EXTENDED ABSTRACT

Soil mineral nitrogen dynamics in cover-cropped irrigated vineyards with contrasting soil textures

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ABSTRACT

Cover cropping in vineyards supports grape yield, quality, and soil health. This study evaluated the effects of alleyway and undervine cover crops on soil mineral nitrogen (N) at 0–30 cm depth over three years in two organic vineyards with distinct soil textures in the Okanagan Valley, British Columbia, Canada. Sites included loamy sand soil in Oliver (site 1) and sandy loam soil in West Kelowna (site 2). In 2021, three selected cover crop mixtures were established in alley and undervine areas, with annual species reseeded in 2022. Undervine treatments comprised Ladino white clover, winter lentil, and annual ryegrass + birdsfoot trefoil, whereas alley treatments consisted of perennial ryegrass + Daikon radish + white clover, fescue mixture + white clover, and fall rye + hairy vetch. Soil samples (0–15 cm and 15–30 cm) were analyzed for KCl-extractable nitrate (NO_3^--N) and ammonium (NH_4^+-N). Fall soil mineral N concentrations were low, typical for organic vineyards, with higher levels in finer-textured soils. NH_4^+-N ranged from 0.08–8.96 mg kg^{-1} (site 1) and 0.30–13.1 mg kg^{-1} (site 2), while NO_3^--N ranged from 1.73–9.82 mg kg^{-1} and 2.30–19.04 mg kg^{-1}, respectively. Cover crops significantly influenced mineral N at site 1 (coarse texture), particularly undervine, with marked annual variability. Undervine NO_3^--N exceeded NH_4^+-N concentrations consistently. Although single treatments alone were not significant, interactions between undervine and alley treatments significantly affected NH_4^+-N, particularly undervine. A significant year × undervine × alley treatment interaction occurred for all mineral N components undervine and NH_4^+-N at the alley 15–30 cm depth. The undervine winter lentil combined with perennial ryegrass + Daikon radish + Dutch white clover in alley plots yielded higher NH_4^+-N in 2021–2022, likely due to early maturity and mid-season drying of winter lentil. Ladino white clover undervine consistently produced the highest NO_3^--N, highlighting its superior N contribution. At site 2, cover crop effects were minimal, except alley NO_3^--N at 15–30 cm, where perennial ryegrass + Daikon radish + Dutch white clover had the highest and fall rye + hairy vetch the lowest levels, indicating stronger N input from Dutch white clover.

INTRODUCTION

The documented positive effects of vineyard cover cropping on grape yield, wine quality, and soil function have encouraged its use in many winegrowing regions (Messiga et al. 2015). As reviewed by Garcia et al. (2018), inter-row cover crops provide numerous agroecosystem benefits, including improved nutrient supply, enhanced soil carbon sequestration, improved soil water infiltration and moisture conservation, increased biological pest control (Sáenz-Romo et al. 2019), weed suppression through resource competition and physical barriers, stimulation of soil microbial activity and diversity, and reductions in soil erosion and nitrate leaching. Cover crops also influence vineyard water and nitrogen (N) dynamics, often driving grapevine roots deeper into the soil and closer to the vine row (Celette and Gary 2013; Celette et al. 2008). By increasing biodiversity, cover cropping further supports ecosystem services such as pest and weed management, nutrient cycling via soil microbial activity, and erosion control (Vukicevich et al. 2016; Winter et al. 2018). Recent studies in the Okanagan region indicate that even relatively short-term changes in groundcover management can alter soil microbial N cycling processes and overall biological activity (Sharifi et al. 2021; Sharifi et al. 2025). However, despite these well-documented benefits, growers may be hesitant to adopt cover crops because certain species can compete with grapevines for water and N (Celette and Gary 2013). A better understanding of soil mineral N status at the end of the growing season under different cover crop treatments would provide valuable information for assessing and optimizing N management in vineyards.

RESEARCH OBJECTIVES

We propose to enhance our understanding of how non-crop vegetation can be managed to augment ecosystem services in vineyard agro-ecosystem, with the broader goals of reducing inputs while maintaining, or enhancing wine grape quality. Specifically, this study examined cover crops' effects in alleyway and undervine locations on soil mineral nitrogen at 0-30 cm over three years in two organic irrigated vineyards with different soil textures in the Okanagan Valley, British Columbia (BC), Canada.

MATERIAL AND METHODS

Superior cover crop species were selected through prior screening. Two organic vineyards in Oliver (loamy sand soil; site 1) and West Kelowna (sandy loam soil; site 2), BC, received three cover crop mixtures in alleyways and undervine areas in 2021, with annual species reseeded in 2022. Undervine crops included Ladino white clover, winter lentil, and annual ryegrass + birdsfoot trefoil, while alley treatments included perennial ryegrass + Daikon radish + Dutch white clover, fescue mixture + Dutch white clover, and fall rye + hairy vetch. Soil samples (0-15 cm and 15-30 cm) were collected in October every year. The soil NH_4^+-N and NO_3^--N were extracted with 2 M KCl and analyzed colorimetrically using an Astoria-Pacific Segmented Flow Analyzer (Astoria-Pacific Inc., Clackamas, OR). Data processed using repeated measures method in JMP v.18.

RESULTS

Fall soil mineral N concentrations within the 0–30 cm depth were generally low in irrigated organic vineyards, although they were higher in finer-textured soils compared to coarser-textured soils. Over three years, fall NH_4^+-N values ranged from 0.08–8.96 mg kg^{-1} at site 1 (coarse soil) and 0.30–13.1 mg kg^{-1} at site 2 (fine soil). NO_3^--N concentrations ranged from 1.73–9.82 mg kg^{-1} at site 1 and 2.30–19.04 mg kg^{-1} at site 2. These values, while low for general agricultural systems, fall within typical ranges for organic vineyards.

Cover crop treatments had a more substantial effect on fall soil mineral N concentrations in coarser soil (site 1) compared to finer soil (site 2), with significant year-to-year variability. The influence of cover crops was more pronounced in the undervine location than in the alley at site 1 (Table 1). At this site, undervine NO_3^--N concentrations were consistently higher than NH_4^+-N at the 0–30 cm depth. Although individual treatments alone did not significantly affect mineral N levels, the interaction between undervine and alley cover crop treatments significantly influenced NH_4^+-N concentrations, particularly in the undervine location across both soil depths (Table 1). Additionally, a significant three-way interaction (year × undervine treatment × alley treatment) was observed for all soil mineral N components in the undervine location and only for NH_4^+-N in the alley at the 15–30 cm depth.

Fall NH_4^+-N concentrations were highest in 2020 at site 1 and lower, yet similar, in 2021 and 2022. In the 15–30 cm soil depth, the undervine winter lentil combined with perennial ryegrass + Daikon radish + Dutch white clover in alley plots resulted in higher NH_4^+-N concentrations compared to other treatments in fall 2021 and 2022, possibly due to the early maturity and mid-season senescence of winter lentil (since August). In this same depth interval, undervine treatments with Ladino white clover and annual ryegrass + birdsfoot trefoil had higher NO_3^--N levels compared to winter lentil, suggesting their superior nitrogen-supplying capacity (Figure 1). At 15–30 cm depth, undervine NH_4^+-N patterns were unclear; however, NO_3^--N concentrations were consistently highest with Ladino white clover, underscoring the importance of this perennial legume for N supply. At site 1, alley soil mineral N was unaffected by treatments or their interaction with the year. Alley NH_4^+-N concentrations were notably low, particularly at the 15–30 cm depth (<2 mg N/kg), indicating NO_3^--N as the dominant form of mineral N.

At site 2, cover crop treatments had no significant effects on NH_4^+-N and NO_3^--N concentrations in undervine and alley locations at both depths, except for alley NO_3^--N at 15–30 cm. Here, the perennial ryegrass + Daikon radish + Dutch white clover treatment produced the highest concentrations, while the fall rye + hairy vetch treatment yielded the lowest. This suggests that Dutch white clover, particularly in the second year, contributed more effectively to soil mineral N compared to hairy vetch.

CONCLUSION

Overall, fall soil mineral N concentrations within 0-30 cm depth were low in irrigated organic vineyards, but were higher in finer than coarser soil textures. Cover crop treatments had a more profound effect on fall soil mineral N in coarser than finer soil textures, which varied significantly from year to year. This effect was more pronounced in undervine than alley location. Our findings suggest that when cover cropping, more attention need to be made in soil mineral N in vineyards located on coarse than fine soil textures and perennial legumes such as Dutch white clover can make a significant contribution to soil N supply particularly in their second year of establishment.

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TABLES AND FIGURES

Table 1. ANOVA table showing the effects of cover crop treatments on fall soil mineral nitrogen (0–30 cm depth) in undervine and alley locations of two irrigated organic vineyards over a three-year period.

Source of Variation	df	NH_4^+ Alley 15	NO_3^- Alley 15	NH_4^+ Alley 30	NO_3^- Alley 30	NH_4^+ Undervine 15	NO_3^- Undervine 15	NH_4^+ Undervine 30	NO_3^- Undervine 30
					Site 1				
Undervine (UTRT)	2	NS	NS	NS	NS	NS	NS	NS	NS
Alley (ATRT)	2	NS	NS	NS	NS	NS	NS	NS	NS
UTRT x ATRT	4	NS	NS	NS	NS	*	NS	*	NS
Year x UTRT x ATRT	-	NS	NS	*	NS	*	*	*	*
					Site 2				
UTRT	2	NS	NS	NS	NS	NS	NS	NS	NS
ATRT	2	NS	NS	NS	NS	NS	NS	NS	NS
UTRT x ATRT	4	NS	NS	NS	NS	NS	NS	NS	NS
Year x UTRT x ATRT	-	NS	NS	NS	*	NS	NS	NS	NS

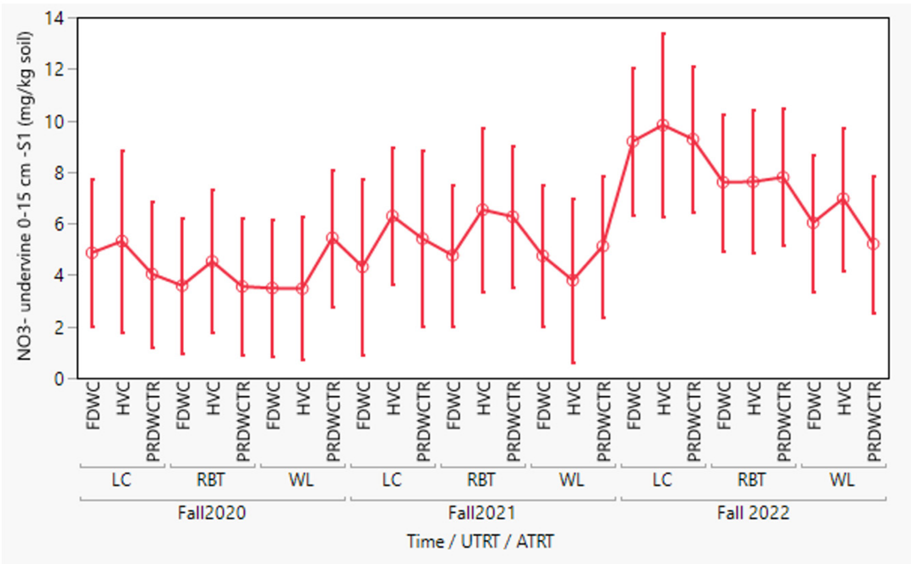

Figure 1. Mean fall undervine soil NO3-N concentrations at 0-15 cm in site 1 over a three-year period. LC, Ladino white clover; RBT, Annual ryegrass + Birdsfoot trefoil; WL, Winter lentil; FDWC, Fescue mixture + Dutch white clover; PRDWCTR, Perennial ryegrass + Daikon radish + Dutch white clover. Figure 1. Mean fall undervine soil NO3-N concentrations at 0-15 cm in site 1 over a three-year period. LC, Ladino white clover; RBT, Annual ryegrass + Birdsfoot trefoil; WL, Winter lentil; FDWC, Fescue mixture + Dutch white clover; PRDWCTR, Perennial ryegrass + Daikon radish + Dutch white clover.