COVER SHEET FOR GRANT PROPOSALS

State Board of Education

SBOE PROPOSAL NUMBER: (to be assigned by SBOE)	AMOUNT REQUESTED: $72,900

TITLE OF PROPOSED PROJECT: Plant Extracts as Natural Pesticides and Potato Sprout Inhibitors

SPECIFIC PROJECT FOCUS: Mustard plants contain bioactive compounds that act as natural pesticides. The highest concentrations of the natural pesticides are in seed meal; solid materials remaining after oil for biodiesel is removed from the seed by crushing. The primary obstacle in using mustard seed meals as biopesticides is the bulky nature of the materials. We have developed methods to extract, concentrate, dry, and formulate seed meal extracts, thus generating natural pesticide products targeting weeds, nematodes, and sprout inhibition of stored potatoes. The products will cost less to transport, can be applied more easily, and will be more efficacious than seed meals. Procedures for generating the products have been optimized at the laboratory scale. Our objective is to produce formulated natural pesticides from mustard seed meal extracts such that efficacy testing by our commercialization partners, Farm Fuel, Inc. and 1,4GROUP, Inc., is possible. We propose to produce 25 lbs. of formulated natural pesticide products as shelf-stable powders from each of two different mustard species. Funding in the amount of $72,900 is requested to purchase specialized spray drying equipment and to provide salary dollars for producing the proposed products. Our commercial partners will produce efficacy data, assist with EPA registration, and potentially market the developed natural pesticide formulations.

PROJECT START DATE: July 1, 2015	PROJECT END DATE: June 30, 2016
NAME OF INSTITUTION: University of Idaho	DEPARTMENT: Plant, Soil, and Entomological Sciences

ADDRESS: 875 Perimeter Dr., MS 2339, Moscow, ID 83844-2339

E-MAIL ADDRESS: mmorra@uidaho.edu	PHONE NUMBER: 208-885-6315

	NAME:	TITLE:	SIGNATURE:
PROJECT DIRECTOR/PRINCIPAL INVESTIGATOR	Matthew J. Morra	Professor of Soil Science	Matthew J. Morra
CO-PRINCIPAL INVESTIGATOR			

NAME OF PARTNERING COMPANY: Farm Fuel, Inc.	COMPANY REPRESENTATIVE NAME: Stefanie Bourcier

NAME: Stefanie Bourcier SIGNATURE:

NAME OF PARTNERING COMPANY: 1,4 Group, Inc.	COMPANY REPRESENTATIVE NAME: Addie Waxman

NAME: Addie Waxman SIGNATURE: Addie M. Waxman

Authorized Organizational Representative	Dr. John McIver	VP of Research and Economic Development
		DATE 4-1-15

SUMMARY PROPOSAL BUDGET

Name of Institution: University of Idaho

Name of Project Director: Matthew J. Morra

A. PERSONNEL COST (Faculty, Staff, Visiting Professors, Post-Doctoral Associates, Graduate/Undergraduate Students, Other)

Name/ Title	Salary/Rate of Pay	Fringe	Dollar Amount Requested
Matthew J. Morra/ Professor of Soil Science	2,400	700	3,100
Unnamed new employee/ Technical support staff	18,700/ $18/hour	8,100	26,800

% OF TOTAL BUDGET:	41	SUBTOTAL:	29,900

B. EQUIPMENT: (List each item with a cost in excess of $1000.00.)

Item/Description	Dollar Amount Requested
Buchi Spray Dryer model B-290	43,000
SUBTOTAL:	43,000

G. TRAVEL:

Dates of Travel (from/to)	No. of Persons	Total Days	Transportation	Lodging	Per Diem	Dollar Amount Requested
SUBTOTAL:						

H. Participant Support Costs:

	Dollar Amount Requested
1. Stipends	
4. Other	
SUBTOTAL:	

I. Other Direct Costs:	Dollar Amount Requested
1. Materials and Supplies	
2. Publication Costs/Page Charges	
3. Consultant Services (Include Travel Expenses)	
4. Computer Services	
5. Subcontracts	
6. Other (specify nature & breakdown if over $1000)	
SUBTOTAL:	
J. Total Costs: (Add subtotals, sections A through I) **TOTAL:**	72,900
K. Amount Requested: **TOTAL:**	72,900
Project Director's Signature: Matthew J. Morra	Date: 4/01/15

INSTITUTIONAL AND OTHER SECTOR SUPPORT
(add additional pages as necessary)

A. INSTITUTIONAL / OTHER SECTOR DOLLARS

Source / Description	Amount

B. FACULTY / STAFF POSITIONS

Description
Analytical Instrumentation Supervisor- approximately 25% time will be devoted to this project.

C. CAPITAL EQUIPMENT

Description

D. FACILITIES & INSTRUMENTATION (Description)

Agilent HPLC-MS TOF used to measure pesticide concentrations. Original purchase cost of $250,000.

1. *Name of Idaho public institution:* University of Idaho (UI)

2. *Name of faculty member directing project:* Matthew J. Morra (PI)

3. *Past Incubation Fund Award:* None

4. *Executive Summary:* There is a critical need for natural pesticides that can be used in organic and high value agricultural and horticultural crops. Mustard plants (*Brassica juncea* and *Sinapis alba*) contain natural pesticides that kill weeds and nematodes, and inhibit the sprouting of stored potatoes. Highest concentrations of the natural pesticides occur in seed meal; solid materials remaining after oil for biodiesel is removed from the seed by crushing. The primary obstacle in using mustard seed meals as natural pesticides is the bulky nature of the materials. The PI has developed methods to extract, concentrate, dry, and formulate natural pesticide powders from mustard seed meals (Fig. 1). The products will cost less to transport, can be applied more easily, and will be more efficacious than seed meals. Funds are requested for scale-up to produce sufficient amounts of the natural pesticide powders for commercialization partners to generate efficacy data necessary for registering the formulations with EPA. Commercialized products will target markets for which the few alternative products available are expensive, ineffective, or potentially harmful to humans or the environment.

Fig. 1. Concentrated natural pesticide extract.

5. *"Gap" project objective and total amount requested:* Commercialization of natural pesticides derived from mustard seed meals requires efficacy testing under real-world conditions. **Our objective is to produce formulated natural pesticides from mustard seed meal extracts in sufficient amounts such that efficacy testing by our commercialization partners is possible.** We propose to produce 25 lbs. of formulated natural pesticide product from each of

two mustards, *B. juncea* and *S. alba*. Funding in the amount of **$72,900** is requested to purchase specialized spray drying equipment and to provide salary dollars for producing the specified amounts of shelf-stable natural pesticide powders.

6. *Description of how resource commitments reflect the priorities of the home institution(s):*

Fundamental research leading to the practical applications proposed here was funded by federal grants supporting the PI during the last 26 years. This line of research is consistent with the UI's land-grant mission. Instrumentation used to quantify natural pesticides was purchased with UI funds at a cost of $250,000. Operation of this instrumentation and general laboratory oversight is performed by a full-time Ph.D. technical support person working exclusively for the PI. Laboratory space for the PI's research and additional space for scaling up the technology have been and will continue to be made available for the duration of this project.

7. *Evidence that the project will have a potential impact to the economy of Idaho:*

Economic impacts will be generated across a spectrum of activities ranging from additional sales of seed (an existing market and income stream) to the development of start-up industries associated with seed processing and natural pesticide formulation. Mustard varieties (IdaGold and Pacific Gold) to be used in producing the proposed products are licensed by UI, and thus development of expanded markets for use of the seed will increase seed sales and associated royalties to a public university within the State. Because these varieties were bred specifically for production in the Inland Pacific Northwest, a demand for natural pesticides will provide the market pull for growing mustard crops within the region. Transportation cost advantages of processing the crop near the geographic site of production will provide the incentive for development of crush plants that will generate oil for biodiesel and seed meal for natural pesticides. The ready availability of oil and seed meal feedstocks will increase the likelihood of

co-locating biodiesel production and seed meal extraction/formulation facilities. In addition, residual seed meals from which the natural pesticides are removed are detoxified making them viable nitrogen fertilizers or animal feeds for dairy cattle. Potential economic impacts will thus result from various industries involving crushing, feedstock oils for biodiesel, natural pesticide extraction/formulation, natural fertilizers, and animal feed production.

Natural herbicides and nematicides developed in collaboration with one of our collaborators Farm Fuel, Inc. (FFI) will have economic value to ID as export items to other states and for use on agricultural products within the State. Natural pesticides developed in this project will be of value to organic and high-value fruit and vegetable growers. FFI is well placed to market natural pesticides produced from ID-grown crops and potentially extracted in ID facilities to CA growers, one of the largest U.S. markets for our proposed products. Sprout inhibitors for potato storage will be developed in collaboration with the 1,4GROUP, an ID business, thus providing economic benefits to the supplier and end users within the region.

8. <u>*The market opportunity:*</u> This project will address society's need for safer and more environmentally friendly natural alternatives to synthetic pesticides. More specifically, we will produce shelf-stable powdered extracts from *S. alba* and *B. juncea* seed meals that when dissolved in water, yield biopesticides that control weeds (**Fig. 2.**) and nematodes, and inhibit the sprouting of stored potatoes (**Fig. 3**). The target markets are organic and high value agricultural and horticultural crops for which the few alternative products available are expensive, ineffective, or harmful to humans or the environment.

Fig. 2. Weed untreated (left) and treated with mustard seed meal extract (right).

Organic cropland has increased from 1.3 million acres in 2000 to over 3 million acres in 2011. Organic food revenues in the U.S. have grown to $31 billion a year. Organic vegetable and fruit acres, crops most relevant to the proposed products, have increased 300% during that same time period. CA continues to lead in certified organic cropland, with nearly half of its total 405,000 acres used for fruit/vegetable production. These 200,000 acres are the initial target for our natural weed and nematode control products.

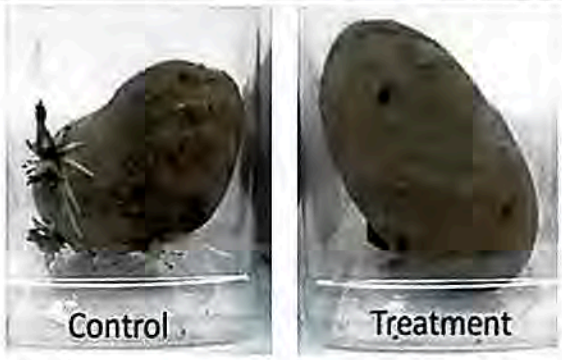

Fig. 3. Potato sprout inhibition by *B. juncea* seed meal extract.

The need for pesticides to control weeds in agriculture and horticulture is illustrated by the fact that approximately 44% of all pesticides used in the U.S., as expressed on a weight basis for the active ingredients, are herbicides and four of the top five pesticides used in the U.S. are herbicides. Weed competition with major U.S crops costs approximately $8.9 billion annually, including total expenditures of $2.1 billion for herbicides alone. **Weed control is ranked as the number one problem inhibiting further expansion of organic agricultural operations.** Relatively few methods that vary in their applicability and effectiveness are available for weed control in organic agriculture. Current weed control methods involve hand labor, flaming, or relatively ineffective products such as vinegar, corn gluten, or citrus oil. All of the commercially available products are contact herbicides, burning the leaves of the plant. None of the commercially available organic products are systemic such that they are taken up by the roots and kill the entire plant. **Our proposed natural herbicide fills an intense need for a systemic natural herbicide that may be legally applied to organic crops.**

Per acre costs of flame weeding have been documented to about $80.00 per acre, whereas soil solarization costs approximately $600 per acre and hand labor about $2,500 per acre. Our natural herbicide must be lower in cost than hand labor, but the limitations of flame weeding and solarization along with the advantages of our product make it feasible that a $1,000 per acre cost will be competitive.

Our estimates using 100 lbs of seed include a seed cost of $35 and crushing costs of $20 yielding 70 lbs of meal and 30 lbs of oil. The oil is worth $9 ($0.30/lb) and the seed meal as a soil amendment is valued at $56 ($0.80/lb). The profit on 100 lbs of seed is $10. If the seed meal is instead used as a feedstock for extraction of pesticides, 70 lbs of meal yields 50 lbs of detoxified meal for N fertilizer and 20 lbs of natural pesticide. The N fertilizer is worth $25 ($0.50/lb). In order for increased profits to accrue beyond that achieved by marketing the meal as a soil amendment, the natural pesticide must be valued at more than $31 ($1.55/lb). Our predicted use rate for the natural herbicide ranges from 100 to 500 lbs per acre, thus accommodating a price ranging from $10.00 to $2.00/lb to reach our goal of $1,000/acre in weed control costs to be competitive with existing alternatives. Thus using the highest rate (500 lbs/acre) and an estimated natural pesticide production cost of $0.20/lb, a $0.25/lb profit is predicted for the worst case scenario. Lower use rates or the lack of suitable weed control alternatives to meet the $1,000/acre target will result in a higher profit margin.

Although nematodes cause less crop damage than weeds, a survey of 35 states in the U.S. indicated nematode-derived losses of up to 25% on various crops. It is estimated that 10% of a U.S. potato crops are lost to nematode damage. Worldwide crop losses by nematodes are estimated at $120 billion a year. Nematode-caused losses of wheat yields in the Pacific Northwest alone are estimated to be $51 million a year. Nematodes are typically controlled using

high toxicity, synthetic pesticide fumigants that sterilize the soil. Many of the products such as methyl bromide are being phased out or are under scrutiny by EPA. Nematode control in organic agriculture where synthetic fumigants are not allowed is especially challenging. Amendments to increase beneficial organisms that suppress nematode activity and solarization are the primary approaches. Effective alternatives for nematode control are especially needed in organic agriculture and as replacements for methyl bromide.

Our focus will be on high value crops or specific cropping situations that don't have nematode control alternatives. Costs for producing the natural nematicidal product will be similar to those for the natural herbicide, and thus the product must have a value greater than $1.75/lb. Application rates to control nematodes will range from 500 to 1000 lbs/acre, thus generating break-even price points from $875 to $1,750/acre. These costs will be competitive with the most effective nematicide methyl bromide, given that methyl bromide application costs are approximately $3,000/acre. The natural nematicide product will not be capable of competing with synthetic fumigants such as Vapam ($500/acre) and Telone ($1,000/acre). However, we are not targeting crops that use less effective fumigants, but will direct our product towards the organic market and those crops that still require methyl bromide (1/3 of all CA strawberries are still fumigated with methyl bromide). Another potential competitor, Dominus, is a new synthetic fumigant registered with EPA in 2013. Testing in different crops and environments is ongoing. Because this is a synthetic fumigant, our natural pesticide will not be a direct competitor.

We have taken a conservative approach and assume a CA organic fruit and vegetable market only. Natural pesticides will be used once a year on 10% of the 200,000 acres at an average rate of 250 lbs/acre for weed control and 5% of those acres at an average rate of 500 lb/acre for

nematode control. Total product used in CA would thus amount to 10 million lbs at an estimated minimum value of $20 million ($2.00/lb).

The final market for a product more relevant to ID agriculture includes that of a sprout inhibitor for stored potatoes to maintain quality and marketability. A total of 40 billion pounds of potatoes were produced in the U.S. in 2012, with 14 billion pounds of that production occurring in ID. Eighty percent of those potatoes are stored for some period of time requiring sprout inhibitors costing $7-9 million in the Northwest alone. Chlorpropham (CIPC) is the most widely used sprout inhibitor in the world and although it is effective and inexpensive, human health impacts of residues in the potato are of concern particularly in the European Union (EU). If the EU bans CIPC for use on potatoes, it is likely that the U.S. will reevaluate its use as well, thus establishing a critical need for alternative sprout inhibitors.

A single storage shed holds 100,000 to 500,000 cwt (100 weight). CIPC costs $0.03/100 cwt, clove oil $0.11/cwt, and new product Smart Block $0.20/cwt. For conventionally grown potatoes, our proposed product would not have to compete with CIPC or clove oil, but would have to have a cost similar to Smart Block. For organic potatoes, few alternatives without unwanted flavor impacts such as occur with clove oil are available, thus allowing for a higher market price for a new organic sprout inhibitor. Actual cost for a recommended use rate of our sprout control product per 100 weight has not yet been determined. Once a use rate is determined by the 1,4GROUP, a profit margin can be estimated.

Entry of new products based on natural sources such as that proposed here has potential benefits that will make market entry feasible. The largest barrier to market entry is the need to register all products as biopesticides with EPA. The project will serve to generate the materials necessary for efficacy testing, thus demonstrating the market potential of our products to

commercialization partners. Because registration of biopesticides is less costly than for synthetic compounds, commercial partners will be more willing to fund EPA registration costs.

9. The technology and path to commercialization:

a. Describe the technology and the current state of the technology. The technology includes all processes related to extraction, concentration, drying, and formulation of two natural pesticide products. Thus both the methods leading to the formulated product and the contents of the final product represent technological advances previously unknown. Bioassays demonstrating pest control efficacy have shown that the products control weeds (**Fig. 2**) and nematodes, and inhibit the sprouting of potatoes (**Fig. 3**). The developed products have shown efficacy results equivalent to or better than other competing products currently available for organic agriculture.

b. Describe how the technology contributes to the product and market need and its intellectual property status. We propose to deliver a tangible product to our commercialization partners so that product feasibility testing is possible. Once our commercialization partners verify efficacy within the target markets, they will pursue EPA registration of the products as biopesticides. Techniques for extraction, drying, and formulation have not been previously disclosed to the public, thus inhibiting market entry by potential competitors. Intellectual property will be further protected through registration of the products as biopesticides with EPA.

c. Identify who developed the technology and with what funding. The technology was developed in the PI's laboratory. Federal funding from USDA and DOE has been used during a 26-year period to conduct the fundamental and applied studies that have led to the proposed products.

d. Identify the concrete steps to bring technology to market. Shelf-stable powders will be produced using the requested funding and transferred to our commercialization partners for

efficacy testing under real-world conditions. Commercialization partners are expected to recommend changes to our formulation and to propose use rates that lead to acceptable control. Assuming viability of the products, commercializatioin partners will agree to license the technology and pursue EPA registration of the products. FFI will have responsibility for marketing natural herbicides and nematicides. The 1,4GROUP will have responsibility for marketing the natural sprout inhibitor.

10. *Commercialization partners:* We currently have two potential commercialization partners, FFI based in Watsonville, CA and 1,4GROUP, Inc. operating out of Meridian, ID. Collaborations with FFI have been ongoing since 2007. **FFI currently markets mustard seed meals as soil amendments.** FFI representatives have visited UI several times and the PI has toured field plots in CA that were used to test mustard seed meal biopesticides. The PI's laboratory provides analytical services for quality control of seed meals marketed by FFI and frequently consults on technical aspects related to the chemistry of seed meal biopesticides. A non-disclosure agreement (NDA) exists with this company. Collaborations with 1,4GROUP, Inc. have developed only in the last year and an NDA is in the process of being signed. **The 1,4GROUP markets potato sprout inhibitors for conventional and organic markets.**

Our partners will be responsible for efficacy testing, and based on those studies will determine if the provided formulations should be modified for improved efficacy, safety, or application considerations. Meetings will be scheduled on a monthly basis to inform our partners as to our progress in generating relevant biopesticides for testing. The PI will participate in designing the efficacy studies and in developing label recommendations for the potential products. Successful completion of the project will result in discussions on licensing the technologies, scaling up production facilities, and EPA registrations.

11. *Specific project plan and detailed use of funds:* Seed meals will be extracted with ethanol solutions ranging from 30 to 70% depending on the desired product. Ethanol will be removed from the extract and the remaining material concentrated to contain approximately 20% solids. Spray drying will be performed using equipment to be purchased with requested funding producing shelf-stable powders that are freely water soluble. The powdered product will be formulated with additional constituents shown in preliminary experiments to enhance activity. The PI will be assisted by a full-time Ph.D. analytical chemist and one part-time employee supported by grant funds. A half-time employee will be hired to extract and dry the extracts. Milestones include production of two different products including an extract from *S. alba* seed meal with herbicidal activity and an extract from *B. juncea* seed meal with nematicidal and sprout inhibiting activities. Performance metrics will include the amount of powdered product generated and the active ingredient concentration of that respective material. The requested budget amount of $72,900 will be used to purchase, ship, and install a Buchi Mini-Spray Dryer model B-290 ($43,000) and pay salary ($18,700) and fringe benefits ($8,100) of a half-time employee for one year at a rate of $18/hour. The PI has requested 2% of his academic year salary for summer support ($2,400) with associated 30% fringe benefits on that salary ($700).

The project timelines includes natural pesticide formulation in months 1-6 and efficacy testing by commercialization partners in months 7-12. Initiation of EPA registration will commence in month 12 and take approximately 2 years to complete.

12. *Institutional and Other Sector Support:* Salaries of the PI and 50% of the Ph.D. analytical chemist are funded by the UI. Sufficient laboratory space and relevant equipment will also be provided. Two ongoing funded projects will provide supplemental financial support for reagents, chemicals, glassware, and chromatographic columns (see Current Support in Appendix 2).

Appendices:

1. Facilities and Equipment: The PI has available a fully equipped 1500-ft^2 laboratory staffed by a full-time staff Ph.D. chemist. Relevant equipment in his laboratory includes an Agilent 1200 Series High Performance Liquid Chromatograph equipped with 6210 TOF MS and diode array detectors and a Dionex Ion Chromatograph equipped with GP40/ED40/AS40 units. Seed crushing and engineering space for scale-up activities are available through existing collaborations with investigators in the field of agricultural engineering. On-campus greenhouse space and local field space are also available. FFI maintains a seed crushing facility, greenhouses, and field sites that will be used for efficacy testing. The 1,4GROUP has facilities available to determine application rate, application methods, efficacy rates with time, and conduct upscale studies on 200 to 36,000 pounds of stored potatoes.

2. Biographic Sketch and Individual Support:

MATTHEW J. MORRA

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Division of Soil & Land Resources
University of Idaho
875 Perimeter Drive MS 2339
Moscow, ID, 83844-2339, USA

Phone: 208-885-6315
Email: mmorra@uidaho.edu

Education/Experience

Professor of Soil Biochemistry, University of Idaho, 1997-present
Affiliate Professor, CATIE (Centro Agronómico Tropical de Investigación y Enseñanza), Turrialba, Costa Rica, 2001-present
Visiting Professor, Plant Industries, CSIRO, Canberra, Australia, 2000
Soil & Land Resources Division Chair, University of Idaho, 1999-2007
Associate Professor of Soil Biochemistry, University of Idaho, 1992-1997
Assistant Professor of Soil Biochemistry, University of Idaho, 1986-1992
Ph.D., Agronomy (Soil Biochemistry), 1986, Ohio State University, Columbus, OH
M.E.M., Environmental Management, 1982, Duke University, Durham, NC
B.A., Biology, 1981, College of Wooster, Wooster, OH

Honors and Awards

Department of Plant, Soil and Entomological Sciences in Teaching Award, 2008
University of Idaho Environmental Science Program Outstanding Faculty Award, 2008
Alumni Award for Excellence, University of Idaho Alumni Association, 2002
Department of Plant, Soil, and Entomological Sciences Teaching Award, 2002
University of Idaho Research Excellence Award, 1999
Gamma Sigma Delta Outstanding Research Award, 1992
Nominated for NSF Presidential Young Investigator Award, 1988

Relevant Peer-Refereed Papers (total = 81; h index = 27)

Meyer, S.L.F., I.A. Zasada, S.M. Rupprecht, M.J. VanGessel, C.R.R. Hooks, M.J. Morra, K.L. Everts. 2014. Mustard seed meal applications for suppression of plant-parasitic nematodes and weeds on tomato. Horttechnology (in press).

Popova, I, and M.J. Morra. 2014. Simultaneous quantification of sinigrin, sinalbin, and anionic glucosinolate hydrolysis products in *Brassica juncea* and *Sinapis alba* seed extracts using ion chromatography. J. Agric. Food Chem. 62:10687-10693.

Popova, I, and M.J. Morra. 2014. Sinigrin and sinalbin quantification in mustard seed using high performance liquid chromatography-time-of-flight mass spectrometry. J. Food Comp. Anal. 35:120-126.

Main, M., J.P. McCaffrey, and M.J. Morra. 2014. Insecticidal activity of *Brassica juncea* seed meal to the fungus gnat *Bradysia impatiens* Johannsen (Diptera:Sciaridae). J. Appl. Entomol. 139:701-707.

Dubie, J., A. Stancik, M Morra, and C. Nindo. 2013. Antioxidant extraction from mustard (*Brassica juncea*) seed meal using high-intensity ultrasound. J. Food Sci. 78:E542-E548.

Hansson, D., M.J. Morra, V. Borek, and S.D. Eigenbrode. 2013. Green peach aphid [*Myzus persicae* (Sulzer) (Hemiptera: Aphididae)] control using Brassicaceae ethyl-ester oil sprays. J. Appl. Entomol. 137:530-539.

Hendrix, K.M., M.J. Morra, H.-B. Lee, S.C. Min. 2012. Defatted mustard seed meal-based biopolymer film development. Food Hydrocolloids 26:118-125.
Meyer, S.L.F., I.A. Zasada, S.B. Orisajo, M.J. Morra. 2011. Mustard seed meal mixtures: phytotoxicity to lettuce and pepper and management of *Meloidogyne incognita* on pepper. J. Nematology 43:7-15.
Boydston, R.A., M.J. Morra, V. Borek, L. Clayton, and S.F. Vaughn. 2011. Onion and weed response to mustard (*Sinapis alba*) seed meal. Weed Sci. 59:546-552.
Snyder, A.J., J.L. Johnson-Maynard, and M.J. Morra. 2010. Nitrogen mineralization in soil incubated with ^{15}N-labeled Brassicaceae seed meals. Appl. Soil Ecol. 46:73-80.
Morra, M.J. and V. Borek. 2010. Glucosinolate preservation in stored Brassicaceae seed meals. J. Stored Prod. Res. 46:98-102.
Zasada, I.A., S.L.F. Meyer, and M.J. Morra. 2009. Brassicaceous seed meals as soil amendments to suppress the plant-parasitic nematodes *Pratylenchus penetrans* and *Meloidogyne incognita*. J. Nematol. 41:221-227.
Brown, P.B. and M.J. Morra. 2009. Brassicaceae tissues as inhibitors of nitrification in soil. J. Agric. Food Chem. 57:7706–7711.
Snyder, A., M.J. Morra, J. Johnson-Maynard, and D.C. Thill. 2009. Seed meals from Brassicaceae oilseed crops as soil amendments: Influence on carrot growth, microbial biomass N, and N mineralization. HortScience 44:354-361.
Hansson, D., M.J. Morra, V. Borek, A.J. Snyder, J.L. Johnson-Maynard, and D.C. Thill. 2008. Ionic thiocyanate (SCN^-) production, fate, and phytotoxicity in soil amended with Brassicaceae seed meals. J. Agric. Food Chem. 56:3912–3917.
Brown, B.D., R.C. Gibson, B. Geary, and M.J. Morra. 2008. Biofumigant biomass, nutrient content, and glucosinolate response to phosphorus. J. Plant Nutr. 31:743-757.
Rice, A.R., J.L. Johnson-Maynard, D.C. Thill, and M.J. Morra. 2007. Vegetable crop emergence and weed control following amendment with different Brassicaceae seed meals. Renew. Agric. Food Systems 22:204–212.
Borek, V. and M.J. Morra. 2005. Ionic thiocyanate (SCN^-) production from 4-hydroxybenzyl glucosinolate contained in *Sinapis alba* seed meal. J. Agric. Food Chem. 47:3837-3842.
Morra, M.J. 2004. Controlling soil-borne plant pests using glucosinolate-containing tissues. Agroindustria 3:251-255.
Smolinska, U., M.J. Morra, G.R. Knudsen, and R.L. James. 2003. Isothiocyanates produced by Brassicaceae species as inhibitors of *Fusarium oxysporum*. Plant Dis. 87:407-412.

Current Support

Multiple Enhanced-value Co-products from Regionally Important Oilseed Feedstocks, USDA-NIFA, $599,000, 2011-2016.
Chemicals of Emerging Concern in the Eastern Snake River Plain of Idaho: A Threat to Irrigated Agriculture, Dairy, and Aquaculture? USDA-NIFA, $499,458, 2013-2016.
Eradication Strategies for *Globodera pallida*, the pale cyst nematode (PCN), USDA-APHIS, $36,410, 2014-2015.
Eradication Strategies for *Globodera pallida*, the pale cyst nematode (PCN), USDA-APHIS, $39,270, 2015-2016.

3. Provide documentation of other sector resource commitments: See attached letters of support from FFI and 1,4GROUP, Inc.

Farm Fuel Inc.
organic soil amendment & mustard seed biodiesel

March 25, 2015

To Whom It May Concern:

The project put forth in this proposal is complementary to the ongoing work at Farm Fuel, Inc. (FFI). FFI was started by a group of organic farmers and scientists in 2007 interested in reducing energy costs and increasing on-farm sustainability. What originated as a rotational oil seed crop has grown into a small industry offering plant-based solutions to commercial agriculture's pest control needs. Mustard seed was chosen as our initial crop for its high oil content and low cultivation inputs. In the past 8 years we have developed a commercial fertilizer and are working towards an EPA approved biopesticide from mustard seed meal.

It is with this background and intention that FFI looks to develop a wider portfolio of solutions for growers. The potential for mustard-based weed suppression exists. This grant funding will help us determine how mustard extracts can be utilized for the best economic and commercial purposes. Our preliminary research has demonstrated that using *S. alba* meal as a top dressing can control liverwort in ornamental production without negatively impacting the ornamental cash crop. Additionally, in-house trials in 2007 demonstrated how *S. alba* meal can be used to burn down poison oak. It is these types of efficacies that offer the best market ready solutions to homeowner and agriculturalist weed control needs. With the product supplied using the requested funding, we will better define these and other applications while adding to our understanding of the control of pre- and post- emergent weeds for a variety of commercial and environmental purposes.

FFI will test the supplied mustard extracts on various crops to confirm efficacy and define use recommendations. We will provide efficacy data to the UI and make recommendations on how the extracts might be improved for increased consumer acceptance. Pending acceptable performance of the extracts to control plant pests, FFI will work with the UI to register the products as biopesticides with EPA and develop a plan for expanding extraction capabilities to a level necessary for producing commercial amounts of the product in an economically viable manner.

The results of our tests will apply to the commercialization of *S. alba* extract in two parts. First, we will have a better understanding of what is required to manufacture *S. alba* extract on a large scale, allowing for economic modeling to scale up production. Second, the preliminary direction of *S. alba* extract usage will be better defined. The next steps will involve more extensive trials in commercial nurseries, orchards, and environmental restoration sites.

As all of FFI's products are available for use by both conventional and organic growers, we are often presented with a spectrum of challenges faced by today's commercial grower. As a farming industry, we are facing severe restrictions on

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pesticides use, and as a result conventional growers face new challenges with emerging diseases and weed pests. The development of a novel herbicide available for use for both organic and conventional growers would be an important new tool. Weeding time, and thus cost, can add up for growers and with labor shortages throughout the country, weed control continues to be a high priority for growers. Weed control is a vital area of research and development. Through the development of the proposed mustard-based products, we plan to generate a new generation of tools for farmers and homeowners. We look forward to working on this project with Dr. Morra and collaborators.

Sincerely,

March 29, 2015

Stefanie Bourcier, CEO Farm Fuel Inc.

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Higher Education Research Council
Idaho Incubation Fund Program
March 25, 2015

Dear Incubation Fund Review Team,

Potatoes are a unique crop in that they are harvested in the autumn months of August, September, and October and are stored in large storage units until needed for processing or for the retail market. Since the worldwide appetite for potato goods is quite large, processing and shipment occurs year round, thus requiring that potatoes are stored year round. Storing the potatoes in such a way that prevents sprouting is crucial for acquiring optimum end-product quality. One a potato begins to sprout, or break dormancy, then physiological changes occur that affect the texture, flavor, and color of the French fry or potato chip. For the retail market, sprouting potatoes are extremely undesirable in the grocery store and result in rejection by the consumer.

Storage units are designed to provide the optimum temperature, humidity, and air flow to naturally prevent sprouting. However, this method only provides control until the early winter months of December and January. After that period of time, sprouting naturally occurs and the end-product quality declines rapidly. Therefore, it is necessary to apply chemicals within the storage to maintain dormancy and prevent the potatoes from sprouting.

Post-harvest chemicals that inhibit sprouting fall into three families; traditional, bio-control, and organic. Currently, chlorpropham (CIPC) is the most widely used traditional chemical around the world for the prevention of sprouting. It was originally developed and approved for herbicidal use in 1953, but was quickly moved to potato storages to prevent sprouting. CIPC is inexpensive and it works well, however, environmental concerns about this chemical are under the scrutiny of the European Union. CIPC breaks down in potentially cancer causing agents at high temperatures and is toxic to water fowl and fish. Once the EU bans CIPC, which seems more likely every day, the United States will soon follow their lead. The need for a Bio-Control or Organic means to control sprouting will be necessary for potato storage units around the world.

Dr. Matt Morra has developed a potential Bio-Control for controlling sprouting in storage through the use of volatiles from mustard seed. The market potential for this product is quite large and could provide storage shed managers with another means to control sprouting in storage without the use of CIPC. A single storage shed can hold 100,000 to 500,000 cwt (100 weight) of potatoes and there are at least 2000 storage units in the United States. Last year, Idaho alone produced 2 billion tons of potatoes. In the United States, 3 billion pounds of potatoes produced $635 million dollars in French fry sales, 543 million pounds of potatoes produced $178 million of chips, 966 million pounds of potatoes produced $82 million in dehydrated flakes, granules, meal, and cubes.

Currently, all three families of chemicals are heat treated and fogged into storage sheds. However, the methods developed by Dr. Morra uses a new type of technology that would remove the need for heat treating.

The road to becoming a commercialized product begins with efficacy testing, i.e. proving that the chemical works. The chemical will be tested on dormant potatoes to determine if inhibition of sprouting truly occurs. 1,4GROUP will start on a small scale testing on 4 pound samples. If successful, the chemicals will be tested on 35 pounds, then 200 pounds, then 6,000 pounds samples. If the chemical is successful at the 6,000 pound level, then paperwork will be submitted to the EPA, USDA and the regulatory agencies at the Federal and State level for approval.

We at 1,4GROUP are very excited to begin this endeavor and look forward to researching this potential Bio-Control. We see great possibilities with Dr. Morra's discovery.

Sincerely,

Addie Waxman

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