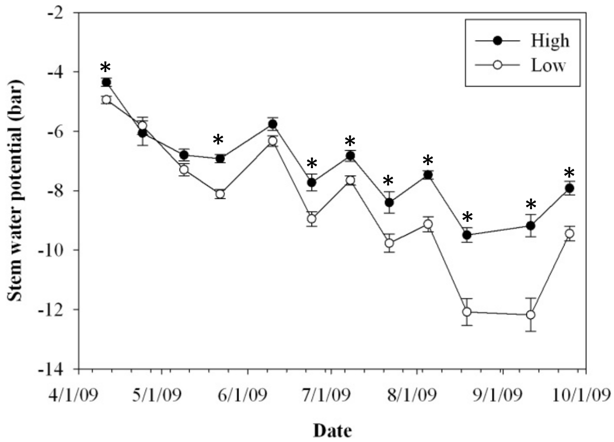

Fig. 1. Seasonal midday stem water potential of almond trees under two irrigation treatments (high and low flow rates).

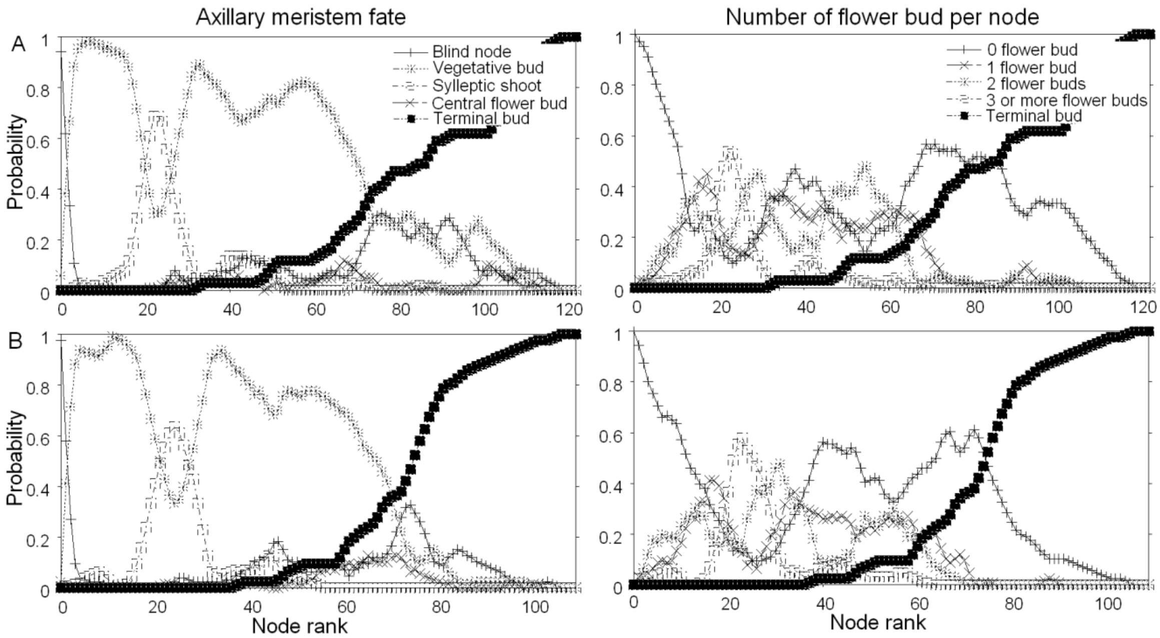

Fig. 2. Probability of the different fates of the axillary meristems and of number of flower buds per node rank observed on proleptic shoots on high (A) and low (B) irrigation.

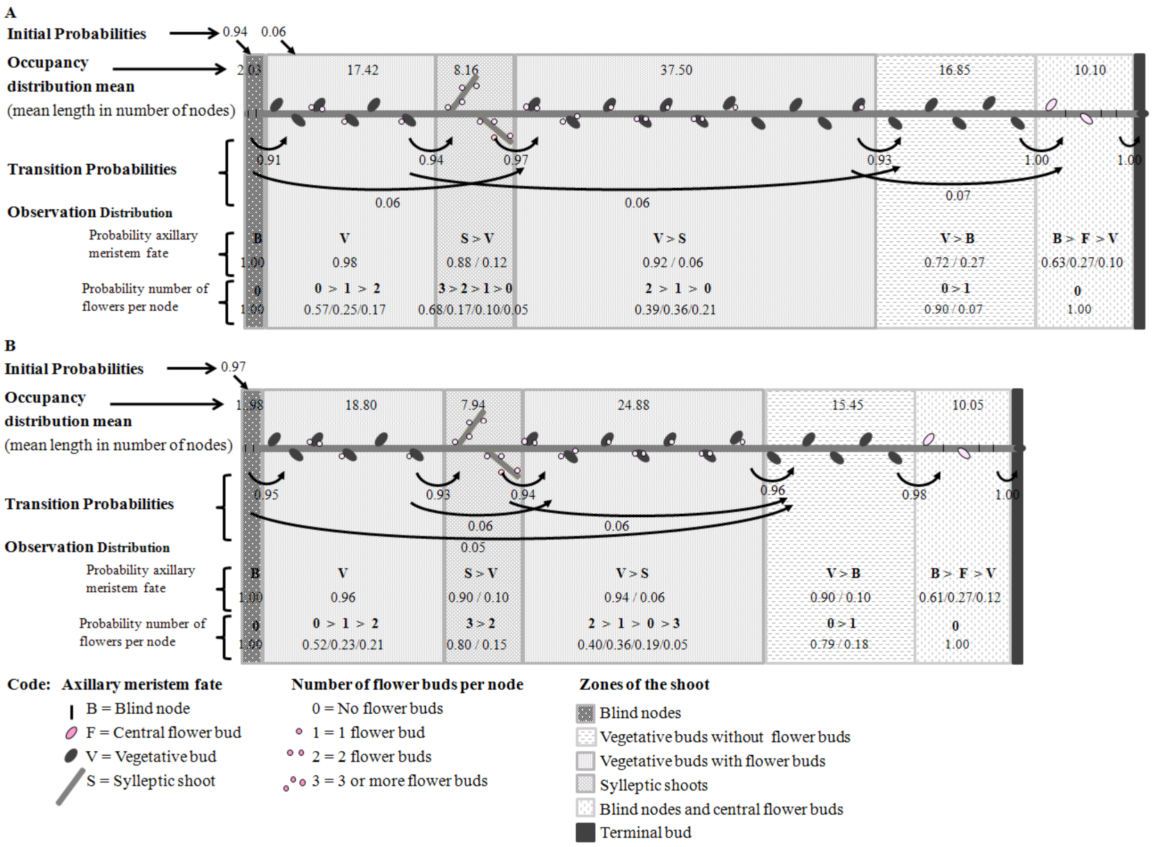

Fig. 3. Schematic representation of HSMMs for proleptic shoots growing under the high (A) and the low (B) irrigation treatments. Diagram show observation that had probability greater than 0.05.