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Linked crop production and soil organic matter impacts of winter annual legumes in upper Midwest organic agroecosystems

This work addresses two linked areas: 1) plant-soil interactions governing nutrient cycling in cover-cropping in annual cropping systems and 2) development of interdisciplinary agronomic perspectives to address complex eco-social issues in agroecosystems. Accordingly, research covers how specific agronomic systems interface with contested, shifting, and unequal political and social realities and what forms of knowledge generation and praxis support sustainable development, considering both ecological and social aspects of sustainability. Focus #2 integrates multiple disciplinary perspectives, in the spirit of transdisciplinary approaches in soil and weed science (*1, 2*), that contend with systems complexity, uncertainty, and multiple problem formulations. The historical perspectives on the nature of capitalist development are also employed to expand agronomic frames of reference from those solely of production to those of exchange, thus exposing a long history of exploitative human-nature relations(*3*). Lastly, agronomy's roots in applied economics, rural sociology, and biology, and the rise of agroecology as 'science, movement, and practice'(*4*), can inform emerging transdisciplinary agronomy scholarship. In better understanding how unequal power relations(*5*), processes of agrarian dispossession(*6*), and ecological crisis(*7*) are closely linked, agronomic science can better support just and sustainable systems of food production and exchange.

Applied research regarding area #1 is as follows: Cover crops (non-harvestable crops grown between cash crop production) are an agroecological approach that can increase ecosystem service provisioning, with benefits of erosion reduction, spatial and temporal biotic diversification, nutrient additions, and increased soil organic matter (SOM)(*8*). SOM influences soil structure, water retention, and nitrogen (N) availability through microbial mineralization(*9*). Leguminous cover crops increase soil N by converting atmospheric N into plant soluble forms, and may also increase organic carbon (C)(*10*). However, implementation of cover crops in the upper Midwest is limited by short growing seasons and harsh winters with variable temperatures and snowfall.

Our experimental objectives were three-fold: 1) assess viability of fall-planted, winter annual legume cover crops in the upper Midwest, 2) quantify cover crop contribution to labile soil C pools, and 3) improve understanding of C decomposition and N mineralization in organic production. The experiment compared two hairy vetch genotypes (V1 and V2), winter rye (RYE), red clover (CLO), vetch/rye biculture (V2 MIX), and bare-ground control (noCC), planted in a randomized 4-block design at two UMN research stations in southwest (SWROC) and north-central (NCROC) Minnesota. Cover crops were established in fall and terminated in spring prior to sweet corn planting. Aboveground biomass and soils were sampled at termination. Soils were sampled again two weeks after termination. To measure linked soil C and N dynamics, we determined microbial biomass C(*11*), permanganate-oxidizable C (POX-C)(*12*), size-fractionated particulate organic matter (POM-C), total C, and extractable soil N via 7-day anaerobic potentially mineralizable N (PMN) assays(*13*).

We hypothesized 1) V1, V2, and CLO would increase labile soil C and N levels compared to noCC and RYE treatments, 2) legume cover crop biomass N would provide significant N for crop production, 3) increased labile soil C would be correlated with organic N mineralization, and 4) succeeding crop yield drag due to cover cropping would be reduced with legumes. Preliminary results indicate integration of winter annual legume cover crops may be a viable tool in upper Midwest organic crop production. V1 and V2 biomass ranged from 1300 – 2000 kg dry matter ha^{-1}, resulting in 60-90 kg N ha^{-1}. KCl extractable N increased after cover crop termination at both sites, approaching 100 mg N kg $soil^{-1}$ in vetch at NCROC. At NCROC, post-termination PMN in all cover-crop treatments was > 200 mg N kg $soil^{-1}$, increasing from ~ 50 mg N kg soil $^{-1}$ pre-termination. Yet, soil N results displayed major site differences, with PMN declining in SWROC pre-termination to post-termination. Soil C results were variable, indicating time effects yet no treatment differences for POX-C or microbial biomass C. However, microbial biomass C was correlated with PMN (Pearson's correlation = 0.24, $p = 0.002$), indicating labile C may be an effective indicator of N dynamics. Corn yield in V1 and V2 was about 14 mg ha^{-1}, compared to state conventional average (16 mg ha^{-1}) and out-yielding RYE (~ 8 mg ha^{-1}). Our project suggests winter annual legume cover crops may achieve multiple ecosystem services including winter soil protection, SOM development, and coupled C and N cycling.

The type of biophysical experiment detailed above can form components of new agronomic research and pedagogy specifically oriented towards emerging beginning and immigrant farm movements in the upper Midwest. These networks challenge traditional agronomic knowledge production and information transfer but also provide significant opportunity to reorient and innovate research. Agronomy could play a key role in the design and development of alternative agroecosystems at a time of increasing ecological stressors, rural demographic crisis, and limited research funding. New farmer networks have developed largely outside of university support, are often precarious and marginal, and have additional production concerns outside of the realm of commodity systems. Thus, research engaging these new sites of agronomic research requires integrated 'soft' and 'hard' skills(*14*), must navigate explicitly political components(*15*), and must adapt to and support community-driven experimentation and knowledge transfer networks(*16*).

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