RGR as a tool to evaluate the relative performance of a plant-herbivore system as affected by temperature

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INTRODUCTION

The different species that form an ecosystem are susceptible to the changes in the temperature around them, since it is the abiotic factor with most influence in their biology, phenology and metabolism, causing cascading effects that might affect the stability of the community (Campbell et al. 1974, Hance et al 2007, Roy 2002, Schoonhoven et al. 2005).

We are particularly interested in evaluating the relative performance of the organisms that form a food-web, as affected by temperature, as this will allow us to understand and foresee the effects of climate change in a given ecosystem. This has proven to be difficult, since there is a lack of 'common-currency' for the performance of the different organisms of a food-web (i.e. plants and insects).

We propose the use of the rate of biomass accumulation, which is a shared-trait of all organisms, as the 'common-currency' to evaluate the performance of the food-web. This is possible by obtaining the Relative Growth Rate (RGR) (i.e. relative increase of the biomass accumulation in a period of time), for each of the organisms of the plant-herbivore system and then using the ratios of their RGR's to compare the relative performance of the herbivore in relation to that of the plant. Lamb (2008) used a similar approach to measure the efficiency of biomass conversion between trophic levels.

Thus, the objective is to evaluate the relative performance of players in a plant-herbivore system, formed by one variety of potato (*Solanum tuberosum*), and two varieties of bell pepper (*Capsicum annum*), with three host plant-related biotypes of the potato aphid *Macrosiphum euphorbiae* at six constant temperatures (8, 12, 16, 20, 24, 28°C).

HYPOTHESES

1. The relative performance of the host plants (measured as RGR) will be differently affected by temperature.
2. The RGR of the plant and the aphid will be affected by the association host plant*biotype.
3. The aphid's performance relative to that of the plant will vary depending on the temperature and the host plant (ratio ≠1:1)

MATERIALS AND METHODS

The plant-herbivore system is formed by: one variety of potato (*Solanum tuberosum* var. "Norland") and two varieties of greenhouse bell pepper (*Capsicum annum* var. 'Crosby'© and 'Fascinato'©). The variety 'Fascinato is olerant to high temperatures, whereas 'Crosby'© is a variety adapted to more temperate climate. This will allow us to evaluate the response of different host plants to the temperature and the presence/absence of the herbivore. The herbivore is represented by three biotypes ("STQC", "SMQC" and " CAONT") of the potato aphid (*Macrosiphum euphorbiae).* All the colonies are kept at 16D: 8N, 20°C and 65% RH.

We used 3 different levels of herbivore infestation (0, 10 and 40 aphids) for each combination of host plant * biotype at for each temperature : 8, 12, 16, 20, 24, 28°C (Conviron Ltd). Plants were used when they reached 4 to 5 true leaves. Since the RGR measures the growth of an organism in a period of time, to calculate it, it is necessary to obtain the weight of the organism at two different times. Then we can use the formula suggested by Hunt (1982):

$$\text{RGR} = \frac{\ln(\text{weigth at time 2}) - \ln(\text{weight at time 1})}{(\text{time 2} - \text{time1})}$$

MATERIALS AND METHODS (cont)

In our case, to obtain the RGR of the plant, we took the dry weight of 5 plants of the same cohort of the experimental plants as well as the dry weight of the experimental plants at the end of the experiment. To obtain the RGR of the aphid, we froze and weighted aphids of larval stage 1 as well as adults. For both plants and aphids, the experimental time, was the time it took the aphid to become adult. After obtaining the RGR for each organism, we obtained the ration of the aphid's RGR/ host plant's RGR. The experimental design was split plot with random blocking with 3 repetitions in time. The data was analyzed using Proc Mixed Models of SAS (SAS Institute, 2009)

RESULTS AND DISCUSSION

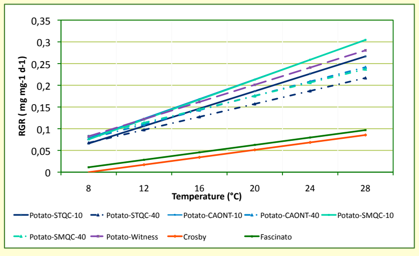

Figure 1. RGR of the potato (at 3 levels of infestation) and the bell peppers, at six constant temperatures.

The RGR change with temperature of the potato was linear at the experimental temperatures (Figure 1). However, the literature shows that the optimal temperature for the growth of the potato is 21 °C) and that the growth is limited below 7 °C and above 30 °C (Tomasiewicz et al 2003, Harahagazwe, 2010). Experimentation at higher temperatures (above 28 °C) might allow us to determine the maximum temperature for growth for this particular system.

For the potato-aphid system, the temperature, biotype and biotype*infestation were highly significant (p=0.0001). In general, we can say that **the RGR of the potato plant increases 9% for each 10°C increase in temperature.**

In the case of the bell peppers (Figure 1), the response of the RGR to temperature was also linear, which concurs with the existing literature that shows that the optimal growth of the bell pepper is between 24 and 30 °C and it starts showing signs of damage around 32 °C.

When analyzing the RGR for the bell pepper, only the temperature and the host plant were significant (p<0.0001 and p=0.0079, respectively). The fact that the presence of the aphids (up to 40 per plant) was not significant, strongly suggest that the varieties show some degree of tolerance to that degree of infestation of the aphid. The RGR of both bell pepper varieties increases in **4.2% for each 10°C increase in the temperature,** almost half the rate of growth of the potato.

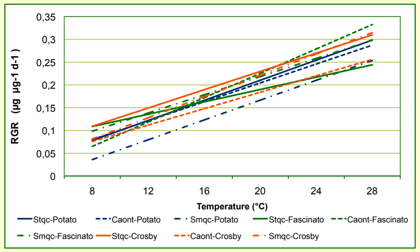

Figure 2. RGR of three biotypes of the potato aphid *M. euphorbiae* raised three different host-plants: one otato or two varieties of bell pepper at six constant temperatures.

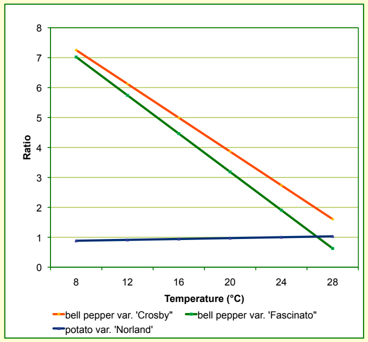

Figure 3.. Aphid RGR/ Plant RGR ratio.

The aphid's RGR response to temperature is also linear (Fig. 2) . **The RGR of the aphid increases 10.8% for each increase of 10°C.** The literature shows that the mortality of the potato aphid, highly increases around 30 °C (Barlow, 1962) So, we expect, that the growth rate reaches a maximum around 30°C. For the aphids, the effect of the temperature, host plant and biotype*host plant were significant (p= 0.007, 0.036 and 0.04, respectively). Francis et al (2010) determined that the capability to infest a plant depends on the variety of the host plant and the biotype of the aphid, and that the particular endo symbionts present on each biotype of aphid seemed to actively play a role on the adaptation to the host-plant.

The ratio of aphid RGR/plant RGR shows, that **on both bell pepper varieties, aphids perform 7 times better,** however, as the temperature increases, the aphid's relative performance decreases to about 1:1 at 28**°C. In contrast, the aphid's relative performance equals that of the potato across the experimental temperatures.**

CONCLUSIONS

1. **Hypothesis 1 (performance of the host plant):**

✓ The growth of different host plants is differently affected by temperature. Potatoes' rate of growth twice as fast as bell peppers over the same range of temperatures.

2. **Hypothesis 2 (association host plant*biotype):**

✓ The RGR of the potato, was affected by the host plant * biotype association, whereas it was NOT significant for the bell peppers varieties.

✓ The aphid's RGR is affected by the type of host-plants and biotypes of the aphid.

3. **Hypothesis 3 (aphid/plant ratio):**

✓ Rising temperatures should decrease aphid performance relative to its host plant for pepper systems, while it should have no such effect for potato based systems.

REFERENCES

Barlow, C. A. (1962). "Influence of temperature on growth of experimental populations of *Myzus persicae* (Sulzer) and *Macrosiphum euphorbiae* (Thomas) (Aphididae)." Canadian Journal of Zoology **40**(2): 145-&.

Campbell, A., B. D. Frazer, et al. (1974). "Temperature requirements of some aphids and their parasites." Journal of Applied Ecology **11**(2): 431-438.

Francis, F., F. Guillonneau, et al. (2010). "Tritrophic interactions among *Macrosiphum euphorbiae* aphids, their host plants and endosymbionts: Investigation by a proteomic approach." Journal of Insect Physiology **56**(6): 575-585.

Hance, T., J. van Baaren, et al. (2007). "Impact of extreme temperatures on parasitoids in a climate change perspective." Annual Review of Entomology **52** (1): 107-126.

Harahagazwe, D., J. F. Ledent, et al. (2010). "Effects of rice straw mulch and planting density on potato growth and performance in lowlands of Burundi " Experimental Agriculture **46**(04): 501-518.

Hunt, R. (1982). Plant growth curves : the functional approach to plant growth analysis. London, Edward Arnold Ltd.

Lamb, R. J. and L. Grenkow (2008). "Efficiency of a herbivore-plant interaction: conversion of biomass from flax (Linaceae) to aphid, *Macrosiphum euphorbiae* (Hemiptera: Aphididae)." Canadian Entomologist 140(5): 600-602.

Penaloza, P., B. Palma, et al. (1996). "Plant growth and reproductive development of *Capsicum annuum* L." Phyton-International Journal of Experimental Botany **59**(1-2): 187-195.

Roy, M., J. Brodeur, et al. (2002). "Relationship between temperature and developmental rate of *Stethorus punctillum* (Coleoptera : Coccinellidae) and its prey *Tetranychus mcdanieli* (Acarina : Tetranychidae)." Environmental Entomology **31**(1): 177-187.

SAS-Institute-Inc. (2009). SAS. Cary, NC, SAS Institute Inc.

Schoonhoven, L. M., J. J. A. van Loon, et al. (2005). Insect-plant biology, Oxford University Press.

Tomasiewicz, D., M. Harland, et al. (2003). Commercial Potato Production - Irrigation. Guide to Commercial Potato Production on the Canadian Prairies. W. P. Council. Manitoba, Ca, Manitoba Agriculture, Food and Rural Initiatives: 107.

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