IOBC / WPRS

Working Group "Integrated Control in Glasshouses"

OILB / SROP

Groupe de Travail "Lutte Intégrée en Cultures sous Verre"

Origineel

CONTRIBUTIONS WORKING GROUP MEETING

at

Vienna (Austria)
20 - 25 May 1996

Edited by J.C. van Lenteren

IOBC wprs Bulletin
Bulletin OILB srop Vol. 19 (1) 1996

Calculation of the influence of the vertical distribution of feeding injury by two-spotted spider mite (*Tetranychus urticae*) on photosynthesis and respiration of cucumber

W. van der Werf[1], H. Gijzen[2], W.A.H. Rossing[1], R.T. Dierkx[1] & A. Tomczyk[3]

[1] Wageningen Agric. Univ., Dept of Theoretical Production Ecology, P.O.B. 430, 6700 AK Wageningen, the Netherlands

[2] Wageningen Agric. Univ., Dept of Horticulture, Haagsteeg 3, 6708 PM Wageningen, the Netherlands

[3] Warsaw Agric. Univ., Dept. of Applied Entomology, Nowoursynowska 166, 02-766 Warsaw, Poland

ABSTRACT

The relationship between the severity of pest attack and the amount of crop damage depends on the position of injury in the crop. We use a mechanistic simulation model for daily photosynthesis and respiration of a cucumber crop to quantify the relationship. Two effects of mite feeding on the functioning of leaves are taken into account: the effect on gross photosynthesis and the effect on respiration. The calculations show that the reduction of photosynthesis is greatest when injury occurs predominantly at the top of the canopy. The effect of mite injury on respiration is also affected by the injury profile, but the effects are substantially smaller than for photosynthesis. The calculations suggest that rather high levels of injury, up to 40%, can be tolerated. The results of these calculations are guidelines when developing sampling plans for mite damage with the purpose of estimating the relationship between injury and damage.

INTRODUCTION

Spider mites are important pests in a wide range of crops (Helle & Sabelis, 1985). They feed on the contents of mesophyll cells (van de Vrie et al., 1972), causing leaf bronzing or browning and early senescence. In earlier work (Tomczyk, 1989; Tomczyk et al., in prep.), we quantified three mechanisms by which two-spotted spider mites (*Tetranychus urticae)* affect the carbon economy of cucumber. Photosynthesis at light saturation is initially stimulated by a small percentage of spotted leaf area. Maximum stimulation (about 9%) is reached at about 16% leaf injury (Fig. 1A). Beyond this point, photosynthesis declines again. Dark respiration increases with leaf injury. It follows a saturation type of relationship characterized by a maximum respiration increase of 18 % and an initial slope of 1% respiration increase per % spotted leaf area (Fig. 1B). Biomass consumption by mites - as quantified by ^{14}C labeling - amounts to approximately 10 μg dry matter per mite per day.

The three mechanisms were included in a dynamic simulation model of the carbon economy and growth of cucumber plants under optimal water- and nutrient supply to ascertain whether these mechanisms can account for the reduction of yield, caused by spider mites in glasshouses, and to determine the relative importance of the three mechanisms. The model was validated using data from three glasshouse experiments, and found suitable for making estimates of the growth of mite-infested cucumber under optimal water- and nutrient supply and an ambient CO_2 concentration of 350 μl/l.

Sensitivity analysis of the model showed that at high mite densities, the reduction of the maximum rate of photosynthesis accounts for about 70% of total damage, assimilate withdrawal for 15-20% and increased respiration for 10-15%. At intermediate and low mite densities, there

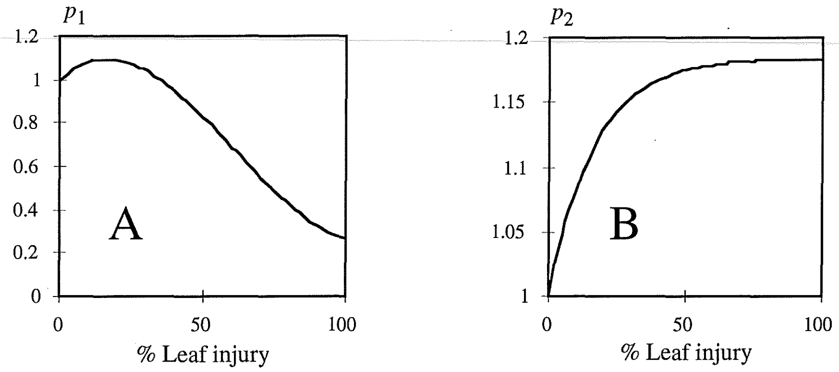

Fig. 1: Relationship between gross photosynthesis (as proportion of photosynthesis of un-injured leaves, p_1) and leaf injury by mites (A) and between maintenance respiration (as proportion of maintenance respiration of un-injured leaves, p_2) and leaf injury by mites (B; Tomczyk et al., in prep.).

was a small positive effect of mites on photosynthesis, but this effect was overshadowed by the negative influences of the other two damage mechanisms.

In this paper we describe simulation experiments with the validated model. The purpose of these simulations is to estimate the effect of different levels of mite injury on crop photosynthesis under bright and dim light conditions and to determine the influence of the vertical profile of injury on crop photosynthesis.

MATERIALS & METHODS

We use the model ASKAM (Gijzen, 1992). This model calculates daily photosynthesis of a standard cucumber crop (e.g. leaf area index = 3), based on the amount and angle of incidence of incoming radiation and on photosynthesis parameters. Calculations are made for an arbitrary spring day, 16 May. Two situations are distinguished: a sunny day and a cloudy day. For the sunny day, we take the 90% percentile of the observed probability distribution of incoming radiation: 24.79 MJ global radiation m^{-2} d^{-1}. For the cloudy day, we take the 10% percentile: 7.73 MJ global radiation m^{-2} d^{-1}. Leaf canopy is subdivided in layers of 0.03 LAI units thickness. Leaf injury is distributed over these layers according to five different profiles (Fig. 2):

1. homogeneous;
2. linear decrease from a maximum percentage at the top of the canopy (equal to twice the average leaf injury) to 0 at the bottom. For leaf injuries above 50%, the linear decrease is from 100% at the top of the canopy to a minimum percentage at the bottom. This minimum percentage is equal to twice the average percentage leaf injury minus 100;
3. as 2, but with the highest leaf injury at the bottom;
4. 100% leaf injury in the top x leaf layers, where x is the average percentage leaf injury;
5. as 4, but with injury concentrated at the bottom.

The effect of mite injury was included in the model using two equations, one expressing the maximum rate of gross photosynthesis (for each leaf layer), and the other expressing the rate of maintenance respiration of leaves, both depending on leaf injury (Fig. 1).

1: $p_1 = 2.368\ 10^{-6}\, x^3 - 0.000431\, x^2 + 0.0121\, x + 1$

2: $p_2 = 1 + 0.184\,(1-e^{-0.011\, x/0.184})$

In these equations, p_1 and p_2 are multipliers for gross photosynthesis and leaf respiration in a leaf layer, while x is leaf injury in that layer.

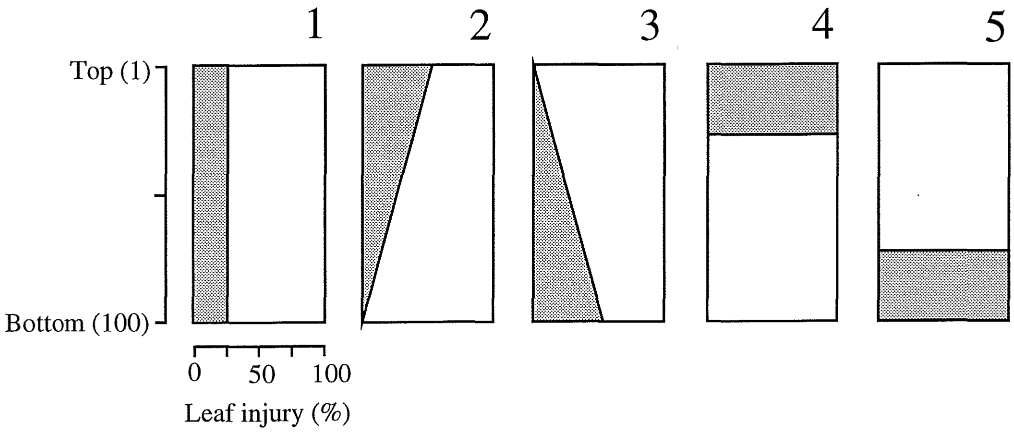

Fig. 2: Five injury profiles used in simulations of the effect of mite injury on crop photosynthesis of cucumber. Here, the profiles represent a total injury of 25%.

RESULTS

For the profiles 1, 2 and 3, gross photosynthesis has an optimum response to leaf injury (Fig. 3A,B). The shape of the responses is similar for high and low light intensities. The maximum stimulation of photosynthesis is in the order of 4% at high light intensity and 1% at low light intensity. Profiles 4 and 5 lack the stimulation effect because they have either 0 or 100% leaf injury in a layer, and no intermediate injuries at which stimulation can occur. Thus, strong clustering of injury results in greater photosynthesis reduction at low to intermediate total leaf injuries. The reduction of photosynthesis is greatest for the profiles where injury is concentrated in the top of the canopy (2 and 4).

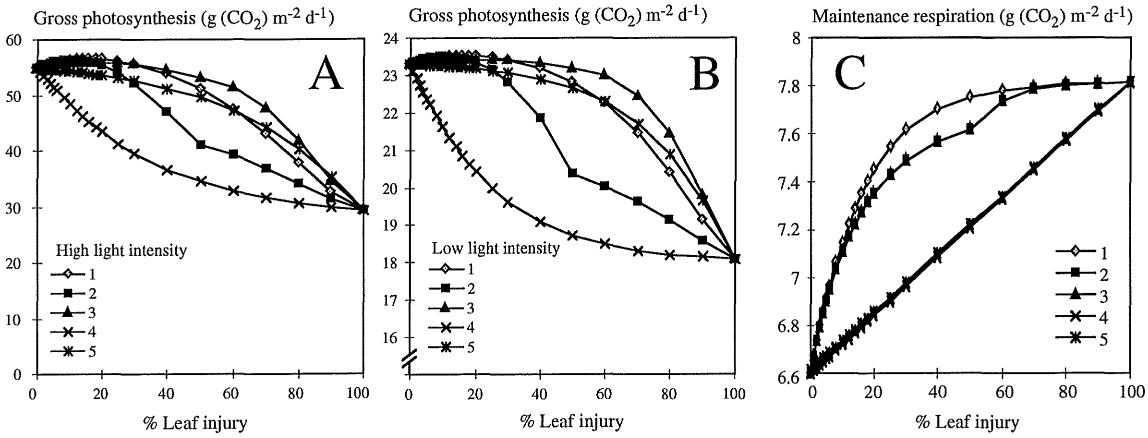

Fig. 3: Gross photosynthesis at two light intensities (A,B), and crop maintenance respiration (C) of a standard cucumber canopy with different degrees of leaf injury by mites (x-axis), for five profiles of mite injury over leaf layers (cf. Fig. 1).

The effect of mite injury on maintenance respiration is greatest when a homogeneous profile is assumed (profile 1 in Fig. 3C). This is because the relationship between respiration in a layer and injury in that layer is characterized by 'diminishing returns' (Fig. 1B). The greatest stimulation of respiration is achieved by 'adding' injury to the layer with the lowest injury, resulting in a homogeneous distribution giving the greatest stimulation. Profiles 2 and 3 have the same respiration-injury relationship, and so do profiles 4 and 5. The similarity is due to the fact that for respiration, light intensity plays no role. Hence, the profile can be flipped vertically without consequence for calculated respiration. The difference between the profiles is maximally 1 g (CO_2) m^{-2} d^{-1}, which is small compared to the differences in calculated gross photosynthesis among profiles. Hence, in the discussion of these calculations, we concentrate on gross photosynthesis.

DISCUSSION

The feasibility study in this paper is based on empirical quantification of mechanisms of damage by mites and the incorporation of these mechanisms in a validated crop growth model. The objective is to obtain estimates of the influence of the vertical profile of mite injury on damage that results from such injury, based on knowledge about crop physiological effects of these mites. The highest reduction of photosynthesis occurs when injury is concentrated in the top of the canopy. In practice, injury done by *T. urticae* will often be concentrated on the older leaves, in lower leaf layers, or be distributed more or less homogeneously throughout the canopy. Simulations indicate that for these cases, the relationship between injury and photosynthesis is only marginally affected by the shape of the injury profile. This suggests that precise observations of the vertical distribution of injury are not necessary to calculate expected damage. The simulations also suggest that for leaf injuries up to about 40%, the reduction of photosynthesis is rather insignificant, provided injury is in lower layers and LAI is not less than 3. This finding suggests that rather high levels of injury can be tolerated, even if the effects of mites on respiration and their assimilate withdrawal are taken into account when calculating their impact. For mite species that feed more predominantly in the higher leaf layers, such as *T. cinnabarinus* (Tomczyk et al., 1992), different conclusions would be drawn.

REFERENCES

Gijzen H., 1992. Simulation of photosynthesis and dry matter production of greenhouse crops. Simulation Report CABO-TT, nr 28. CABO-DLO, Wageningen; 70 pp.

Helle, W., & M.W. Sabelis (Eds), 1985. Spider mites; their biology, natural enemies and control. Volumes A and B. Elsevier Publ, Amsterdam.

Tomczyk, A. 1989. Physiological and biochemical responses of different host plants to infestation by spider mites (*Acarina: Tetranychidae*). Treatises and Monographs, Warsaw Agricultural University Press, Warszawa 1989. 112 pp.

Tomczyk, A., D. Kropczynska & I. Elst, 1992. Studies on competitive displacement of *Tetranychus urticae* by *Tetranychus cinnabarinus* on cucumber and gerbera. Proc. 2nd Symp. EURAAC, Krynica, Poland, 1992 (in press).

van de Vrie, M., McMurtry, J.A., Huffaker, C.B. 1972. Ecology of Tetranychid mites and their natural enemies. A review. III. Biology, ecology and pest status, and host plant relations of Tetranychids. Hilgardia 41, 343-432.