CROP GROWTH & PHYSIOLOGY

RESEARCH

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10. TITLE: Effects of Warming on Wild Blueberry Production and Pests

OBJECTIVES
<u>This project aims to</u>

- Evaluate the impact of warming on wild blueberry growth and productivity.
- Study the effects of warming on weed and insect pressure, and disease incidence.

LOCATION: UMaine Blueberry Hill Farm Experiment Station, Jonesboro ME
PROJECT TIMEFRAME: December 2018 – March 2020

INTRODUCTION
Global warming has changed the growth pattern of many crops and brought great challengers to agricultural systems across the world (Bita & Gerats 2013). Warming is predicted to accelerate in this century and global surface temperatures will increase by 1.8 to 4.0ºC at the end of the century (IPCC 2014). In Maine, atmospheric temperatures will increase further by 2 to 6ºC (3 to 9ºF) by 2100 (University of Maine Climate Change Institute 2015).

Warming has already changed the growth rhythm and increased the duration of the growing season of wild blueberries in Maine (Drummond and Yarborough 2014). Warming will also change the soil water availability, crop water consumption and nutrient needs of the wild blueberry system, which has not been studied. In addition, warming will lead to changes in weed pressure, the activity of pollinators, insect pest and pathogen disease pressure (Drummond et al. 2016). All these changes will need adjustment in management timing and strategies to maintain crop health and productivity. Therefore, studies are needed to provide necessary information for developing adjusted management recommendations.

A lot of physiological processes of crops including photosynthesis, respiration, water use, and nutrient absorption are sensitive to changes in temperature (Magan et al. 2011). Previously, warming has been found to have negative impacts on a variety of temperate crops (Lobell & Field 2007). Increased temperatures can cause higher atmospheric vapor-pressure deficit (VPD), which leads to higher plant water loss and higher plant water deficits. In addition, increased temperatures increase soil evaporation and plant transpiration, which consequently decreases soil moisture content. How warming will affect the physiology and productivity of wild blueberries has not been studied until now.

METHODS

Data Collection

This study was carried out at the Blueberry Hill Farm in Jonesboro, Maine. Five wild blueberry genotypes (clones) were chosen based on their genetic and physiological diversity. Each genotype has one active-heating open-top chamber (OTC) (Figure 1), one passive-heating open-top chamber and one control (no chamber). The OTCs are constructed with LEXAN polycarbonate sheet (glass substitute) of the following dimensions: 3 mm thickness with a 100 cm base, 70 cm top, and 55 cm sides cut at an angle of 60°. For the active heating OTC, a 12-m-long waterproof silicone heating tape with a 240 W power rating (Briskheat, Columbus, OH, USA) was coiled around a hexagon with metal tubing, and fixed inside the OTC (using timber stakes) at a height of 15 cm. Active heating chambers can increase the temperature about 7.2 to 9º F compared to the ambient, while passive heating chambers can raise the temperature about 3 to 5º F (Figure 2). Weather stations were installed inside the OTCs or in the middle of the control, which recorded the temperature, relative humidity, soil temperature, and soil volumetric water content every 30 minutes.

Figure 1. Climate change chambers used to study warming effects on wild blueberries and pests. Chambers are installed at Blueberry Hill Research Farm, Jonesboro, ME.

From May to October of 2019, the average temperatures in the passive heating (passive) and active heating (active) treatments were approximately 4ºF and 8ºF higher, respectively, compared to the control (Figure 1). The relative humidity (RH) in the active treatment was significantly lower compared to the control, while that of the passive was similar to the control. The average air vapor pressure deficit (VPD) in the passive and active treatments were higher than that of the control from June to September. The soil volumetric water contents of passive and active were significantly lower compared to the control (Figure 2).

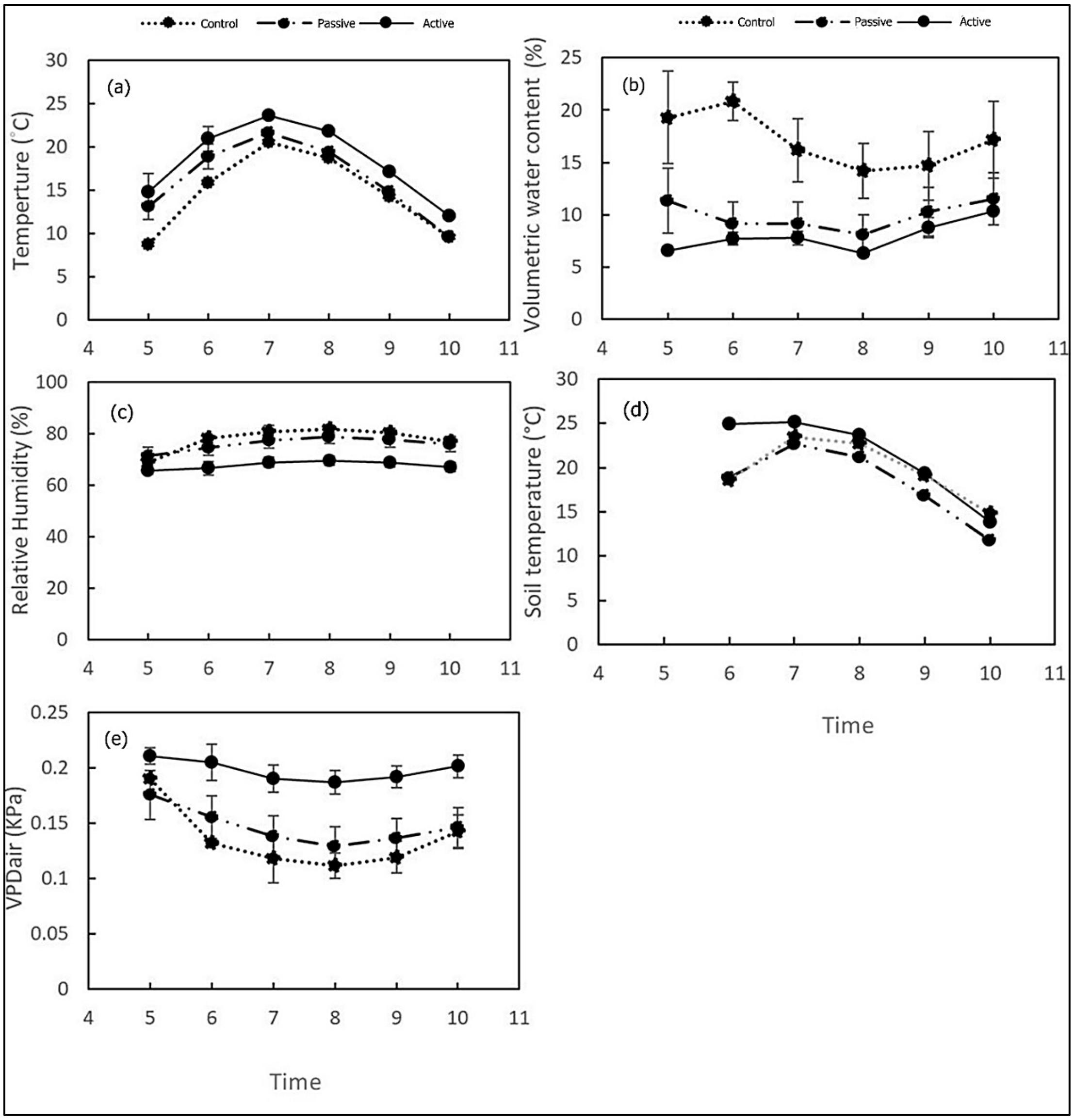

Figure 2. Monthly averages of (a) Atmospheric temperature, (b) Volumetric water content in soil, (c) Relative humidity, (d) Soil temperature, and (e) Vapor pressure deficit of air (VPDair) from May 2019 to October 2019, for the control, active heating (active) and passive heating (passive) chambers.

The measurements included crop physiological traits and pest rating. The physiological traits measured were leaf chlorophyll content, anthocyanin content, water use, water status, transpiration, stomatal conductance, and photosynthesis. Leaf chlorophyll content was measured by a SPAD Chlorophyll Meter (SPAD 502; Minolta Corp., Osaka, Japan). Leaf anthocyanin content (the antioxidant rich, flavonoid in the berry) was measured with an ACM-200 anthocyanin meter (Opti-Sciences Inc., Hudson, NH, USA). Leaf photosynthesis, transpiration, and stomatal conductance were measured using an LI-6800 portable photosynthesis system (Li-Cor, Lincoln, NE, USA). The leaf water status was quantified with leaf water potential determined by a leaf pressure chamber (PMS Inc., Albany, OR, USA). The weed, disease and insect pest pressures were also rated based on the severity. Weed, disease and insect pest pressures were ranked from 0 to 5, where: 0 = not present, 1 = ≤20%, 2 = 20%-40%, 3 = 40%-60%, 4 = 60%-80%, 5 = 80%-100.

Data Analysis

The effects of the temperature on blueberry were statistically compared using a one-way ANOVA in SPSS 25 ($\alpha = 0.05$ and $\alpha = 0.01$) with the genotype (clone) as a fixed factor.

RESULTS

Warming significantly altered the growth pattern of the wild blueberries in the vegetative growth (prune) year. Wild blueberries in the active heating dropped leaves much later compared to that of the control (Figure 3a) and maintained leaves until early December (Figure 4). The remaining leaves of the plants under the active treatment also maintained high anthocyanin contents from October to December (Figure 3b).

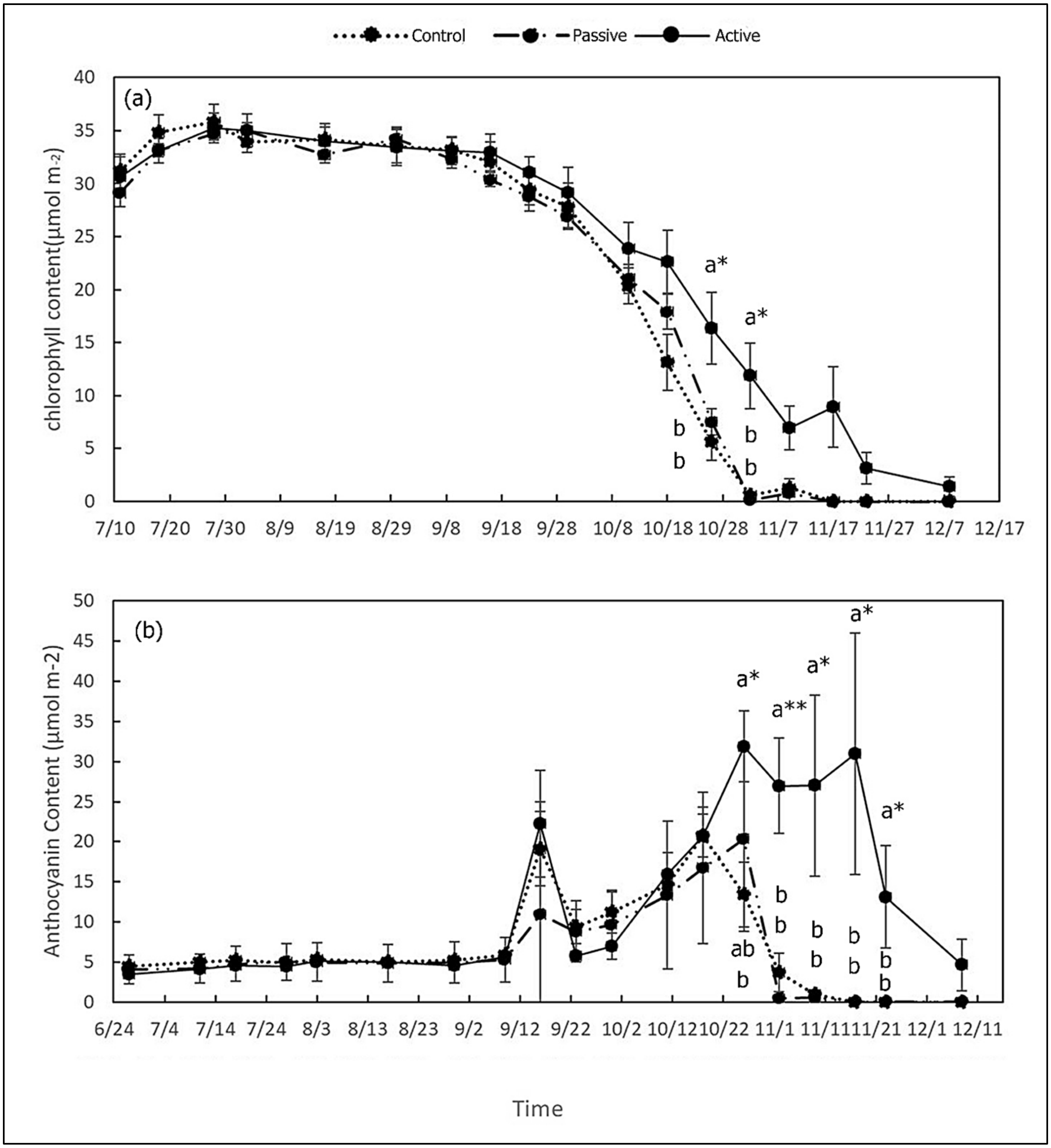

Figure 3. Seasonal dynamics in (a) Leaf chlorophyll content from June 2019 to December 2019, and (b) Anthocyanin Content from July 2019 to December 2019, for the control, active heating (active) and passive heating (passive) chambers. Data are averages ± S.E. (n = 15). Points with the same letter do not differ significantly ($P < 0.05$* and $P < 0.01$**).

Wild Blueberry Morphology

Warming significantly changed the leaf morphology and structure of the wild blueberry plants. Wild blueberries under warming (passive and active) showed a higher number of leaves and longer stems compared to the control. Plants in active heating chambers also showed larger but thinner leaves compared to the control (Figures 4 & 5).

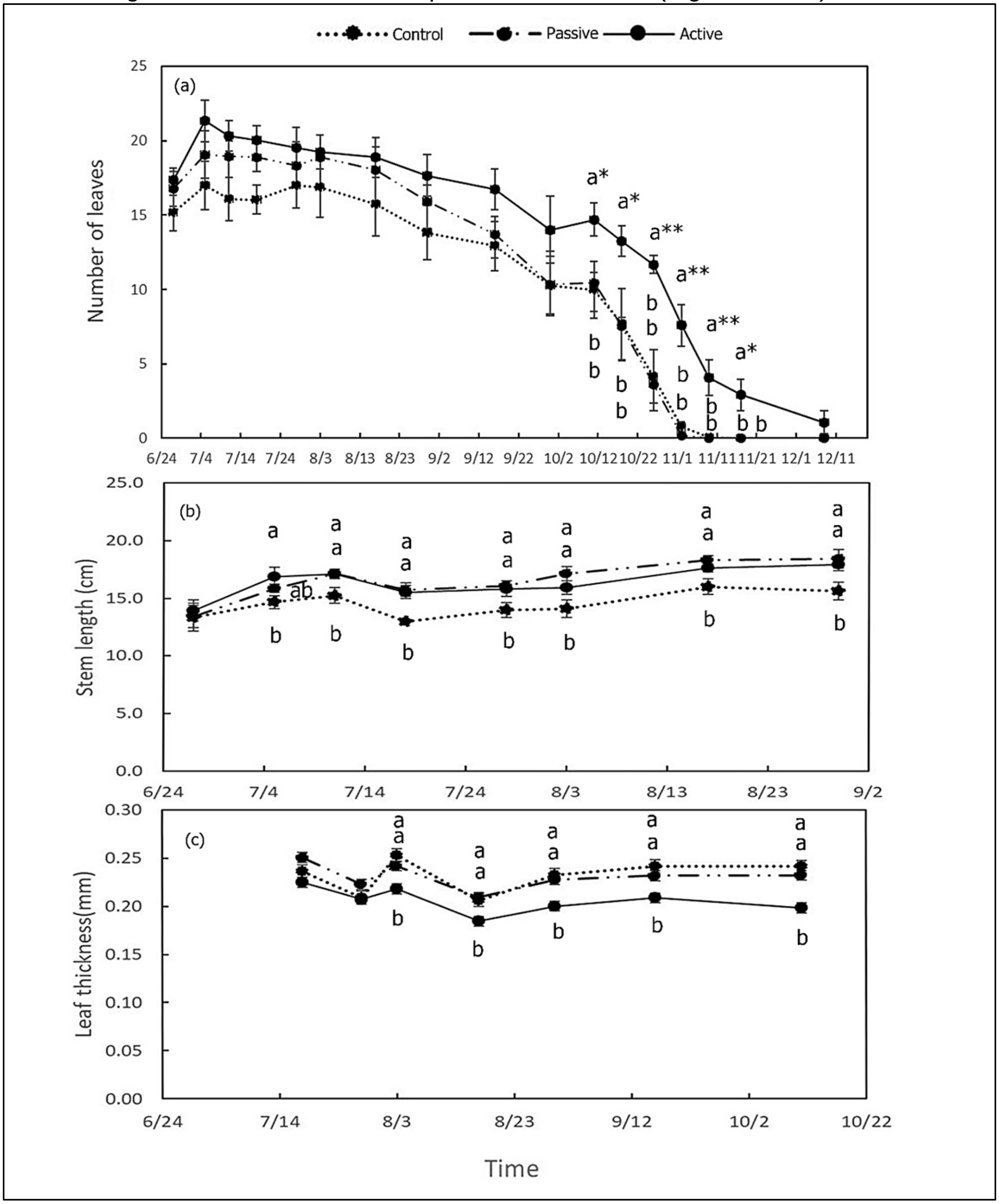

Figure 4. Seasonal dynamics in (a) Number of leaves, (b) Stem length, and (c) Leaf thickness for the control, active heating (active) and passive heating (passive) chambers from June 2019 to December 2019. Data are averages ± S.E. (n = 15). Points with the same letter do not differ significantly (P < 0.05* and P < 0.01**).

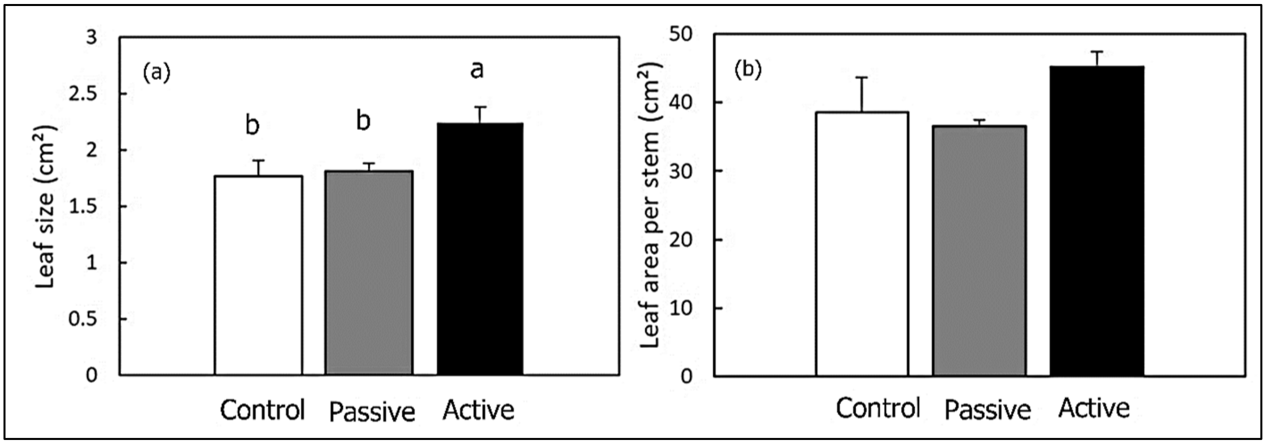

Figure 5. (a) Average leaf size, and (b) Leaf area per stem, for the control, active heating (active) and passive heating (passive) chambers. Data are averages + S.E. (n = 15). Bars topped by the same letter do not differ significantly ($P < 0.05$).

Wild Blueberry Physiology

Warming treatments also significantly altered the physiology of wild blueberries. No significant differences in leaf photosynthetic rate were detected among different treatments (Figure 6a). However, the photosynthetic electron transport rates were significantly lower under the active treatment compared to the control (Figure 6b). Wild blueberries under both passive and active treatments showed higher stomatal conductance compared to the control (Figure7b). Plants in the active warming treatments were also drier compared to the control, as indicated by lower mid-day leaf water potentials (Figure 7d). No significant differences were detected in leaf respiration rate among different treatments.

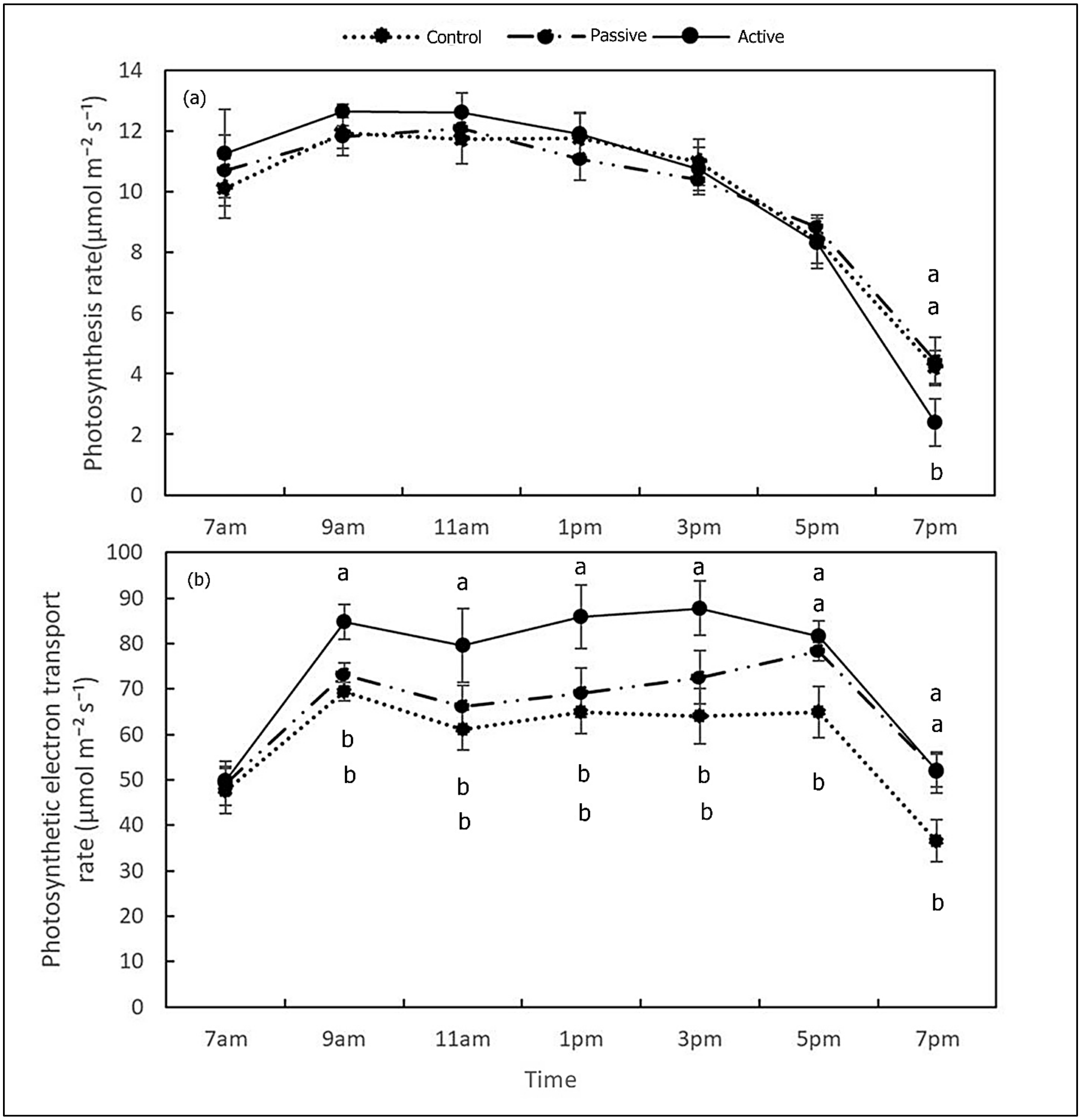

Figure 6. Diurnal changes in (a) Photosynthesis rate, and (b) Photosynthetic electron transport rate, for the control, active heating (active) and passive heating (passive) chambers. Data are averages ± S.E. (n = 15). Points with the same letter do not differ significantly ($P < 0.05$).

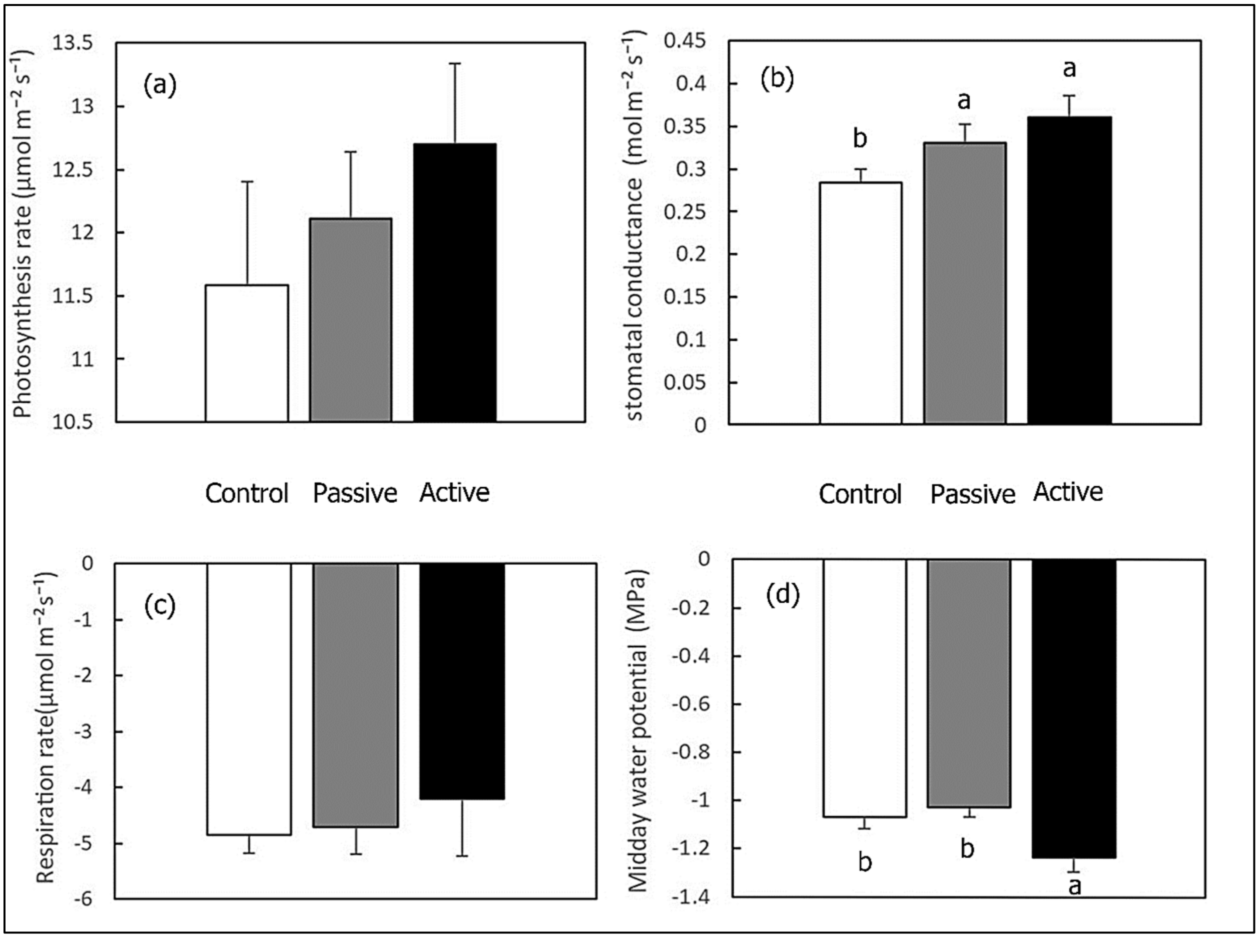

Figure 7. (a) Maximum photosynthetic rate at 11 am, (b) Maximum stomatal conductance at 11 am, (c) Respiration rate, and (d) Mid-day water potential, for the control, active heating (active) and passive heating (passive) chambers. Data are averages + S.E. (n = 15). Bars topped by the same letter do not differ significantly (P < 0.05).

Pest Pressures

In general, no significant differences in tip midge, blueberry thrips, red-striped fireworm, leaf spot, stem blight, and weed coverage were detected among different treatments (Figure 8). Septoria leaf spot disease was detected to be lower under the active treatment compared to the control (Figure 8g).

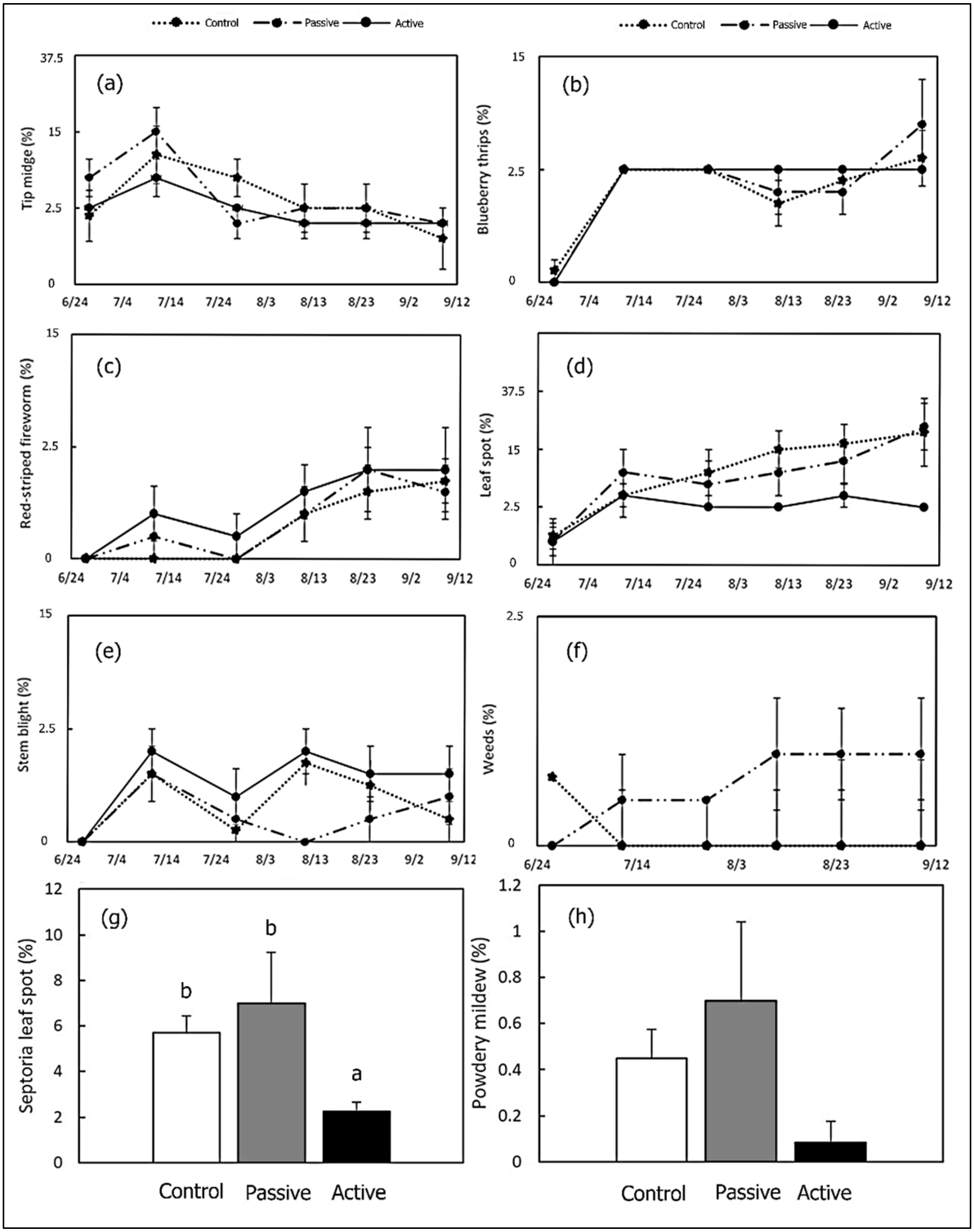

Figure 8. Disease and insect pest severity (%) for the control, active heating (active) and passive heating (passive) chambers in (a) Tip midge, (b) Blueberry thrips, (c) Red-striped fireworm, (d) Leaf spot, (e) Stem blight, (f) Weeds, (g) Septoria leaf spot on August 21st,

2019, and (h) Powdery mildew, on August 21st, 2019. Data are averages ± S.E. (n = 15). Bars topped by the same letter do not differ significantly ($P < 0.05$).

DISCUSSION

Warming by 7 to 9ºF has greatly altered the growth rhythm, morphology, structure, and physiology of wild blueberries. Warming extended the length of the growing season, which agrees with a previous report (Drummond and Yarborough 2014). While an extended growing season could extend the time for plant photosynthesis, it can inhibit cold hardening during the fall and increase the risk of winter damage. Warming also decreased leaf photosynthetic electron transport rates but did not affect photosynthetic CO_2 assimilation. The mechanism explaining this pattern needs to be studied with further experiments.

Warming significantly increased leaf stomatal conductance, transpiration and plant water loss, which consequently decreased soil water availability in the wild blueberry system. Therefore, the wild blueberry system in a warmer future may need more water supply through irrigation to maintain good water status of crops. Decreased soil availability will also potentially decrease nutrient availability to the crop. Therefore, the future wild blueberry system may require more fertilizer applications to maintain crop productivity. Many temperate crops are expected to benefit from 1 to 3ºC warming of ambient temperature (Easterling et al. 2007; Hatfield et al. 2011). Photosynthetic rates of plants generally are expected to increase with an increasing temperature between 13ºC and 25ºC assuming that changes in no other limiting factors such as light, nutrient, and atmospheric CO_2 concentrations occur (Curtis & Clark 1950). However, in our study, photosynthesis of wild blueberries did not change under warming treatment. This could be because of decreased soil water and nutrient availability under warming. Overall, warming has a negative impact on wild blueberry production by decreasing soil water and nutrient availability. The warming effects on fruit production and quality will be tested in the 2020 crop year.

CURRENT RECOMMENDATIONS

Increased irrigation and fertilizer applications will be necessary in warmer years and in the future with warmer temperatures.

NEXT STEPS

- Carry out the crop year (2020) measurements.
- Monitor crop growth, physiology, and health in the crop year.
- Monitor pest pressure (weed, insect, disease) in the crop year.
- Harvest blueberries to compare warming effects on crop yield and quality.

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