Production and Persistence of Self-Regenerating Annual Clovers in the Pacific Northwest

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Abstract. Self-regenerating annual legumes are commonly included in dryland pastures to increase the production of high-quality forages to meet the nutritional demands of growing and lactating animals. Balansa clover (*Trifolium michelianum* Savi), not as widely evaluated as subterranean clover (*Trifolium subterraneum* L.), has shown promise in Western Oregon. However, there is a paucity of information on the productivity and persistence of annual clover cultivars that have various flowering times. This study investigates the biomass production and persistence of early, mid and late flowering subterranean clover and balansa clover cultivars in Corvallis, Oregon. Averaged across the cultivars, the total annual dry matter yield (DMY) of subterranean clover was greater than balansa clover by 15% (3085 vs. 3612 kg DM ha^{-1}) in the 2021/2022 growing season. Mintaro was the highest yielding subterranean clover cultivar with over 4465 kg DM ha^{-1} annual DMY. The biomass production of Campeda, Antas and Denmark was comparable to Mintaro. In contrast, the early flowering cultivar, Dalkeith was the lowest producing subterranean clover cultivar with less than 1500 kg DM ha^{-1}. Herbage yield of balansa clover cultivars Border, Taipan and Viper ranged from 3446 to 3866 kg DM ha^{-1} and was comparable to the highest yielding subterranean cultivars. However, DMY of balansa clover cultivars Paradana, Fixation and VNS was lower than the other three highest-producing balansa cultivars. In the following fall, mean seedling number of subterranean clover (991 seedling per m^2) was substantially greater than balansa clover (78 seedling per m^2). Our preliminary findings indicated that mid to late maturing subterranean and balansa clover cultivars are well-suited to the agroecological conditions of the Pacific Northwest but regeneration of balansa clover cultivars was poor possibly due to hardseededness.

Introduction

Herbage and animal production from dryland pastures can be improved substantially through overseeding self-regenerating annual legumes (Ates *et al*., 2010). These legumes avoid dry conditions by dying in early summer after seed set and have an advantage of growing earlier in spring due to their lower temperature requirement than perennial legumes (Moot *et al*., 2010; Anderson *et al*., 2021). While subterranean clover is the most commonly grown annul pasture legume, balansa clover can be an excellent alternative to subterranean clover in heavy clay soils of Western Oregon due to its higher tolerance of poor drainage. Potential of balansa clover to support high animal production was highlighted in a sheep grazing study in Oregon where lambs that grazed tall fescue (*Schedonorus arundinaceus* (Schreb.) Dumort.)-balansa clover pastures grew faster than those that grazed tall fescue pastures containing either sub clover, white clover or birdsfoot trefoil (Gultekin *et al*., 2020). The greater liveweight gain obtained from balansa clover was mainly due to higher clover content of tall fescue-balansa clover pastures (over 35% vs. <20%) in the late spring. However, a disadvantage of balansa clover is its poor self-regeneration even at high seed production due to a high level of hardseedness (Monk *et al*., 2016).

Self-regenerating annual clovers need to produce an adequate quantity of seeds to persist in a permanent pasture. The production and persistence of annual clovers are mainly dependent on rainfall, grazing management, and flowering time (maturity) of the cultivars (Ates *et al*., 2015). Early flowering cultivars exploit winter rainfall and ensure high quality forage and seed production early in spring (Smetham, 2003). Later flowering annual clover cultivars always produce greater herbage biomass, if soil moisture is present. Current subterranean clover seeds available on the market are predominantly earliest flowering cultivars due to lower seed cost. However, the amount and seasonal distribution of rainfall in Western Oregon would permit successfully growing of mid-late flowering subterranean clover cultivars and therefore producing a greater amount of high-quality forage. Therefore, it is critical to investigate the herbage production and persistence of subterranean and balansa clover cultivars for optimized production in the Pacific Northwest. Thus, in this study, we quantified the total annual herbage production and seedling numbers of balansa and subterranean clover as an indication of persistence in Oregon in 2021-2022. It is of note that this study is still ongoing to investigate the long-term persistence, herbage production, and nutritive quality of annual clover cultivars.

Methods and Study Site

Establishment: This study was conducted at the USDA Natural Resources Conservation Service Plant Materials Center in Corvallis, Oregon, USA (44° 37' N; 123° 12' W; elevation 68 m). Soils are largely Willamette silt loam, with a small area of Amity silt loam, both with slopes of less than 3 percent. Both are formed from glaciolacustrine deposits and are prime farmland soils. Plots were seeded on October 7, 2021 into a firm seedbed with a precision cone-seeder drill. Seeds were sown at rates of 6 kg ha^{-1} pure live seed for balansa clover cultivars and 20 kg ha^{-1} pure live seed for subterranean clover cultivars. Prior to seeding, seeds were inoculated with *Rhizobium*. Rows were 15 cm apart, and individual plots consisted of 7 rows, 3 m long. Plots were arranged in a randomized complete block design with three replicates.

Daily air temperatures during summer were often greater than the long-term mean (LTM, Table 1). Rainfall from March through June was 67% greater than the LTM. It was of note that the onset of sufficient fall rains in 2022 was delayed until late October. Consequently, the rainfall from August through October was 94 mm less than the LTM (128 mm).

Table 1. Monthly rainfall and mean daily air temperatures over two growing seasons.

Months	Air temperature (ºC)			Rainfall (mm)		
	2021	2022	LTM*	2021	2022	LTM*
January		4.4	4.7		119	160
February		5.0	6.2		39	133
March		8.6	8.2		111	111
April		8.0	10.1		146	79
May		12.0	13.1		113	60
June		16.7	16.1		60	36
July		20.7	19.3		4	14
August		21.5	19.4		0	13
September	17.4	18.6	16.8	72	8	34
October	11.3	14	11.9	70	26	81
November	9.3	5.4	6.7	127	171	174
December	4.8		4.5	269		194

*LTM: Long-term means of air temperature and rainfall are for the period 1997-2018. The reported values are from Hyslop farm in Corvallis, near the study site.

Management and sampling: Plots were harvested up to several times throughout the year at an interval indicated by plant growth stage. Plots were harvested at an average growth stage of 10% bloom. Prior to harvest, the following variables were recorded: days after planting, growth stage, and percent stand composition of the target plant. Harvest was performed using an 18 horsepower, 30-inch-wide walk behind flail mower with a hopper to collect the cut material. The entire 3m length of the five inner rows of each plot were harvested at 5cm height, leaving an outer row on either side of the plot unharvested. Total fresh weight of the harvested material was recorded. Fresh weight of a subsample was also recorded. Subsamples were dried at 50˚C until the weight remained stable, generally 24-36 hours, and dry weight was recorded. Unharvested outer rows of each plot were cut to the ground with a string trimmer after plots were harvested and the entire plot was allowed to regrow until another harvest was performed. In year two, seedling establishment from self-sowing was assessed on November 18, 2022 by randomly placing three 100 cm^2 plots within a plot of a single cultivar, counting the number of seedlings of the target plant, and calculating the mean.

Results and Discussion

Total annual herbage production of subterranean clover was greater than balansa clover by 527 kg DM ha^{-1}. This was despite early maturing Dalkeith producing substantially lower DMP than other tested cultivars of subterranean and balansa clover. Mintaro, was the highest yielding subterranean clover cultivar with over 4,465 kg DM ha^{-1} annual DMY. The biomass production of Campeda, Antas and Denmark was comparable to Mintaro. In contrast, the early flowering cultivar, Dalkeith was the lowest producing subterranean clover cultivar with less than 1500 kg DM ha^{-1}. This was not surprising since Dalkeith is the earliest maturing cultivar in this study. Its poor performance as compared to other subterranean clover cultivars indicate its unsuitability for the high rainfall conditions of Western Oregon despite the lower cost of its seed. DMY of balansa clover cultivars, Border, Taipan and Viper ranged from 3446 to 3866 kg DM ha^{-1} and was comparable to the highest yielding subterranean cultivars. However, DMY of balansa clover cultivars Paradana, Fixation and VSN was lower than the other three, highest-producing balansa cultivars.

Table 2. Total annual herbage production and seedling recruitment of balansa and subterranean clover cultivars in 2021/2022 growing season in Corvallis, Oregon.

Clover	Cultivar	Maturity	Origin	DMP kg ha^{-1}	Seedling numbers m^2
Balansa clover	Border	Mid	Australia	3182bc	22d
	Fixation	Mid	Oregon, USA	2969c	322cd
	Paradana	Mid	Australia	2932c	0d
	Taipan	Mid	Australia	3336bc	67d
	Viper	Early	Australia	3603abc	11d
	VNS	Early	Oregon, USA	2489cd	44d
Subterranean clover	Antas	Mid-late	Australia	4199ab	122d
	Campeda	Mid	Australia	4161ab	1689a
	Dalkeith	Early	Australia	1700d	1733a
	Denmark	Late	Australia	3617abc	833bc
	Mintaro	Mid	Australia	4729a	333cd
	Woogenellup	Mid	Australia	3264bc	1233ab
SEM clover				168.3	100.5
P value				0.05	0.01
SEM cultivar				402.8	204.3
P value				0.01	0.01

Different letters in the DMP and seedling columns indicate significant differences.

Averaged across the cultivars, seedling numbers of subterranean clover in the following fall was substantially greater ($P<0.01$) than balansa clover. Among subterranean clover cultivars only Antas and Mintaro had seedling numbers that are low enough to be considered agronomically unsuccessful for the reestablishment of annual clovers, despite their high herbage production exceeding 4 t DM/ha. Smetham

(2003) indicated that germination of a range of 500-1000 seedlings per m^2 is required for the desirable forage production from annual clovers. It is of note that none of the balansa clover cultivars reached that number of seedlings. This was with high rainfall spring conditions and under optimized management for herbage and seed production. However, the poor establishment of balansa clover may also be related to the late onset of fall rainfalls.

Conclusions

Our preliminary findings indicated that mid to late maturing subterranean clover is better suited to the agroecological conditions of the Pacific Northwest with substantial high-quality forage biomass production potential in dryland pastures. However, the effect of the maturity time was less profound on balansa clover even in an unusually wet spring. Overall, Australian balansa clover cultivars provided similar or greater DMP than Oregon cultivars. The study will continue in multiple years to make more robust conclusions on the productivity and persistence of these self-regenerating annual legumes.

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