2023-2024 Cabbage Funding Meeting
Cornell AgriTech
Jordan Hall Auditorium
March 2, 2023; 1pm – 4pm

1:00 – 1:15 – Welcome – Roundtable Discussion of Growing Season

1:15 -1:45 – Chris Smart (via zoom)

1:45 – 2:15 – Christy Hoepting

2:15 – 2:45 – Lynn Sosnoskie

2:45 – Board Decisions – Ag & Market Discussion

- Grower Reports
    - 2022 Crop Year Overview
    - 2023 Outlook
    - Industry Issues

- CRDP Board Motions
    - 2022-23 Budget Determination
    - 2022-23 Carryover Funds
    - 2022-23 Assessment Rate

PI Name
Hoepting, Christy
Sosnoskie, Lynn
Smart, Chris
Vegdahl, Ann

2023 - 2024 Cabbage Research and Development Program

Project Title
Optimizing Herbicide Weed Control and Crop Safety in Transplanted Cabbage
Evaluating Novel, Non-Chemical Weed Control Strategies in NY Cabbage
Surveying NY cabbage fields for a new black rot pathogen
Safety and quality evaluation of sauerkraut fermentation using postassium chloride as a substitute for sodium chloride

Total Request

Request
$11,000
$6,929
$5,310
$7,390

$12,239

Cabbage Research and Development Program
2023-2024 Proposal

Funding Period: April 1, 2023 – March 31, 2024

Project Title:

Safety and quality evaluation of sauerkraut fermentation using postassium chloride as a substitute for sodium chloride

Principal Investigator:
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Extension Associate, Department of Food Science
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Co PI's:
Randy Worobo
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Associate Director, USAID Food Safety Innovation Lab
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New Research ☒

Amount Requested: $ 7,390.20

Is this a duplicate submission to another entity **Yes** ☐ **No** ☒

Project Summary/Scope of Work:

New York is in the top three states nationally for fresh cabbage and kraut cabbage. More than 12,000 acres are used annually for production. Fresh cabbage is sold at retail and wholesale, and is used for coleslaw, egg roll filling, sauerkraut and etc. Interestingly, the majority of cabbage farmers are concentrated between Lake Ontario and the Northern Finger Lakes region. Sauerkraut is a traditional dish consumed in many parts of the world including Central and Eastern Europe, United States, and Asia. The cabbage is generally trimmed, shredded, mixed with salt, and fermented. Sauerkraut is known to have many health benefits, because it is rich in vitamins, contains probiotics, antioxidants and anticarcinogenic properties. Vegetable fermentations typically contains 2-3 % (w/w) NaCl, and sauerkraut is no different. The addition of salt is necessary in sauerkraut production for the following reasons: 1) it increases osmotic pressure which allows water and sugar to be pulled from the cabbage cells walls which are used by Lactic Acid Bacteria (LAB) 2) It prevents spoilage and pathogenic microorganisms from growing and 3) It prevents texture softening as a results of the decrease in endogenous pectolytic enzyme activity, naturally found in cabbage (1). While the addition of NaCl is essential in the production of fermented cabbage, there is pressure from consumers to reduce the salt percentage.

Excess sodium chloride has been linked to numerous heath concerns including loss of muscle mass, renal insufficiency, hypertension, cardiovascular diseases and many more (2). Therefore, it is important to reduce the amount of salt consumed in all food products, including fermented foods. Many researchers have studied the effect of no to low sodium during sauerkraut fermentation. There was an attempt to make salt free sauerkraut, but the product was not viable regarding texture and taste (3). Others showed sauerkraut and sauerkraut juice can be produced with a very low NaCl concentration as well low mineral salt percentage. The final product is often described as mushy and needs to be masked with spices or other additives (4, 5). Nevertheless, reducing salt amount in fermented products such as sauerkraut could have direct consequences for food safety.

Foodborne outbreak associated with fermented vegetables is uncommon but not unlikely. Foodborne pathogens can be found on raw vegetables, and they may be introduced because of poor manufacturing practices and hygiene. In 2012, there was *E. coli* O157:H7 outbreak in Japan associated with pickled cabbage resulting in 7 deaths. Many research studies investigated the survival of pathogens during fermentations. Inastu *et al* studied *E. coli* O157:H7 and *S. enteriditis*, *S. aureus* and *L. monocytogenes* in kimchi. *E. coli* persisted during the fermentation and remained high 4-5 log CFU/g. *S. aureus* was below the detection limit after 16 days of fermentation (6). Niksic and *et al* investigated the survival of *L. monocytogenes* and *E. coli* O157:H7 during and after lactic fermentation of sauerkraut from whole head and shredded cabbage. The pathogens persisted after 15 days of fermentation regardless of the fermentation temperatures and different salt concentrations (7). However, the survival of foodborne pathogens in low NaCl or sodium alternative like KCl has not been investigated. A study done by University of Maine in 2019 evaluated the effect of low NaCl concentrations of survival of pathogens during cabbage fermentation. That study found that there was no significant difference on the survival of *L. monocytogenes*, *S. aureus* and *E. coli* O157:H7 (1). Unfortunately, this study was not peer-reviewed and they did only 16 samples total for the entire study which is insufficient. Dupree *et al* compared the effect of various sodium chloride and calcium chloride concentration during cabbage fermentations on Lactic Acid Bacteria (LAB) and Shiga toxin producing *E. coli* O157:H7. They found there was no signigicant difference between 1.% NaCl and 1.1% $CaCl_2$. Higher salt concentration of 6% decreased the levels of *E. coli* O157:H7 to a lesser extent but LAB growth was reduced as well (8). This is all important information but they are insufficient to provide guidance to food manufacturers wanting to produce low NaCl or KCl fermented cabbages.

The production of fermented foods by small business in the US, including value added products such as sauerkraut and other fermented vegetables has increased tremendously. The Cornell Food Venture Center (CFVC) reviews and validates new food products for safety and stability. The center is essential for the food industry, and its economic impact is immeasurable. The CFVC provides guidance to thousands of food manufacturers, and validates approximately 2500 new products every year. CFVC issues a final document called a Scheduled Process or Process Review which help manufacturers meet the Food Safety Modernization Act (FSMA) regulation. Since 2015, the CFVC reviewed at least 500 vegetable fermented products. To be approved, the pH must drop to ≤ 4.40 within 24 hours, fermentation temperature between 20 and 30°C, and the salt concentration must be at least 2.25%. If those requirements are not met, CFCV will not issue a process review letter. Food producers often push back requesting approval for low sodium sauerkraut or salt aternative. Unfortunately, there is insufficient data to support the lower salt levels being able to provide sufficient protection from potential foodborne pathogen growth. While there are many peer reviewed research publications on sauerkraut fermentation, none of them provide the necessary data to approve low sodium or potassium chloride (KCl) sauerkraut.

The objectives of this project is to generate microbial data to provide better food safety guidance for fermented cabbage producers, which will increase the sale and usage of fresh cabbage in the production of value added products. In this study, we are proposing to

1) Study the physiochemical and microbial changes of reduced NaCl concentrations substituted with KCl during cabbage fermentation.

2) Evaluate the survival of *E. coli* O157:H7, *S. enterica* and *L. monocytogenes* in reduced NaCl concentrations substituted with KCl during cabbage fermentation.

Organizational Capacity:

Dr. Ann Charles Vegdahl is an Extension Associate with Food Science Department under the supervision of Dr. Randy Worobo. Ann has been working at Cornell University for 4.5 years supporting small food manufacturers helping bring new food product in the market. She worked 3 years at the Cornell Food Venture Center (CFVC) as Process Authority where she reviewed new food recipes for safety and stability. She currently manages the Microbial Food Safety Extension Lab and the Cornell High Pressure Process (HPP) Validation Center. She designs experiments and conducts shelf life study, UV validations, HPP validations, and challenge studies. She works closely with a technician and an extension specialist Jason Curran and Gerard Huminston, respectively. They primarily perform the laboratory experiments and assist in all aspect of data collection and analyses.

At Cornell AgriTech, Ann has access to a many resources. The Food Research Laboratory houses the Cornell Food Venture Center Pilot plant which is a food processing facility helping manufacturers scale up production. The Craft Beverage Institute supports the wine and craft beverage industry. They can perform many product analyses. Ann is also passionate about Diversity, Equity and Inclusion (DEI) on Cornell's campus. She served on various (DEI) committees. She currently co-leads an affinity group on campus "Minority Gender in STEM". She also was recently part of team that was awarded a Belonging at Cornell grant that is leading various DEI workshops on campus.

Objective 1: To evaluate the physiochemical and microbial changes of reduced NaCl with KCl substitution during cabbage fermentation with the goal of providing better guidance to the small food manufacturers.

Sub-ojectives include:

1) Study the physiochemical and microbial changes of reduced NaCl concentrations during cabbage fermentation
2) Study the physiochemical and microbial changes during cabbage fermentation with 2.25% potassium chloride.

Task 1.1: *Study the physiochemical and microbial changes of reduced NaCl concentrations during cabbage fermentation.* Fresh white cabbages and NaCl will be purchased from a local supplier. Cabbage will be trimmed, shredded and and mixed at the **Cornell Food Venture Center Pilot Plant**. Several batches will be prepared with different NaCl concentrations 0, 0.5, 1, 1.5, 1.75, 2 and 2.25%. Samples will be divided into 32 oz mason jars or similar container , and fermented at 20°C for 4 weeks. Sampling will be performed frequently at the beginning of fermentation. Product will be sampled on days 0, 1, 2, 3, 4, 7, 14, 21 and 28 days. The pH, the sugars (fructose, glucose, sucrose), lactic acid bacteria (LAB), and spoilage organism (yeast) will be monitored. Approximately 5 mililiter of the brine will be sent to the **Craft Beverage Institute** for the sugar analyses. The LAB and yeast counts will be determined using deMan, Rogosa and Sharpe media, Acidified Potato Dextrose Agar respectively. Microbiology experiment will be done in the **Microbial Food Extension Lab**. All experiment will be performed in triplicate.

*Study the physiochemical and microbial changes during cabbage fermentation with 2.25% potassium chloride***.** The CFVC approves vegetable fermentation with at least 2.25% NaCl. The proposed study will help us determine if KCl is a suitable substitute for NaCl during cabbage fermentation. Similar to Objective 1, cabbage will be prepared in the **Cornell Food Venture Center Pilot Plant**. There will be two batches, one with 2.25% KCl and the other 2.25% NaCl for comparison. Cabbage will be measured in 32 oz jars, and fermented for at 4 weeks. Products will be sampled on Day 0, 1, 2, 3, 4, 7, 14, 28 days. The pH, the sugars, LAB and spoilage count will be monitored. Approximately 5 mililiter of the brine will be sent to the **Craft Beverage Institute** for the sugar analyses. The LAB and yeast counts will be determined using deMan, Rogosa and Sharpe media, Acidified Potato Dextrose Agar. Experiments will be performed in triplicate.

Performance Measure 1.1.1
Early June 2023-August 2023. Cabbage will be purchased and laboratory experiments will be performed. And data will be collected.

Performance Measure 1.1.2
September -November 2023. Data analysis and summary.

Performance Measure 1.1.3
December- March 2024. Write final report. Report to CRDP. Create extension materials and publicized results in the appropriate newsletter and journal.

Objective 2: Evaluate the survival of *E. coli* O157:H7, *S. enterica* and *L. monocytogenes* in reduced NaCl concentrations substituted with KCl during cabbage fermentation.
Sub-ojectives include:

1) Study the survival of *E. coli* O157:H7, *S. enterica, and L. monocytogenes* in reduced NaCl substituted with KCl concentration during cabbage fermentation.

2) Study the survival of *E. coli* O157:H7, *S. enterica* and *L. monocytogenes* in during cabbage fermentation with 2.25% KCl.

Task 2.1: *Study the survival of E. coli O157:H7, S. enterica and L. monocytogenes in reduced NaCl concentrations during cabbage fermentation*. Shredded cabbbage will be mixed with different NaCl concentrations at the **Cornell Food Venture Pilot Plant**. They will dispensed in 8 oz mason jar or similar container. Samples will be transferred to the **Microbial Food Extension Laboratory**. Each jar will be inoculated with a cocktail of 5-strains of *E. coli* O157:H7, *S. enterica* and *L. monocytogenes* separately. The initial inoculum (~3-4 log CFU/g) needs to be low enough to monitor the potential growth of the pathogens, and high enough so we can monitor the death over time. Products will be sampled on 0, 6 h, 12 h, 24h, and days 2, 3, 4, 7. The microbial counts will be analyzed using Violet Red Bile Agar for *E. coli* O157:H7, Bismuth Sulfate Agar for *Salmonella,* and Modified Oxford Agar for *L. monocytogenes,* respectively. Experiments will be performed in triplicates.

Study the survival of E. coli O157:H7, S. enterica, and L. monocytogenes in during cabbage fermentation with 2.25% KCl. Shredded cabbage will be mixed with 2.25% NaCl and KCl at the **Cornell Food Venture Pilot Plant**. They will be dispensed in 8 oz mason jar or similar container. Samples will be transferred to the **Microbial Food Extension Laboratory**. Each jar will be inoculated with ~3-4 log CFU of *E. coli* O157: H7, *S. enterica* and *L. monocytogenes* separately. The initial inoculum need to be low enough to mProduct will be sampled on Day 0, 1, 2, 3, 4, 7. The microbial counts will be determined using Violet Red Bile Agar for *E. coli* O157:7, Bismuth Sulfate Agar for *Salmonella*, and Modified Oxford Agar for *L. monocytogenes* respectively. Experiments will be performed in triplicates.

Performance Measure 2.1.1
Early June 2023-August 2023. Cabbage will be purchased and laboratory experiments will be performed. And data will be collected.

Performance Measure 2.1.2
September -November 2023. Data analysis and summary.

Performance Measure 2.1.3
December- March 2024. Write final report. Report to CRDP. Create extension materials and publicized results in the appropriate newsletter and journal.

Outcome and Benefits Expected:
The objectives of this proposal is to assess the microbial safety of low sodium and sodium alternative during cabbage fermentation. This is to help small manufacturers to produce an heathier and safer sauerkraut. The data generated will help us know the minimum salt concentration that allows LAB to thrive and still inhibit pathogen growth. This data will have huge economical impact for sauerkraut manufacturers wanting to produce healthier and safer sauerkraut.

Research Experience Relevant to the Proposal:
Ann Charles Vegdahl received her doctorate degree in Microbial Biology at Rutgers University in 2017. For the last 4.5 years, she supports small food manufacturers helping them bring new products in the market. She worked as Process Authoriy reviewing new food recipes for safety and stability. In her current role, she conducts shelf life studies, microbial challenge studies, HPP and UV validation studies supporting. She is interested in traditional fermented foods.

Budget: –

2023-24 Budget Sheet				
Vegdahl- Safety and quality evaluation of sauerkraut fermentation using postassium chloride as a substitute for sodium chloride				
SALARY				
POSITION TITLE (non-Exempt) **Example: Extension Associate, Technician, Temp Service Tech**	**HOURLY PAY RATE PER POSITION**	**STANDARD WORK HOURS PER WEEK**	**NUMBER OF WEEKS FUNDED**	**TOTAL**
Temp Service Tech, Unbanded, 10986	$15.00	20	12	$3,600.00
			Subtotal	$3,600.00
TOTAL SALARY				
			SALARY TOTAL	$3,600.00
OPERATING EXPENSES - TYPE/DESCRIPTION				**TOTAL**
Materials & Supplies - Field and lab supplies				$2,663.00
			OPERATING EXPENSES - TOTAL	$2,663.00
OTHER EXPENSES - TYPE/DESCRIPTION				**TOTAL**
Indirect Costs - Direct Costs x 18%				$1,127.00
			OTHER EXPENSES - TOTAL	$1,127.00
			Total Funding	**$7,390.00**

Budget Justification: .

Salary and Wages- $3,600

Temporary Laboratory Technician: These funds will be used to support a summer staff that will help with experiment, data collection, and data analysis.

Materials and Supplies-$2,663

Petri Dish (2 boxes of 500 each),Potato Dextrose Agar (500g),Violet Red Bile Agar (500 g),DeMan Rogosa Sharpe Agar (500g), Modified Oxford Agar (500g), Oxford Agar Supplement, Bismuth Sulfate Agar (500 g) Stomacher Bags, Fresh Cabbage, Mason Jars or similar containers.

Other Expenses- $1,127

Indirect costs 18%

References

1. Khanna S. 2019. Effects of salt concentration on the physicochemical properties and microbial safety of spontaneously fermented cabbage. The University of Maine.
2. Ortega RM, López-Sobaler AM, Ballesteros JM, Pérez-Farinós N, Rodriguez-Rodriguez E, Aparicio A, Perea JM, Andrés P. 2011. Estimation of salt intake by 24 h urinary sodium excretion in a representative sample of Spanish adults. British Journal of Nutrition 105:787-794.
3. Owades JL. 1991. Method of making salt/free sauerkraut. Google Patents.
4. Viander B, Mäki M, Palva A. 2003. Impact of low salt concentration, salt quality on natural large-scale sauerkraut fermentation. Food Microbiology 20:391-395.

5. Wiander B, Ryhänen E-L. 2005. Laboratory and large-scale fermentation of white cabbage into sauerkraut and sauerkraut juice by using starters in combination with mineral salt with a low NaCl content. European Food Research and Technology 220:191-195.
6. Inatsu Y, Bari M, Kawasaki S, Isshiki K. 2004. Survival of Escherichia coli O157: H7, *Salmonella enteritidis*, *Staphylococcus aureus*, and *Listeria monocytogenes* in Kimchi. Journal of food protection 67:1497-1500.
7. Niksic M, Niebuhr SE, Dickson JS, Mendonca AF, Koziczkowski JJ, Ellingson JL. 2005. Survival of *Listeria monocytogenes* and *Escherichia coli* O157: H7 during sauerkraut fermentation. Journal of food protection 68:1367-1374.
8. Dupree DE, Price RE, Burgess BA, Andress EL, Breidt F. 2019. Effects of sodium chloride or calcium chloride concentration on the growth and survival of *Escherichia coli* O157: H7 in model vegetable fermentations. Journal of food protection 82:570-578.

Cabbage Research and Development Program
2023-2024 Proposal

Funding Period: April 1, 2023 – March 31, 2024

Project Title:
Evaluating Novel, Non-Chemical Weed Control Strategies in NY Cabbage

Principal Investigator:
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229-326-2676

New Research ☒

Amount Requested: $6,928

Project Summary/Scope of Work:

Weed management remains one of the highest research priorities for the CRDP. Weeds that evade control can compete, directly, with the cabbage crop for water and nutrients, resulting in yield loss. Weeds can also interfere with production operations, indirectly, by impeding harvest. Additionally, weed seeds can contaminate cabbage heads reducing their quality and increasing the labor required to clean them up. Furthermore, weeds of the mustard family, such as Shepherd's purse, field pennycress and wormseed mustard, can serve as alternate hosts for the pathogens that cause Alternaria leaf spot, bacterial black rot, and club root diseases. While herbicides are significant components of cabbage production programs, the limited number of registered products and their narrow spectrums of control can result in significant in-season escapes and require the need for costly hand-weeding. Furthermore, the number of companies involved in the discovery and registration of new crop protection chemicals has decreased by more than 70% over the last 40 years. An additional concern is the classification of important agricultural pesticide active ingredients as "forever chemicals" or chemicals identified as per- and polyfluoroalkyl substances (PFAS) (https://www.epa.gov/pesticides/pfas-packaging). According to the US EPA (Per- and Polyfluoroalkyl Substances (PFAS) | US EPA):

- *PFAS are widely used, long lasting chemicals, components of which break down very slowly over time. PFAS are found in water, air, fish, and soil at locations across the nation and the globe*
- *Because of their widespread use and their persistence in the environment, many PFAS are found in the blood of people and animals all over the world and are present at low levels in a variety of food products and in the environment.*
- *Scientific studies have shown that exposure to some PFAS in the environment may be linked to harmful health effects in humans and animals.*

While significant effort has focused on fluorinated packaging, the state of Maine has listed numerous active ingredients as possible PFAS chemicals, including trifluralin and oxyfluorfen, which are important herbicides in cabbage production (https://www.maine.gov/dacf//php/pesticides/documents2/bd_mtgs/Oct22/3a-2022%20PFAS%20October%20Memo%20Tox.pdf). Even though there is no immediate threat to these chemicals in NYS, awareness about their PFAS status and thoughtful investigation of novel weed management strategies is crucial.

According to Melander et al. (2015, Crop Protection 72:1-8): "*Non-chemical methods will be necessary to fill the gaps where herbicides are no longer available or where those approved do not cover the spectrum of weed species causing problems*". This includes camera-guided, "intelligent" cultivators, which have been successfully deployed in minor crops in Europe, the Salinas and Imperial Valleys of California, and in Arizona. In 2022, Cornell AgriTech purchased a camera-guided K.U.L.T. cultivation unit (K.U.L.T.iVision PV – KULT Kress – German Engineered Fingerweeder & High-End Agriculture Equipment (kult-kress.com)) for use in annual cropping systems, including vegetables, to manage weeds under no-herbicide and reduced-herbicide production environments. The Cornell unit uses a camera to detect row patterns and guide the cultivation system to follow the rows (i.e., adjust to deviations or "wobbles"). Another less explored strategy is interrow mowing (Row Shaver System - Rowshaver Weed Management System, IRM-X4 Inter-Row Mower | R-Tech (r-techind.com)), which uses shrouded cutting tools to eliminated unwanted vegetation. Interrow mowing is actively being evaluated at Cornell University in the lab of Dr. Matt Ryan (Weed between the lines: Inter-row mowing for weed control in row crops - YouTube) for the control of weeds in no-till, organic soybean production.

The goal of this proposed project is to evaluate the performance of smart cultivation and interrow mowing for early weed control in commercial cabbage production. The desired outcomes include increased knowledge about the efficacy and safety of novel weed control technology in cabbage and guidance for growers, both organic and conventional, looking to adopt new tools for the control of unwanted vegetation in-crop.

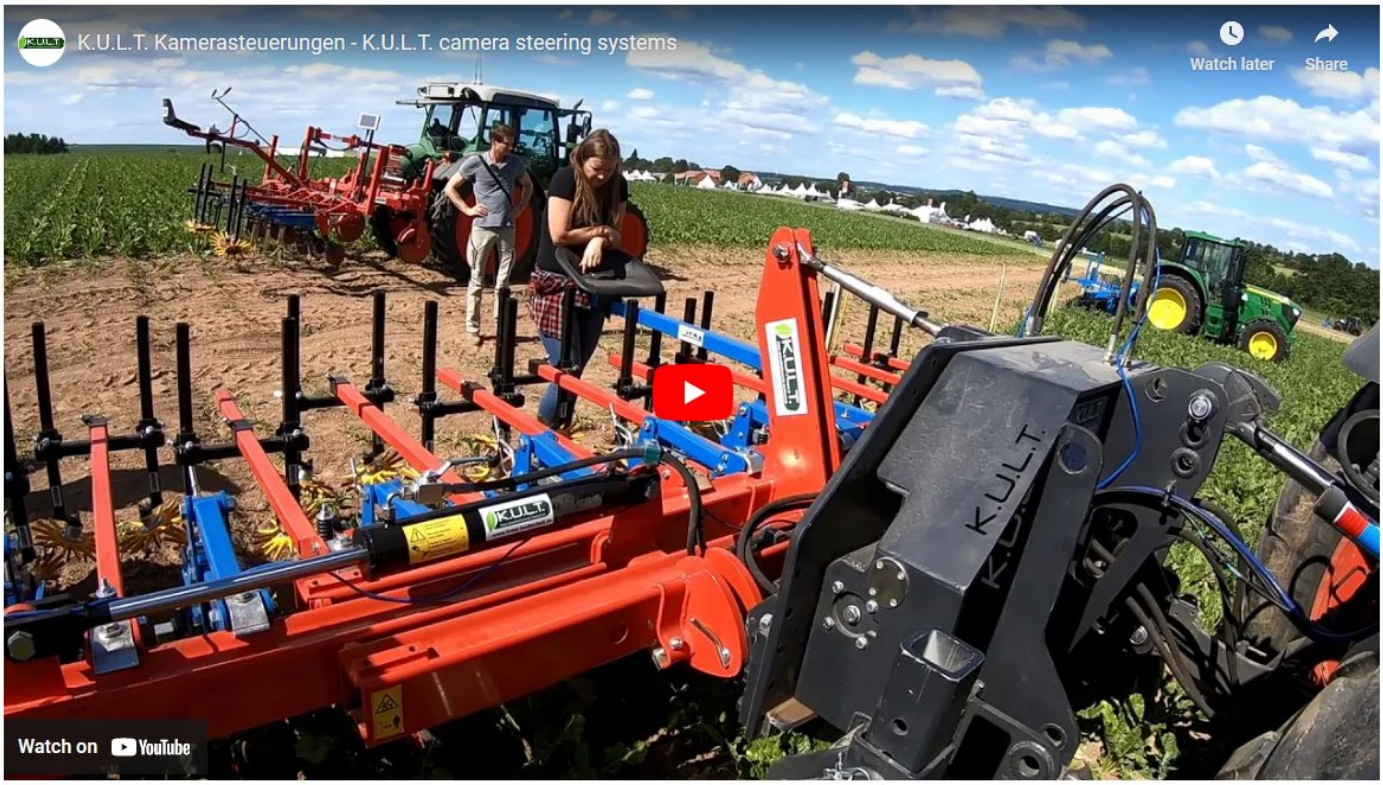

Figure 1. A K.U.L.T Kress live-image camera guidance weeder.

<u>Organizational Capacity</u>: Describe the staffing, qualifications and ongoing staff development/training activities, and relevant experience of the provider organization (Cornell University) to support the project.

Sosnoskie received in PhD in Weed Science from Ohio State University in 2005. For the last 16 years she has worked, extensively, in annual specialty crop systems in Georgia and California. Much of her research has focused on identifying strategies to maximize weed management within and across cropping seasons to build more resilient and sustainable production environments. Sosnoskie contributes extensive experience working with the herbicides included in this trial (with respect to both weed control efficacy and crop safety concerns). At Cornell AgriTech in Geneva, Dr. Sosnoskie has conducted three years of research activities, both in the field and in the greenhouse to evaluate weed control and crop safety in cole crops, other fresh market and processing vegetables, hemp, perennial fruit crops, and hops.

At Cornell AgriTech, Sosnoskie has access to a minimum of 7 acres of annual crop land for weed control research. The research farm in Geneva is equipped with the necessary tractors, transplanters, and spray rigs to establish and maintain trials; Sosnoskie's program owns CO2-pressurized backpack sprayers to apply treatments to individual plots. The Sosnoskie lab are the primary operators of a K.U.L.T. camera-guided cultivation system (https://kult-kress.com/kultivision-pv/) and have access to mowing equipment for treatment implementation. Weather stations

supported by the Northeast Weather Association (NEWA) are located on the AgriTech farms to generate real-time weather data summaries and IPM forecasts.

With respect to staffing, more than 20 technical personnel are employed by AgriTech during the summer, all of whom are available to assist with greenhouse and large-scale field activities. Currently, Sosnoskie's lab consists of a full-time technician, a technical research assistant, and three graduate students. Last summer, four temporary summer hires assisted with summer studies and a similar amount are expected to be hired in 2023. All staff at Cornell receive training regarding best worker safety practices when participating in research activities. This includes responses to inclement weather and avoiding heat-related illnesses. All safety-related training is updated yearly.

Cornell is and Equal Opportunity Employer and is committed to inclusion. As such, all employees are required to take anti-discrimination and workplace diversity training.

Objective 1: **Describe the weed control efficacy and crop injury potential of a tractor drawn, camera-guided cultivator and an interrow mower in transplanted cabbage.**

Task 1.1 New, commercially available weed control technologies can manage weeds both between and within crop rows, including around the base of crop plants. Camera guidance allows for tighter/closer cultivation, which dramatically improves performance from a weed control standpoint. Because camera-based systems self-adjust to "follow the row", the safety and speed of cultivation operations also increases. Studies conducted in cabbage in Europe showed that camera-guided (also called 'intelligent weeding') was almost equal to the standard herbicide treatment with respect to weed control and better than conventional (i.e., 'non-intelligent') cultivation practices (Melander et al. 2005. Crop Protection 72:1-8). Interrow mowing has been explored in agronomic cropping systems (e.g., corn, soybean, small grains) and can be an effective tool for weed suppression particularly when paired with banded, in-row herbicides (Donald et al. 2001. Weed Technology 21:576-584; .

We will conduct field trials to evaluate the efficacy and safety of camera-guided cultivation and interrow mowing alone and in combination with each other and with pre-emergence herbicides in cabbage with the goal of identifying tradeoffs between weed control efficacy and crop injury. Studies will be conducted Cornell's AgriTech facility in Geneva, NY; soil at the station is a Honeoye loam with a lower clay surface. The Honeoye series is the state soil of New York, covering 500,000 acres in the state. Field selection will focus on existing infestations of problematic weed species including ragweed, lambsquarters, pigweeds, barnyardgrass and foxtails. Treatments will be arranged as a randomized complete block design with 3-4 replications. Individual plots will be 2 rows of cabbage wide (~5 feet) and 30 to 50 feet long. Cabbage transplants will be placed in rows using a C&M UniTrium transplanter and then set with overhead sprinkler irrigation to reduce shock. Crop production (e.g. fertility) and pest management practices, except for weed control, will adhere to guidelines established by Cornell university for commercial systems.

Experimental treatments (Table 1) will include non-treated (weedy) and herbicide (weed free) controls. The herbicide control will include GoalTender applied at 16 oz/A pre-transplant and Dual Magnum at applied at 0.67 pt/A post-transplant with postemergence herbicides used if needed. Interrow mowing will be applied twice with an interval of 10-14 days between treatments beginning 10 to 14 days after transplanting, based on crop and weed development stages. Camera-guided cultivation will be applied similarly to the interrow mowing, i.e., two times at 10 to14-day intervals beginning 10-14 days after transplanting. It will include the use of stacked sweeps and finger weeders following the work of Brown et al (2018, Improving mechanical in-row weed control for vegetables and row crops (cornell.edu)). Mowing

and cultivation events will be limited to no more than two times early in the season to as later and more frequent operations can reduce head quality and yield. Soil moisture conditions at the time of weeding will be recorded.

Table 1. Proposed treatments for the study to evaluate novel, non-chemical weed control strategies in cabbage.

Treatment	Timing
Weedy Control	N. A.
Herbicide Control	GoalTender 16 oz pre-transplant, Dual Magnum 0.67 pt/A post-transplant, postemergence herbicides as needed
Interrow Mowing	Two times (10 to 14 day separation between events) beginning 10 to 14 days after transplanting depending on crop and weed development
Conventional Cultivation	Two times (10 to 14 day separation between events) beginning 10 to 14 days after transplanting depending on crop and weed development
Camera-Guided Cultivation	Two times (10 to 14 day separation between events) beginning 10 to 14 days after transplanting depending on crop and weed development
Interrow Mowing plus Camera-Guided Cultivation	Two times (10 to 14 day separation between events) beginning 10 to 14 days after transplanting depending on crop and weed development
Interrow mowing and cultivation can also be integrated with an herbicide program where a single mowing or cultivation event occurs 20 to 28 days after transplanting depending on crop and weed development.	

Performance Measure 1.1.1
May-June, 2023. Establish cabbage research trial at Cornell AgriTech in Geneva, including the implementation of herbicide, mowing, and cultivation treatments.

Performance Measure 1.1.2
June-August, 2023. Weed control: Total weed cover per plot will be visually rated on a scale of 0% (no weeds) to 100% (complete weed cover) at 7, 14, 21, and 28 days after each treatment application. Weed density counts, both in-row and between-row, will also be taken at the same time. All species will be identified and counted in replicate 50 cm by 50 cm quadrats in each plot. Weed biomass estimates will be collected at harvest.

Performance Measure 1.1.3
June-August, 2023. Crop safety and yield: Crop injury will be rated on a scale of 0% (no injury) to 100% (complete crop death) at 7, 14, 21, and 28 days after each treatment application. Specifically, we will evaluate stand loss due, leaf and stem damage, and stunting. The weights and diameters of individual cabbage heads will be collected at harvest.

Performance Measure 1.1.4
September-November, 2023. Data entry, analysis, and summary.

Performance Measure 1.1.5
December, 2023-March, 2024. Write final report. Report to CRDP. Communicate results to stakeholders at field days and Cornell Cooperative Extension sponsored meetings.

Outcome and Benefits Expected:
Determine if interrow mowing and camera-guided cultivation can effectively eliminate weeds in transplanted cabbage compared to standard herbicide treatments

1. Determine if interrow mowing and camera-guided cultivation is safe to use in transplanted cabbage compared to standard herbicide treatments
2. Describe the tradeoffs between weed control and crop injury for novel non-chemical technologies
3. Present results to local and regional stakeholders and industry representatives, host field demonstrations, support dialog with equipment manufacturers

Accomplishments/Benefits to Date:
In 2020, NuFarm acquired marketing rights in 2020 to the Goal 2XL and GoalTender brands that had previously been held by Corteva. As part of the transition of the Goal brands, supplemental labels needed to be renewed, including the post-emergence 24c registration. Dr. Sosnoskie used data from 2020 research trials to generate a document in support NuFarm's submission to the DEC. In 2021, Dr. Sosnoskie had conversations with the weed scientist in the USDA's Office of Pest Management Policy to discuss potential label changes for numerous herbicide active ingredients, including oxyfluorfen, according to the EPA's recently released Preliminary Interim Decisions (PIDs). Data generated in 2020 Field trials confirming the safety and efficacy of the oxyfluorfen were included in the talks, as well as impressions collected from CCE specialists about the possible impacts of label changes for cabbage growers in New York.

In 2021, Sosnoskie conducted research with a novel formulation of pyridate (Lentagran, from Belchim Crop Protection) that is registered for use in cole crops in Europe. Despite acceptable safety data in NY trials (less than 5% crop injury), the manufacturer decided not to proceed with the registration because of damage observed in other US cabbage production regions. Field trials in 2022 found that the substitution of an encapsulated formulation of acetochlor (Warrant, Bayer Crop Science) was as safe or safer to use as S-metolachlor (Dual Magnum, Syngenta) in cabbage and broccoli when included as part of a diversified herbicide program. When used as a post-transplant application, in combination with GoalTender, mean head weights in Warrant treated plots were 300% to 400% greater than those from untreated check plots. The same trial was also conducted at Rutgers University; collective data will be shared with the USD IR-4 Project and the manufacturer in support of residue testing for potential label expansion. Data is also being prepared for publication in Weed Technology.

Dr. Sosnoskie has received additional grant support (USDA-SCRI) to investigate the potential for adopting novel weed control technology in specialty crops, including cabbage. Producers in New York have actively expressed interest in these new weed management tools and strategies because of 1) widespread herbicide resistance, 2) a slowdown in the registration and release of new active ingredients, 3) concerns about crop safety and worker health, and 4) changes in public perception regarding the sustainability of local, regional, and national agriculture. As part of a nationwide team of weed scientists, Sosnoskie has helped to develop a survey to describe current producer weed management practices and identify grower interest in and barriers to the adoption of novel weed control technology. A full SCRI proposal is being prepared to selectively acquire and evaluate equipment that regional growers have explicitly expressed interest in.

Research Experience Relevant to the Proposal
Sosnoskie received in PhD in Weed Science from Ohio State University in 2005. For the last 16 years she has worked, extensively, in annual specialty crop systems in Georgia and California. Much of her research has focused on identifying strategies to maximize weed management within and across cropping seasons to build more resilient and sustainable production environments. Sosnoskie contributes extensive experience working with the herbicides included in this trial

(with respect to both weed control efficacy and crop safety concerns). At Cornell AgriTech in Geneva, Dr. Sosnoskie has conducted two years of research activities, both in the field and in the greenhouse to evaluate weed control and crop safety in cole crops. This includes trials that have been conducted in support of renewing 24c labels and facilitating the registration of new chemistries. In addition to cabbage and broccoli studies, Dr. Sosnoskie and her team also conduct research on other fresh market and processing vegetables including sweet corn, pumpkins, snap beans, carrots, and beets. With respect to novel technology, Sosnoskie has been in discussion with precision sprayer and cultivator manufacturers such as Vision Robotics, Carbon Robotics, Verdant Robotics, Naiö, Farmwise, Garford, Trimble, Kult Kress, and Blue River Technology to identify equipment will be best suited for New York production conditions

Budget: –

2023-24 Budget Sheet

Sosnoskie-Evaluating Novel, Non-Chemical Weed Control Strategies in NY Cabbage

SALARY				
POSITION TITLE (non-Exempt) **Example: Extension Associate, Technician, Temp Service Tech**	**HOURLY PAY RATE PER POSITION**	**STANDARD WORK HOURS PER WEEK**	**NUMBER OF WEEKS FUNDED**	**TOTAL**
Technician I, Band A, 10952	$18.00	8	12	$1,728.00
Temp Service Tech, Unbanded, 10986	$16.00	8	12	$1,536.00
			Subtotal	$3,264.00
TOTAL SALARY				
			SALARY TOTAL	$3,264.00

OPERATING EXPENSES - TYPE/DESCRIPTION	TOTAL
Materials & Supplies - Field and lab supplies	$1,000.00
Services:	
Fuel (Cornell Pumps) (Program Vehicle) (27 gallons x $4.47 gallon)	$120.00
Geneva Farm Crew Services - General or Pesticide Labor	$740.00
Geneva Farm Crew Services - Set-up fee for pesticide spraying or equipment preparation time.	$247.00
FRU Land Use	$500.00
OPERATING EXPENSES - TOTAL	$2,607.00

OTHER EXPENSES - TYPE/DESCRIPTION	TOTAL
Indirect Costs - Direct Costs x 18%	$1,057.00
OTHER EXPENSES - TOTAL	$1,057.00
Total Funding	**$6,928.00**

Budget Justification:

Wages and Salary - $3,264
Research Technician: These funds will be used to support trial design, treatment application, data collection, data analysis, and outreach (Sosnoskie Program)

Temporary Summer Technician: These funds will be used to support trial design, treatment application, data collection, data analysis, and outreach (Sosnoskie Program)

Operating Expenses - $2,607
Materials and Supplies: Seeds and transplants, stakes, flags

Services:
Fuel Cornell Pumps (Program Vehicle): Fuel the program vehicle to visit field sites. 27 gallons @ $4.47/gallon

Geneva Farm Crew Charges for plot maintenance (spraying, mowing and pruning (Sosnoskie Program)

Geneva Farm Crew Services: Set-up fee for pesticide spraying or equipment preparation time calculated at 1/3 of Labor cost (Sosnoskie Program)

FRU Land Use: 1 acre

Other Expenses: **$1,057**
Indirect Costs 18%

Cabbage Research and Development Program
2023-2024 Proposal

Funding Period: April 1, 2023 – March 31, 2024

Project Title:
Surveying NY cabbage fields for a new black rot pathogen

Principal Investigator:
Christine Smart
Section of Plant Pathology and Plant- Microbe Biology
School of Integrative Plant Science Cornell University
cds14@cornell.edu

New Research ☒

Amount Requested: $5,310

Is this a duplicate submission to another entity **Yes** ☐ **No** ☒

- If funding is also being sought from other sources to support the proposed project is it
- Full Funding ☐ Partial Funding ☐
- Indicate the following: Smart is working with breeders and pathologists from around the US to improve control strategies for black rot. She will be submitting a planning grant to the USDA in January to bring together public and private researchers to develop objectives specifically to control black rot in brassicas, and these objectives will be part of a large USDA grant to be submitted in about a year. The funds she is requesting from CRDP will be used to collect data that will be needed for the USDA grant. There is no overlap between the research conducted as part of this project and the USDA grants that will be submitted in the future.

Project Summary/Scope of Work:
Black rot of crucifers caused by the bacterium *Xanthomonas campestris* pv. *campestris* (*Xcc*), is one of the most important diseases of cabbage in New York and is listed as a top priority for research by the Cabbage Research and Development Advisory Board. Past CRDP-funded work by the Smart lab has shown that *Xcc* is introduced into the state each year, resulting in a highly diverse pathogen population. The recent variety trials conducted by the Smart lab showed that commercial cabbage varieties grown in New York have different levels of susceptibility to five genetically different isolates of *Xcc*. Smart has recently learned that the bacterium *Xanthomonas perforans* (normally attacking tomato causing bacterial spot) was isolated from at least two different cabbage fields in Florida. While only representing a small fraction of the isolated collected from diseased cabbage (roughly 4 out of 200 isolates) it is alarming that these *X. perforans* isolates can cause systemic black rot in cabbage and can also cause leaf spots on tomato. In contrast, isolates of *X. perforans* collected from tomato do not cause disease on cabbage. It is critical to survey black rot outbreaks across NY to determine if isolates of *X. perforans* are causing disease here as well. Colleagues in Florida are currently looking at aggressiveness of these new isolates on different cabbage cultivars as well as different brassica crops.
The overall goal of this project is to determine if *X. perforans* is causing black rot in NY.

Black rot outbreaks on cabbage, (and potentially cauliflower and other cruciferous crops, but the focus is on cabbage) will be located and samples collected from growing regions throughout NY with the help of extension educators, crop consultants and growers. The black rot pathogen will be isolated from leaf tissue of each sample and grown on culture medium. We will also sample symptomatic weed leaves that are in or near fields with outbreaks. Because it is impossible to tell the difference between Xcc and *X. perforans* on culture medium, isolate will be screened using a DNA-based PCR assay. All isolates collected will be immediately frozen and added to the culture collection of isolates from NY. If any bacterium other than Xcc is identified, we will perform greenhouse assays to determine pathogenicity.

Organizational Capacity:
Smart has technical staff that will isolate the pathogen from the cabbage or weed leaves. They will also perform PCR to determine the identity of all isolates collected. This will enable us to determine if the new black rot pathogen is in NY.

Objective 1: Rigorously sample fields and transplant production greenhouses where black rot outbreaks are observed.

Task 1.1 Collect diseased cabbage and weed leaves from cabbage fields or transplant production greenhouses where black rot outbreaks are observed.

Performance Measure 1.1.
We will perform a minimum of 100 bacterial isolations, and up to 300 isolations from fields with black rot outbreaks

Performance Measure 1.1.2
All isolates will be frozen and added to the NY black rot bacterial collection

Objective 2: Determine the causal organism of black rot that was isolated from each infected leaf from objective 1.

Task 2.1 Perform PCR assay with species-specific PCR primers to determine the identity of each isolate collected

Performance Measure 2.1.1
Species identification will be completed for each of the 100-300 isolates collected during the 2023 season.

Task 2.2 Perform greenhouse assays using any bacteria other than Xcc that were identified in task 2.1.

Performance Measure 2.2.1
All non-Xcc isolates will be tested on three cabbage cultivars.

Outcome and Benefits Expected:
Outcome Objective 1: The NY survey will provide knowledge of the diversity of pathogens that cause black rot of cabbage in NY. Depending on disease severity and occurrence in 2023, we will collect 100-300 isolates from diseased cabbage fields and they will be used in the molecular assays of objective 2.

Outcome Objective 2: We will know if *X, perforans* is common, and if there are new isolates of Xcc. The PCR-based DNA analysis will identify bacterial pathogens isolated in objective 1 and provide a 2023 snapshot of the pathogens causing disease in NY.

Research Experience Relevant to the Proposal:
Smart has worked on black rot of cabbage since she started as an assistant professor in 2003. She is well-known by the industry and has provided information on the source of inoculum from epidemic outbreaks in the past.

Budget: –

2023-24 Budget Sheet				
Smart -Surveying NY cabbage fields for a new black rot pathogen				
OPERATING EXPENSES - TYPE/DESCRIPTION				**TOTAL**
Materials & Supplies - Field and lab supplies				$4,500.00
			OPERATING EXPENSES - TOTAL	$4,500.00
OTHER EXPENSES - TYPE/DESCRIPTION				**TOTAL**
Indirect Costs - Direct Costs x 18%				$810.00
			OTHER EXPENSES - TOTAL	$810.00
			Total Funding	**$5,310.00**

Budget Justification:

Materials and Supplies: Funds are requested to pay for supplies to isolate and characterize pathogens causing black rot in NY. **For isolation**, supplies include: Petri dishes, bleach, scalpels, agar, media ingredients (yeast, dextrose, calcium carbonate), Sharpie markers to label Petri dishes, microbiology loops, glycerol, cryovials, MicroBank vials for isolate freezer storage. This will cost $2,000 for a minimum of 100 isolates. **For characterization**, supplies include: DNA extraction kits, microfuge tubes, PCR reagents, pipette tips, agarose for gel electrophoresis. This will cost $2,500 for a minimum of 100 isolates.

Other Expenses: $810
Indirect Costs 18%

Cabbage Research and Development Program
2023-2024 Proposal

Funding Period: April 1, 2023 – March 31, 2024

Project Title:
Optimizing Herbicide Weed Control and Crop Safety in Transplanted Cabbage

Principal Investigator:
Christy Hoepting
Senior Extension Associate, CCE Cornell Vegetable Program
12,690 State Route 31, Albion, NY 14411
cah59@cornell.edu; 585-721-6953

Continued Research ☒

Amount Requested: $11,000

Is this a duplicate submission to another entity **Yes** ☐ **No** ☒

If this is a multiple year project, the following **MUST** be completed:

- Year in which project began: 2017 (Telenko & Hoepting), 2018 (Wallace), 2019 (Hoepting), 2020, 2021, 2022 (Sosnoskie & Hoepting)
- Anticipated years remaining for project: as necessary
- Estimated total cost of project: $7,000 to $10,000 per year

Project Summary/Scope of Work:

Weed escapes compete with the cabbage crop for nutrients and can directly cause yield loss, as well as interfere with harvest operations. Additionally, weed seeds can contaminate cabbage heads, reducing their quality and increasing the labor required to clean them up. Brassica weeds such as Shepherd's purse and marsh yellowcress can harbor diseases including Alternaria leaf spot, bacterial black rot and club root, which can spread to the cabbage crop, as well as carry these diseases over to the next cabbage crop grown in rotation. With labor issues on the rise including availability of workers, increased minimum wage and minimum 60-hour work week (40-hour week to be phased in by 2032), **reducing the need to hand weed cabbage would be desirable. Weed management continues to be a high priority for the Cabbage Research and Development Program (CRDP).**

Cabbage removed from Command label. Command (WSSA group 13) was applied pre-transplant (PRE-T) as a surface application primarily for control of velvet leaf, but it also had some activity (= fair) on Lamb's quarters (LQ), ragweed (RW), smartweed (SW), hairy galinsoga (HG), Shepherd's purse and some grasses (Fall panicum and foxtails). Prowl H2O should be as good as Command on VL, and Goal products also has some activity (fair to good). Although, we have not generated data on VL specifically in our on-farm trials yet, we anticipate that the loss of Command should be compensated for in the programs that we are developing that include Goaltender and Prowl H2O.

Dual Magnum (WSSA group 15) + Goaltender (WSSA Group 14). Dual Magnum is labeled in cabbage from 0.5 to 1.3 pt/A PRE-T or within 48 hours of transplanting (POST-T), while Goaltender 0.5-1 pt/A is labeled PRE-T. Goaltender 4-6 fl oz (maximum 8 fl oz per crop) is also labeled for post-emergent weed control from 14 days after planting (DAP) to within 36 days of harvest with a maximum 1 pt allowed between PRE-T and POST-T. CRDP-funded on-farm trials from 2019 to 2022 have demonstrated that **Dual Magnum 1 pt + Goaltender 0.5 pt is one of the most effective treatments for broad spectrum weed control** including RW, LQ, pigweed (PW), mustards (such as marsh yellowcress and Shepherd's purse), purslane and annual grasses, and is the only cabbage herbicide with activity on yellow nutsedge (YNS). However, **the crop safety of this combination has been variable.** In 2021, Goaltender 0.5 pt PRE-T + Dual Magnum 1 pt POST-T was safe (0-3.8% injury, maximum 7%) in both plug and bareroot cabbage herbicides trials, but in 2020 this treatment resulted in almost 20% injury from stunting and necrosis. In 2021 trials, Goaltender 0.5 pt + Dual Magnum 1 pt PRE-T reached 26% injury 23 days after treatment (DAT). POST-T application of Goaltender 0.5 pt + Dual Magnum 1 pt had ≤ 10% injury in 2021 and 2019 plug trials, but had 40% injury in the 2021 bareroot cabbage herbicide trial. In 2022 trial, where Dual Magnum + Goaltender was used in combination with Command 8 fl oz PRE-T, plant quality was highly variable and there were no significant differences between tank mixes of Dual Magnum 1 pt + Goaltender 0.5 pt applied PRE-T or POST-T or when applied separately in different order between PRE-T and POST-T. The labeling of these products is such that Goaltender be applied PRE-T followed by (fb.) Dual Magnum POST-T for least risk of crop injury.

In 2022 trial, increasing the rate of Goaltender from 0.5 pt to 1 pt PRE-T fb. Dual Magnum 1 pt did not affect injury or weed control. Weed pressure was quite low in the 2022 trial, and it is expected that the higher rate of Goaltender would improve weed control significantly, especially of RW, LQ and VL. In 2022 trial, decreasing rate of Dual Magnum from 1 pt to 0.5 pt when used with high rate of Goaltender (1 pt) resulted in less injury. Generally, crop injury in the form of stunting (plus necrosis if applied POST-T) caused by Dual Magnum is more severe than necrosis type of injury caused by Goaltender. Plants that initially take a beating from Goaltender usually grow out of the injury within 2 weeks, whereas stunting from Dual Magnum often continues to worsen for 3 weeks or more before plants grow out of the injury. **It is worthwhile to pursue Dual Magnum + Goaltender combinations that use higher rate of Goaltender 1 pt and lower rate of Dual Magnum 0.5 pt for improved crop safety and comparable weed control.**

Satellite Hydrocap (= generic Prowl H2O; WSSA group 3) is a generic version of Prowl H2O that unlike Prowl H2O, which can only be used in cabbage as a directed row middle spray, Satellite allows for "broadcast postemergence foliar spray". In 2019-2021 CRDP-funded on-farm field trials, Prowl H2O 2 pt (high rate) demonstrated very good to excellent control

of LQ, and was better than Treflan, Devrinol and Dual Magnum. It has demonstrated very good crop safety when applied POST-T alone and in tank mixes with Dual Magnum, Chateau and Spartan. It has also had good crop safety when applied at delayed timings (28-35 DAP) alone and with Chateau and Spartan, but tank mixes with Goaltender caused greater than 10% injury. Tank mixes of Prowl H2O with either Goaltender or Chateau improved control of pigweed (PW), RW, LQ and grasses. **Delayed application of Prowl H2O with or without Chateau 28 DAP (targeted to after the last nitrogen side-dress application, cultivation and hand weeding, and before row closure) has consistently improved weed control at harvest to almost 100%.** Since Satellite has a 70 day preharvest interval, delayed applications would technically only work for varieties with 98+ days to maturity. However, as long as the spray goes on before cupping and the sprayed part of the plant does not end up in the marketed potion of the plant (cabbage head), there should be no issues with residuals. Results from 2022 trial indicated that replacing Dual Magnum with Prowl H2O/Satellite in a program decreased weed control. **It is worthwhile to continue to optimize the addition of Satellite/Prowl H2O into cabbage herbicide program with Dual Magnum and Goal, especially for improved LQ and VL control, and for improved residual weed control when applied 21-35 DAP.** The label states that Satellite must be applied to cabbage plants with 2-4 leaves within 1-3 days POST-T. However, the manufacturer of Satellite, UPL NA Inc. is very interested in extending this window to "up to cupping" on the label. They would also like to see Satellite + Stinger trialed since the delayed application of Satellite may align with application of Stinger (for POST control of weed escapes).

Chateau (a.i. flumioxazin) is another WSSA herbicide group 14 like Goaltender. It has excellent activity on PW, Lady's thumb (LT), nightshade (NS) and certain species of annual mustards (e.g. marsh yellowcress), and it has some activity on annual grasses, RW and VL. When Chateau was tank mixed with Prowl H2O it improved control of RW and LQ, and would likely improve VL control. Like the other WSSA 14 herbicides, Chateau offers both pre- and post-emergent weed control. It is labeled in cabbage in other states as a directed row middle spray. There may be interest in getting cabbage added to the Chateau label in NY, especially if herbicide-resistant Palmer amaranth becomes a problem, as Chateau is excellent on PW. In 2018 and 2019 CRDP trials, Chateau at 1 oz/A had very good crop safety POST-T both at-planting and 28 DAP, both alone and tank mixed with Prowl H2O 2 pt. In 2019, it was safer in combination with Trifluralin, Devrinol and Prowl H2O than Goaltender, while Chateau 1 oz + Dual Magnum 1 pt killed cabbage plants. In 2022 trial, Chateau POST-T 1 d and 14 d resulted in unacceptable cabbage injury (19-25% 9 DAT) and even ended up killing some cabbage transplants. In the same trial, application 35 DAP to pre-cupping cabbage resulted in 10% necrosis 7 DAT and tank mixes of Chateau and Satellite did not cause any more injury than Chateau alone. When Chateau is used at this late timing, it can also kill weed escapes 1-2 inches, especially PW and MYC. The 2022 trial was the first herbicide trial that had plant tape transplants and the conditions during trial set up were very hot and humid. After transplanting, newly set plants were flaccid and stressed. Even though POST-T application was delayed until the morning following transplanting when the plants had perked up a bit, they must have been too stressed to tolerate Chateau. **Since Chateau has demonstrated relatively good crop safety, broadens the weed control spectrum and delayed applications at 28-35 DAP offer extended residual control through harvest, it is worthwhile to continue to explore incorporating Chateau into cabbage herbicide program.**

Soil adjuvants are supposed to improve the efficacy and adsorption of soil-applied herbicides by providing even distribution including into hydrophobic zones (pockets of soil that don't wet easily) and by keeping pre-emergent herbicides in the weed germination zone, so that there are fewer weed escapes. As herbicide resistance to post-emergent herbicides in row crops has increased, growers have been forced to achieve better control with pre-emergent herbicides, and the use of soil adjuvants with pre-emergent herbicides is now more common. In 2022 cabbage herbicide trial, **addition of soil adjuvant Oro-RZ** (Ori-Agri USA) PRE-T to Treflan 1 pt PPI fb. Dual Magnum 0.5 pt + Command 8 fl oz PRE-T and again to Satellite 2.1 pt 35 DAP did not affect crop injury or weed control. Alternatively, in a 2021 muck-onion herbicide trial in Oswego (Hoepting), addition of Oro-RZ to 2 of 3 pre-emergent herbicide applications in a program increased weed control from 82% to 95% due to improved control of RW and LT. In 2022 cabbage herbicide trial, **addition of soil adjuvant Grounded** (Helena Agri-Enterprises) had no effect when added to PRE-T application as

described for Oro-RZ, but when added to the 35 DAP application with Satellite, it extended residual control of sod by ~ 1-2 weeks. **Given how readily soil adjuvants could be adopted by NY cabbage growers, continuing to study their ability to improve weed control is warranted.**

Almost there!
In the 5 on-farm CRDP funded trials that we conducted from 2019 to 2022, 3 were planted in late-May, 1 was planted in mid-June and 1 was planted in late-July, of which 2 were bare root transplants, 2 were plug transplants and 1 was plant tape transplants. We have collected decent data on LQ, MYC (and some other mustard species), PW, RW, annual grasses (mostly crabgrass), purslane and sod, but usually only 2-3 species per trial and never with the same treatments per trial. Crop injury data has been inconsistent due to the high degree of variation that we see among cabbage plants in our small-plot trials. We are getting really close to figuring out how to achieve best weed control in cabbage, but need to fine-tune the crop tolerance aspect of it. **Thus, the logical next step is to trial fewer treatments per trial (select the most promising) with more replications per trial (to overcome variability in plant quality) in more trials at different times during the growing season.**

Objective 1.
To optimize crop safety and weed control with herbicides in cabbage production with the goal of providing season long weed control.

Sub-objectives include:
1. To optimize use of Dual Magnum and Goaltender for crop safety and weed control with emphasis on using higher rate of Goaltender and lower rate of Dual Magnum.
2. To explore whether Chateau may be incorporated into cabbage herbicide program with emphasis on crop safety.
3. To explore utility of delayed applications of Satellite (= generic Prowl H2O) and Chateau prior to row closure (after final cultivation) for extended residual weed control (ideally season long).
4. To explore use of soil adjuvants to improve the efficacy and residual activity of pre-emergent herbicides in cabbage.

The intended outcome of this proposed research is to achieve season long weed control while minimizing crop injury in transplanted cabbage so that cabbage growers can drastically reduce need for hand weeding.

Organizational Capacity:
Christy Hoepting has been a Vegetable Specialist with the Cornell Cooperative Extension Vegetable Program since 2001. She now has over 20 years of experience conducting on-farm research studies in several aspects of cabbage production including variety evaluation, slug control, insect control (thrips, diamondback moth, swede midge, cabbage maggot), Alternaria leaf spot, nitrogen dynamics, and now weed management with herbicides. Christy has completed 5 on-farm cabbage herbicide trials in the past 4 years with emphasis on pre-emergent herbicides, but has over a decade of experience conducting onion herbicide trials. She specializes in testing the limits of herbicide rate and timing for crop safety, and in strategically designing comprehensive herbicide programs for optimal weed control and crop safety. The year 2023 will mark the fifth growing season Field Technician, Sarah Caldwell will have worked with Hoepting; she has assisted with all aspects of data collection for Hoepting's cabbage and onion research trials, and has become especially astute at herbicide evaluations. Hoepting will also have another full time Field Technician in 2023. Hoepting has her commercial pesticide applicator license, a 4-wheel drive extended cab half ton pick-up truck and CO_2 pressurized backpack sprayer, and is absolutely capable of carrying out the proposed research.
Objective 1: To optimize crop safety and weed control with herbicides in cabbage production with the goal of providing season long weed control.

Task 1.1 Treatments and Trial Set up.

Treatments:

1. Goaltender **0.5 pt** PRE-T fb. Dual Magnum **1 pt** POST-T (safest application timing)
2. Goaltender **1 pt** PRE-T fb. Dual Magnum **1 p**t POST-T (increased rate of Goaltender)
3. Goaltender **1 pt** PRE-T fb. Dual Magnum **0.5 pt** POST-T (increased rate of Goaltender with low rate of Dual Magnum)
4. Goaltender **0.5 pt** PRE-T fb. Dual Magnum **1 pt** POST-T fb. **Satellite 2.1 pt + Chateau 1 oz POST-T 28 d** (100% season long weed control in 2022)
5. Goaltender **1 pt** PRE-T fb. Dual Magnum **0.5 pt** POST-T fb. **Satellite 2.1** pt **POST-T 28 d**
6. Goaltender **1 pt** PRE-T fb. Dual Magnum **0.5 pt** POST-T fb. **Chateau 1 oz POST-T 28 d**
7. Goaltender **1 pt** PRE-T fb. Dual Magnum **0.5 pt** POST-T fb. **Satellite 2.1 pt + Chateau 1 oz POST-T 21 d**
8. Goaltender **1 pt** PRE-T fb. Dual Magnum **0.5 pt** POST-T fb. **Satellite 2.1 pt + Stinger 6 fl oz POST-T 21 d**
9. Goaltender **1 pt** PRE-T fb. Dual Magnum **0.5 pt** POST-T fb. **Satellite 2.1 pt POST-T 21 d**
10. Goaltender **1 pt** PRE-T + **Grounded 2.5 pt** fb. Dual Magnum 0.5 **pt** POST-T fb. **Satellite 2.1 pt** + **Grounded 2.5 pt POST-T 28 d** (Trt. 5 with soil adjuvant)
11. Goaltender **1 pt** PRE-T + **Oro-RZ 1 pt** fb. Dual Magnum **0.5 pt** POST-T fb. **Satellite 2.1** pt + **Oro-RZ 1 pt POST-T 28 d** (Trt. 5 with soil adjuvant)
12. Grower standard
13. Improved grower standard - TBD
14. Hand weeded control
15. Untreated control

Treatments will focus on Goaltender 0.5-1 pt PRE-T fb. Dual Magnum 0.5-1 pt POST-T with emphasis on the high rate of Goaltender 1 pt and low rate of Dual Magnum 0.5 pt, as our previous research has suggested that this is the safest rate and timing combination without compromising weed control. Treatments will also focus on delayed applications of Satellite +/- Chateau, and compare 21 d to 28 d POST-T. In addition, upon the request of UPL NA, we will trial Satellite + Stinger 6 fl oz POST-T 21 d. Since the use of Goaltender + Dual Magnum may cause stunting, we will not add any other herbicides at planting, including not using Treflan PPI, Command (banned), Satellite or Chateau. Similarly, we will also not use two products that belong to the same WSSA group (such as Goaltender and Chateau, both WSSA group 14 or Treflen and Prowl, both WSSA group 3) at the same timing to reduce the risk of injury from that WSSA group. Soil adjuvants Oro-RZ and Grounded will be included with PRE-T and POST-T 28 d timings with Goaltender 1 pt PRE-T fb. Dual Magnum 0.5 pt POST-T fb. Satellite 2.1 pt POST-T 28 d. Soil adjuvants will not be tank mixed with WSSA group 15 herbicides (Chateau and Goaltender) because their adjuvant properties could increase necrosis type of crop injury. We will include the grower cooperator's standard herbicide program, as well as an improved grower standard, prescribed by Hoepting. Untreated and handweeded controls will also be included.

Trial Set up:

We will conduct **3 trials in commercial cabbage fields**, ideally in fields that have a history of heavy weed pressure especially LQ, RW and or VL. One trial each will be set up in **May, June and July** and may be in bare root, plug or plant tape transplants. The trial will be set up as a randomized complete block design with 15 treatments and 6 replications. The number of replications was increased from 4 in previous trials to 6 in order to overcome the inherent variability in cabbage plant quality, so that we can hone in on the actual treatment effects, mostly with respect to crop injury. The individual plot size will still be 2 rows wide x 10 ft long with 3 ft between tiers and adjacent plots to give us a good read on the background weed pressure as we rate weed control in each plot. The grower will be asked to not apply Treflan to the trial area. After the cabbage is set by the grower's transplanting crew, we will set up the trial plots. For treatments that require a PRE-T application, we will pull out the freshly planted cabbage transplants, spray the plot and then

promptly re-plant them. Treatments will be applied using a $C0_2$ pressurized backpack sprayer with 40 gpa, ~30 psi and 3 Teejet VS 8005 nozzles spaced 19 inches apart.

Evaluation. Crop injury in terms of necrosis, puckering and stunting will be visually assessed compared to the adjacent guard rows using a 100% scale (0% = no injury, 100% = all plants dead) 7, 14, 21, and 28 days after treatment. Percent weed control by species will be visually estimated compared to guard rows 28 DAP. After this assessment, nitrogen will be applied as a side-dress and the whole trial will be cultivated and hand weeded. Then, the 28 DAP treatments will be applied. Weed control by species will be assessed at harvest by visual estimate of % control, fresh biomass, or ground cover using whichever variables are appropriate, always using the weed pressure in the guard rows for comparison. Each marketable cabbage head per plot will be weighed individually. Differences among treatments will be analyzed using general analysis of variance (ANOVA) and means will be separated using Fisher's Protected LSD test with 95% confidence interval.

Performance Measure 1.1.1
May-October: Set up 3 herbicide trials in commercial cabbage fields, apply herbicide treatments, collect data, harvest trials.

Performance Measure 1.1.2
Winter 2022-2023: Enter data, analyze and summarize results. Write CRDP progress report. Share results with cabbage growers and allied industry representatives, as appropriate.

Task 1.2 Extension and Outreach. Results will be shared with CRDP board and with rest of NY cabbage industry as appropriate. Potentially, new recommendations will be made for developing safe and effective herbicide programs in cabbage. Such information will be made available via newsletter article(s) published in Extension newsletters or direct emailing, and/or a "cheat sheet" that will be available on the CCE CVP website. Presentations may be made at grower meetings. If the on-farm cabbage herbicide trial is "showy", cabbage growers and allied industry representatives will be invited for a trial tour, likely either at 28 DAP or at harvest.

Performance Measure 1.2.1
Growers will attend presentations made at grower meetings. They will be asked to fill out an evaluation survey and be asked to share what new techniques they will implement on their farm next year. Grower cooperators who host on-farm trials will make changes to their spray programs.
Performance Measure 4.1.3

Outcome and Benefits Expected:
The objective of this research proposal is to optimize weed control and crop safety in cabbage by strategically building herbicide programs with currently registered and novel herbicides. Specifically, this project is designed to identify chemical programs that can provide NY cabbage growers with extended, in-season weed suppression that reduces the need for costly labor inputs while maximizing cabbage yield and quality. Improved weed control will reduce need for expensive hand weeding, which can cost $225 per acre just to put a crew through a field, and will eliminate the extra labor required to trim away weed contaminants and diseased leaves from harvested cabbage heads. Further, large weed escapes can interfere with proper deposition of fungicides and reduce aeration within the crop canopy, which results in poorly protected cabbage exposed to more favorable disease conditions. Identifying herbicide programs that strategically reduce crop injury without compromising weed control will result in high quality and high yielding cabbage. **Through our pursuit of creative and novel approaches using the current roster of herbicides labeled in New York, we are hoping to pinpoint a program that utilizes 2-4-products, has excellent crop safety, and will result in near-perfect season long control with labeled herbicides.** This will improve the bottom line for NY cabbage growers.

In this proposed project, we will continue to trial Chateau, which has a Special Local Needs label in Georgia. **If our research results indicate that Chateau would be an asset for weed control in cabbage in New York, we will work with Valent to pursue its registration for cabbage in New York**. Similarly, **if this research identifies new herbicide use patterns,** such as delayed application of Satellite, that improve weed management with acceptable risk of crop injury, we will **work with the appropriate parties (UPL NA Inc. in the case of Satellite) to seek such label changes for their use in New York cabbage production.**

Accomplishments/Benefits to Date

Herbicide program development has proven time-consuming, because of the many products, timings, rates, and combinations that can be tested. We have generated very good data on ragweed (RW), Lamb's quarters (LQ), marsh yellowcress (MYC) and some annual grasses (mostly crabgrass), and we just collected good data on purslane in 2022. In grower fields, weed pressure is often patchy and dominated by a couple of species, which makes accurate evaluation of pre-emergent herbicide efficacy challenging. Regardless, we highly value the importance of conducting herbicide trials in commercial cabbage fields with different soil types and weed spectrums, and over multiple years with different growing conditions.

- We have focused on **improved control of ragweed (RW) with pre-emergent herbicides** and identified that a new formulation of Devrinol (2XT) resulted in better RW control than the 50DF formulation and Dual Magnum. Although some growers have trialed Devrinol 2XT, incorporating it into an herbicide program is a challenge because it is a WSSA group 15 herbicide. Dual Magnum, also a WSSA group 15 herbicide, is often used at planting; however using two WSSA 15 herbicides at planting is risky because this chemistry is notorious for causing stunting injury, especially in cold soils. Between Dual Magnum and Devrinol, Dual Magnum offers a wider spectrum of weed control and is often preferred.
- This work also demonstrated the **importance of using Goaltender at planting for improved control of RW, especially when used in combination with Dual Magnum.** We have seen an increase in the use of Goaltender at planting for this purpose, but its risk of injury, especially when used POST-T, can be concerning.
- **Dual Magnum in combination with Goaltender at planting has emerged as the top performing treatment for broad spectrum weed control.** Last year, we trialed a lot of Dual Magnum/Goaltender combinations at-planting by adjusting rates and timing, and splitting the applications between PRE-T and POST-T to find the safest one. We have settled on Goaltender PRE-T fb. Dual Magnum POST-T, and will be focusing on using a higher rate of Goaltender 1 pt and lower rate of Dual Magnum 0.5 pt for best crop safety moving forward (e.g. this proposal).
- Our research has highlighted the **potential that Prowl H2O has for improved LQ control** in a cabbage herbicide program. It has also been consistently safe when applied to foliage POST-T within 24 hours of, and 28-35 days after, planting (despite being labeled as a directed row middle spray). It has also been a safer tank mix partner than Dual Magnum with Goaltender, Chateau and Spartan. We will **now be working with UPL NA Inc. who make a generic version of Prowl H2O, called Satellite Hydrocap, and this product is not restricted to POST-T directed row middle sprays and can be sprayed over the top of cabbage.** This product should provide control of velvet leaf, especially when used in a program with Goal in the absence of Command (cabbage removed from label).
- There was **a lot of interest among cabbage growers about Spartan when our trials showed that it had phenomenal control of LQ and very good crop safety** when applied POST-T to foliage within 24 hours and 28 days after planting. FMC even pursued options to get Spartan labeled on cabbage in NY. Unfortunately, NYDEC determined that it could not be registered due to groundwater concerns involving the active ingredient.
- Finally, our experimentation with **delayed applications of pre-emergent herbicides 28 DAP just after nitrogen side-dressing, cultivation, and hand weeding (if necessary), and before row closure have shown tremendous potential to extend residual control through harvest.** Of all the different treatments that we have tried at this timing, Satellite Hydrcap +/- Chateau are the only treatments left on the table, which we will continue to trial as part of a program with Dual Magnum and Goaltender (this proposal).

We have been careful not to make new herbicide recommendations too hastily, as we have experienced a lot of variability in crop injury over the years and we want our recommendations to stand the test of time. **After trials in 2023, where we plan to trial fewer treatments (the most promising ones) with more replications in three on-farm trials across the season, we are hoping to be able to provide some new suggestions that NY cabbage growers may implement to improve their overall weed control, which will result in reduced labor expenses for hand weeding.**

Budget: –

2023-24 Budget Sheet

Hoepting-Optimizing Herbicide Weed Control and Crop Safety in Transplanted Cabbage

SALARY				
POSITION TITLE (Exempt) **Example: Sr. Research Support Specialist, Post Doc, Sr Extension Associate**	**ANNUALIZED SALARY PER POSITION**		**PERCENT OF EFFORT FUNDED**	**TOTAL**
Sr. Extension Associate, Unbanded, 11155	$91,730.00		4.250%	$3,899.00
			Subtotal	$3,899.00
POSITION TITLE (non-Exempt) **Example: Extension Associate, Technician, Temp Service Tech**	**HOURLY PAY RATE PER POSITION**	**STANDARD WORK HOURS PER WEEK**	**NUMBER OF WEEKS FUNDED**	**TOTAL**
Technician II, Band B, 10953	$24.00	40	2.80	$2,688.00
Technician I, Band A, 10952	$17.51	40	1.50	$1,051.00
			Subtotal	$3,739.00
TOTAL SALARY				
			SALARY TOTAL	$7,638.00

TRAVEL - TYPE/DESCRIPTION	**TOTAL**
Albion to each of 3 field sites (average 40 miles/site): 10 trips x 80 miles return x 3 trials = 2400 miles @ $0.625/mile	$1,500.00
TRAVEL TOTAL	$1,500.00

OPERATING EXPENSES - TYPE/DESCRIPTION	**TOTAL**
Materials & Supplies - Field and lab supplies	$184.00
OPERATING EXPENSES - TOTAL	$184.00

OTHER EXPENSES - TYPE/DESCRIPTION	**TOTAL**
Indirect Costs - Direct Costs x 18%	$1,678.00
OTHER EXPENSES - TOTAL	$1,678.00
Total Funding	**$11,000.00**

Budget Justification:

Salaries and Wages: $7,638

Sr. Extension Associate (Hoepting Program): These funds will be used to support trial design, treatment application, data collection, data analysis, and outreach

Technician I (Hoepting Program): These funds will be used to support trial design, treatment application, data collection, data analysis, and outreach

Technician II (Hoepting Program): These funds will be used to support trial design, treatment application, data collection, data analysis, and outreach

Travel - $1,500
Travel to site plots for treatment application, data collection, data analysis, and outreach. (Hoepting Program)

Other Expenses: $184
Materials and Supplies -Stakes, flags, sharpies, sample bags, PPE, CO_2 tank refill (Hoepting Program)

Other Expenses: $1,678
18% Indirect Costs

Cabbage Research & Development Program
Collections Report
April 1, 2022 through March 1, 2023

	Apr 1, '22 - Mar 1, 23	2022 CRDP Collections (as of 3/1/23) Apr 1, '21 - Mar 1, 22
Income		
Assessments		
2022 Cabbage Assessment		
2022 Voluntary Contribution	250.00	0.00
2022 Cabbage Assessment - Other	20,132.80	0.00
Total 2022 Cabbage Assessment	20,382.80	0.00
2021 Cabbage Assessments		
2021 Voluntary Contribution	0.00	283.00
2021 Cabbage Assessments - Other	0.00	21,856.92
Total 2021 Cabbage Assessments	0.00	22,139.92
2020 Cabbage Assessments		
2020 Voluntary Contribution	0.00	100.00
2020 Cabbage Assessments - Other	0.00	1,340.00
Total 2020 Cabbage Assessments	0.00	1,440.00
2019 Cabbage Assessments	0.00	172.00
2017 Cabbage Assessments	236.00	0.00
Total Assessments	20,618.80	23,751.92
Total Income	20,618.80	23,751.92
Expense	0.00	0.00
Net Income	**20,618.80**	**23,751.92**

Cabbage Research & Development Program
Collections Report
April 1, 2022 through March 1, 2023

	$ Change	% Change
Income		
Assessments		
2022 Cabbage Assessment		
2022 Voluntary Contribution	250.00	100.0%
2022 Cabbage Assessment - Other	20,132.80	100.0%
Total 2022 Cabbage Assessment	20,382.80	100.0%
2021 Cabbage Assessments		
2021 Voluntary Contribution	(283.00)	(100.0%)
2021 Cabbage Assessments - Other	(21,856.92)	(100.0%)
Total 2021 Cabbage Assessments	(22,139.92)	(100.0%)
2020 Cabbage Assessments		
2020 Voluntary Contribution	(100.00)	(100.0%)
2020 Cabbage Assessments - Other	(1,340.00)	(100.0%)
Total 2020 Cabbage Assessments	(1,440.00)	(100.0%)
2019 Cabbage Assessments	(172.00)	(100.0%)
2017 Cabbage Assessments	236.00	100.0%
Total Assessments	(3,133.12)	(13.19%)
Total Income	(3,133.12)	(13.19%)
Expense	0.00	0.0%
Net Income	**(3,133.12)**	**(13.19%)**

Cabbage Research & Development Program
Comparative Balance Sheet
As of

CRDP Account Balance
(as of 3/1/23)

	Mar 1, 23	Mar 1, 22	$ Change
ASSETS			
Current Assets			
Checking/Savings			
ESD	32,354.18	15,869.87	16,484.31
Total Checking/Savings	32,354.18	15,869.87	16,484.31
Accounts Receivable			
Assessments Receivable	2,525.40	1,165.80	1,359.60
Total Accounts Receivable	2,525.40	1,165.80	1,359.60
Total Current Assets	34,879.58	17,035.67	17,843.91
TOTAL ASSETS	**34,879.58**	**17,035.67**	**17,843.91**
LIABILITIES & EQUITY			
Equity			
Retained Earnings	14,425.77	5,079.59	9,346.18
Net Income	20,453.81	11,956.08	8,497.73
Total Equity	34,879.58	17,035.67	17,843.91
TOTAL LIABILITIES & EQUITY	**34,879.58**	**17,035.67**	**17,843.91**

CRDP Assessments - Average Collections
8-Year Average

Year	Current Year Collections	Prior Year Collections	Accounts Receivable	Total Collections	Yr. to Yr. Change (Amount)	Yr. to Yr. Change (Amount)
2013	$ 22,692.28	$ 1,103.82		$ 23,796.10		
2014	$ 19,138.95	$ 4,233.00		$ 23,371.95	$ (424.15)	-2%
2015	$ 20,813.52	$ 1,158.00		$ 21,971.52	$ (1,400.43)	-6%
2016	$ 19,753.05	$ 630.00		$ 20,383.05	$ (1,588.47)	-7%
2017	$ 23,423.40	$ 114.00		$ 23,537.40	$ 3,154.35	15%
2018	$ 23,953.92	$ 5,304.00		$ 30,244.92	$ 6,707.52	28%
2019	$ 22,514.05	$ 784.00		$ 23,298.05	$ (6,946.87)	-23%
2020	$ 21,711.96	$ 48.00		$ 21,759.96	$ (1,538.09)	-7%
2021	$ 22,139.92	$ 1,612.00		$ 23,751.92	$ 1,991.96	9%
2022	$ 20,382.80	$ 236.00	$ 2,525.40	$ 23,144.20	$ (607.72)	-3%
Average Collection	**$ 21,652.39**	**$ 1,665.20**		**$ 23,568.32**		

*Includes current collections plus accounts receiveable (grower reports returned but invoice not yet paid); does not include unreturned grower reports.

New York State Cabbage Research and Development Program
Actual Budget (Cash Basis)
April 1, 2023 – March 31, 2024

***Projected Cash Balance available for Carryover April 1, 2023**		$ 22,204
(*anticipated account balance less 2022-23 contract value of $12,676)		
Estimated Receipts:		
Collections – 2023 Crop Year (at $4.00/acre)	$ 21,652	
Collections - Prior Crop Years	$ 1,665	
Seneca Foods Contribution	$ 1,320	
Total Receipts		$ 24,638
Available Funds		$ 46,842
Estimated Expenses:		
Contracted Research ($12,676 funded in 2022-23)	$ 21,919	
Administration **(5 Percent Maximum)**	$ 1,096	
Total Expenses		$ 23,014
Projected Cash Balance March 31, 2024		$ 23,827