Increasing profitability of organic vegetable farms through improved integrated weed management.

Montana State University

Cover Sheet

Organization Information			
Company/Organization Name	Montana State University		
Business/Organization Type (select one)	University/College		
Grant Project Contact	Dr. Zach Miller/Montana State University		
Mailing Address	MSU-Western Ag Research Center, 580 Quast Ln, Corvallis MT 59828		
Physical Address	MSU-Western Ag Research Center, 580 Quast Ln, Corvallis MT 59828		
Project Information			
Project Title (limited to fifteen words)	Increasing profitability of organic vegetable farms through improved integrated weed management.		
Award Request	$463,122		
Project Start Date	09/30/2022	Project End Date	10/01/2025
Crop(s) benefitting from project	Vegetables with an emphasis on Cabbage, Carrots, Onions, and Garlic		
Will project benefit beginning farmers?*	Yes	Will project benefit socially disadvantaged farmers?**	Yes
Is this a multi-state project?	No	List partnering state(s)	Montana State University
Does project include market adaptations for COVID-19?		If yes, explanation	

*__Beginning farmers__ - individuals or entities who have not operated a farm for more than 10 years and substantially participates in the operation.

**__Socially disadvantaged farmers -__ means a farmer who is a member of a socially disadvantaged group. A "Socially Disadvantaged Group" is a group whose members have been subject to discrimination on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program

Narrative

Abstract

Include a project summary of 250 words or less, suitable for dissemination to the public. It should include:

1. *The name of the applicant organization*
2. *A concise outline the project's outcome(s), and*
3. *A description of the general tasks to be completed during the project period to fulfill reach outcomes.*

Montana's local food systems rely on diversified, organic vegetable growers. Weed management is one of the most important issues identified by these growers. Weeds reduce marketable yields, can harbor insect pests and pathogens, and their control represents a significant labor cost. The integration of cultural and mechanical weed management tools can improve efficacy and efficiency. To identify optimal integrated weed management practices in a range of vegetable crops, our team at the Montana State University will survey organic vegetable growers to identify specific needs for weed management and successful practices. To address the general need to reduce labor and increase efficacy of weed management, we will 1) evaluate the potential of integrating labor-saving mechanical weeding tools and 2) assess the critical period of weed control in four representative field-grown crop types: cabbage, carrots, onions, and garlic. To improve the weed management practices for specialty crop growers, we will partner with six farms to conduct on-farm trials and offer educational opportunities, and integrate our results with education and outreach activities aimed and increasing growers' ability to manage weeds in vegetable farms.

Project Purpose

1. **What is the specific issue, problem or need**?
   - What is the problem or need that you are trying to address?
   - Why is the project important and timely?
   - What is the importance to specialty crop stakeholders?

Diversified, organic vegetable farms are a critical part of Montana specialty crop industry and local food systems. These approximately 60 farms supply a large consumer base through CSA's, 78 farmers markets, restaurants, and grocery stores. This project will address the two main challenges identified by organic vegetable producers: weed management and labor. Vegetables require high levels of weed control since these crops are not very competitive and must meet market standards for quality. Weed competition reduces both marketable yields and current weed management require large amounts of labor, representing a significant input cost. Hand weeding labor varies with crop and weed pressure, but estimates range from 40 to 243 hours per acre per season (Melander et al. 2005). COVID-19 has only exacerbated farm labor shortages and inputs costs. In the last two years, Montana farms were desperate for labor offering wages of $15 to $20 an hour. At these wages, the costs of the higher levels of hand weeding ($3,600 per acre) may not be sustainable.

The integration of cultural and mechanical weed management tools can improve efficacy, improving marketable yields, and efficiency, reducing labor costs. For example, mechanical cultivation between and within rows in an onion crop reduced labor by over 90% compared to hand weeding (Melander et al. 2005). Also, cultural practices such as cover crops can reduce weed pressure and weeding labor. Yet, little research

exists to inform what cover crops and management practices optimize the weed management and soil health benefits for Montana vegetable growers.

One of the innovative cultural practices we propose to evaluate is covering fields with plastic tarps in the early spring to warm the soils and encourage weed seed germination. Many of the weeds die under the tarp and survivors can be removed by tillage prior to planting. Research from the North-East US assessing the effects of tarping for 3 to 10 weeks prior to planting beets demonstrated they reduce weed biomass by 96% ten days after planting, a critical period for weed management. Tarps increased beet yields by both reducing weed biomass and increasing available soil nitrogen (Rylander et al. 2020).

Once the vegetable crop is planted, tractor-mounted, mechanical weed management tools offer the potential to improve efficiency and efficacy. For crops planted in rows, different mechanical weeding tools can be applied to the space between rows (interrow space) and between plants within the row (intra-row space). Interrow weed control practices include flame weeding and shallow cultivation with tine harrows, basket weeders, and sweep blades. These tools keep the interrow free of vegetation and do not need to be selective between crop and weeds. Intra-row tools target weeds near and within the crop rows and need to minimize injury to the crop. These tools include torsion weeders, finger weeders, and nylon brush weeders. These tools achieve selective weed control by applying less physical force and precise placement and are particularly effective when applied to emerging weeds in crops that are well anchored to the soil.

The approaches and potential integration of post planting mechanical weed management practices vary by crop. The crop type-specific integrated mechanical weed management approaches are based on the crops resilience to getting uprooted or damage by weeding tools and the size of the intra-row space. These crop types include: 1) direct seeded crops planted at high density with small spaces between the plants like carrots or spinach; 2) transplanted crops planted at high density like onions or garlic; and 3) transplanted crops planted with larger spaces between plants within the row at low density like cabbage or broccoli. Several studies have demonstrated the integration of mechanical weeding tools in the same weeding pass or sequentially at different times can dramatically increase the weed control, crop yields, and reduce labor costs (Melander et al. 2005), but have not been evaluated in the weed communities and climates of Montana.

Similar to comedy, the effectiveness of the weeding depends on timing. Not only is weeding most effective when used on seedling weeds, the sensitivity of the crop to weed competition is typically greatest when the crop is small, but varies from crop to crop. The period in the crop growth cycle during which weeds must be managed to prevent yield to avoid economic losses is called the critical period of weed control. This information allows producers to invest weeding efforts to maximize benefits and profits and can help them if and when to till in (abandon) a crop that's too weed infested. Yet, the critical period of weed control are largely unknown for organic vegetable crops grown in Montana. Our recent research has begun to determine this period for carrots and have shown clear results that have been useful for stakeholders.

2. **What are the objectives of the project**? Provide a listing of the objectives that this project hopes to achieve

Objective Name	Objective Description
1) 1) Identify optimal integrated weed management practices	1a) In the fall of year one, we will survey growers to determine needs for weed management and identify successful practices. This information will be used to identify specific weed management needs and practical constraints (potential barrier to adoption) that will be incorporated into our research and outreach. We will also use surveys and interviews to identify barriers to adoption of integrated weed management tactics (e.g. cost of equipment, knowledge of how to effectively use the tools, limited time). 1b)

	Research trials will be conducted at MSU-Townes Harvest and the Western Ag Research Center (WARC) on a range of transplanted and direct seeded vegetables to evaluate approaches to integrate weed management practices. Specifically, we will use 4 representative vegetable crops: carrots (high density-direct seeded), onions (high densitytransplanted), cabbage (low density-transplanted), and garlic (high density-fall planted). These crops were identified as needing improved weed management in consultations with growers. The trials at WARC, directed by Drs. Miller and Svyantek, will integrate various types and timing of mechanical weeding tools (brush weeders, finger weeders, tine harrow, basket weeders, flame weeders) and cultural practices (using tarps to warm soils and stimulate weed emergence prior to seeding, other stale seed bed type practices). Experimental design: In each crop, we will compare 5 integrated mechanical approaches (combining various tools and timings) informed by the grower survey to a hand-weeded control. Treatments will be replicated in 4 blocks. Plots will be planting beds ~50 ft. long. Tarp treatments (3-6 weeks duration) will be applied, randomly to one half of the plot. Trials will be repeated over two years. Across treatments, we'll compare weed density at planting and two weeks post planting, hand weeding labor, crop marketable yields, and basic economics (net returns). In the final two years, the best performing treatments will be demonstrated at MSU- Towne Harvest and in grower fields where similar weed abundance and labor data will be collected. 1c) In addition, at WARC Drs. Miller and Svyantek will evaluate which cover crops and planting practices (seed rate, plant date, irrigation, termination) optimize weed control and soil nutrition/quality. Cover crop mixtures and planting dates will be informed by the grower survey, but will include a minimum of 6 cover crop mixtures x 3 planting dates. 1d) Replicated trials at MSU-Townes-Harvest directed by Drs. Menalled and Burgess, we will determine the critical period for weed control for garlic, cabbage, and onions, and carrots. This period is defined as the period between the maximum time or crop growth stage that early season weeds can be left with minimal impact on yields and quality (critical time of weed removal, CTWR) and

	the crop growth stage (or time) at which additional weeding no longer improves yields and quality (critical weed-free period, CWFP). In each crop, we will compare how crop yields, quality metrics, and gross profits vary across eight weeding treatments that vary when weeding begins and ends relative to crop growth stages. 1e) Compare weed communities among organic vegetable farms. Weed species respond differently to integrated weed management practices and thus optimal weed management practices may depend on what weeds are present on the farm. Most larger-scale, conventional farms have largely similar weed communities and thus research-based, weed management recommendations can apply to broadly to many farms. We lack this basic information on how weed communities vary across organic vegetable farms in Montana, but preliminary studies conducted by MSU-WARC on farms in Ravalli County suggests that farms differ in weed communities and density of weeds in the seed banks. We will use surveys to identify common and problematic weeds across organic vegetable farms. We will also collect soil samples from several fields at 20 farms and measure the density and identity of weed species in the seed bank. Soils from each farm will be mixed with weedfree potting mix and placed in a greenhouse for six weeks. Weed emerging from the soil will be identified to species and removed. We will use these data to compare similarity of weed communities among farms in the state and if specific, more long-term, weed management practices are associated with differences in weed abundance in the seed bank.
2) 2) Improve efficiency and efficacy of weed practices on MT vegetable farms	Our team will increase grower knowledge and adoption of integrated weed management practice through outreach activities that includes workshops, videos, extension guides, and on-farm demonstrations. On-Farm research/ demonstrations: Identify 6 farm-partners. In year one, farms will measure yields and weeding labor in 2-3 crops selected by the farmer. In year two and three, we'll work with farms to design, implement, and track improved IWM practices. The project will supply up to $4000 for new tools/supplies for these improved IWM practices. Each farm will host a field tour in the last two years of the

	project. Farms will be selected from across the state to ensure the impacts of the on-Farm research/demonstration trials are spread to as many farms in the state (e.g. not just farms near Corvallis and Bozeman). At MSU-Townes Harvest, graduate and undergraduate students will be engaged in project activities, training future farmers and farm educators in IWM practices. The results of this study will be presented at several undergraduate level courses at Montana State University, including Weed Ecology and Management (ENSC 443, Menalled) and Field Crop Production (AGSC 341- Burgess)
3)	
4)	
5)	

Potential Impact

1. **Who are the beneficiaries of the project?** Be as specific as possible, describe the population affected and where they are located. Use statistics to describe the target population.

The primary target population that will benefit from the project are organic vegetable growers across Montana. These farms are concentrated near larger cities in the state, but exist in most regions of the state. Many of these farmers are beginning farmers that grow a wide variety of vegetables. Farms are typically less than 10 acres and employ 4 to 6 seasonal farm laborers. These farms supply produce to Montana consumers through direct sales (farmers' markets, CSA's) and sales to restaurants, grocery stores, and distributors.

2. **How many beneficiaries will be impacted?** The answer to this must include a number.

Exact estimates for the numbers of organic vegetable farms are not available in Montana. Based on the Abundant Montana directory, we estimate that there are 55 farms and approximately 200 farmers, assuming ~4 farmers and farm laborers per farm.

3. **How will the beneficiaries be impacted by the project?** Be specific and refer to the target population. Discuss their current condition and how the activities performed will improve that condition.

This project will address the two main current challenges identified by Montana organic vegetable producers: weed management and labor. Weeds have a major impact to the sustainability of these farms as weeds reduce crop marketable yields and weeding represents a major labor investment. The project will combine research and outreach aimed at increasing the efficacy and efficiency of integrated weed management. Especially with increasing labor costs, we expect the impacts of this project to be significant. We estimate that growers will both increase marketable yields of their vegetables and reduce labor associated with weeding by at least 30%. Based on the estimates of 50 farms, an average farm size of 5 acres, 200 hours of weeding labor per acre, and wages of $15 per hour, farmers across Montana are spending a total $750,000 per year on hand weeding. If we reduce weeding labor by 30%, this project will save these growers $250,000 per year (or $5,000 per farm per year). This estimate also does not include any increases in marketable yields and farm profits, which are also expected outcomes of this project. Improving the weed management and labor efficacy not only improves yields, but also frees up labor that can be invested into other farm needs. There are also longer-term impacts that are expected from this project. The improving the efficacy of weed management create feedbacks that drive the long-term sustainability of these farms. Improving weed

management decreasing the weed seed bank and overall weed pressure in subsequent years, increasing marketable yields with reduced labor over time.

Outreach

Describe how you will share the results of the project with specialty crop growers and other interested specialty crop stakeholders.

Project objectives and outcomes will be shared with specialty crop growers in a variety of formats and media. We'll share project objectives and outcomes at annual field days at MSU-WARC, MSU-Townes Harvest, and at the six participating partner farms. We will also present our findings at the Montana Organic Association Conference, and through Extension and grower workshops. We anticipate publishing at least two peer-reviewed journal articles at the conclusion of this 3-year research project and results will be shared at national horticulture meetings. Information will also be disseminated through a Montana State Extension MontGuides, MSU-WARC website, and social media (e.g. YouTube videos).

External Project Support

Describe the individuals and organizations that support the nature of the support they are providing.

Montana State University Project Leaders: Drs. Zach Miller and Andrej Svyantek are faculty at MSU-Western Ag. Research Center in Corvallis, MT. They will lead research trials at WARC, mentor graduate students, coordinate four on-farm research/demonstration sites in Western MT, and contribute to outreach. Drs. Fabian Menalled, Macdonald Burgess, and Roland Ebel are faculty at MSU-Bozeman. Dr. Mac Burgess directs the Townes Harvest vegetable farm student internship program. Drs. Burgess, Menalled, and Ebel will coordinate graduate and undergraduate integrated weed management research and assist in outreach. The Montana Organic Association will assist in outreach, providing project personnel opportunities to present project outcomes at their annual conference and field tours.

Eligibility

By marking the box below, I confirm that this project enhances the competitiveness of specialty crops in accordance with and defined by 7 U.S.C. 1621. Further information regarding the definition of a specialty crop can be found at www.ams.usda.gov/services/grants/scbgp.

Yes	X

Previous Efforts

Does the project build on a previously funded SCBG project?

No

If YES,

1. Describe how the project differs from and builds on the previous project.

2. Provide a summary (3 to 5 sentences) of the outcomes of the previous project(s).

3. What was learned from implementing this project, including potential improvements?

4. How are the lessons-learned being incorporated to make the ongoing project more effective and successful at meeting goals and outcomes?

5. Describe the likelihood of your efforts becoming self-sustaining and not indefinitely dependent on grant funds.

Support from Other Federal or State Grant Programs

Did you submit this project to a Federal or State grant program other than the SCBGP for funding and/or is a Federal or State grant program other than the SCBGP funding the project currently?

Yes

If YES,

- Identify which Federal and/or State grant program

A proposal to work on a portion (only in carrots) of the critical period of weed control sub-objective was submitted to WSARE-Graduate student program in 2022.

- Describe how the SCBGP project differs from or supplements the other grant program(s) efforts.

This SCBG proposal has much broader and comprehensive objectives. The WSARE proposal (if funded) would provide primarily support for a current graduate student (e.g. tuition, research salary). If both proposals are funded, we will use the SCBG funding t

Project Funding

Provide the following information in this section:

Could the outcomes of this project be accomplished with a reduced budget?

Yes, we would accept a reduced amount that, if granted, could still accomplish the outcomes of this project.

If NO, you are indicating that the project could not be accomplished with a reduced budget (i.e. the funding decision must be "all or nothing").

If YES, indicate which areas of the project could be cut and any resulting changes in project outcomes.

Explain:	Subobjectives 1c and 1e would be cut and in objective 2 we'd reduce the number of partner farms to 4 (decreasing other costs by $8,000). The project personnel would be limited to one graduate student, reducing budget by (cutting $120,993 from personnel a

Citations (Optional)

A list of citations may be added to the application but is strictly optional.

Melander, B., I. Rasmussen, P. Barberi. 2005. Integrating physical and cultural methods of weed control-examples from European research. Weed Science 53: 369-381.
Rylander, H., A. Rangarajan, R. Maher, M. Hutton, N. Rowley, M. Mcgrath, and Z. Sexton. 2020. Black plastic tarps advance organic reduced tillage I: Impacts on soils, weed seed survival, and crop residue. Hort Science 55: 819-825.
Rylander, H., A. Rangarajan, R. Maher, M. Hutton, N. Rowley, M. Mcgrath, and Z. Sexton. 2020. Black plastic tarps advance organic reduced tillage II: Impacts on weeds and beet yield. Hort Science 55: 826-831.