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The challenge of manipulating seed quality traits in pea for multiple end uses

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The biochemical definition of target seed quality traits in pea, coupled with an understanding of their genetics, will provide tools and resources that may be exploited for a broad range of end-uses by the feed and food industries. Some end-uses make conflicting demands on seed product composition, for example where so-called anti-nutritional components in animal feed are now recognised as having health-promoting properties. Novel variants for the anti-nutritional proteins, pea albumin 2 and trypsin/ chymotrypsin inhibitors, have been isolated and provide tools for examining the contribution of such proteins to human health, as well as their potential for improving digestibility in animal feed. Metabolite analyses have identified downstream changes to pathways and compounds as a consequence of genetic background, as well as changes that can be attributed to the environment. The further identification of seed metabolites linked to food quality will provide links to pathways and markers for improved selection processes. The loss or retention of green colour by vining and marrowfat pea seeds is an economically significant quality parameter. Lines with stable green colour have been identified and used to develop recombinant inbred lines with associated maps to define genetic loci involved in seed colour stability. Allelic variation in candidate genes of the chlorophyll degradation pathway is providing markers for the selection of backcross lines for field analysis. Alongside the selection of novel germplasm, the TILLING platform (http://urgv.evry.inra.fr/UTILLdb) is being exploited to identify mutants in a number of seed protein gene families. The activities of the Pulse Crop Genetic Improvement Network (http:// www.pcgin.org) funded by Defra, UK, together with the EU-funded Grain Legumes Integrated Project (http://www.eugrainlegumes.org) and its associated technology transfer platform (http://www.gl-ttp.com/), have provided a mechanism to foster direct links between this research and the relevant industry.

Ferric reductase activity and *PsFROl* sequence variation in *Pisum sp.*

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Physiological studies in pea *(Pisum sativum)* suggest that the reduction of iron (Fe) is the rate-limiting physiological process in Fe acquisition by dicotyledonous plants. Previous molecular work suggests that ferric reductase activity is regulated at both the transcriptional and post-translational levels. In order to further dissect the regulation of ferric reductase transcription and activity, we are conducting a survey of 32 pea accessions derived from single-seed descent (obtained from the USDA Germplasm Collection, Pullman, WA). Plants were grown under low and high Fe conditions (0.5 and 15 μM Fe[III]-EDDHA) and analyzed for root ferric reductase activity. In addition, *PsFROl* was isolated and sequenced from all lines. Across the accessions, ferric reductase activity was variable and several polymorphisms were identified in *PsFROl.* This variation will be used to discuss the genetic and functional attributes that contribute to the regulation of iron homeostasis at the whole-plant level in pea.

Preliminary assessment of the genetic diversity of *Pisum sativum* USDA core seed collection for seed sugar composition and concentration

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Introduction

There is interest in enhancing the nutrient content (nutritional quality) of our food supply in order to help people attain the recommended daily allowances of various nutrients (5). Pea seeds are a good source of the sugars, starches and amino acids needed for energy and protein synthesis requirements in humans. Sugars, or low molecular weight carbohydrates (LMWC) in mature pea seed include simple sugars (glucose, fructose, sucrose, sorbitol) and raffinose family oligosacchardies (RFos) (raffinose, stachyose, verbascose)(4). RFos are important to plants for frost tolerance, desiccation protection during seed maturation, and carbohydrate transport in the phloem. RFos have been implicated in anti-nutritional effects like gastric upset in monogastric animals, but also probiotic effects (1). Previous studies have indicated that genetic variation for LMWC in pea seeds is highly influenced by the environment (1), however no evaluations of a significant number of landrace genotypes have been reported. Starch mutants within pea *(Pisum sativum,* L.), which induce wrinkling of the seed as a result of differences in seed LMWC composition, have been identified and characterized for variation at six rugosus loci (2). Our objectives are to evaluate a set of mostly wrinkled pea accessions from the PI collection at green harvest stage and to identify new genotypes for crop improvement. We will present our preliminary results on 16 landraces and cultivars.

Materials and methods

Six plants from each of 120 wrinkle-seeded *Pisum sativum* accessions were grown in 4.4 L pots of a commercial soilless mix (Sunshine #4) in a greenhouse under 16hr/8hr day/night 20/15 C°. Pods were

Table 1. Results of 16 accessions of seven low molecular weight carbohydrates (µg/g fresh weigh) using β-D-phenylglucopyranoside as an internal standard and fructose, glucose, raffinose, stachyose and verbascose as external standards for gas-liquid chromatography analysis.

Accession	Fructose	S.E.	Glucose	S.E.	Sorbitol	S.E.	β-phenyl Glucoside	S.E.	Sucrose	S.E.	Raffinose	S.E.	Stachyose	S.E.	Verbascose	S.E.
W 6 17516	273.1	49.9	543.3	124.5	366.1	44.4	555.5	101.7	41311.0	9306.6	51.6	14.9	311.6	46.2	0.0	0.0
PI 236492	451.8	30.0	435.4	69.9	76.9	12.6	519.8	45.9	14256.5	2449.6	138.9	17.3	1194.4	74.0	9.1	5.8
PI 279825	525.6	5.4	664.4	8.5	126.8	0.2	662.7	60.6	19927.3	731.7	22.4	4.8	20.9	2.7	5.9	0.4
PI 413703	300.6	136.8	253.9	86.5	96.1	19.9	369.3	159.2	15074.7	4711.5	15.3	6.2	12.8	1.5	1.5	1.0
PI 244093	460.6	79.2	651.8	89.7	83.8	29.3	300.2	85.9	15596.2	6235.0	12.7	5.9	2.9	0.8	1.3	0.4
PI 269821	264.9	42.6	63.8	4.3	116.9	27.9	262.1	96.1	11725.5	5917.6	438.2	224.4	5922.2	2304.9	3.1	1.1
PI 574510	338.3	1.5	105.9	0.1	126.3	5.4	276.2	7.6	15692.2	1199.3	1970.8	101.6	15131.6	2270.9	4.9	1.0
PI 411143	460.9	41.1	412.2	113.0	202.0	17.1	371.6	12.7	30543.3	1620.8	45.5	2.5	8.6	4.9	0.8	0.3
PI 356974	532.4	111.8	511.9	108.1	352.9	20.1	594.2	21.1	33706.9	1772.7	35.5	1.0	6.4	2.6	4.1	3.2
PI 413684	583.6	163.4	701.4	141.5	105.6	36.8	400.1	51.2	19812.9	3580.8	21.7	8.6	6.5	4.1	15.0	9.5
PI 244150	880.6	189.7	882.8	111.9	147.9	10.8	740.2	28.8	15538.4	247.0	498.8	106.0	1995.6	680.7	45.6	19.5
PI 261636	482.8	152.3	534.2	136.1	160.2	34.9	593.6	69.8	30206.3	3970.5	68.2	21.4	34.7	26.8	19.6	13.1
PI 343990	418.9	78.1	381.4	100.5	64.2	4.2	299.3	84.1	16163.7	4618.5	164.4	62.5	603.1	402.8	20.3	10.1
PI 654781	451.6	32.9	311.0	24.3	143.8	41.5	313.6	7.3	20902.3	3096.9	28.2	5.8	0.0	0.0	0.0	0.0
PI 288026	423.40	7.9	441.8	10.2	220.3	21.1	377.4	29.1	27041.7	2752.6	44.3	5.0	0.0	0.0	0.9	1.0
PI 206781	410.59	108.4	117.9	14.3	151.3	34.9	462.7	70.4	8615.1	1283.1	1180.5	182.2	26674.6	3844.0	24.4	1.5

S.E. = standard error of the mean of three replications.

harvested at the immature green pea stage and frozen at -20 C°. Pea seed was removed and three samples of uniform color and size seed of one gram each were ground using a homogenizer and processed for LMWC analysis using gas-liquid chromatography as described by McPhee et al. (3).

Results and discussion

The preliminary analysis of the USDA from the core collection based on 16 accessions (Table 1) indicates a wide range of low molecular weight carbohydrate concentrations expressed as |g/g fresh weigh were identified. In this subset of accessions the highest concentrations of LMWC were sucrose and stachyose which range from 9,294 to 42,493 and 0 to 26,674 |g/g fresh weigh, respectively. While significant variation for LMWC was identified, the absence of method to select uniform immature green pea for analysis, such as a tenderometer reading, is a significant problem. We plan to use a uniform harvest using days after pollination for the next experiment.

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Variation for seed mineral and protein concentrations in diverse germplasm of lentil

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Lentil *(Lens culinaris)* is an important food legume that can provide significant amounts of dietary minerals and other essential nutrients to humans. To understand the nutritional diversity that exists within this species, we measured seed mineral and protein concentrations in 350 diverse accessions of the lentil single-plant derived core collection that is maintained by USDA. Plants were grown to maturity in a greenhouse using a soil mix and were irrigated daily with a complete nutrient solution. At maturity, all seeds collected from six plants per accession were combined, dried at 70 C, and finely ground to homogenize the bulk sample prior to further analysis. Ranges of seed mineral concentrations and protein percentages, along with correlations between traits, will be presented. Results will focus on Ca, Mg, K, P, Fe, Mn, Zn, Cu, and total protein. Data for individual accessions will be available in the USDA-ARS Germplasm Resource Information Network (GRIN) database, where it can be accessed by breeders and other scientists.

Creating an integrated genomic technology platform for lentil breeding

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In an effort to develop an integrated genomics technology platform to assist in lentil crop development, we have undertaken deep sequencing of expressed genes in selected genotypes that represent a wide range of cultivated germplasm used in the Canadian lentil breeding program. A high throughput SNP discovery and mapping platform is being built in collaboration with Canadian and international collaborators to map a large number of gene-based markers and integrate the lentil sequence information and mapping data with model legume genomes. Efforts to translate these genomic resources into crop development tools will be presented.

Variation in fungicide sensitivity and mycelial compatibility between two field populations of *Sclerotinia sclerotiorum*

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Sclerotinia sclerotiorum is a ubiquitous necrotrophic pathogen. It causes white mold on more than 400 plant species including chickpea, lentil, pea and potato. In order to understand the effect of host plants, cropping history and cultural practices on evolutionary potential of *S. sclerotiorum,* a pathogen population from pea was compared with a population from potato in terms of mycelial compatibility grouping (MCG) and fungicide sensitivity. Fungicide application and irrigation are regular practices in potato production, whereas no fungicides or irrigation are used in dry pea production. A total of 57 isolates (31 from a commercial dry pea field and 26 from a commercial potato field) were used in the comparison. Twenty-three MCGs were found among 31 pea isolates (G:N ratio 0.74), and 17 MCGs in 26 isolates of the potato population (G:N ratio 0.65), suggesting that relatively higher genetic diversity exists in the pea population. Variation in sensitivity to two fungicides between the two populations was also compared. Colony diameters were determined 36 hrs after inoculation on PDA plates amended with Benomyl (0.2 |_ig a.i./ml) and Quadris (0.8 |_ig a.i./ml). Pea field population showed greater variance than did the potato population for both the fungicides, suggesting that the pea population has higher diversity for loci controlling fungicide sensitivity and has more potential to adapt into new environments. No variation was found in sclerotial dry weight between the two populations suggesting that life history traits are less prone to selection pressure. These two populations are being assessed for variation at 12 microsatellite loci to estimate genetic differentiation at neutral markers between the two populations.

Utilization of disease resistance genes in chickpea and lentil and their wild relatives

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Incorporation of disease resistance genes in crop varieties begins with a search for lines of the cultivated species that are resistant to pathogen isolates representative of the area for which the varieties are intended. This presentation will focus on progress in the incorporation of resistance to anthracnose *(Colletotrichum truncatum)* and ascochyta blight *(Ascochyta lentis)* in lentil *(Lens culinaris)* and ascochyta blight *(Ascochyta rabiei)* in chickpea *(Cicer arietinum).* Screening at PGRC of about 2000 *L. culinaris* lines identified resistance to either ascochyta blight or anthracnose. ILL358 and ILL5588 were resistant to only 22% and 35% of the Canadian *A. lentis* isolates tested while cv. Indianhead and ILL7537 were resistant to all and therefore ideal for variety improvement. A specific line by isolate interaction was observed, indicating the presence of pathogen races also described in Australia and New Zealand. Resistance to *C. truncatum* race Ct1 was identified in several *L. culinaris* lines. Partial resistance to the other more aggressive race, CtO, was initially found in only a single line, ILL421. Recently, screening of new germplasm resulted in more lines with good levels of CtO resistance which will be amendable to breeding. Co-dominant molecular markers in lentil are sparse, and we are in progress of developing SSR markers from lentil expressed sequence tags in an effort to better map disease resistance in ILL7537, PI320937, Indianhead and the new lines with CtO resistance. Several non-allelic dominant or recessive genes in *L. culinaris* are available for crop improvement reducing the need for introgression of resistance from wild lentil. We are also studying resistance in chickpea lines originally identified at ICARDA and ICRISAT. Some of these lines were resistant to all Canadian *A. rabiei* isolates while others were resistant to only a portion. Fifteen QTLs associated with ascochyta resistance in chickpea were identified in eleven mapping populations. Linkage analysis of marker data from *C. arietinum* x *C. reticulatum* revealed a high degree of segregation distortion in certain linkage groups which prevented mapping of some of the loci contributing to ascochyta resistance. We plan to pyramid selected QTLs by crossing *C. arietinum* lines with high yielding chickpea varieties. F1 progeny will be selfed to allow selection of both dominant and recessive resistance loci in F_2 using markers flanking each resistance QTL. Inter-crossing of F_2 and selfing will continue until QTLs from 2 or 3 lines are combined into breeding materials. A study of the molecular interaction on the leaf surface between chickpea and *A. rabiei* has shown the presence of effector and suppressor molecules secreted by both the host and pathogen. We intend to identify the underlying defense genes in this interplay and determine if some genes co-locate with the known QTLs for ascochyta resistance.

Improving resistance to mycosphaerella blight and powdery mildew by using wild *Pisum* resistance sources

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Recent studies by Fondevilla *et al.* identified high levels of resistance to ascochyta blight and a new gene *(Er3)* for resistance to powdery mildew in accessions of *Pisum fulvum,* a wild relative of field pea. We have initiated research to evaluate these new resistance sources, as well as other wild *Pisum accessions,* under Saskatchewan conditions. In the case of mycosphaerella blight, fifty three wild accessions (including *P. fulvum, P. sativum,* ssp. *elatius, P. sativum* ssp. *abyssinicum, P. sativum* ssp. *asiaticum, P. sativum* ssp. *transcaucasicum, and P. sativum* var. *arvense)* from USDA and CSIC (Spain) were evaluated under greenhouse conditions, with the most promising of these further evaluated under field conditions. The wild accessions differed significantly in their resistance level, with W6 15O17 and P-651 (P. *fulvum),* as well as PI 344538 (P. *sativum,* ssp. *elatius),* showing greater resistance than the most resistant check Radley. In the case of powdery mildew, seven accessions carrying resistance gene *er1,* one accession with er2, two accessions with Er3, along with two susceptible checks were evaluated for powdery mildew at two locations in Saskatchewan in 2OO9. Accessions carrying *Er3* were found to be completely resistant to powdery mildew, as were accessions carrying er1. Accessions with *er2* developed disease 2-3 weeks after the susceptible checks, with the disease developing to a moderate level towards maturity.

Lentils in Alaska: Potential and prospects

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The Western Regional Plant Introduction Station at Pullman, Washington holds the USDA collection of cool-season pulses. The USDA lentil collection consists of 2798 accessions (1), including an established core collection of 280 accessions (2, 5). This core collection was collaboratively grown out at the Sub-arctic Agricultural Research Unit's Germplasm (SARU) site in Palmer, Alaska. Five commercial check varieties were included in the study: Crimson, Eston, Laird, Pardina and Redchief. Two replications in a randomized complete block design were planted for a total of 570 plots. Although lentils have been previously tested in Alaska for nitrogen fixation (3, 4), they had not been seriously considered for use as a grain crop. To our knowledge, this is the first major screening of lentil germplasm in Alaska.

Table 1:	Rep 1		Rep 2		
	Range	Mean	Range	Mean	Pr >|t|
Days to emergence	8-19	8.86	7-14	8.43	0.0359*
Days to flowering	39-65	51.14	51-64	54.00	<0.0001*
Plant vigor	1-5	2.89	1-5	3.79	<0.0001*
Pod set vigor	1-3	1.91	1-3	1.97	0.3827
Plant height	6-33	18.26	10-40	21.43	<0.0001*

The Alaska growing season is unique in that it is very short (approximately 9O-1OO days) with up to 22 hours of continuous daylight. Planting took place

the first week of June in cool, damp soils. The 2OO9 growing season consisted of mostly warm, dry days with an average high temperature of 75.3°F and average day length of 18 hours. There was very little rain and supplemental irrigation was used when necessary. The major impediment during the season was a healthy weed population consisting mostly of Lambsquarters and chickweed.

Data were collected on days to emergence, days to 50% flowering, and plant height (Table 1). Plots were also scored for both plant vigor and pod set vigor. only two accessions failed to germinate in one replication. Only 6 plots failed to produce pods at all. Twenty-nine accessions, including two check varieties, showed advanced pod set in both replications. A total of 77 accessions, including two check varieties, showed advanced pod set in one of the two replications. Those accessions with a combination of excellent vigor and advanced pod set will be analyzed for nitrogen content to test their potential as a cover crop or forage.

Although no accession made it to full maturity, a number of accessions made it to advanced pod fill. The core collection does contain accessions known to be early maturing (5). Planting date and weed issues may have resulted in delayed maturity overall. However, the results presented here show that there is potential for lentils as a grain crop in Alaska. In addition, the vigorous vegetative growth in a number of accessions shows promise for forage production.

We will replant the most promising accessions from the core collection in spring 2O1O. In addition, one cultivar (Morton) and 12 breeding lines were planted in October 2OO9 in an attempt to increase the growing season. We would also expect that early maturity varieties or breeding lines to perform well. We thus seek cold tolerant, short season cultivars/breeding lines to test their potential in Alaska for both fall and spring planting. Alaska SARU is open to collaboration for those wishing to test such varieties.

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Evaluation of fungicide seed treatments as management tools for root rot of dry peas in North Dakota

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North Dakota is the largest producer of dry pea *(Pisum sativum)* in the United States with approximately 520 thousand acres planted in 2OO9. Root rots are a major disease problem statewide. Fungicide seed treatments can be used as management tools, but few trials have been done in North Dakota. The objectives of this study were to determine the effects of fungicide seed treatments on stand, disease severity, and yield and to identify the causal pathogen(s). Field trials were conducted in 2008 and 2009 at the Carrington Research Extension Center in Carrington, ND and an on-farm location near Newberg, ND. Trials included multiple rates and combinations of fungicides including; mefenoxam, fludioxonil and trifloxystrobin. A yield increase and reduction in disease severity over the untreated control were observed with some fungicide seed treatments. Pathogen isolations from infected roots indicate *Fusarium* species were primarily responsible for causing root rots.

Soybean *(Glycine max* L.) as potential forage in the northern high plains of USA

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Soybean was introduced to the USA and initially promoted as forage crop in mid 1800S. However, the focus was shifted to as grain crop rather than forage in late 1940S. Livestock is a major component of agricultural production in northern High Plains of the USA and high quality forage is essential to support the industry. Foxtail, sorghum/Sudan grass, oat, alfalfa are the commonly grown forage in the area. High yielding legume forage is desirable because of its high feed quality and ability to add nitrogen to the soil through biological nitrogen fixation. Alfalfa is the only high quality major legume forage grown in the region. Therefore, availability of alternative or complementary legume forage will be significant in supporting livestock industry in the region because of high price and decreased reliance on alfalfa by livestock producers.

The objective of this study was to test feasibility of soybean as forage crop in northern High Plains and to determine the best stage to harvest forage without losing its quality. In 2009, eight forage soybean varieties (RR5519, RRJ7609, Ozark, RR-Large Lad, RR-Big Fellow, RR4818, Derry, and Laredo) were planted on May 29 at Scottsbluff, NE following randomized complete block design under flood irrigation as single plot (7.6 m long 4 rows with 0.5 m spacing). Height (m) and plants were harvested from 1 m plot to determine forage yield (fresh and dry matter) in Mg/ha were recorded at different development stages starting from R1 stage (beginning bloom) until R7 stage (full seed stage). Three harvests were made on September 3, 16 and 30 and data were recorded.

Table 1: Forage soybean height and yield at different growth stage based on 2009 trial at Scottsbluff, NE.

Harvest	Growth Stage Range (Av. Stage)	Average Height (m)	Average Fresh Yield (Mg/ha)	Average Dry Matter Yield (Mg/Ha)
Sept. 3, 2009	V-R1 (V)	0.76	20.756	5.325
Sept. 16, 2009	R1-R3 (R2)	0.86	24.393	6.874
Sept. 30, 2009	R3-R6 (R4)	0.94	26.411	8.627

Height and fresh and dry matter yield increases as plants were maturing from R1 to R6 stage (Table 1). However, overall quality of the forage may be reduced as plants get older. Forage quality analysis is in progress and we will know the best developmental stage for optimum forage yield and forage quality. Although more trials need to be conducted, this first year preliminary data indicates that soybean is a potential forage crop in northern High Plains of USA.

Effects of fungicide usage on chickpea rhizospheric bacterial community

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Chickpea *(Cicer arietinum* L.), as an annual grain legume crop, is the third most important food legume in the world after dry bean *(Phaseolus vulgaris* L.) and pea *(Pisum sativum* L.) (1), and has been used for crop diversification in wheat-based rotation in dry areas of Canada. In order to prevent ascochyta blight *(Ascochyta rabiei)* outbreaks and yield loss, fungicide applications is common practice in chickpea production (2). Some bacterial species have a similar chemical binding site as fungi and the fungicides used in chickpea field may influence the soil bacterial community. Wether or not effects of foliar fungicide application on soil bacteria are important is a matter of debate (3, 4), and a question that we addressed.

Soil samples were collected in 2008 from a field experiment where 2 chickpea cultivars received one of 4 different fungicide treatments involving Bravo® and Headline Duo®. The diversity of the bacterial communities in rhizospheric soil from plots under different treatments was analysed using a molecular (polymerase chain reaction - denaturing gradient gel electrophoresis) and a physiological (phospholipid fatty acid methyl esters) 'fingerprinting' methods.

Results showed that chickpea genotypes influence their microbial environment differently, as Luna was associated with a higher Gram- bacterial biomass than Vanguard. Fungicide applications on above ground chickpea parts had no effect on bacterial biomass in the rhizosphere of field-grown chickpea, but decreased the diversity of dominant bacterial DNA sequences. The negative effect on fungicide application on bacterial diversity increased with the number of fungicide application on chickpea aerial parts. Applying Bravo® at the vegetative stage between applications of Headline Duo® at seedling and early flowering stages of chickpea growth had no detectable effect on related rhizospheric bacteria. We conclude that fungicide application on chickpea leaves can reduce bacterial diversity in chickpea rhizosphere. This effect may be indirect and mediated by chickpea response to fungicide application.

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First-year results of evaluating winter-hardiness of 55 faba bean (*Viciafaba* L.) accessions from the NPGS collection

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Introduction
Grain legumes are the ideal crops in rotation with cereal crops (1) since legumes have the ability to fix atmospheric nitrogen via symbiosis with nitrogen-fixing rhizobia bacteria. Currently, only winter-hardy peas and lentils are used in rotation with wheat in the Palouse region of Washington and Idaho. Murray et al. (2) reported that faba bean (*Vicia faba* L.) has the same winter-hardiness as lentil and better than pea. The objective of this project is to evaluate the winter-hardiness of the faba bean accessions in NPGS collection in Pullman and identify winter-hardy genotypes for future crop development.

Materials and methods
Forty-three faba bean accessions maintained by the USDA-ARS Western Regional Plant Introduction Station in Pullman, WA, were used for the first year experiment. These included 15 accessions from Afghanistan, six from Bulgaria, 13 from China, two from Finland, two from Hungary, four from Nepal and one from Poland. In addition, 12 cultivars and breeding lines obtained from Professor W. Link, Department of Crop Sciences, Georg-August University, Germany, were included in the trial for these lines were reported have good level of winter hardiness (3.4).

Thirty seeds from each entry were planted in single row plot (3.05 m long with 1.52 m between rows) in a replicated field trial at two locations (on September 29 in Pullman and on October 8 in Central Ferry). Observation notes were taken through the growing season and a one-to-four scale was used to score the winter hardiness (1: no or little damage, 2: slight damage, 3: intermediate damage and 4: severe damage). The plots were harvested on June 2009 and seed yield was measured for each plot.

Results and discussion
There is a high level of variation in winter hardiness among the accessions, which showed different responses to the low temperature during the winter. Some exhibited little or no damage and others were severely damaged in both locations. All accessions survived in Central Ferry while several accessions were completely dead in Pullman. There is a high level of variation in winter hardiness among the accessions under evaluation and the variation is heritable as the same accession expressed similar hardiness in both locations. Figure 1 depicts the average yield per plot of the 55 entries in the Central Ferry location. A significant correlation exists between the winter hardiness score and the average plot yield ranging from 27 to 405 grams. The mean yield per plot for 32 accessions with winter hardiness scores above 2 was 160 grams and that of 23 accessions with winter hardiness scores 1 and 2 was 230 grams. It was observed that some accessions had the ability to send out shoots from the lower nodes of the stem. This "regrow" ability was observed after the leaves of the upper nodes were damaged or killed by low temperatures and could be used as one of the criteria to measure winter hardiness of faba bean. One accession had a winter hardiness score of 4 but also had the highest yield per plot due to its strongest regrow ability. Further investigation into this trait is needed to elucidate this winter survival mechanism. Our preliminary results suggested that the

accessions with high level of winter hardiness have the potential to be developed into an alternative fall-planting rotation crop for the Palouse region of Washington and Idaho.

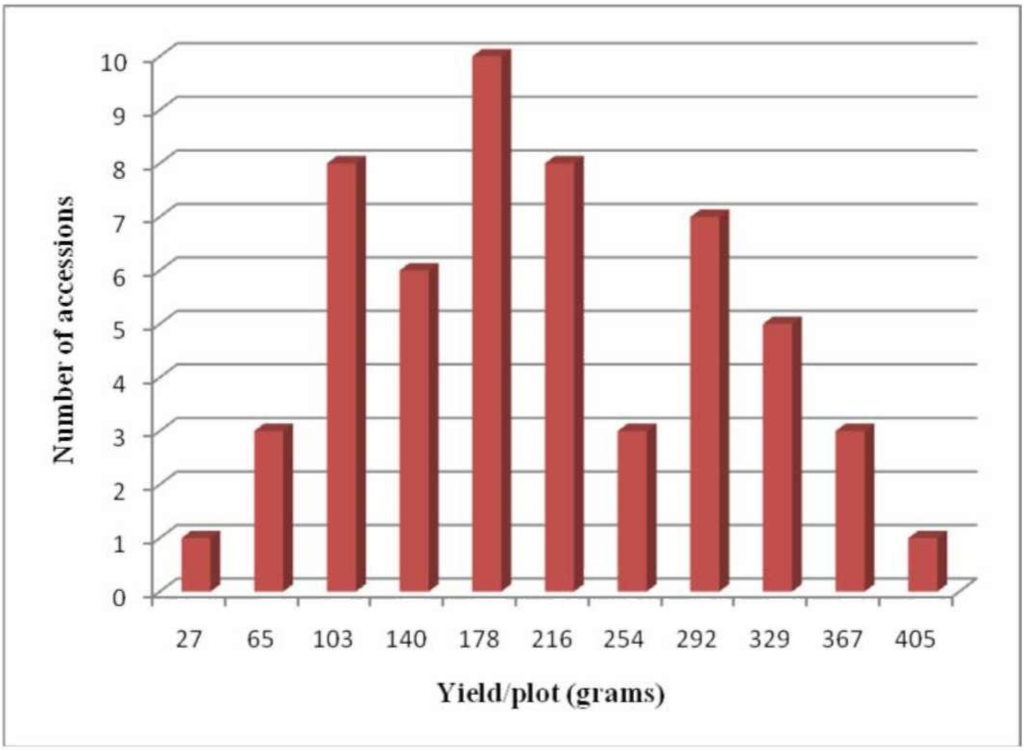

Figure 1. ***Histogram of average seed yield (grams/plot) of the 55 entries harvested from the Central Ferry location.***

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Epidemiology and management of ascochyta blight in improved Australian pulse crops

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Control of ascochyta blight in cool season winter grown pulse crops in Australia is reliant on a combination of strategies. Historically Australian cultivars of field pea, faba bean, chickpea and some lentil were susceptible to ascochyta blight. Successful crop production depended upon wide rotations of the same crop type to limit pathogen carryover, distance from infested stubble, strategic delayed sowing dates and regular fungicide applications. The fungicide strategies have been developed around the registered products, chlorothalonil and mancozeb. Chemical companies have not registered other actives for pulse crops in Australia, possibly due to the high costs for a relatively small industry. Chlorothalonil and mancozeb have protective rather than curative properties. While the efficacy of these fungicides was demonstrated in several studies around the world, the application of fungicide sprays ahead of rain events was found to be critical in the Australian crops. Winter grown pulse crops in Australia are reliant upon winter and spring rainfall. Since rain splash is a critical factor in the spread of ascochyta blight regular rainfall events over this period make the disease particularly difficult to control in this region. From the year 2000 a number of faba bean, chickpea and lentil cultivars with effective resistance to foliar ascochyta blight infection have been released to the Australian pulse industry. This has reduced the reliance on fungicides; however, strategic fungicides are still necessary to complement moderate levels of resistance. In particular, the resistances are often not expressed in pods and seeds, leading to the necessity for fungicide sprays during the maturation phase of the crop to prevent pod abortion and/or seed staining. Seed quality is an important component in the Australian pulse crop since much of the crop is sold into human food markets through Middle East, Africa and South-East Asia, particularly the Indian sub-continent.

Ascochyta blight of field pea is still a major concern, as high level resistance has not been identified in this crop. This disease, caused by a complex of fungi i.e. *Didymella pinodes* (synonym: *Mycosphaerella pinodes), Phoma medicaginis* var. *pinodella, Ascochyta pisi* and *Phoma koolunga,* is the most common disease in field peas. Research in the 1990'S found that foliar fungicides were uneconomic in field peas and the most effective disease control was gained by delaying sowing three or four weeks beyond the season opening rains in autumn, the rains usually start in late April or May. This delay in sowing minimises infection from airborne ascospores which are released from infested stubble with rain. Delayed sowing is still a major recommendation for the pea industry across South Australia. However with expansion of the crop into low rainfall areas (<375 mm per annum) and the increasing frequency of low rainfall seasons, the potential yield loss through delayed sowing is often now greater than the loss from ascochyta blight. The agronomic risk of delayed sowing has been amplified by the lack of spring rain in the past three seasons, and growers are planting crops as early as is practical.

The risk of ascochyta blight infection from airborne ascospores can vary with seasonal conditions. Following a wet summer, the release of ascospores can occur earlier than crop emergence, so that early sown field peas are not as exposed to infection as in other seasons. This provides some flexibility in sowing date, without increased disease risk. A predictive model, 'Blackspot Manager', has been developed that predicts % ascospore release from ascochyta blight-infested pea stubble for a given time of sowing. This model is used in Western Australia and South Australia to determine optimum sowing dates for field peas to reduce ascochyta blight risk from primary inoculum. Weekly updates of the model predictions are available to the industry on the website 'http://www.agric.wa.gov.au/cropdiseases' beginning in March and continuing until mid June, by which time the majority of pea crops have been sown. Further research is being conducted in South Australia to determine the likely disease severity associated with the predictions from 'Blackspot Manager'. In medium (400 mm per annum) and medium-high (450 mm per annum) rainfall regions a high disease risk has been associated with 40% ascospores remaining on stubble at sowing, while in the low rainfall region (<400mm per annum) there was little disease irrespective of ascospore numbers. In the medium rainfall area, crops distant (>400m) from infested stubble had reduced risk so that >50% ascospores needed to be remaining on stubble at sowing for disease risk to be high. This model may be used in conjunction with 'Blackspot Manager' to optimise management strategies that reduce ascochyta blight on field peas in different rainfall and cropping regimes.

The Australian pea industry has also adopted higher yielding cultivars including early maturing erect semi-leafless types e.g. cv. Kaspa. Research is being conducted on economic fungicide strategies to control ascochyta blight and to identify optimum sowing dates in low to medium rainfall areas for these cultivars. Epidemiology studies in these trials have identified the timing of primary inoculum (ascospore release from infested stubble), and the timing of secondary inoculum within the crop. Fungicides need to be applied to minimise infection from both of these sources. To date these trials have shown foliar fungicides (mancozeb) can reduce disease severity by a small amount (6-12%), but in seasons with no spring rain this did not translate into additional grain yield. Anecdotal evidence, from commercial crops grown in average rainfall seasons, and treated with similar fungicide strategies, has shown that similar small reductions in disease levels lead to economical yield gains. Further research is required to confirm this in trials with more favourable spring rainfall.

Ascochyta blight infection levels were lower in new cultivars and breeding lines, indicating that improved ascochyta blight resistance is becoming available to the Australian pea industry. The semi-leafless more erect pea types are better adapted to earlier sowing dates, while some lines have similar high yields when sown at early or mid sowing dates providing flexibility with respect to sowing date. By comparison, Australian cultivars of faba bean, lentil and chickpea have good foliar resistance to ascochyta blight, although plant breeders continue seek multiple sources of resistance to prepare for potentially virulent pathogen populations.

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Fusarium avenaceum as a causal agent of root rot in field pea and its control

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Root rots are a major concern in field pea production areas of the North-Central United States including North Dakota. Disease surveys conducted in the recent past have revealed that *Fusarium* species are largely associated root rots in this region with *Fusarium avenaceum* being the most prevalent. The objectives of our research have been to study the phylogenetic relatedness between *F. avenaceum* isolates obtained from field peas and those from other hosts; to evaluate the variation in aggressiveness within *F. avenaceum* isolates from fields peas; and to assess the efficacy of seed treatments and lime based soil amendments for control of *Fusarium* species associated with field pea roots. All these studies, apart from the seed treatments, were conducted under laboratory and greenhouse conditions. Initial results demonstrate a variation in the ability of *F. avenaceum* isolates to cause root rots and a reduction in disease severity associated with use of seed treatments and soil amendments under field and greenhouse conditions respectively. *F. avenaceum* has often been associated with Fusarium head blight of cereals commonly grown in rotation with field peas , therefore, these findings are crucial for the development of integrated disease management strategies.

A preliminary report on green peas in Alaska

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Western Regional Plant Introduction Station at Pullman, Washington, and Seneca Foods Corporation in Dayton, WA, collaborated with the Sub-arctic Agricultural Research Unit (SARU) to test a set of established cultivars and breeding lines of green peas under sub-arctic growing conditions. Although wide scale pea production is unlikely due to transport cost of export, there is an increasing need for productive, early maturing, green pea cultivars for farmers' markets as well as a potential market in local grocery stores(1). Seventeen lines of 30 treated seeds were planted in three replications in a randomized complete block design at the SARU's Germplasm site in Palmer, Alaska.

The Palmer, Alaska (61.60 latitude 149.08 longitude) growing season is very short (approximately 90¬100 days) with up to 20 hours of continuous daylight. Treated seeds were planted on June 1st in cool, damp soils. The 2009 growing season consisted of mostly warm, dry days with an average high temperature of 75.3°F and average day length of 18 hours. There was very little rain and

supplemental overhead irrigation was applied when necessary. The field site had some issues with weeds, and plots were hand-weeded as necessary. No noticeable diseases were present.

Data were collected on days to emergence, days to 50% flowering, days to maturity, and plant height (Table 1). All of the plots matured and were harvested at the physiologically immature stage used for fresh/processing pea cultivars. Interestingly, while the seed was not inoculated, a subset of roots dug revealed heavy nodulation. The field site has a native population of vetch which could be a source of rhizobia.

Table 1:	Rep 1		Rep 2		Rep 3		
	Range	Mean	Range	Mean	Range	Mean	Pr >F
Days to 50% flowering	39-54	46.5	39-52	46.0	39-54	47.2	<0.0001*
Days to maturity	68-74	70.1	69-74	70.10	68-78	70.40	0.0002*
Ave. Plant height	64-90	76.06	57-82	71.53	55-85	71.00	0.0611
Total fresh weight (kg)	3.3-8.5	5.03	2.2-6.8	4.16	2.8-6.9	4.52	0.0002*
Total pod weight (kg)	1.6-2.6	2.09	1.2-2.7	1.90	1.4-2.9	1.99	0.0002*

Total fresh harvest and total pod weight were collected for each plot. Total combined fresh weight for all plots was 293 kg. The total combined pod weight was 102 kg with an average of just less than 2 kg of pods per plot.

Five plants were randomly chosen at harvest and more extensive data were taken including number of pods per plant and number of peas per 10 pods (Table 2). There was a mean of ten pods per plant. Each pod had an average of 6.7 seeds.

Table 2:	Rep 1		Rep 2		Rep 3		
	Range	Mean	Range	Mean	Range	Mean	Pr >F
Plant length	44-132	79.1	46-106	73.4	39-108	73.9	0.0002*
Node of 1st flower/pod	4-19	11.7	4-20	12.2	4-35	11.8	0.0015*
Number of nodes w/pods	2-23	6.0	2-12	5.5	1-16	5.8	0.2607
Number of pods/peduncle	1-2	1.9	1-2	2.0	1-3	1.9	0.291
Number of pods/plant	3-40	10.7	3-23	9.5	1-36	10.4	0.069
Number of seeds/5 pods	11-48	35.5	14-49	33.2	9-49	33.3	<0.0001*

The results presented here show that there is huge potential for green pea as a fresh market crop in Alaska. We will replant the most promising lines in spring 2010 at a number of locations. In addition, we seek cold tolerant, short season cultivars/breeding lines to test their potential in Alaska for both fall and spring planting. We are also interested in fall planted dry peas and spring planted snow peas. Alaska SARU is open to collaboration for those wishing to test such varieties.

1. USDA Vegetables and Melons Outlook,
www.ers.usda.gov/publications/vgs/2009/06Jun/VGS333.pdf

Variety adaptation and agronomic study at central Montana for pulse crop yield improvement and cropping systems

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Pulse crops are not only important commodities to the Montana economy, but also serve as crucial rotation crops in a cereal-based production system, which dominates Montana's agricultural production, for better disease and weed control as well as reduction of nitrogen fertilizer input due to biological nitrogen fixation. To increase pulse crop variety adaptation and sustainability of yield, several research projects were coordinated and carried out at the Central Agricultural Research Center (CARC), Montana State University at Moccasin, MT. Specifically, 1) a multi-year variety trial was conducted at multiple locations across Montana with diverse climate and soil conditions; 2) a multi-year crop rotation study was conducted at the CARC where winter wheat was grown following winter pea harvested for hay and spring pea harvested for grain; and 3) winter pea and lentil grown as forage for livestock grazing or hay. Through variety selection and testing as well as improvement of agronomic practices grain yields have increased from 1000 kg ha^{-1} to 2000 kg ha^{-1} for spring pea, and from 800 kg ha^{-1} to 1400 kg ha^{-1} for spring lentil in the past 10 years, even though the yields varied greatly from year to year and location to location due to the great variations of weather and soil conditions. Winter wheat yields following spring and winter peas were greater than following spring wheat. Winter pea and lentil produced 2100 kg ha^{-1} and 1400 kg ha^{-1} high quality hay respectively, and the yield of winter wheat following winter pea or lentil cut for hay or grazed by cattle yielded very well especially at low N input level. The yield was equivalent to that following summer fallow.

Identification of organic seed treatments for organic green pea production

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Organic green pea production in Washington state makes up approximately 16% (2,114 hectares) of the green pea production. organic peas are planted in late winter to early spring. The primary challenge to growing organic green peas is poor stand development due to *Pythium* seed and seedling rot, which is compounded by the low soil temperatures at planting. The present research identified potential organic seed treatments effective against seed rotting pathogens. Results suggest that biological seed treatments in general do not perform well under organic green pea growing conditions, and corn flour, cuprous oxide, Bio N, Triggrr and calcium need further investigation as potential organic seed treatments.

Pulse Crop improvement at North Dakota State University

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Pulse crops provide a broad and diverse array of benefits to production agriculture and, more generally, to society worldwide. They benefit production agriculture as a break crop in cereal-based rotations for disease and grassy weed control in addition to improving soil nutrition through fixation of atmospheric nitrogen. Pea, lentil and chickpea also serve as a cash crop improving on-farm profitability. The pulse crops, pea, lentil and chickpea, are highly nutritious, providing a significant portion of dietary protein in human diets and pea, in particular, plays a significant role in livestock rations. Production of pulse crops in North Dakota and the Midwest region including eastern Montana and South Dakota has increased over the past 15 years to become the primary production region for these crops in the US. In the fall of 2008, North Dakota State University established a pulse crop breeding program. The focus of this program is to develop improved, agronomically suitable cultivars for North Dakota and, more broadly, the Northern Plains region. Goals of the program include increased yield, disease resistance, superior quality attributes and agronomic adaptation. As much as 80% of US production of pea and lentil is exported and a significant portion going into the human food markets making crop quality a primary goal of the pulse industry. Despite an increasing amount of chickpea production being consumed domestically due to increased hummus consumption, premium export markets for chickpeas demand premium quality based on visual attributes. Although visual quality criteria have dominated evaluations in the past, the expanding use and value of pulse crops as ingredients in foods will require greater focus on component analyses. Future success of the pulse industry in the northern plains will require a coordinated effort between the breeding program and affiliated research programs at NDSU and other institutions. Improved crop quality attributes will require significant attention to traditional visual quality criteria as well as attention to functional analyses of seed components. These efforts will identify elite crop varieties with high yield potential and superior seed quality.