Environment and Natural Resources Trust Fund
Peer Review Research Addendum template

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Project Title: Harnessing Cover Crops and Roots for Sustainable Cropping
Project number: 2024-247

1. Abstract

Current Minnesota's cropping practices have led to biodiversity loss and environmental degradation. This project addresses the pressing need for sustainable production of major crops in the state, including corn (*Zea mays* L.), soybean [*Glycine max* (L.) Merr.], and spring wheat. It highlights the use of cover cropping as a long-term practice aiming to enhance both sustainability and profitability while simultaneously mitigating environmental degradation. The goal of the project is to fill knowledge gaps on cover crop agronomics in the region. Specifics objectives are to determine the cover crops potential for carbon (C) sequestration, nitrogen (N) credit, and water use. Using a combination of existing and new research results and modeling, the project will further assess cover cropping in corn-soybean and corn-soybean-wheat rotation practices across multiple locations in southern Minnesota. Expected outcomes include estimates of the potential of cover crops to sequester C, credit N to cash crops, and use water. By advancing the adoption of cover crops in major cropping systems, this project is poised to deliver significant agroecological benefits to create sustainable practices that promote crop diversity, improve soil health, and benefit the environment, all while maintaining high crop yields.

Keywords: cover crops, root system, carbon sequestration, N credit, water use, soil moisture, sustainable cropping

2. Background

Agricultural systems aim to maintain or even increase output while increasing resource use efficiency (Milestad, Darnhofer, & Taylor, 2008; Urruty, Tailliez-Lefebvre, & Huyghe, 2016), a concept generally referred to as sustainable intensification (Godfray et al., 2010). This has been possible thanks to specialization, efficiency, and timely logistics, mostly controlled by a few factors (Rice et al., 2020). Corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] production in the intensively cultivated U.S. Midwest region (Hatfield, 2012), is an example. Much so that the corn-soybean rotation is synonymous of the region's landscape (Bigelow & Borchers, 2017). More diverse rotations, such as corn-soybean-wheat, are more resilient to adverse growing conditions and effective to increasing productivity of crops (Bowles et al., 2020; Janovicek, Hooker, Weersink, Vyn, & Deen, 2021). Yet, current cropping practices have led to biodiversity loss and environmental degradation. The use of cover crops in these rotations may further enhance both sustainability and profitability while simultaneously mitigating environmental degradation.

The adoption of cover crops in Minnesota is low, mainly due to uncertainties on their growth (Fig. 1) and of benefits as a result of our short growing season (Rusch et al., 2020; Wilson, Baker, & Allan, 2013). Additionally, critical cover crop information in our continental climate, such as seeding and termination timing, seeding rates, roots' contribution to carbon (C) sequestration, nitrogen (N) credit, and water use, remains poorly understood. Our research proposal aims to determine how can the uncertainties on cover crop growth and their benefits be better understood in our conditions to promote adoption and address the loss of diversity and environmental degradation in crop production. Our approach, consisting on research and ancillary data coupled to crop models to synthesize current cover crop knowledge, will allow extending our findings beyond research sites. This strategy will further support research results and the development of applied, ready-to-use information to help cover crop decision-making in corn-soybean and corn-soybean-wheat rotation practices in southwestern MN.

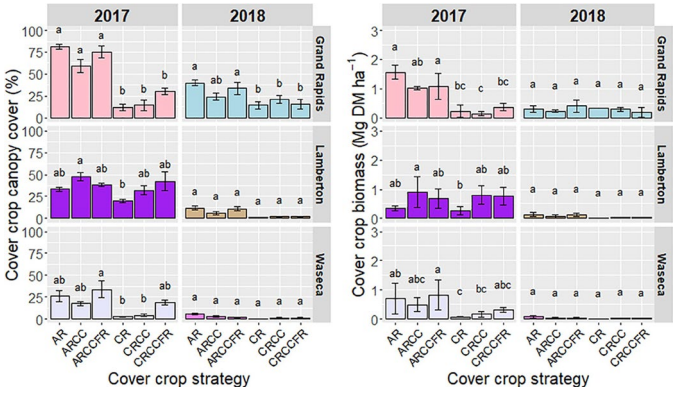

Fig. 1 – Fall performance of cover crops interseeded at V4 corn. For a given year within location, bars with different letters differ significantly at $P < 0.05$. Error bars are standard errors of the mean. AR = annual ryegrass, CC = crimson clover, FR = forage radish, CR = cereal rye (Rusch et al., 2020).

3. Hypotheses/objectives

The low adoption of cover crops in Minnesota rises farmer's concerns about time, labor investment, and a perceived lack of financial return (CTIC, SARE, & ASTA, 2017). These concerns stem from uncertainties about cover crop growth (production of dry biomass), a problem potentially magnified by the state's short growing season and cropping systems. Critical information, such as seeding and termination timing, seeding rates, roots' contribution to C sequestration, N credit, and water use in cropping systems with cover crops in our continental climate, remains poorly understood.

Despite decades of research, by 2021 cover crops were used in around 7% of cropland in the upper Midwest, with Minnesota ranking among the states with lower adoption rates (Zhou et al., 2022). Currently, there is a lack of vital information on cover crop root system contribution to C sequestration, N credit, and water use. This deficiency is affected by cropping practices and systems within the state, thus underscoring the need for additional research. **We hypothesize that the lack of essential information regarding the benefits of cover crops in our short growing season region contributes to their low adoption rate.** Through comprehensive

research, synthesis of existing information, and disseminating knowledge regarding the potential C sequestration, N credit, and water use of cover crops, we aim to promote the adoption of the practice in the state. Our general hypothesis will be tested via three specific objectives, including:

a. Determine the C sequestration and N credit potential of cover crops. **We hypothesize that the selection of cover crops and cropping systems will significantly influence their C sequestration and N credit potential**. We based our hypothesis on the fact that different cover crops have distinct characteristics, such as root growth, C assimilation efficiency, and N use, which can directly affect the C and N dynamics in the system.

Activity Milestones:

Description	Completion Date
Determine the C, N, and C:N ratio of cover crop residue	June 30, 2026
Determine C sequestration and N credit potential of cover crops and crop systems	June 30, 2027

b. Characterize the water use of cover crops. **We hypothesize that the selection of cover crops will significantly affect soil water balance and availability for major crops**. The basis for this hypothesis lies on the fact that different cover crops have varying water requirements and effects on soil available water.

Activity Milestones:

Description	Completion Date
Determine the total, fall, and spring water use of cover crops	June 30, 2026
Characterize the soil-water dynamics in crop rotations with cover crops	June 30, 2027

c. Evaluate the performance of CR cover crop at multiple locations in southwest Minnesota. **We hypothesize that combining research results and modeling will lead to the development of high-efficiency cropping systems with regards to C and N contributions and water use**. We expect that integrating research data with modeling will allow for a more accurate simulation of cover crop performance in southern MN.

Activity Milestones:

Description	Completion Date
Model cover crop C and N contribution and water use	June 30, 2027
Model the effect of long-term cover cropping in corn-soybean and corn-soybean-wheat rotations	June 30, 2027

4. Methodology

Study location and design

Fig. 2 - The University of Minnesota Long-Term Agricultural Research Network (LTARN). A platform for research and education that emphasizes agricultural production through a unified network approach. The LTARN is an outcome-based research, outreach, and education entity.

Field trials will be conducted at the University of Minnesota (UMN) Research and Outreach Centers (ROCs) located in the North Central (NCROC), Southwest (SWROC), and Southern (SROC) regions of the state (Fig. 2). At each ROC, experiments will be set within the UMN Long-term Agricultural Research Network (LTARN; www.ltarn.cfans.umn.edu/) and at adjacent fields. The LTARN sites are strategically located in regions to represent the most important crops in Minnesota. The three sites cover a broad spectrum of cropping system practices. Additionally, they encompass a range of soil type, precipitation, and temperature gradients that help to provide comprehensive research data relevant to a wide array of environmental conditions. Trials within the LTARN will be used in objectives [a], [b], and [c] while trials adjacent to LTARN will be used in objective [c], specifically for model calibration. Different locations often exhibit varying gradients of precipitation and soil conditions, which in turn can have a significant effect on cover crop growth. Collecting cover crop data that reflect those variations, will allow for a more accurate model calibration and better simulation results, and more precise predictions.

Studies within the LTARN will consist of monocrop cover crops in the corn-soybean and corn-soybean-wheat rotations. In both rotations, all phases (main crop) are represented each year. Within each phase, experiments will be set as RCBD with three replicates at NCROC and four replicates at SWROC and SROC. Cover crops, including cereal rye (CR; *Secale cereale* L.), red clover (RC; *Trifolium pratense* L.), and winter camelina (WC; *Camelina sativa* L.), will be seeded following main crops harvest. In spring, cover crops will be terminated 10-d before and at main crop planting, the latter known as 'planting green.' Main crops will be planted at best planting date, usually around May 5 – 15.

Cereal rye, RC, and WC are known to have varying capabilities in C sequestration and N credit due to their diverse growth patterns. In addition, the choice of cropping system could have significant implications on soil health and nutrient cycling, further influencing such capabilities. For example, corn-soybean and corn-soybean-wheat rotations, the most prevalent in the region, may exhibit distinct differences in terms of organic matter input, nutrient availability, and residue decomposition rates. Moreover, different locations will likely provide varying levels of

weather and soil conditions, which can significantly impact cover crop growth, nutrient uptake, and residue decomposition rates, ultimately influencing their potential benefit. By conducting field trials at multiple locations representing various gradients of precipitation and soil conditions, the study can account for regional variation and provide more robust insights to generalize results across different locations. The C and N potential of cover crop residue will be determined as the product of the dry weight biomass by the percentage of C and N in that biomass. Not all carbon and N in the biomass will be sequestered or available in the soil. This can vary based on crop type, soil conditions, and decomposition rates so, several years of research are needed to determine C and N changes in the soil. Due to the short timing of the project, modeling will be used to estimate the proportion of biomass C and N that is likely to be sequestered or added into the soil. Ultimately, our hypothesis suggests that the combination of cover crops and cropping systems, along with the effects of diverse environmental factors from different locations, will have a significant effect on the potential for C sequestration, credit N, and use water.

Field results from this study and existing research results will be used to synthesize cover crop performance in southern MN. The platform of the Decision Support System for Agrotechnology Transfer (DSSAT; www.dssat.net), including the Crop Environment REsource Synthesis maize and wheat (CERES-Maize and -Wheat) and CROPGROW-soybean models (Jones et al., 2003), will be used. DSSAT encompasses several process-based crop models that predict growth, development, and yield as a function of local weather, soil conditions, crop management scenarios and genetic information. Input data to DSSAT include daily weather, soil properties, specific-crop information, and agronomic management (Hoogenboom et al., 2019). This project will integrate knowledge on above- and below-ground biomass of crops for high-efficiency cropping systems.

Studies adjacent to each LTARN node will consist of CR cover crop seeding rates as well as seeding and termination timing. Our choice for CR stems from the fact that it is the most important and suitable cover crop for conditions in the state (CTIC, SARE, & ASTA, 2023). These studies aim to collect vital data for model calibration. Trials will be established after a small grain harvest (early July) to cover the entire possible period (July to September) of cover crop seeding after the main crops harvest in Minnesota. Seeding rate trials will be set in a 2 x 6 factorial design with four replications. Factor A will be two CR genotypes (Aroostook hybrid – good spring recovery and early-season vigor, and VNS – variety not stated, most used by farmers) and factor B will be six seeding rates (0, 30, 60, 90, 120, and 150 kg/ha). Seeding and termination timing trials will be set in a 6 x 3 factorial design with three replications. Factor A will be six seeding dates (15-d intervals, starting July 21) and factor B will be three termination timing (10-d interval, starting April 25).

Data Collection

In all studies, a 1-time soil sampling will be conducted for characterization. In each field, samples will be obtained at 15, 30, 45, and 60 cm depths. Samples will be sent for analysis to an

MDA-certified lab for texture, total C and N, as well as soil water at saturation, field capacity, and permanent wilting point. This information is necessary for modeling.

Data collection in the LTARN will start with baseline measurements obtained before starting the experiments. Residue sampling of previous crop will be collected randomly across each field. Samples will be dried, ground, and analyzed for total C and N content. Soil samples at 15 cm and 30 cm depths will also be collected across each field and sent to the same lab used for the soil characterization samples for fertility analysis (pH, organic matter, Phosphorous, Potassium, CEC, Calcium, Magnesium, and % Base Saturation). After cover crop seeding, access tubes will be installed in each plot to monitor soil moisture at 10, 20, 30, 40, 60, and 100 cm depths. Soil volumetric water content will be collected weekly with a PR2/6 probe (Delta-T, UK); from establishment to frost in the fall and regrowth to termination in spring. A 0.50m x 0.50m quadrat will be used to collect above- and below-ground biomass and take photos for canopy cover at fall frost and spring termination, before planting the next main crop. Leaf area index (LAI; Accupar LP-80, www.metergroup.com) will be obtained at termination as well. Biomass samples will be dried, ground, and analyzed for total C and N content. Canopy cover will be obtained from the photos taken using the Canopeo App (Patrignani & Ochsner, 2015). At termination, soil samples will be collected at 15 cm and 30 cm depths in all plots. Then, residue will be chopped and plots will be split in two sub-plots; one sub-plot will have the residue slightly incorporated and the second sub-plot will be kept with residue not incorporated. The UMN guidelines (https://extension.umn.edu/crop-production) will be used to manage crops. Basic information, including biomass, stages of development, and maximum LAI, will be obtained. Near maturity, both above- and below-ground (roots) biomass will be obtained in each main crop plot. After harvest, soil samples will be collected at 15 cm and 30 cm depths in all plots. Subtracting the baseline values from the post-experiment values will give an estimate of the proportion of C sequestered by the cover crops to be returned into the soil. Plant and soil samples will be sent for analysis to a certified lab. Plant samples will be submitted for C and N analysis while soil samples for C, N, and fertility analysis. Data collection in trials near the LTARN nodes will consist on above- and below-ground biomass at frost and termination, stages of development, and LAI at termination. Biomass samples will be sent to the lab for total C and N content.

All ROCs and LTARN nodes are equipped with automated weather stations. We will collect daily weather data including precipitation, air temperature, and solar radiation. This information will be used to perform a field water balance and run crop models. The water balance will provide insights into the overall water use of cover crops during their growing season. In turn, such information will be used to determine the effects of cover crop water use on main crops. Overall, our hypothesis will reveal a relationship between cover crop, soil moisture levels, and the water availability for main crops, contributing to our understanding of the potential benefits or limitations of cover cropping practices in different crop systems.

Data analysis

Results will be subjected to ANOVA using R (R Core Team, 2023) and appropriate statistical packages. Main crops, cover crop biomass, canopy cover, LAI, and water use will be subjected to separate ANOVAs using a linear mixed-effects model to test for significance of main and interactions effects. Normality will be assessed using the Use Shapiro-Wilk normality test and visually with Q-Q plots. As needed, transformations will be performed to meet assumptions of normality and constant variance. Post-hoc comparisons will be performed at alpha = 0.05. Visual representation will be performed using the *ggplot2* package (Wickham, 2016).

Crop models calibration will be assessed with root mean square error – *RMSE* – (Kobayashi & Salam, 2000), normalized *RMSE* (Loague & Green, 1991), index of agreement *d* (Willmott, 1982), and the Pearson's correlation coefficient, *r*. Model performance will be assessed based on (Jamieson, Porter, & Wilson, 1991).

5. Timetable

Starting July 2024, this project has a duration of three years, to June 2027. The timetable below is divided in quarters, starting July 2024 (Year 1 / Q3) and ending June 2027 (Year 3 / Q2).

Activity	Year 1				Year 2				Year 3			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Planning	x		x		x		x		x			
Field preparation, baseline measurements	x				x				x			
Establish cover crops	x	x			x	x			x	x		
Establish main crops	x			x				x				
Data collection	x	x	x	x	x	x	x	x	x	x	x	x
Lab analysis of soil and plant samples		x	x			x	x			x	x	
Extension and outreach activities			x		x		x		x		x	
M.S. student			x	x	x	x	x	x	x	x	x	
Manuscript preparation									x	x	x	
Reporting		x		x		x		x		x		x

6. Outcomes

The project aims to synthesize current and new cover crop research results for conditions in southwest Minnesota through modeling to advance sustainability efforts in major cropping systems in the state. Key results will be used to prepare a) materials for extension and outreach activities highlighting C sequestration potential, N credit, and soil-water dynamics as related to benefits to Minnesota's natural resources, b) online content for the MN Crop News Blog (www.blog-crop-news.extension.umn.edu), fact sheets targeting the Midwest Cover Crop Council website (www.midwestcovercrops.org), a peer-reviewed article that may include a permanent link to data shared in a data repository. Key measurable outcomes from results include: a) quantification of potential C sequestration and storage increase in the soils, b) quantification of potential N credit and estimates of quantifiable provision of N to main crops as well as insights into a potential reduction of synthetic N fertilizer use, c) estimates of water used by cover crops and effects on productivity of main crops, and d) productivity metrics for cover crop and main crops at multiple locations. These outcomes will benefit society, especially rural communities, and future generations, by promoting sustainable crop production practices.

7. Budget

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Research Technicians		Support field data collection at three locations			33.5%	2 – 17% & 25%		$100,000
Summer helpers		Support research technicians with data collection			7.7%	2 – 3 mo summer		$36,000
Research Assistant		Oversee field trials and synthesize results			25.1%	1 – 100%		$115,000
Researcher		Oversee the completion of the project, summer salary			37.1%	1 – 3 mo summer		$75,000
							Sub Total	**$326,000**
Contracts and Services								
Minnesota Valley Testing Laboratories, Inc. (MVTL)	Professional or Technical Service Contract	Fees for lab analysis of plant and soil samples						$21,000
							Sub Total	**$21,000**

Equipment, Tools, and Supplies								
	Equipment	1 Pr2/6 probe and accessories	Probe to monitor soil moisture					$4,700
							Sub Total	**$4,700**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Trips from and to research sites located in Grand Rapids, Lamberton, and Waseca	Establish field experiments, data collection, and present results as required by LCCMR					$14,500
							Sub Total	**$14,500**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Printing	Bulletins summarizing findings	For extension and outreach purposes					$2,500
	Publication	A scientific paper	Cost of publication of scientific findings					$3,500
							Sub Total	**$6,000**
Other Expenses								
		Land use	Research plot fees					$2,800
							Sub Total	**$2,800**

							Grand Total	**$375,000**

Personnel

Support is requested for one graduate student (research assistant), who will dedicate 100% of their research time to the project, two research technicians, 2.5 summer helpers, and the researcher (PI). Fringe and benefits for the PI are set at 33.5% by the UMN. We will recruit a graduate student at M.S. level to start in spring of 2025. Research technicians will work with PI and graduate student on the establishment and management of the field trials as well as lab-related activities. The summer helpers will support the graduate student and technicians with field work and data collection at all three research sites. The PI will be responsible for project oversight, guidance of the graduate student, data interpretation and analysis, and report preparation and submission.

Contract and services

Over the course of the 3-year project, requested funds ($2334/year/site) will cover lab analyses. The average price of lab analysis/sample was estimated at $9.00. More than 2000 soil, cover crop, and main crop samples will be submitted to lab analysis. Soil samples will be submitted for texture, water-holding characteristics, fertility, and C, and N content analyses. Above- and below-ground biomass samples of cover crops and main crops will be analyzed for C and N. Plant and soil samples will be sent to an MDA-certified lab (e.g., MN Valley Testing Lab, Inc.; www.mvtl.com) or UMN lab (e.g., SWROC Soil and Plant Labs) for analysis. If the latter, chemical reagents, distilled water, and minor accessories will be purchased.

Equipment, tools, and supplies

The purchase of a PR2/6 (Delta-T; UK) soil moisture probe and accessories (access tubes, caps, hand-held reader, cables, etc.) and maintenance was budgeted at $4,700. The device will be used to monitor soil-water content over the course of the 3-year project.

Travel in Minnesota

Researchers, student, and technicians will travel between research sites and from ROCs to St. Paul over the course of the 3-year project. Funds requested average $4833/year. Mileage will be reimbursed at the current UMN reimbursement rate of $0.65/mile.

Printing and publication

Funds are requested to cover the cost of printing material for extension activities at $2,500 and a scientific publication at $3500.

Land use fees

Funds are requested to cover land use fees at $275/acre, for a total of $311/site/year.

8. Credentials

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Education

University of Sao Paulo, Brazil	Ph.D.	Agronomy/Crop Sciences, 2002
University of Sao Paulo, Brazil	M.S.	Agronomy/Irrigation, 1997
University of San Carlos, Guatemala	B.S.	Agronomy/Crop Systems, 1991

Professional Experience

Associate Professor / Sustainable Cropping Systems Specialist	2020 – *present*
Assistant Professor / Sustainable Cropping Systems Specialist	2014 – 2020
Assistant Professor / Agronomy of Irrigated Crops	2009 – 2014
Visiting Scientist / Postdoc, The University of Georgia	2003 – 2009

Honors and Awards

1. Editor's Citation for Excellence, 2023. Outstanding contributions to SSSAJ as Associate Editor.
2. Award of Excellence. 2014. W2128: Microirrigation for Sustainable Water Use. Western Association of Agricultural Experiment Stations Directors
3. Outstanding Advisor (Nomination). 2012 – 2013. Department of Plant Sciences, U of Wyo.
4. Certificate of Recognition. 2003-2008. Young Scholar Program, The University of Georgia

Selected Publications (*Postdoc-visiting scholar[§], Graduate student[*], and Undergrad student[**]*)

1. Liu[§], R, Gregg, S, and **Garcia y Garcia**, A. 2023. Nitrogen use in double cropping soybean with non-fertilized winter oilseed crops. Int J Agric & Biol Eng, 16(2):159–164. doi: 10.25165/j.ijabe.20231602.7547
2. KC[*], R, Jordan, N, Strock, F, Johnson, G, and **Garcia y Garcia**, A. 2023. Tillage and cover crop mixtures interseeded in maize-soybean in upper Midwest. Agron J. doi: 10.1002/agj2.21322
3. Smith, ME, G Vico, A Costa, T Bowles, ACM Gaudin, S Hallin, CA Watson, R Alarcón, A Berti, A Blecharczyk, FJ Calderon, S Culman, W Deen, CF Drury, A **Garcia y Garcia**, A García-Díaz, E Hernández Plaza, K Jonczyk, O Jäck, RM Lehman, … R Bommarco. 2023. Increasing crop rotational diversity to enhance cereal yields. Communications earth & environment. Commun. Earth Environ. doi: 10.1038/s43247-023-00746-0
4. Ahmad, S, MA Raza, SH, G Abbas, Z Fatima, M Ahmed, MA Goheer, CJ Wilkerson, A **Garcia y Garcia**, G Hoogenboom. 2023. Identification of weak links in production technology for bridging canola yield-gap in southern Punjab, Pakistan. J. Agric. Sci. doi: 10.1017/s0021859623000187
5. Gregg[*], S.; Coulter, J.A.; Strock, J.S.; Liu, R.; **Garcia y Garcia**, A. 2022. Double-cropped winter camelina with and without added nitrogen: effects on productivity and soil available nitrogen. *Agriculture.* doi: 10.3390/agriculture12091477
6. Kusi[*], N, WB Stevens, HY Sintim, A **Garcia y Garcia**, and AO Mesbah. 2021. Phosphorus fertilization and enhanced efficiency products effects on sugarbeet. Industrial Crops and Products, 171, 113887. doi: 10.1016/j.indcrop.2021.113887
7. Joshi[*], VR, M Kazula, JA Coulter, S Naeve, A. **Garcia y Garcia**. 2021. In-season weather data provide

reliable yield estimates of maize and soybean in the US central Corn Belt. *Int. J. Biometeorol*. doi: 10.1007/s00484-020-02039-z

8. Rusch*, HL, JA Coulter, JM Grossman, GA Johnson, PM Porter, and A **Garcia y Garcia**. 2020. Towards sustainable maize production in the U.S. upper Midwest with interseeded cover crops. *PLoSONE*. doi: 10.1371/journal.pone.0231032
9. Nilahyane*, A, MA Islam, AO Mesbah, SK Herbert, A **Garcia y Garcia**. 2020. Growth, water productivity, nutritive value, and physiology responses of silage corn to water stress. *Agron J*. doi: 10.1002/agj2.20015
10. Bowles, T, M Mooshammer, Y Socolar, F Calderón, M Cavigelli, S Culman, W Deen, A **Garcia y Garcia**, A Gaudin, WS Harkom, RM Lehman, S Osborne, GP Robertson, J Salerno, M Schmer, J Strock, AS Grandy. 2020. Long-term evidence shows crop rotation diversification increases agricultural resilience to adverse growing conditions in North America. *One Earth*. doi: 10.1016/j.oneear.2020.02.007
11. Liu§, R, MS Wells, and A **Garcia y Garcia**. 2019. Relay and sequential cropping corn with winter oilseed crops in northern climates. *Nutr Cycl Agroecosyst*. doi: 10.1007/s10705-019-10036-x
12. Joshi*, VR, KR Thorp, JA Coulter, JA Johnson, PM Porter, JS Strock, and A **Garcia y Garcia**. 2019. Improving site-specific maize yield estimation by integrating satellite multispectral data into a crop model. *Agronomy*, 9:719. doi: 10.3390/agronomy9110719
13. Liu§, R, MS Wells, and A **Garcia y Garcia**. 2019. Cover crop potential of winter oilseed crops in the Northern U.S. Corn Belt. *Arch. Agron. Soil Sci.*, 65(13): 1845-1859. doi: 10.1080/03650340.2019.1578960
14. Nilahyane*, A, MA Islam, AO Mesbah, A **Garcia y Garcia**. 2018. Effect of irrigation and nitrogen fertilization strategies on silage corn grown in semi-arid conditions. *Agronomy*, 8(10), 208. doi: 10.3390/agronomy8100208
15. Liu§, R, EAA Abdelraouf, B Bicego, VR Joshi, A G**arcia y Garcia**. 2018. Deficit irrigation – A viable option for sustainable confection sunflower (*Helianthus annuus* L.) production in the semi-arid U.S. *Irrigation Science*, 36(6), 319-328. doi: 10.1007/s00271-018-0588-6
16. Nilahyane*, A, MA Islam, AO Mesbah, A **Garcia y Garcia**. 2018. Evaluation of silage corn yield gap: an approach for sustainable production in the semi-arid region of USA. *Sustainability*, *10*, 2523. doi: 10.3390/su10072523
17. Lewandowski, A, A **Garcia y Garcia**, C Lenhart, D Mulla, A Pradhananga, and JS Strock. 2018. The future of agriculture in a water-rich state. *Open Rivers: Rethinking Water, Place & Community,* 10. doi: 10.24926/2471190X.4317
18. **Garcia y Garcia**, A and JS Strock. 2018. Soil water content and crop water use in contrasting cropping systems. *Trans ASABE*, 61(1): 75-86. DOI: 10.13031/trans.12118

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Education

University of Nebraska	Ph.D., Agronomy, 1994
University of Missouri	M.S., Agronomy, 1991
University of Minnesota	B.S., IPM, 1988

Research and Outreach Experience

Gregg is an Associate Professor in the Department of Agronomy and Plant Genetics at the University of Minnesota. He specializes in annual and perennial cropping systems with a focus on maximizing productivity, efficiency, and ecosystem services. Gregg's work emphasizes applied production strategies that are designed around multi-value outcomes.

Recent Peer-Review Publications

1. Cubins, J.A., S. Wells, R.W. Gesch, G.A. Johnson, W. Maninder, R. Chopra, M.D. Marks, R. Swenson, K. Frels. 2023. Harvest aids did not advance maturity of non-shatter pennycress. Submitted. Crop Sci. 63(4):2465-2474
2. Rabin, K.C., G.A. Johnson, J.S. Strock, N. Jordon, A. Garcia y Garcia. 2023. Influence of tillage and cover crop mixtures interseeded in maize and soybean. Agron. J. 115(3): 1188-1201.
3. Black, K.L., S. Wells, G.A. Johnson, W.F. Lazarus, and A. Kraus. 2023. Interseeding wide-row corn with cover crops: investigating system potential for expanded Economic Opportunities in corn production systems. *Agronomy* **2023**, *13*, 307. https://doi.org/10.3390/agronomy13020307
4. Liptzin, D., et al. 2023. An evaluation of nitrogen indicators for soil health in long-term agricultural experiments. Soil Sci. Soc. Am. 87(4):868-884
5. Liptzin, D., et al. 2022. An evaluation of soil indicators of soil health in long-term agricultural experiments. Soil Biol. Biochem. 172:108708.
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Education:

M.S.	Agronomy/Weed Science University of Minnesota	1996
B.S.	Agricultural Education/Minor Agricultural Economics (with Distinction) University of Minnesota	1990

Employment History:

Extension Educator - Crops	University of MN Extension Worthington Regional Extension Office	2004 – present
Third Crop Marketing/ Program Assistant	Blue Earth River Basin Initiative Fairmont, MN	2003 - 2004
Research Agronomist	J.C. Robinson Seed Company/Golden Harvest Estherville, IA	1996 - 2002
Graduate Research Assistant	Agronomy Department, University of MN St. Paul, MN	1992 - 1996
Agrisource Support/ Crop Production Specialist	Cenex/Land O'Lakes Inver Grove Heights and DeGraff, MN	1990 - 1992
Farm Laborer	Vest Kaergaard, Denmark	1990
Undergraduate Research Assistant/Junior Scientist	Soils Department, University of MN St. Paul, MN	1989 – 1990
Soil Conservationist Trainee	USDA Soil Conservation Service LeCenter, Stillwater and St. Paul, MN	1988 - 1990

Certifications:

Certified Professional Agronomist - American Society of Agronomy (2000 – present)
Certified Crop Advisor – American Society of Agronomy (2013 – present)

Professional Organizations and Societies:

- North Central Weed Science Society (1992 – 2002, 2004 – present)
- National Association of County Agricultural Agents (2004 – present)
- Minnesota Association of Extension Agricultural Professionals (2004 – present)

Select Educational Programs:

- **"Strategic Farming: Let's Talk Crops!"** Lead coordinator (2020-present) of this online, educational effort targeted to Farmers and Ag Professionals to address diverse crop production issues. In 2023, this series consisted of 12, one-hour sessions. Details @ z.umn.edu/strategic-farming.
- **Private Pesticide Safety Education**. Lead coordinator and presenter of the Private Pesticide Applicator Recertification program in southwestern MN (10 locations/year, 2004-present). Materials developer/contributor and speaker for the Commercial Applicator program statewide.

- **Cover Crop Field Day: Setting up for Success.** Lead coordinator and a presenter at this annual field day highlighting cover crop research at the Southwest Research and Outreach Center by Lamberton (2018-present).
- **Radio spots in SW MN:** Conduct radio spots to discuss research-based information on issues and hot topics related to crops: Weekly (five to seven minutes) on KSUM (Fairmont), twice a month (five to seven minute) on KKOJ (Jackson), and monthly (seven to 10 minute) on KDOM (Windom) (2004-present).
- **SW MN Extension Crops Update:** Produce an email newsletter focused on crop production issues, hot topics, and events pertinent to SW MN farmers and ag professionals on an as-needed basis (1,076 subscribers as of 2/8/23, 2011-present**).**

Select Publications:

- **Stahl, L.,** M. Anderson, D. Nicolai, and T. Peters. (2023) It's All Hands on Deck in the Battle Against Herbicide-Resistant Weeds. Crops & Soils Magazine feature story, https://doi.org/10.1002/crso.20295
- **Stahl, L.,** A. Cates, and A. Garcia y Garcia. Minnesota Cover Crop Recipe – Post Corn Silage, Going to Corn: Use Cereal Rye. Midwest Cover Crop Council, MCCC-130. Available at: https://www.midwestcovercrops.org/minnesota-cover-crop-recipe-post-corn-silage-going-to-corn-use-cereal-rye/.
- **Stahl, L.,** A. Cates, and A. Garcia y Garcia. Minnesota Cover Crop Recipe – Post Corn Silage, Going to Soybean: Use Cereal Rye. Midwest Cover Crop Council, MCCC-131. Available at: https://www.midwestcovercrops.org/minnesota-cover-crop-recipe-post-corn-silage-going-to-soybean-use-cereal-rye/
- **Stahl, L.,** A. Cates, A. Garcia y Garcia, and M.S. Wells. Minnesota Cover Crop Recipe – Post Corn, Going to Soybean: Use Cereal Rye. Midwest Cover Crop Council, Oct. 2019. Available at: http://mccc.msu.edu/minnesota-cover-crop-recipe-post-corn-going-soybean-use-cereal-rye/.
- **Stahl, L.,** and P. Bongard. Prevent plant: Considerations for corn and soybean. MN Crop News 5/31/22. (#6 of top 10 MN Crop News articles in 2022, 1,714 views as of 2/8/23)
- **Stahl, L.** "Remember your goals when planting green", Cover Crop Strategies podcast, 5/21/21. https://www.covercropstrategies.com/articles/1873-podcast-remember-your-goals-when-planting-green?utm_source=omail&utm_medium=email&utm_campaign=weekly&utm_content=ccs&oly_enc_id=8686A6205756B4S.
- **Stahl, L.,** A. Cates, A. Garcia y Garcia, and M.S. Wells. Cover Crop Recipe – Post Soybean, Going to Corn: Use Oats. Midwest Cover Crop Council, Oct. 2019. Available at: http://mccc.msu.edu/minnesota-cover-crop-recipe-post-soybean-going-corn-use-oats/
- **Stahl, L.,** 2016**.** Managing risk when using herbicides and cover crops in corn and soybean. U of MN Fact Sheet. Available at: http://blog-crop-news.extension.umn.edu/2016/04/managing-risk-when-using-herbicides-and.html.
- **Stahl, L.,** F. Fernandez, and D. Kaiser, 2016. Should soil health test results be used when determining fertilizer needs in Minnesota? U of MN Fact Sheet. Available at https://drive.google.com/file/d/0B3cuyvdDn64PdE1JWGNzbmZQUmM/view. 4 pages.

9. Dissemination and Use

Results will be disseminated through both extension and scientific initiatives. Our extension program aims to prepare varied outreach activities and materials, fostering connections with both farmers and policymakers. Our activities will intentionally promote cover crops as a way to make cropping systems more diverse, highlighting C sequestration potential, N credit, and soil-water dynamics as related to benefits to Minnesota's natural resources. In partnership with Extension educators, we will create online content for the MN Crop News Blog (www.blog-crop-news.extension.umn.edu), which serves over 1,600 subscribers linked to the U of MN Extension Cover Crop website. Our dissemination approach includes press releases on our field days, contributions to regional and local newsletters, radio segments, podcasts, and presentations at local and regional meetings. Upon request, curated data will be shared as appropriate. Beyond the project's completion, we intend to publish fact sheets on the Midwest Cover Crop Council website (www.midwestcovercrops.org) and share our results at professional meetings. The culmination of our research will be synthesized in a peer-reviewed article that may include a permanent link to data shared in a data repository.

In the growing seasons of 2025 and 2026, field days will be organized at each LTARN node. These events will not only allow farmer participants to share their insights but also showcase in-field demonstrations and interactive hands-on activities. Additionally, and whenever possible, we will present at existing extension events, such as the ROC field days and various state conferences.

It's important to note that all our dissemination efforts, throughout and beyond the proposal's duration, will acknowledge the contributions of the ENRTF, displaying its logo and using suitable acknowledgment language.

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