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Reducing post-harvest moisture loss in corn salad (*Valerianella locusta*)

Water loss through transpiration is one of the main reasons for optical quality penalties with vegetables during the trading period and above all on display at point of sale. This applies in particular to salad vegetables. Drought stress during plant growth results in transpiration reduction and this continues post-harvest. The study presented here investigates whether this also applies to corn salad. Hereby, plants were grown with two different intensities of insufficient moisture supply. With increasing water deficit, a clear reduction in transpiration could be determined. Simultaneously, however, a marked yield reduction in the variant with lowest level of irrigation also became apparent.

Keywords
Corn salad, deficit irrigation, post-harvest physiology

Abstract
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9 references

With salad plants in general, and leaf salads in particular, retention of quality depends especially on the extent of moisture losses throughout the supply chain and at point of sale. The visual produce quality (fresh or wilting) significantly influence purchase decision of cumsumers. Mild drought stress during growth induces a highly efficient regulation of stomata [1, 2]. This effect continues even after harvest thus limiting postharvest water losses of plants. This indisputable advantage is, however, balanced, due to the lower water availability to the plant, an effect that markedly reduces returns in practice.

Method and materials

Seed of the cultivar ‘Holländischer Breitblättriger‘ was sown on soil (Flora Self), the seedlings subsequently pricked out on the same soil in 5.5 cm Jiffi peat pots (Jiffi Products) and the pots then watered to saturation. The following day any surplus water remaining was run off and the salad plants placed in a controlled climate chamber (**Figure 1**). The following days, water was applied according to requirement (5 to 10 ml; 2 ‰ Osmosol 523 DI, Scots Deutschland GmbH, Nordhorn).

The controls (n = 40) were always optimally watered (257.5 ml over the entire trial period), the water deficit variant I (n = 60) experienced slightly reduced water supply (68 % of control) and variant II (n = 60) a markedly reduced water supply (36 % of control).

In the controlled climate chamber temperatures of 15 °C during the day (12 h) and 10 °C at nigh, and 60 % relative humidity were maintained. Harvesting took place at the commercially accepted growth stage. The harvested plants were uniformly distributed in transparent plastic containers, which were then double-wrapped with moisture retention film (**Figure 2**). To simulate storage and presentation in the trading chain, packed plants were stored in darkness at 20 ± 1 °C at 40 % ± 5 % RH for one week. So that losses in mass during storage could be recorded the containers were weighed every two days and inspected for the presence of condensate.

At the end of the storage period the plants were removed from the containers and weighed. For mass loss analysis [1] six plants from each variant were laid on a mesh grid under free convection (**Figure 3**) and weighed on a set of analytical scales (BP 210 S, Sartorius AG, Göttingen) every 10 min over a period of 90 min. After 24 h of drying at 85 °C the dry matter of the trial plants was determined.

The relative fresh mass, or the relative mass loss, was calculated as follows (where rF = relative humidity (RH) and TM = dry matter):

$$\mathrm{rFM}_{\mathrm{xh\ dehydration}}\ [\mathrm{mg\ g_{FM}^{-1}}] = \frac{\mathrm{FM}_{\mathrm{0h\ dehydration}}\ [\mathrm{g}] \cdot 1000}{\mathrm{FM}_{\mathrm{xh\ dehydration}}\ [\mathrm{g}]}$$

$$\mathrm{rMass\ loss}_{\mathrm{xh\ dehydration}}\ [\mathrm{mg\ g_{FM}^{-1}}] = 1000 - \mathrm{rFM}_{\mathrm{xh\ dehydration}}\ [\mathrm{mg\ g_{FM}^{-1}}]$$

From mass loss and dry matter the transpiration was calculated according to Stocker [3, 4]:

$$\mathrm{Transpiration}_{\mathrm{TM\ x\text{-}x\ h}}\ [\mathrm{mmol\ kg_{TM}^{-1}\ s^{-1}}] = \frac{\mathrm{Moisture\ loss\ [mmol]}}{\mathrm{TM\ [kg]} \cdot \mathrm{time\ [s]}}$$

In that it was not possible to record the total transpiration area of the plant with sufficient precision, and also because the transpiration performance of leaves stems and sprout axes ad-

Fig. 1

Fig. 1: Experimental setup in the climate chamber (Foto: Graf)

Fig. 2

Corn salad plants packed in plastic pots and wrapped in freshkeeping film during a simulated trading period (Foto: Graf)

Fig. 3

Experimental setup for measurement of mass losses (Foto: Graf)

ditionally differed, the result is based on the total dry matter [3, 4, 5].

The statistical evaluation of the trial results took place via WinSTAT 2007.1 (R. Fitch Software, Staufen, Germany).

Results and discussion

During the simulated trading phase no relevant losses in mass for the packaged salad occurred and no condensate formation in the containers took place. But after the plants were unpacked the loss in mass that then occurred clearly depended on the water availability during plant growth. The optimally watered controls showed the greatest initial mass loss (155 ± 37 mg g $FM_{0h\ dehyd.}^{-1}$). In comparison to this, the deficient irrigation variant I was 28 % lower in this respect (112 ± 9 mg g $FM_{0h\ dehyd.}^{-1}$) and in plants of variant II it was 54 % lower (72 ± 14 mg g $FM_{0h\ dehyd.}^{-1}$).

After 10 min as well as after 90 min of free transpiration, there were marked differences in the loss rates of the plants in the three trial variants (**Figure 4**).

The high mass loss of the control plants with optimal water supply compared to those of variant II was due to the markedly higher transpiration rates of the controls (3.96 ± 1.10 mol kg_{TM}^{-1} • s^{-1}) compared to those of the plants with deficient water supply during growth (variants I: 2.88 ± 0.26 mol kg_{TM}^{-1} • s^{-1} and II 1.69 ± 0.30 mol kg_{TM}^{-1} • s^{-1} after 90 min). On the other hand, the transpiration of the control plants and those of variant I did not differ significantly initially. However, they were both markedly different from variant II. With the increasing of the dehydration period there also appeared, however, significant differences in transpiration rates between the control plants and those of water deficit variant I. But comparing control plants and variant II showed that transpiration of the former was always at least double that of the latter (**Figure 5**). The results confirm the existence of a close (R^2 = 0.70) relationship between the water availability during plant growth and transpiration rate and the associated postharvest mass losses.

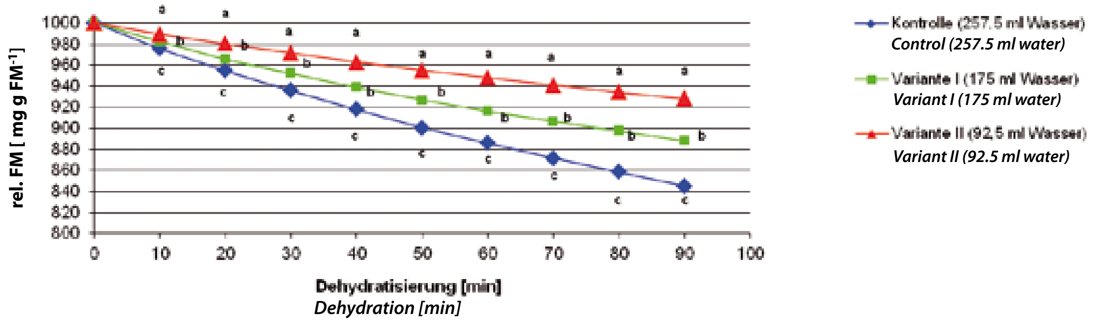
Compared with the controls, the reduction in yield by variant I plants represented 9 %, and 34 % with variant II (**Figure 6**). On the other hand, the yield based on dry matter was not significantly influenced by the amount of water applied (**Figure 7**). For this reason it can be assumed that the content of desired ingredients, which also include taste influencing factors, is not influenced by deficit irrigation, although in this respect no intensification can be expected either.

The definition of optimal deficit irrigation by the amount of water supplied has proven to be accurate. Because of the low substrate volume in the 5.5 cm peat pots and existing problems of measuring soil water tensions in horticultural substrate [6, 7], tensiometers and TDR/FDR sensors cannot be reliably applied. The applied porocedure used permitted reliable control of deficit irrigation and had already proved itself in controlling growth with ornamental shrub production [8, 9].

Conclusions

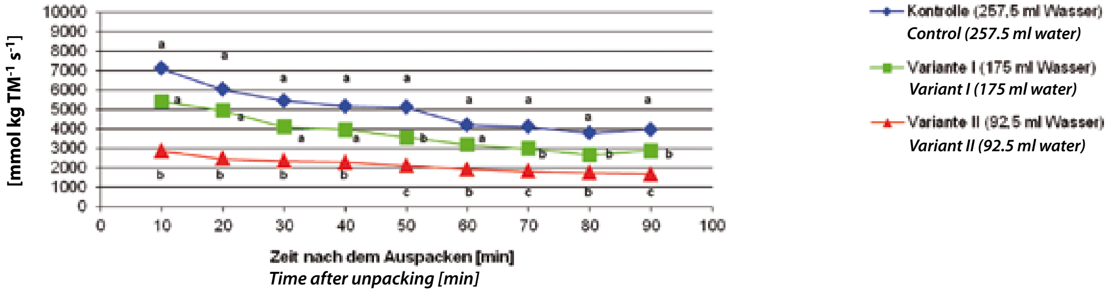
With corn salad, too, deficit irrigation during growth leads to the adjustment of stomata regulatory behaviour and this effect continues post harvest. This highly efficient stomata regulation markedly reduces moisture loss of corn salad plants unpacked by customers, due to the significantly reduced transpiration of plants. The unpacked plant therefore remains fresh over a longer period. Hence, corn salad plants grown under optimized deficit irrigation can be kept longer in the trading chain without quality losses. Most importantly, the salad remains fresh and crisp for longer after purchase by the consumer.

Fig. 4



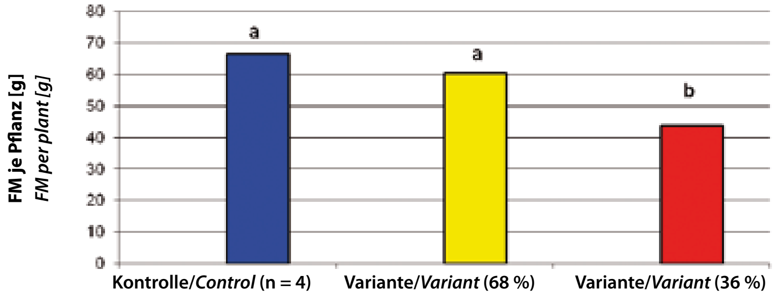
Weight loss of individual corn salad plants after 9 days simulated storage (different letters indicate significant differences; Tukey's test, $p < 0.05$)

Fig. 5



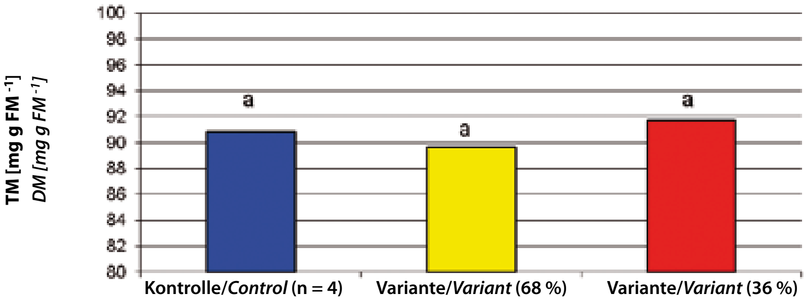
Transpiration of individual corn salad plants after 9 days simulated storage (different letters indicate significant differences; Tukey's test, $p < 0.05$)

Fig. 6



The influence of amount of moisture applied to corn salad plants on respective yields (different letters indicate significant differences; Tukey's test, $p < 0.05$)

Fig. 7



The influence of amount of moisture applied to corn salad plants on the respective dry matter content (different letters indicate significant differences; Tukey's test, $p < 0.05$)

The procedure still has to be optimised so that yield losses can be reduced. Tackling this main problem involves balancing the level of deficit irrigation to an ideal lying between the amounts used in variants I and II, although this must always be adjusted according to the respective production conditions. Analysis of plant ingredients should supply information on the extent to which these, too, may be influenced by insufficient watering.

Literature

[1] Graf, W. (2010): Einfluss von Funktion und Struktur des Blütenstiels auf die Nacherntephase von Schnittrosen. Dissertation Humboldt Universität zu Berlin; dissertation.de – Verlag im Internet GmbH, Berlin

[2] Mortensen, L. M.; Gieslerød, H. R. (2005): Effect of air huminity on powdery mildew and keeping quality of cut roses. Scientia Horticulturae 104, pp. 49–55

[3] Stocker, O. (1929): Eine Feldmethode zur Bestimmung der momentanen Transpiration- und Evaporationsgröße, 2. Bericht Deutsche Botanische Gesellschaft 47, S. 130–136

[4] Stocker, O. (1956): Meßmethoden der Transpiration. In: Ruhland, W.: Handbuch der Pflanzenphysiologie, Band 3, Pflanze und Wasser, Springer Verlag, Berlin, Göttingen und Heidelberg, S. 293–311

[5] von Willert, D. J.; Matyssek, R.; Herppich, W. (1995): Experimentelle Pflanzenökologie, Georg Thieme Verlag, Stuttgart, New York

[6] Graf, W.; Zander, M. (2009): Mangelbewässerung sicher steuern. Deutsche Baumschule (8) S. 47–49

[7] Graf, W.; Zander, M. (2007): Bewässerungssteuerung in Trockenstressgefäßversuchen: Tagungsband der 44. Tagung der Gartenbauwissenschaftlichen Gesellschaft: Erfurt, 21.-24. Februar, BHGL Schriftenreihe 25, S. 89

[8] Graf, W.; Zander, M. (2010): Mangelbewässerung verhilft zu kompakten Pflanzen. Deutsche Baumschule (5), S. 29–31

[9] Zander, M.; Graf, W. (2010): *Salix repens* ssp. *arenaria (*L.) Hiitonen ‘Böschungsprinzessin’, a new creeping willow cultivar with good drought stress tolerance. Acta Horticulturae 885, pp. 429–435

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