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Introduction

- Humulus lupulus* (hops) plants are grown in southern California for the brewing industry; however, it is unclear which strains grow best in our climate.
- We measured the virus damage and the relative growth rate (RGR) of 10 different strains, 5 native to the US and 5 non-native, to see which strains grown best and had less viral damage.

Methods

- We measured the height and width of each plant on 7/11/23 and on 9/12/23. These data were used to calculate the volume (V) of each plant.



Fig. 1. The plants when they first arrived to our CSUSM greenhouse 6/12/2023



Fig. 2. The plants when they reached the trellis line 8/11/2023

- Plant growth rates were calculated as a relative growth rate (RGR) = $[\ln(V_2) - \ln(V_1)] / (t_2 - t_1)$, where V_2 and V_1 are the plant volumes measured on day t_2 (9/12) and t_1 (7/11), respectively.
- Digital images were made from leaves collected from each plant to estimate the proportion of the leaves damaged by viruses (**Fig. 3**).
- Differences in the RGR and percent leaf damage were analyzed using a 1-way ANOVA. Differences in RGR and percent leaf damage between US and non-US strains were analyzed using a 2-sample t-test.

ImageJ Analysis Software
<https://imagej.net/ij/>



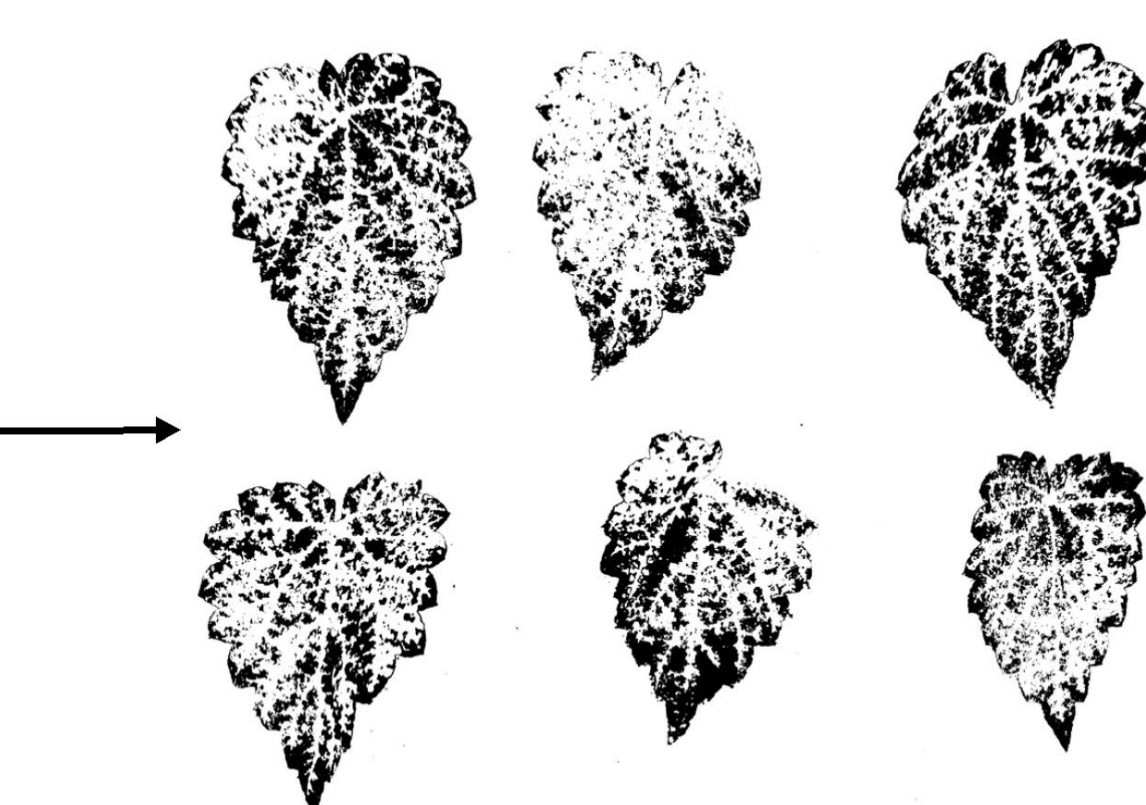
False color image for total leaf area



Binary image for total leaf area calculation



False color image of damaged leaf area

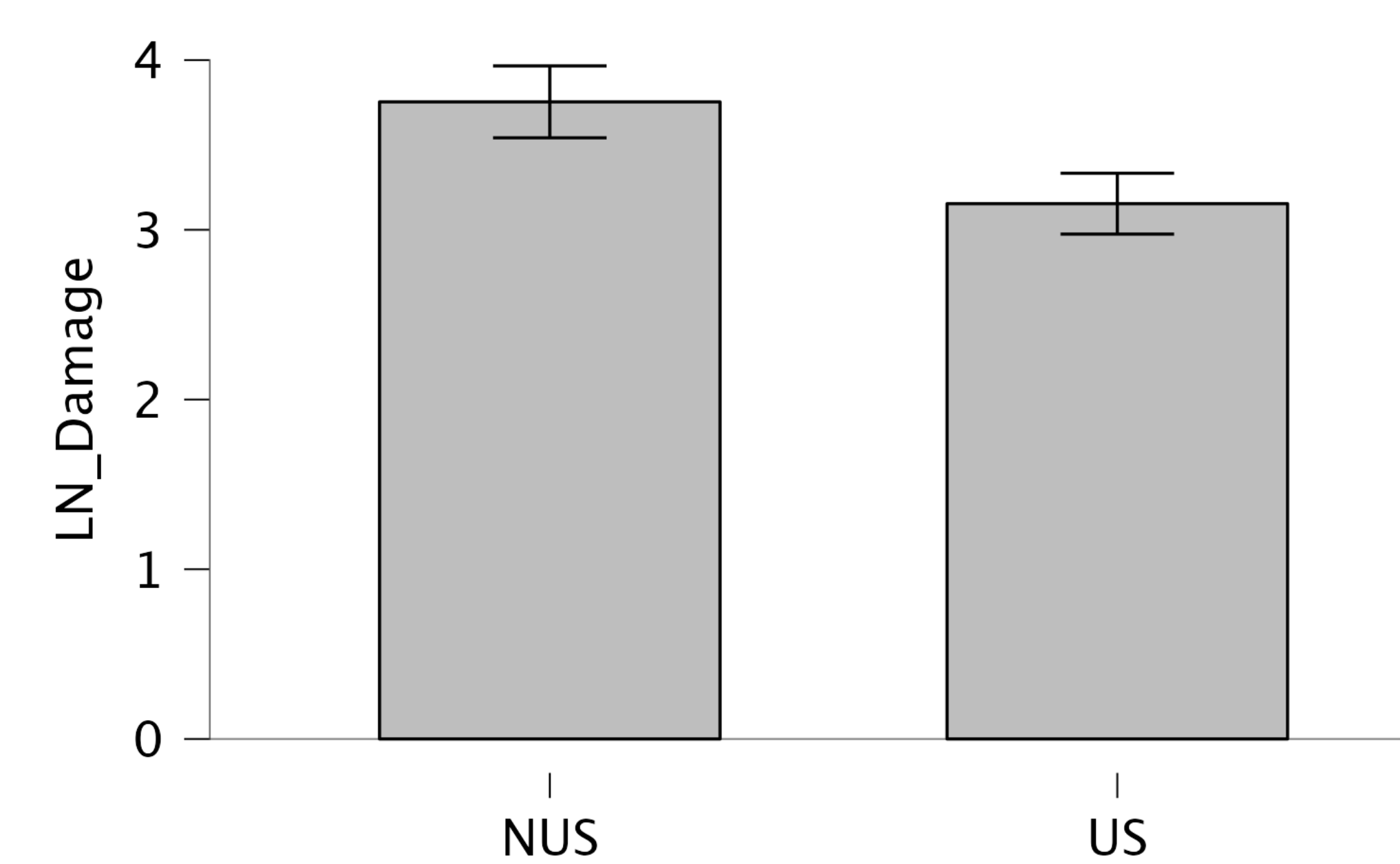
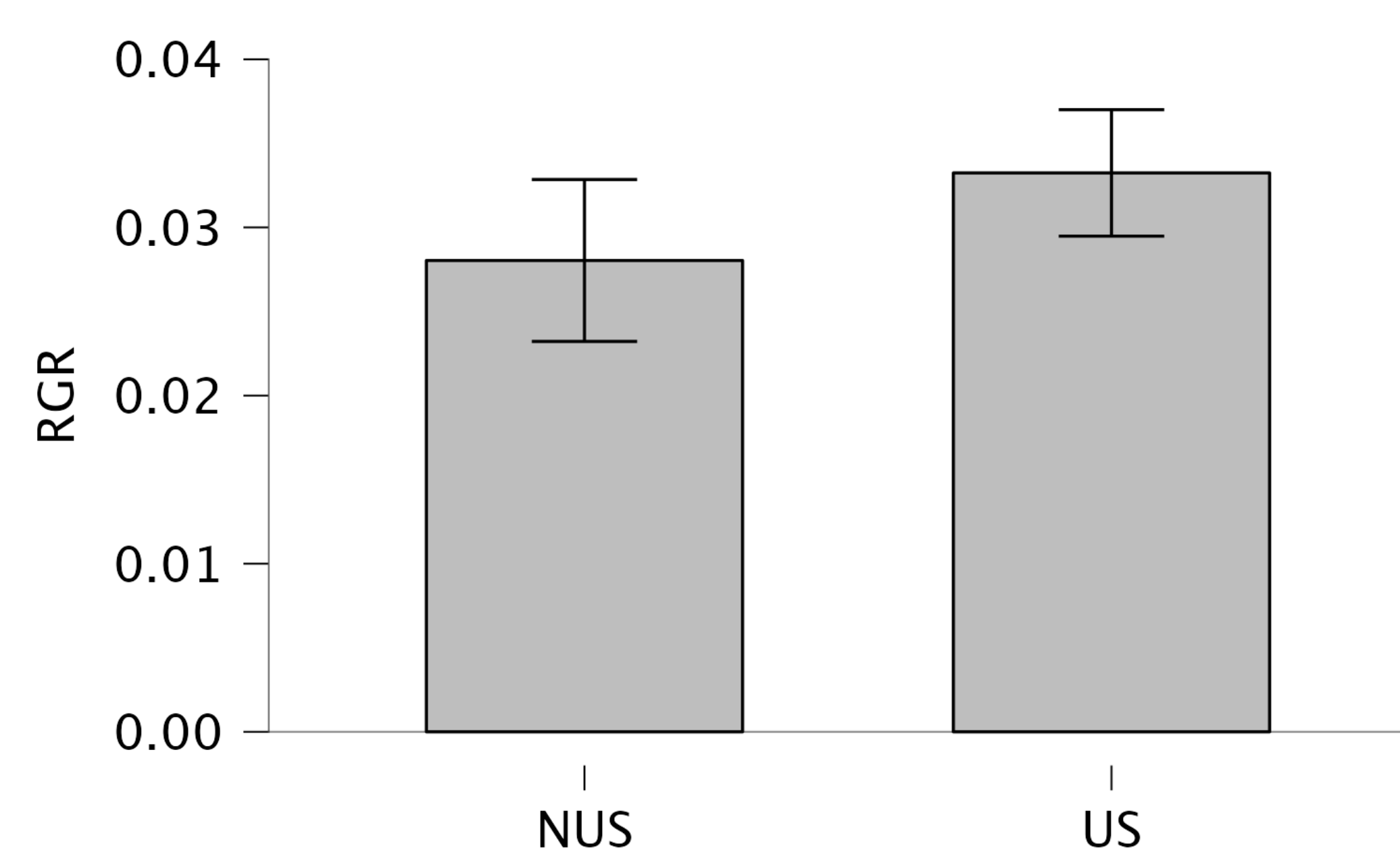
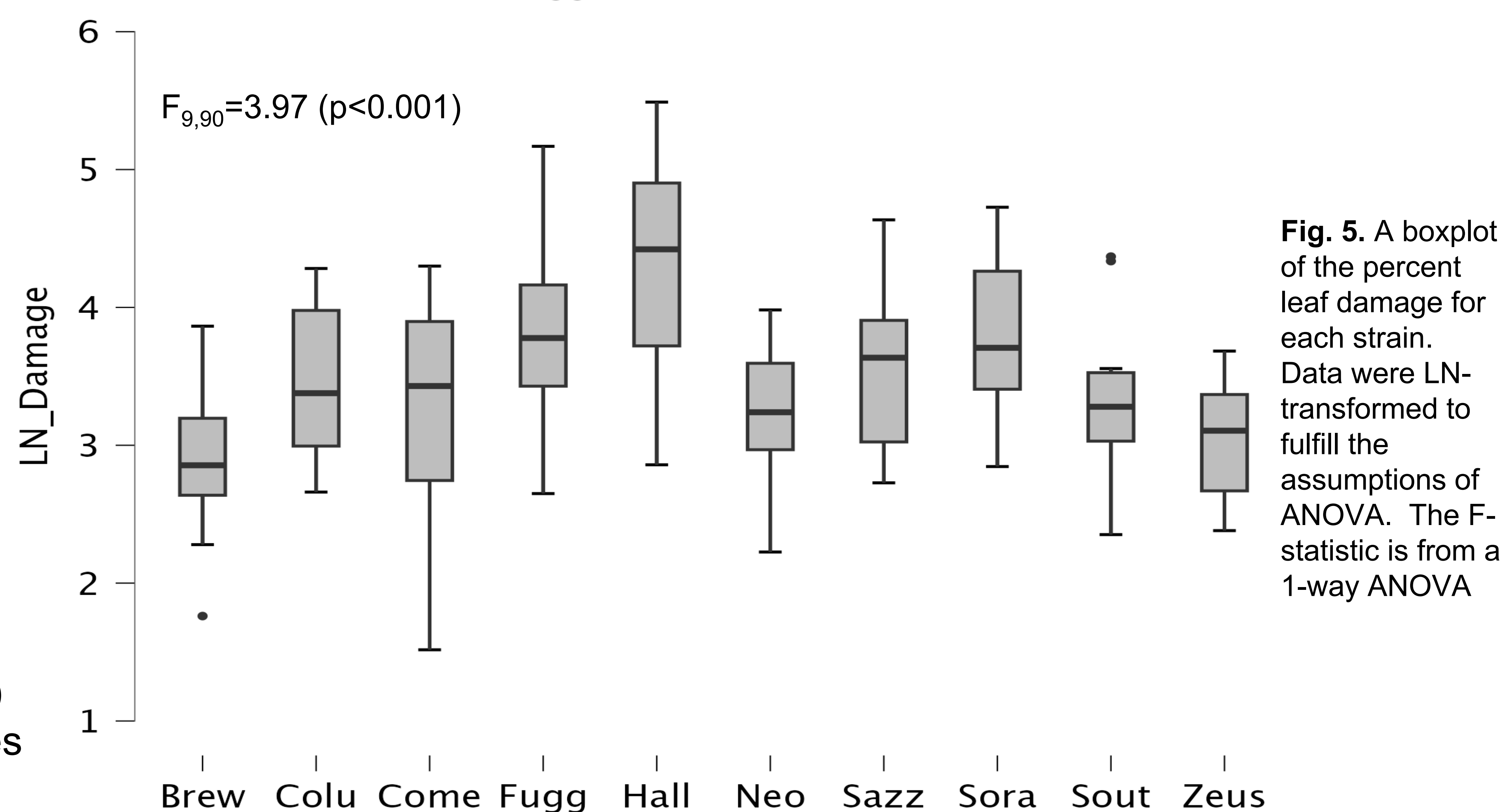
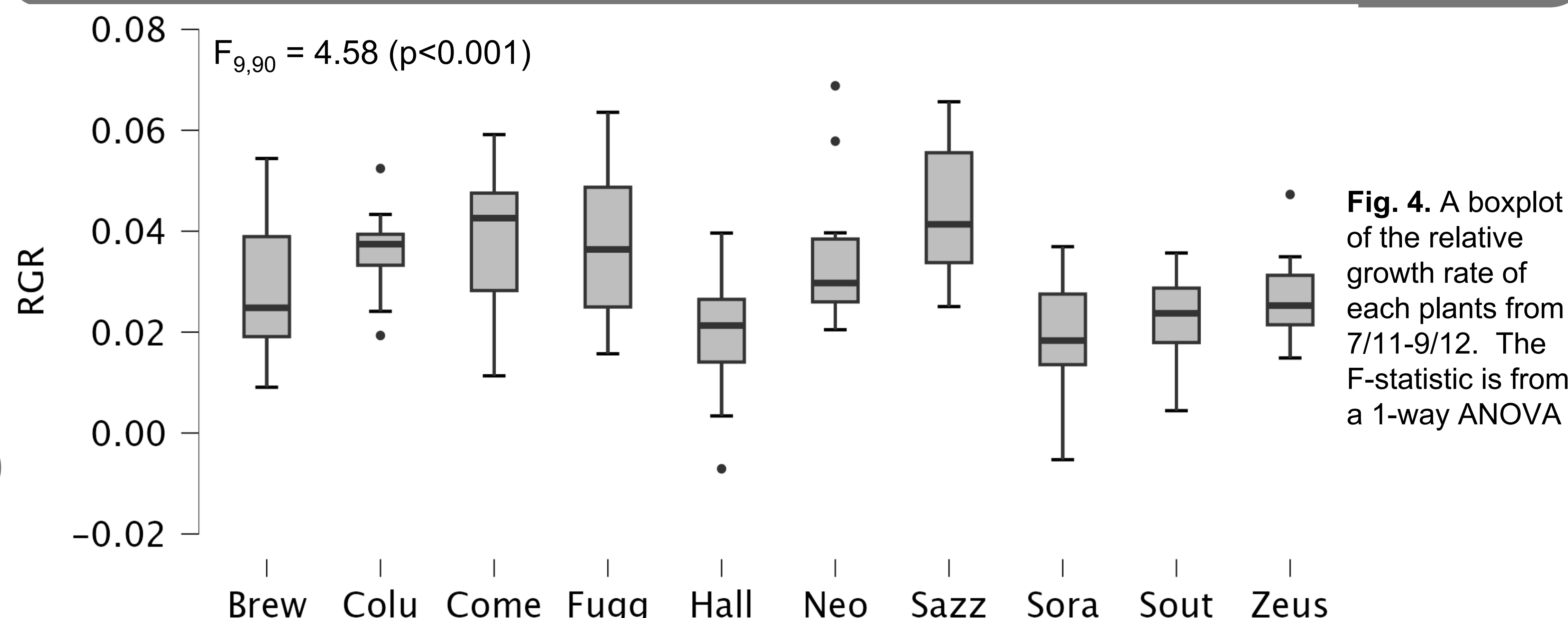


Binary image of damaged area calculation

$$\% \text{ Leaf Damage} = \frac{\text{Area damaged}}{\text{Total leaf area}} \times 100$$

Fig. 3. An example of how the percent leaf damage was estimated. Leaf images were transformed to a false color image and then to a binary image for the calculation of total and damaged leaf area. Percent leaf damage was calculated as the area of leaf damage divided by the total leaf area (x 100)

Results and Discussion



Conclusions

- There was a significance difference in the RGR of different strains. On average, Sazz had the highest RGR and Hallertauer MF (Hall) and Sorachi Ace (Sora) had the lowest RGR (**Fig. 4**).
- Percent leaf damage varied significantly between strains, with Hall having the highest leaf damage and Brewer's Gold (Brew) the lowest (**Fig. 5**).
- Strains native to the US had slightly higher RGR than non-US strains (**Fig. 6**), while non-US strains had significantly higher leaf damage than strains developed in the US (**Fig. 7**).

Acknowledgements

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