**Farmable Vegetative Buffers: MCRPC Final Report**

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The objective of our research over the three years of support from the Minnesota Corn Research and Promotion Council (MCRPC) was to develop and test management practices to establish perennial vegetative buffers that can sustain row-crop production while adhering to the Minnesota Buffer Law mandates. Specifically, we sought to develop guidelines for fertilizer nitrogen (N) management for corn production in a kura clover living mulch (KCLM) cropping system, develop and test methods to promote faster establishment of kura clover, and provide field demonstration of living mulch systems as vegetative buffers.

To address these topics, we established a field experiment for the 2017 – 2018 growing seasons to determine the economic optimum fertilizer N rate for corn grown in a KCLM that was either managed as a forage crop or as a living mulch for corn in the previous growing season. This experiment found that corn grown in a kura clover stand that was used to produce forage in the previous year did not need fertilizer N to maximize yield and profitability. For corn grown in kura clover that was used as a KCLM for corn in the previous year, the optimum fertilizer N rate averaged 162 kg N $ha^{-1}$. In addition to these practical N management guidelines, we created a budget for system inputs, including fertilizer and management costs, and determined that corn production in a KCLM is more costly than conventional management (Table 1). However, with the increased cost associated with the KCLM system, we also saw greater net returns relative to conventional grain production due to the profits from the sale or use of corn stover.

**Table 1:** Partial management cost (in U.S. $ ha$^{-1}$) for maize produced conventionally and in KCLM in 2017 and 2018.

| Management practice | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Conventional | First-year KCLM | Second-year KCLM | Conventional | First-year KCLM | Second-year KCLM |
| Spring mowing§ | | 26.93 | 26.93 | | 26.93 | |
| Spring tillage | 13.59† | 76.78‡ | 76.78‡ | 13.59† | 76.78‡ | 76.78‡ |
| Fertilizer N | 131.88 | 0.00 | 148.68 | 131.88 | 0.00 | 122.64 |
| Mowing§ | | 26.93 | 26.93 | | | |
| Grain handling and storage§ | 231.10 | 170.53 | 186.58 | 215.88 | 182.48 | 185.09 |
| Fall tillage§ | 48.68 | | | 48.68 | | |
| Raking§ | | 13.10 | 13.10 | | 13.10 | 13.10 |
| Baling§ | | 33.36 | 33.36 | | 33.36 | 33.36 |
| Bale handling and storage§ | | 141.16 | 158.73 | | 192.33 | 191.08 |
| Stover nutrient removal‖ | | 37.50 | 42.17 | | 51.09 | 50.76 |
| **Partial management cost** | **425.25** | **526.29** | **713.26** | **410.03** | **576.08** | **672.81** |

Costs obtained from † Plastina, 2019, ‡ Dobbratz et al., 2019, § Plastina, 2018, ‖ Battaglia et al., 2018. Practices not listed are assumed to be equal between management systems (Table A1).

**Table 2:** Economic return (in U.S. $ ha-1) for maize produced conventionally and in KCLM in 2017 and 2018.

| Year | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| Management | Conventional | First-year KCLM | Second-year KCLM | Conventional | First-year KCLM | Second-year KCLM |
| Fixed management cost† | 1235.47 | 1235.47 | 1235.47 | 1235.47 | 1235.47 | 1235.47 |
| Partial management cost‡ | 425.25 | 526.29 | 713.26 | 410.03 | 576.08 | 672.81 |
| Grain value§ | 2221.10 | 1638.95 | 1793.20 | 2074.80 | 1753.83 | 1778.87 |
| Stover value‖ | - | 619.13 | 696.19 | - | 843.57 | 838.07 |
| **Net return** | **560.38** | **496.32** | **540.66** | **429.30** | **785.85** | **708.66** |
| **Partial economic net return#** | **-** | **-64.06** | **-19.72** | **-** | **356.55** | **279.36** |

†Fixed management cost: the sum of land rental, phosphorus and potassium fertilizer not associated with stover removal, fertilizer application, seed, planting, pesticide and application, harvest, labor, and miscellaneous (Table A1). ‡ Partial management cost (Table 4). § Grain value: $133 Mg-1 at 155 g kg-1 moisture. ‖ Stover value: $79.37 Mg-1 at 200 g kg-1 moisture [25]. # Partial economic net return is net return of the treatment minus net return of conventional management in the same year.

Our next experiment supported by the MCRPC was highly focused on the spring management of KCLM systems and how it influences early-season N cycling. In 2018, we compared a pure kura clover stand, and management treatments where the stand was mowed and residue was returned or removed as hay, in combination with row establishment, where rows were either established with herbicides (glyphosate at 9.35 L a.e. ha$^{-1}$) or strip tillage. In this study we found that mowing increases available soil N regardless of whether residues are returned or removed relative to an unmanaged control, and strip tillage increases available soil N relative to herbicide row establishment.

The final project fully supported by the MCRPC was interested in understanding the spatiotemporal root distribution of kura clover and corn in a KCLM system. We hypothesized that we could suppress

clover growth in the spring by applying anhydrous ammonia as the fertilizer N source to kill clover roots in the row zone. We tested a conventional strip tillage tool (Orthman 1tRIPr) against our reference rotary zone tillage tool in combination with 120 kg N $ha^{-1}$ applied as either anhydrous ammonia or ammonium nitrate N fertilizers. In this study, we found no yield differences between treatments, indicating that the more practical conventional strip tillage tool can be used for managing a KCLM. The spatiotemporal root distributions are not yet quantified due to the high labor requirement for the samples, but data will be analyzed and available in a publication and Jonathan Alexander's upcoming Ph.D. dissertation in 2022.

Finally, to address the main barrier for farmers hoping to use a KCLM system as a farmable vegetative buffer, we reached out the Board of Water and Soil Resources to approve the use of this cropping system as an acceptable alternative to perennial options that take land out of corn production. We received regulatory approval and farmers are now able to utilize the management recommendations developed from this work to produce corn on all of their tillable land.

Overall, our research addressed several management considerations for corn production in a KCLM system. We gained a greater understanding of N cycling and management in these systems from the support of the MCRPC and have developed several new hypotheses and experiments to increase the usefulness of KCLM for Minnesotan corn producers. Below is a selected list of outreach activities and publications generated from the support provided by this grant:

REFERREED PUBLICATIONS

Alexander, J.R.; Baker, J.M.; Venterea, R.T.; Coulter, J.A. Kura Clover Living Mulch Reduces Fertilizer N Requirements and Increases Profitability of Maize. Agronomy 2019, 9, 432.

Alexander, Jonathan. (2019). Nitrogen Dynamics and Management for Maize Production in Kura Clover Living Mulch. Retrieved from the University of Minnesota Digital Conservancy, http://hdl.handle.net/11299/206201.

Alexander, J.R.; Venterea, R.T.; Baker, J.M.; Coulter, J.A. Kura Clover Living Mulch: Spring Management Effects on Nitrogen. Agronomy 2019, 9, 69.

EXTENSION PUBLICATIONS

1. JR Alexander, JA Coulter, JM Baker, RT Venterea. 2019. Kura clover living mulch-corn systems provide forage and environmental benefits. In: Forage Focus, May issue, Midwest Forage Assoc., St. Paul, MN. p. 3, 8.

2. JR Alexander, JA Coulter, JM Baker, RT Venterea. 2018. Profitable conservation: Corn production in kura clover living mulch. In: Forage Focus, Dec. issue, Midwest Forage Assoc., St. Paul, MN. p. 18–19.

3. JR Alexander, JA Coulter, JM Baker, RT Venterea. 2018. Kura clover living mulch provides opportunity for high corn yield with reduced nitrogen input. In: Minnesota Crop News, August issue, University of Minnesota Extension, St. Paul, MN.

4. JR Alexander, JA Coulter, JM Baker, RT Venterea. 2018. Kura clover living mulch provides opportunity for high corn yield with reduced nitrogen input. In: The Farmer, August issue, Informa PLC, London, UK.

5. JR Alexander, JA Coulter, JM Baker, RT Venterea. 2018. Nitrogen Management for Corn Grown in Kura Clover Living Mulch. In: Clippings, Feb. issue, Midwest Forage Assoc., St. Paul, MN.

PRESENTATIONS

a) JR Alexander, JM Baker, RT Venterea, JA Coulter. "Kura Clover Living Mulch Reduces Fertilizer N Requirements and Increases Profitability of Maize." American Society of Agronomy Annual Meeting, 11 November 2019, Henry B. Gonzalez Conference Center, San Antonio, TX. [oral presentation].

b) JR Alexander. "Kura Clover Living Mulch Systems." College of Food, Agriculture, and Natural Resource Sciences Presents Science in Seconds, 23 October 2019, Cargill Microbial and Plant Genomics Building, St. Paul, MN. [oral presentation].

c) JR Alexander. "Nutrient and Agronomic Management and its Effect on Global Sustainability." VANTAGE Global Sustainability Program, 30 September 2019, Minnetonka High School, Minnetonka, MN. [guest lecture].

d) JR Alexander, JM Baker, RT Venterea, JA Coulter. "Kura Clover Living Mulch: Conservation Flex Crop for Minnesota Farming Systems." Nitrogen Use Efficiency Workshop, 6 August 2019, University of Missouri, Columbia, MO. [poster].

e) JR Alexander, JM Baker, RT Venterea, JA Coulter. "Nitrogen Dynamics and Management for Maize Production in Kura Clover Living Mulch." Department of Soil, Water, and Climate, 26 June 2019, University of Minnesota, St. Paul, MN. [Thesis seminar].

f) Coulter, J.A., J.R. Alexander, J.M. Baker, and R.T. Venterea. 2019. "Corn production in kura clover living mulch." 72nd Northeastern Corn Improvement Conference, 12 February 2019, Ithaca, NY. [oral presentation].

g) JR Alexander, JM Baker, RT Venterea, JA Coulter. "Kura Clover Living Mulch: Conservation Flex Crop for Minnesota Farming Systems." Plant Science Symposium, 29 March 2019, University of Minnesota. [poster].

h) JR Alexander, JM Baker, RT Venterea, JA Coulter. "Kura Clover Living Mulch: Conservation Flex Crop for Minnesota Farming Systems." Production Agriculture Symposium, 8 March 2019, University of Minnesota. [oral presentation].

i) JR Alexander, JM Baker, RT Venterea, JA Coulter. "Kura Clover Living Mulch: Spring Cultural Practices" Forever Green Initiative, 1 February 2019, University of Minnesota, St. Paul, MN. [guest lecture]

j) JR Alexander, JM Baker, RT Venterea, JA Coulter. (2018, December). “Corn Production in Kura Clover Living Mulch: Response to Nitrogen Fertilization.” Minnesota Crop Production Retailers Trade Show, 11-13 December 2018, Minneapolis, MN. [poster]

k) JR Alexander, JM Baker, RT Venterea, JA Coulter. “High Yielding Corn with Reduced Nitrogen Inputs: Production in Kura Clover Living Mulch.” American Society of Agronomy Annual Meeting, 5 November 2018, Baltimore MD. [oral presentation].

l) JR Alexander, JM Baker, RT Venterea, JA Coulter. “Maximizing benefits of Kura clover living mulch: Nitrogen, economics, and buffer law.” Forever Green Initiative. 2 March 2018, University of Minnesota, St. Paul, MN. [guest lecture].

m) JR Alexander, JM Baker, RT Venterea, JA Coulter. “Corn Production in Kura Clover Living Mulch.” Monsanto Graduate Student Poster Competition. 21 February 2018, University of Minnesota, St. Paul, MN. [poster].

n) JR Alexander. “Kura Clover Living Mulch Systems.” Land and Atmospheric Science Department Presents Science in Seconds, 21 February 2018, Borlaug Hall, St. Paul, MN. [oral presentation].

o) JR Alexander, JM Baker, RT Venterea, JA Coulter. “Corn Production in Kura Clover Living Mulch.” Production Agriculture Symposium. 15 February 2018, University of Minnesota, St. Paul, MN. [poster].

p) JR Alexander, JM Baker, RT Venterea, JA Coulter. “Corn Production in Kura Clover Living Mulch.” Minnesota Agricultural Expo. 24-25 January 2018, Mankato Civic Center, Mankato, MN. [poster].