AGRICULTURAL RESEARCH FOUNDATION
FINAL REPORT
FUNDING CYCLE 2021 – 2023

TITLE: Development of sustainable pasture systems for efficient agrivoltaic production
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SUMMARY/ABSTRACT: Targeted grazing is often applied to control understory biomass accumulation in photovoltaic sites. Management of vegetation through grazing eliminates the need for mechanical harvest or herbicide applications. Photovoltaic panels provide shade and cool microclimate for grazing livestock, but often the quality of understory forages is poor for satisfactory animal production. The renovation of weedy pastures can improve the production and quality of forages, making the photovoltaic sites more attractive to livestock producers and help maximizing the land use efficiency. Designing persistent and productive pasture mixtures that are suitable to agrivoltaics systems is a highly novel concept. There is a paucity of information on the persistence and production of pasture species in various shade zones induced by photovoltaic panels. Thus, the objective of the study is to compare herbage and lamb production from various pasture mixtures established within solar arrays in Pacific Northwest.

OBJECTIVES:

1. Determine the seasonal and total annual dry matter yield and nutritive value of simple pastures, herbal ley pastures, and legume pastures.
2. Assess the carrying capacity and daily growth rates of lambs grazing in traditional and specialized pastures.
3. Assess the effect of shade and pasture types with varying bioactive compounds on animal behavior and welfare.

PROCEDURES:

SIGNIFICANT ACCOMPLISHMENTS:

1- **Pasture establishment and grazing study:** Three pasture mixtures were sown in between solar alleys on 21 September 2020. The experiment layout was a randomized complete block design with three replicates (blocks). A 0.864 ha pasture paddock under solar panels was fenced and divided into three, 0.288-ha blocks to serve as replicates. Each block was divided into three subplots (0.096 ha), which were randomly assigned to the three pasture mixtures: 1) Grass-clover pasture (Lolium perenne, X Festulolium braunii, Dactylis glomerata, Trifolium repens and Trifolium subterraneum); 2) Herbal ley pasture (Lolium perenne, X Festulolium braunii, Dactylis glomerata, Trifolium repens, Trifolium subterraneum, Trifolium michelianum, Trifolium alexandrinum, Cichorium intybus, Plantago lanceolata, Lotus corniculatus, Achillea millefolium and Phacelia tanacetifolia), and 3) Legume pasture (Trifolium repens, Trifolium subterraneum, Trifolium michelianum, Trifolium alexandrinum, Lotus corniculatus, Trifolium pratense and Melilotus alba). The distance between solar panels was 6m giving a 3-m fully shaded and

3-m partially shaded areas. Pastures were grazed continuously by weaned Polypay lambs from 8 April-8 June in the spring, 8 July- 2 August in the summer, and 27 October-18 November in the fall. Prior to start of grazing in each period, lambs were stratified by sex and liveweight and allocated randomly to treatments. The legume pastures were only grazed in spring while they were spelled during summer and fall due to low forage biomass availability. Liveweight of the lambs was determined prior to and following each grazing period, and live weight gain (LWG) was calculated as the difference. Each treatment had a core group of 9 lambs (testers) with spare lambs (regulators). A put-and-take grazing system was used to match feed demand with changing supply. Herbage dry matter production was measured during active growth in spring, summer, and fall under fully shaded (50% of the plots), partially shaded (~25%) and open (~25%) areas using exclosure cages.

2- **Forage biomass and lamb growth data obtained:** Averaged across the shade zones, total annual herbage yield of herbal ley pastures was 4.583 kg DM ha^{-1}. This was comparable to the herbage yield obtained from grass pastures (4.457 kg DM ha^{-1}) but legume pastures had lower ($P < 0.05$) yield (4.023 kg DM ha^{-1}) than other pasture types. A pasture treatment × shade interaction was detected ($P < 0.01$) for the total annual herbage yield (Table 1). Total annual herbage yield of grass-clover and herbal ley and pastures was greater in open (unshaded) than partially shaded areas, while the forage yield of legume pastures in partially shades areas was similar to that from open areas. Regardless of the pasture treatments, the total annual herbage yield was the lowest in fully shaded areas where volunteer annual grasses were the main component of pastures. It is evident from the results that the shade is the major limiting factor reducing the herbage production potential of forages regardless of the pasture types, except for legume pasture in partial shade. To maximize herbage yield and energy production from the same land optimization of the designs of ground mounted photovoltaic panels is needed.

Table 1. Herbage yield (kg DM ha^{-1}) of grass-clover, herbal ley and legume pastures in open, partially and fully shaded areas in a photovoltaics site in 2020 and 2021 growing season.

Pasture treatments	Shade zones	Herbage yield, kg DM ha^{-1}			
		Spring	Summer	Fall	Total
Grass-clover	Open	5887_a	706	1013	7496_a
	Partial shade	3641_c	596	842	5188c
	Full shade	1723_d	515	333	2571_c
Herbal ley	Open	5489_a	806	906	7201_a
	Partial shade	3768_{bc}	1102	964	5835_b
	Full shade	1653_d	540	454	2647_c
Legume	Open	4279_b	517	658	5454_b
	Partial shade	3853_{bc}	819	428	5100_b
	Full shade	1684_d	657	427	2768_c
SEM		177.9	118.3	116.6	209.2
$P_{\text{Pasture (P)}}$		0.05	0.11	0.05	0.01
$P_{\text{Shade zones (S)}}$		0.01	0.05	0.01	0.01
$P_{\text{P×S Interaction}}$		0.01	0.33	0.15	0.01

a–dMeans within a column with different superscripts differ (α = 0.05). SEM: Standard error of means; P: level of significance.

Lambs grew at 175, 200 and 224 g d^{-1} in grass, herbal ley and legume pastures, respectively (*P*=0.06) in spring 2021 (Table 2). Lambs grazing herbal ley pastures tended to (*P*=0.05) have greater daily gains than those grazing grass pastures, in summer. The legume pastures did not support grazing during the summer and fall due to low forage biomass containing mainly broadleaved weeds.

Table 2. Live weight gains (g head d^{-1}) of lambs grazing grass-clover, herbal ley and legume pastures in spring, summer and fall 2021.

Pasture treatments	Liveweight gains, g head d^{-1}		
	Spring	Summer	Fall*
Grass	175	86	
Herbal ley	200	136	
Legume	224	-	-
SEM	10.1	8.8	
P	0.06	0.053	

SEM: Standard Error of means; P: level of significance; *No data were recorded in fall grazing due to a malfunction in the sheep weighing scale.

3- **An abstract was submitted to Agrivoltaics2022** that will take place from June 15-17, 2022 as a hybrid event in Piacenza, Italy

BENEFITS & IMPACT: This study will possibly provide the first scientific data on cultivated pasture production and lamb growth on various pasture mixtures in agrivoltaics systems. The study will quantify the change of seasonal forage growth and nutritive value and how these values relate to the performance of lambs. As a result of this study, scientists and sheep producers will be able to utilize the information as the basis for designing successful grazing systems and feed budgeting through successful matching of animal requirements with seasonal pasture production profiles in agrivoltaic systems.

ADDITIONAL FUNDING RECEIVED DURING PROJECT TERM: No

FUTURE FUNDING POSSIBILITIES: The data will be used to develop USDA grants.