BIOMASS CARBON AND NITROGEN INPUT FROM COVER CROPS IN AN IRRIGATED VINEYARD IN OKANAGAN VALLEY, CANADA

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Abstract:

Context and purpose of the study

The use of cover crops in vineyards has been encouraged by positive effects on wine grape yield and sensory attributes, and improved soil function. This study examined the efficacy of three alleyway and three undervine cover crop treatments in an organic vineyard in the semiarid Okanagan Valley, Canada in 2021.

Material and methods

Superior cover crop species were selected based on previous greenhouse and field species screening experiments. Three alleyway and three undervine cover crop mixtures were established in 2021. The vineyard was equipped with drip lines for irrigating vine rows, and undercanopy sprinklers for irrigating alleys. The dry biomass of cover crops and weeds, and carbon and nitrogen accumulation of the cover crop treatments were measured in the 2021 season and are reported here.

Results

Alley cover crops produced different dry biomass and biomass carbon content in order of *ryegrass+tillage radish+white clover* (1656 kg/ha and 650 kg C/ha) > *fescue+white clover* (952 kg/ha and 393 kg C/ha) > *winter rye+hairy vetch* (431 kg/ha and 184 kg C/ha). The proportion of cover crops dry biomass to total groundcover biomass in alleys followed a similar order. The tissue nitrogen content of the cover crops in alleys was the greatest in *ryegrass+tillage radish+white clover* (45 kg N/ha) and the lowest in *winter rye+hairy vetch* (15 kg N/ha). Total alley dry biomass nitrogen content (cover crops + weeds) was between 50 to 65 kg/ha in cover crops plots, which was significantly greater compared to control (weeds only) plots with nitrogen content of 34 kg/ha. Undervine cover crops produced different dry biomass and biomass carbon content in order of *Ladino white clover* (2029 kg/ha and 839 kg C/ha) ≥ *lentil* (1409 kg/ha and 603 kg C/ha) > *annual ryegrass+birdsfoot trefoil* (155 kg/ha and 64 kg C/ha). The tissue nitrogen content in undervine cover crops was the greatest in *Ladino white clover* (67 kg N/ha) followed by lentil (36 kg/ha) and annual ryegrass+birdsfoot trefoil (2.6 kg N/ha). *Ladino white clover* was more effective in suppressing the weeds (55% total biomass) followed by *winter lentil* (30% total biomass) and *annual ryegrass+birdsfoot trefoil* (4% total biomass) under the vines. We concluded that *white clover*, *tillage radish*, and *perennial ryegrass* mixture in alleys and *Ladino white clover* under vines were best suited to irrigated vineyards in this region.

Keywords: Alley, Cover crops, Ground vegetation management, Undervine

1. Introduction

Cover crops in vineyards supress weeds and contribute to essential services such as water infiltration (Celette and Gary 2013; Ruiz-Colmenero et al. 2013; Medrano et al. 2015), carbon sequestration (Curtis 2013; Kaye and Quemada 2017), soil biological activities and biodiversity (Peregrina et al. 2012), nutrient supply and retention (Novara et al. 2013), biological control (Sáenz-Romo et al. 2019), and reduction of soil erosion (Marques et al. 2010; Tompkins 2010). Furthermore, undervine cover crops also provide an opportunity for reducing the herbicide use in vineyards.

The successful adoption of cover crops in vineyards for each region is highly dependent on selection of appropriate cover crop species and understanding of interspecies interactions. In selecting vineyard cover crops, factors such as vineyard management, local environmental conditions, and the grower's goals, such as reduction of pests and production costs and ease of mechanization need to be taken into account (Olmstead et al. 2001). There is need for comprehensive studies on alley and undervine cover crops species suitable for vineyards in each grape growing region of Canada and for strategies to maximize the ecological benefits. This study examined the efficacy of three alley and three undervine cover crop treatments for enhancing organic carbon and nitrogen inputs to a sandy soil with low organic matter in an irrigated vineyard in the semiarid Okanagan Valley, Canada.

2. Material and methods

Candidate cover crop species for this study were selected based on previous greenhouse and field screening experiments. Three alley and three undervine cover crop mixtures were established in 2021. The vineyard was equipped with drip lines for irrigating vine rows and undercanopy sprinklers for irrigating alleys. The dry biomass of cover crops and weeds, and carbon and nitrogen accumulation of the cover crop treatments were measured in 2021 season and are reported here.

2.1. Experimental setting

The experimental site was a 15 year old organic Merlot block located in the south Okanagan Valley (lat. 49°14'33''N and long. 119°32'22''W) at the Covert Farms Family Estate, Oliver, BC., Canada. The area is characterized by cool winters (mean December to February temperature: -0.5 °C), warm summers (mean June to August temperature: 20.0 °C), and low annual precipitation (346 mm y^{-1}; Environment and Climate Change Canada 2020). The rows were arranged in south – north direction in a loamy sand soil.

Plots were comprised of five vines including a guard vine on either end and three experimental vines. Vines were planted 1.2 m apart in-row and 2.7 m spacing between the rows. General maintenance was performed according to Best Practices Guide by British Columbia Wine Grape Council (BCWGC. 2010). A dual irrigation system was used: drip irrigation in vine rows and understory sprinklers for alleys. Candidate cover crop species for this study were selected based on previous greenhouse and field screening experiments. Alley cover crop treatments included: (1) perennial ryegrass (*Lolium perenne* L.) +tillage radish (*Raphanus sativus*) +Dutch white clover (*Trifolium repens* f. hollandicum) [RgTrWc], (2) fescue (*Festuca arundinacea*) +Dutch white clover [FWc] and (3) winter rye (*Secale cereale* L.) +hairy vetch (*Vicia villosa*) [RHv]. Fescue was a mixture of tall, sheep and creeping fescue. Undervine cover crop treatments consisted of (1) crescendo ladino white clover [LWc], (2) Morton winter lentil (*Lens culinaris*) [WL] and (3) annual ryegrass (*Lolium multiflorum* L.) +birdsfoot trefoil (*Lotus corniculatus* L.) [ArBt]. A control treatment was also established through allowing weeds to grow after cultivation and mow them at the same time as cover crops. Cover crop seeds were sown using a drill seeder in alleys and by hand under the vines in late May 2021. Cover crops were mowed up to twice per each growing season when reaching 30 cm height or 30% flowering. The first year results of a two-year study are presented here.

2.2. Cover crop biomass, carbon and nitrogen content

Cover crop samples were collected before each mowing using a 0.25 m^2 quadrat per alley section of each plot (two quadrates per plot) and 0.25 m^2 quadrat per undervine section of each plot. Cover crops were mowed, as part of the typical management practice in this vineyard, in July and October 2021. Results are the sum of two cover crops harvests. The mowed clippings were not removed from plots, except for clippings in the quadrats. The aboveground biomass in each quadrat was cut at 2.5 cm above the soil surface. The biomass samples were separated into cover crop species and weeds, and samples were immediately dried at 60°C until they reached a constant weight. Oven-dried samples were weighed, ground with a Thomas-Wiley mill (Thomas Scientific) followed by ball milling. Tissue C and N concentrations were measured using a LECO 628 (LECO Corporation, St. Joseph, MI). Cover crop C and N content were calculated by multiplying dry biomass, and tissue C and N concentrations. The values reported for alley and undervine dry biomass, carbon and nitrogen are on a per-ha basis and need to be multiplied by 2/3 and 1/3 to convert to ha-row and ha-undervine basis, respectively.

2.3. Statistical analysis

Data were analyzed with JMP software (SAS Institute, Inc. V. 17.0.0). The normality of data distribution was tested with Shapiro-Wilk test. When normality could not be assumed, data were log transformed. Data were analyzed using a two-way analysis of variance (ANOVA) by considering row and alley cover crop treatments as fixed factors, and replications as a random factors. When a treatment's effect on a parameter was significant, differences between treatment means were evaluated using the Tukey's HDS test at a significant level of $P < 0.05$. Only significant differences at $P < 0.05$ reported as decreased or increased in the Results section.

<u>3. Results and discussion</u>

Alley cover crops produced different dry biomass in order of RgTrWc (1656 kg/ha) > FWc (952 kg/ha) > RHv (431 kg/ha). Dutch white clover comprised 49 and 99% of the dry biomass in RgTrWc and FWc treatments, respectively. The proportion of cover crops in total groundcover dry biomass (cover crops+weeds) in alleys was 68% in RgTrWc, 34% in FWc, and 18% in RHv. Biomass carbon content of alley cover crops followed a similar pattern to dry biomass (Fig. 1). The tissue nitrogen content in alleys was the greatest in RgTrWc (45 kg N/ha) and the lowest in RHv (15 kg N/ha) (Fig. 1). The alley groundcover dry biomass (average 2600 kg/ha) and carbon content (average 1039 kg/ha) were not different among treatments including control. Alley groundcover nitrogen content (cover crops + weeds) was on average 63 kg/ha for RgTrWc and FWc cover crops which was greater than the control (weeds only) treatment with nitrogen content of 34 kg/ha.

All three alley cover crop mixtures established well and supressed weeds in this site. The RHv treatment was very effective in suppressing weeds while it did not produce a large biomass. For the perennial species, including white clover, ryegrass, fescue, and birdsfoot trefoil, the first year is the establishment year during which plants invest in root growth and expansion (Iwasa and Cohen, 1989); therefore, lower biomass relative to reported averages was expected for these species. Grasses in the mixtures grew slowly and produced the least amount of biomass, while tillage radish and white clover produced the greatest biomass in the mixtures that contained these species. The lack of significant differences in total groundcover dry biomass among treatments suggest the possibility that an ecological threshold for groundcover biomass and carbon production had been reached under the environmental conditions in the vineyard. However, use of legume-based cover crops in alleys almost doubled the input of nitrogen to the soil, which has implications for reducing N fertilizer rates and, consequently, greenhouse gas emission mitigation.

Undervine cover crops produced different dry biomass in order of LWc (2029 kg/ha) ≥ WL (1409 kg/ha) > ArBt (155 kg/ha and 64 kg C/ha). Biomass carbon content of undervine cover crops followed a similar pattern to dry biomass (Fig. 1). The percentage of cover crop biomass to total undervine groundcover biomass was 55% in LWc, 30% in WL, and 4% in ArBt. The tissue nitrogen content in undervine cover crops was the greatest in LWc (67 kg N/ha) followed by WL (36 kg/ha) and ArBt (2.6 kg N/ha) (Fig. 2). The total undervine dry biomass (cover crops+weeds; average 4100 kg/ha), carbon content (average 1700 kg/ha), and nitrogen content (average 98 kg/ha) were not different among treatments including the weed-only control.

Utilization of undervine cover crops is a newer concept relative to alley cover crops, with the main goals of undervine cover crops being weed suppression and nitrogen contribution. The LWc and WL established well under the vines and effectively suppressed weeds, while ArBt established poorly. LWc was more productive and efficient (~2 times) in accumulating nitrogen than WL. The lack of significant differences in total groundcover biomass, and carbon and nitrogen content in the undervine location reflects the less favourable growing conditions under vines compared to in alleyways.

4. Conclusions

We concluded that a mixture of *white clover*, *tillage radish*, and *perennial ryegrass* in alleys, and *Ladino white clover* and *winter lentil* under vines were superior species among the evaluated treatments for this region. No signs of competition between cover crops and vines were observed in this study.

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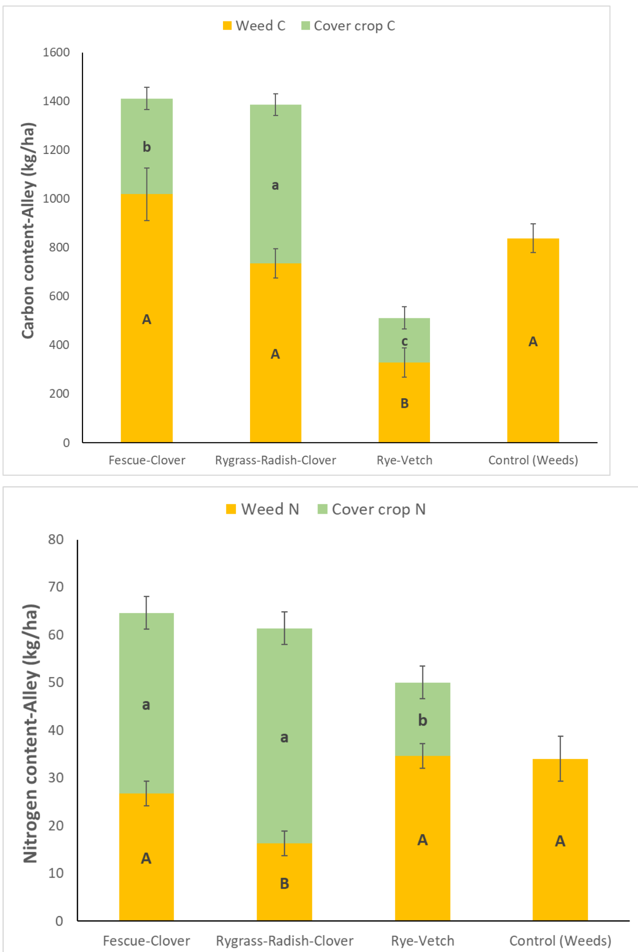

Figure 1: Nitrogen and carbon content in alley cover crops and weeds for each treatment. Error bars shows the standard error mean. Bars with the same letter were not significantly different (*P* < 0.05)

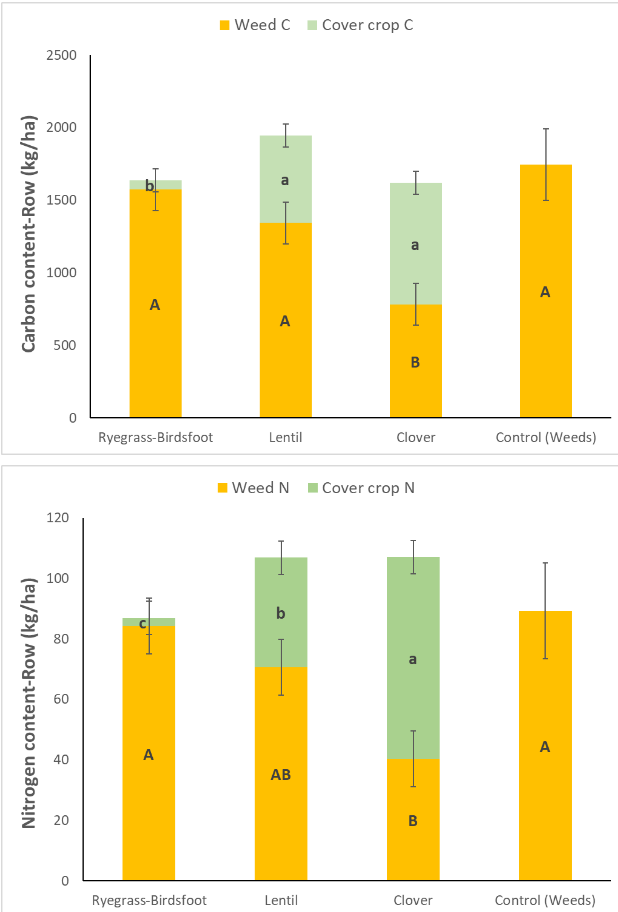

Figure 2: Nitrogen and carbon content in undervine cover crops and weeds for each treatment. Error bars shows the standard error mean. Bars with the same letter were not significantly different (*P* < 0.05)