Pasture production and lamb growth in agrivoltaic system

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Abstract. Grasslands and croplands located in temperate agro-ecologies are ranked to be the best places to install solar panels for maximum energy production. Therefore, agrivoltaic systems (agricultural production under solar panels) are designed to mutually benefit solar energy and agricultural production in the same location for dual-use of land. However, both livestock farmers and energy companies require information for the application of efficient livestock management practices under solar panels. Therefore, this study was conducted to compare lamb growth and pasture production under solar panels and in open pastures in Corvallis, Oregon in spring 2019 and 2020. Averaged across the grazing periods, weaned Polypay lambs grew at 120 and 119 g/head/d under solar panels and open pastures, respectively in spring 2019 (P=0.90). Although a higher stocking density (36.6 lambs/ha) at the pastures under solar panels was maintained than open pastures (30 lambs/ha) in the late spring period, the liveweight production between grazing under solar panels (1.5 kg ha/d) and open pastures (1.3 kg ha/d) were comparable (P=0.67). Similarly, lambs liveweight gains and liveweight productions were comparable in both pasture types (all P>0.05). The daily water consumption of the lambs in spring 2019 were similar during early spring, but lambs in open pastures consumed 0.72 l/head/d more water than those grazed under solar panels in the late spring period (P<0.01). However, no difference was observed in water intake of the lambs in spring 2020 (P=0.42) The preliminary results from our grazing study indicated that grazing under solar panels can maintain higher carrying capacity of pasture toward summer, and land productivity could be increased up to 200% through combining sheep grazing and solar energy production on the same land. More importantly, solar panels may provide a more animal welfare friendly environment for the grazing livestock as they provide shelter from sun and wind.

INTRODUCTION

Energy potential of solar power ranked by land classification, indicating the best place to put solar panels is on croplands and grasslands (Adeh et al., 2019). Therefore, solar installations can occupy large land areas and sometimes compete with agriculture for the land resource. Agrivoltaic systems are created when solar and agricultural systems are co-located for mutual benefit. Higher forage production under the solar panels as compared to open pastures was reported with an increased water use efficiency by 330% in Pacific Northwest (Adeh et al., 2018). However, there is still a need for development of a comprehensive agrivoltaic grazing system to understand how solar energy production interact with the pasture and livestock management. The objective of the study is to investigate the effect of grazing under solar panels on lamb liveweight gains, pasture production and land productivity.

MATERIALS AND METHODS

This study was conducted to compare lamb growth and pasture production under solar panels and in open pastures in Corvallis, Oregon in two consecutive spring seasons in 2019 and 2020. A 0.6 ha pasture paddock under solar panels and in adjacent open areas were fenced and divided into three, 0.2-ha blocks to serve as replicates. Each block was divided into 2 subplots (0.1 ha), which were randomly assigned to the grazing under solar panels and grazing in open pasture fields (control). The experiment layout was a randomized complete block design with three replicates. In solar pastures, the distance between solar panels was 6 m giving a 3-m fully shaded and 3-m partially shaded sites (Adeh *et al*., 2019). Each solar pastures contained four solar arrays and four solar panels. Thus, these pastures had 50% open (partially shaded) and 50% fully shaded areas. A put-and-take grazing system was applied to match feed demand with changing supply. Each treatment had a core group of 3 lambs (testers) with spare lambs (regulators) in spring. The groups of lambs were randomly assigned to one of six, 0.1 ha pastures where they continuously grazed from 17 April to 12 June 2019 and from 30 March to 11 June 2020. Animals had free access to fresh water in open pastures and under solar fields. Herbage dry matter production (kg DM/ha) was measured during active growth in spring, summer, and autumn under fully shaded (directly under solar panels), partially shaded (arrays in between solar panels) areas in solar pastures and in randomly selected sites in open pastures using exclosure cages. Liveweight gain of the weaned lambs was determined prior to and following each grazing period. Group water consumptions of the lambs were determined at each grazing period. Liveweight gain per head (g/d) and per ha (kg/ha/d) were analyzed by one-way ANOVA for each liveweight gain measurement period. Pasture production and water consumption of lambs (L/d) was analyzed by one-way ANOVA with three replicates at each date. The computations were carried out using GENSTAT statistical software version 18 (VSN International Ltd., Rothampstead, UK) by ANOVA (Payne, 2009). Significant differences among treatment means were compared by Fisher's protected least significant difference at $P < 0.05$.

RESULTS AND DISCUSSION

Seasonal Forage Production

Total herbage yield was 4864, 4586 and 3300 kg DM/ha for open pastures, partially shaded and fully shaded solar pastures, respectively (Fig 1). While the DM yield from open and partially shaded areas was similar, pastures under fully shaded sites were substantially lower ($P<0.01$). Seasonal herbage DM production between open pastures and partially shaded areas did not differ in 2019 ($P>0.05$). However, the forage production in the fully shaded areas under solar panels was lower ($P<0.05$) than open pastures on 23 May and 23 October while it was greater ($P<0.05$) than open pastures on 11 July. In spring-summer 2020 total herbage yield in spring-summer period was 8700, 3079 and 8579 kg DM/ha for open pastures, partially shaded and fully shaded solar pastures, respectively (Fig 1). On average, the pasture production was 9-33% less in agrivoltaics systems than open pastures.

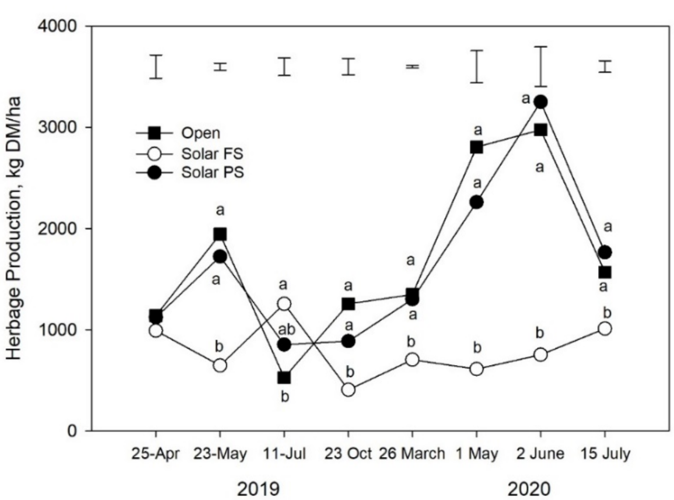

FIGURE 1. Seasonal herbage production (kg DM/ha) in open pastures and fully and partially shaded areas in solar pastures in 2019 and 2020. The bars represent SEM.

Lamb Production

Averaged across the grazing periods, weaned lambs grew at 120 and 119 g/head/d under solar panels and open pastures, respectively in spring 2019 ($P = 0.90$; Fig 2a). Although a higher stocking density (36.6 lambs/ha) at the pastures under solar panels was maintained than open pastures (30 lambs/ha) in the late spring period (May 15-June 12), the liveweight production between grazing under solar panels (1.5 kg ha/d) and open pastures (1.3 kg ha/d) were comparable (P=0.67; Fig 2c). Similarly, in spring 2020, lambs in both solar and open pastures had similar liveweight gains (P=0.64; Fig 2b). In period 1 (March 30-May 4), lambs grew at 129.7 g/ha/d. as the season progressed the average daily liveweight gains of the lambs dropped to 49.7 g/head/d (P<0.01) in period 2 (May 4-June 11). Liveweight production of the lambs were similar as both open and solar pastures were grazed at same stocking rates in both periods (P=0.97; Fig 2d).

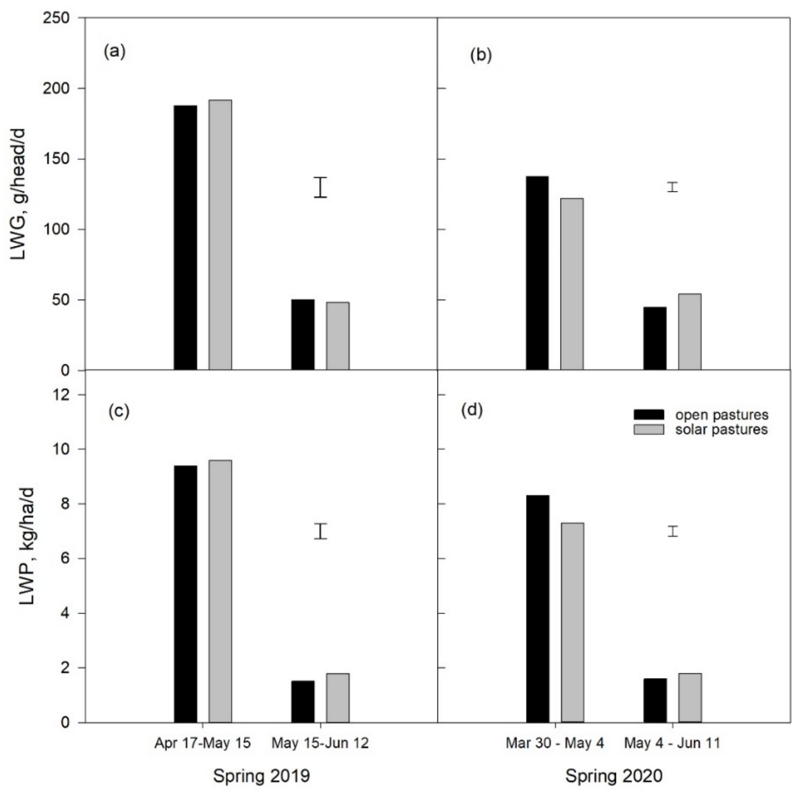

FIGURE 2. Daily lamb growth rates (g/head/d) and production (kg/ha/d) from open and solar pastures in 2019 and 2020. The bars represent SEM.

Water Consumption

In 2019, the daily water consumption of the lambs was similar during early spring (April 17- May 15), but lambs in open pastures consumed 0.72 L/head/d more water than those grazed under solar panels in the late spring period (May 15-June 12) (P <0.01; Fig 3a). In spring 2020, the daily water intake of the lambs was 1.48 and 1.32 L/head/d for the lambs in open and solar pastures, respectively but the difference was not significant at neither early (March 30-May 4) nor late spring (May 4-June 11) periods (P=0.42; Fig 3b). The water intake of the lambs increased from 0.59 L/head/d in early spring to 2.21 L/head/d in the late spring period (P<0.01).

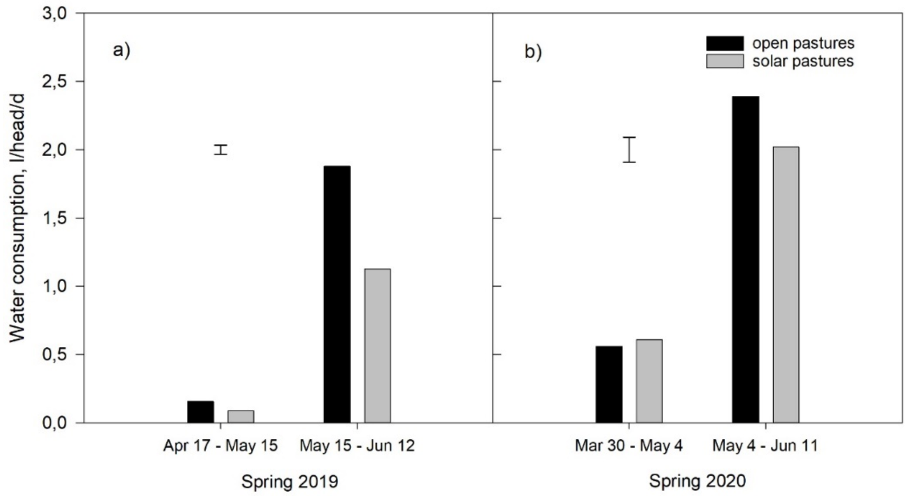

FIGURE 3. Daily water consumption of lambs grazing open and solar pastures in 2019 and 2020. The bars represent SEM.

This study reveals that agrivoltaics production systems can be used to improve lamb production and welfare. While factors such as liveweight gains and early spring water consumption were comparable in the open, partially shaded, and full shaded pastures, this demonstrates that producing lambs in AV systems would not decrease the production value. Furthermore, some aspects were more favorable in the fully solar treatments, including water consumption in late spring 2019, the ability to maintain a higher stocking rate towards summer, and increased herbage yields in July of 2019. In addition to the increased land productivity and improved animal welfare, the results from this study support the benefits of agrivoltaics as a sustainable agricultural system. More work should be done to properly establish pastures when creating an AV system. This can help accommodate for the lower herbage yields in full shade experienced throughout most of the experiment. Additionally, information about agrivoltaics should be made readily available to farmers, energy producers, researchers, and the general public as it becomes available. Further studies should be done to gain opinions of farmers to determine which factors either encourage or discourage from pursuing a change to an AV system. With better knowledge about animal welfare and production, pasture establishment, and public opinion, it is hoped that agrivoltaics will become a more commonly used practice.

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