CERES Trust Final Report

Project: Edible Grain Legumes for Organic Cropping Systems

Craig Sheaffer, Department of Agronomy and Plant Genetics, cooperating with
Tom Michaels, Department of Horticultural Science; and *Kathryn Draeger*, Regional
Sustainable Development Partnerships, University of Minnesota, St. Paul

History

Field beans, or dry edible beans, are types of the common bean (*Phaseolus vulgaris* L.). They are members of the legume family and have characteristics such as seed born in pods, biological nitrogen fixation, and protein-rich vegetation and seed. Field beans are harvested when dry and removed from pods, in contrast to green or snap beans in which immature green pods and seeds are harvested green and consumed as a vegetable. The common bean was domesticated by Native Americans nearly 6,000-8,000 years ago in the Tehuacan Valley of Mexico and in the Peruvian Andes. Field beans were an important protein source in diets and complement energy supplied by corn, which was also domesticated in southern Mexico. Field beans had been dispersed by migration and trading, and when European explorers arrived in the new world, field beans were found growing from South America into Canada. For example, the Hidatsa, a Native American tribe farming along the Missouri River in North Dakota planted black, red, white bean, and spotted field beans between rows of corn (Wilson, 1987). Field bean types originating in Mexico are typically noted by small (<25g 100 seeds-1) and medium (25-40g 100 seeds-1) seed types and are represented in the navy, pinto, and black bean market classes widely grown today. Field beans originating in the Andean region typically have large (>40g 100 seeds-1) seed types and are represented by kidney beans grown today (Figure 1).

Figure 1. Dry bean cultivars vary in seed size and color.

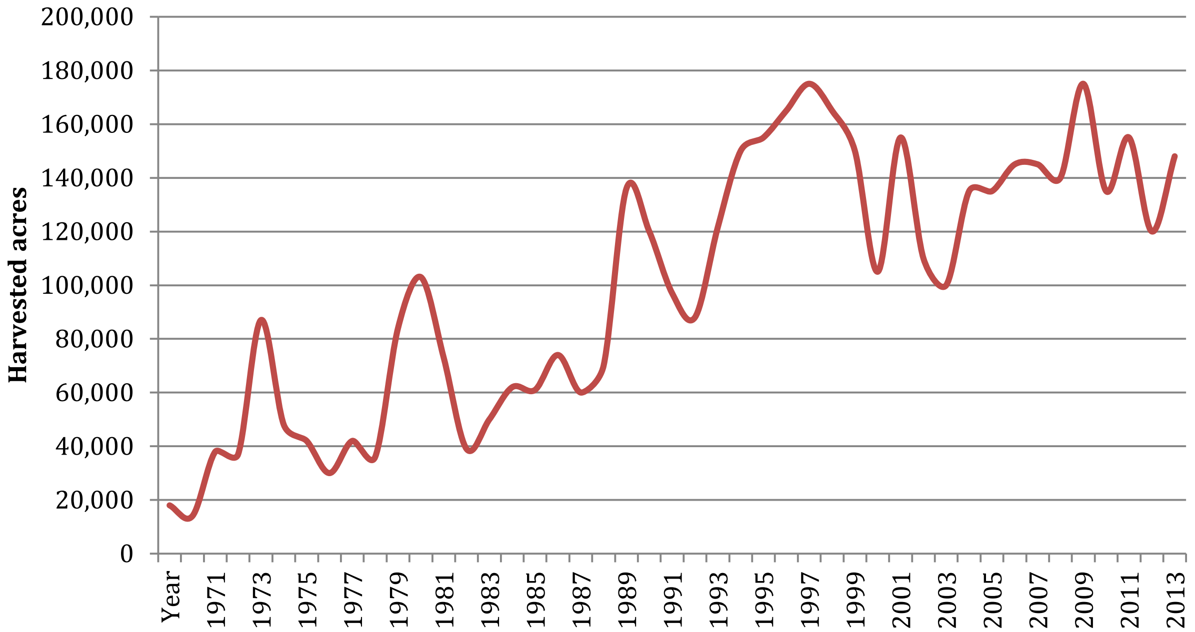
Photo credit: Hannah Swegarden, UMN

Production

Dry beans are an important pulse crop worldwide. The top-five dry bean producing countries of the world are Brazil, Myanmar, India, China, and the United States, respectively (USDA, 2011a). An estimated 584,851 ha (1,445,200 ac) of cropland, with a production value of approximately $763 million, were dedicated to U.S. dry bean production in 2008 (USDA, 2011a; Zahniser and Wells, 2014). The U.S. Midwest is currently the nation's largest producer of dry beans. In 2010, North Dakota (42%), Michigan (13%), Minnesota (10%), Nebraska (8%), and Idaho (7%) had the highest dry bean production (USDA, 2011b).

The dry bean acreage in Minnesota is growing (USDA, 2015; Figure 2). Reports from USDA-NASS estimated 62,726 ha (155,000 ac) of dry beans were planted in Minnesota in 2014 (USDA, 2015). The majority of dry bean production was located in the northwest region. Average reported yields were 2,186 kg ha-1 (1,950 lbs. ac-1) (USDA, 2015). Minnesota's market class production in 2011 was distributed among navy (40%), red kidney (30%), black bean (14%), and other types (16%) (USDA, 2011c). The majority of organic dry bean production is found in the Red River Valley region of Minnesota, where there is also a high concentration of conventional dry bean production (Northarvest Bean, 2015; USDA, 2015). Organic dry beans were harvested from an estimated 1,011 hectares (2,498 acres) in Minnesota in 2011, which accounted for approximately 8.7% of total U.S. organic dry bean cropland (USDA, 2011d).

Figure 2. Minnesota Dry Bean Production, 1970-2014



CERES Trust Final Report

Nutritional value and use

Dry beans have been identified as a component of healthy diets and there appears to be increasing demand. The seed contains 15-25% protein on a dry-weight basis and has a complex carbohydrate profile, a high fiber content, and is low fat. Dry beans are required in U.S. school lunch programs. Schools are required to serve at least 0.4 oz. (½ cup) of dry beans (or peas) per week (USDA, 2012a). Field beans have been identified as a food for farm-to-school lunch programs and recent surveys conducted by the Minnesota Regional Sustainable Development Partnerships (RSDP) suggest demand for organic beans in direct-to-consumer markets. There is demand among consumers and restaurants for locally produced, organic dry beans in the Twin Cities and Greater Minnesota region (RSDP, 2014, unpublished data).

Project Overview

In the Upper Midwest, edible legumes provide an opportunity for year-round access to sustainably grown, nutritious local foods for families and institutions. Dry edible beans have been promoted as components of healthy diets. The demand for organic foods is increasing, yet only 0.3% of total dry bean acreage in MN is organic (USDA, 2012b). Currently, the market for organic edible beans in our region is often supplied by imports from China. Our project promotes diversification of organic cropping systems with grain legumes in order to supply healthy local foods and profitable organic grain legume production.

Research Objective

Our objective is to determine the rotation benefits of edible dry beans and soybeans under organic management.

Methods and Materials

Project description

Replicated rotational experiments were conducted on certified organic land at four locations from 2011 to 2015. We characterized the edible bean yields and weed population densities following corn or alfalfa and measured edible bean effects on yield of a following wheat crop and on soil health.

Year 1. Corn and alfalfa were grown during Year 1. Early in spring, each site was tested for fertility and the soil was amended with manure or compost to obtain recommended soil nutrient levels for optimal crop performance. Weeds were controlled with standard practices for organic systems.

Year 2. Dry beans and soybean were grown during Year 2 of the experiment. Legume seeds were inoculated with *Rhizobia* prior to planting. Weeds were controlled with standard practices for organic systems. Populations were counted within in 4 ¼ m^2 quadrats per plot. Bean yield was measured, following grain maturity and drying.

Year 3. Wheat was drilled in the spring following field bean and soybean treatments. Weeds from each plot were measured on a 4 ¼ m^2 basis. Wheat grain yields were measured within a 1 m^2 area after physiological maturity.

Experimental design and locations

The experimental design was a randomized complete block with treatments in a split plot arrangement. Main treatments were either corn or alfalfa, grown in 10 x 20 foot plots during Year 1. The main plots were split into subplots in Year 2 and planted with 4 market class dry bean, one heirloom dry bean, and a soybean control (Table 1). Finally, in Year 3 all plots were cropped to spring wheat. At each site, there were four replicates of each treatment.

Table 1. Bean cultivars used in this experiment.

Cultivar	**Type**
Eclipse	Black
Lariat	Pinto
MN1505SP	Soybean (food grade)
Red Hawk	Dark Red Kidney
OAC Rex	Navy
Peregion	Heirloom

Experiments were conducted on certified organic land at the Southwest Research and Outreach Center, at Lamberton (certifying agency: Minnesota Crop Improvement, St. Paul) and on two farms: Carmen Fernholz's farm in Madison, MN (certifying agency: International Certification Services, Inc., and Mike Jorgenson's farm in Clinton, MN (Minnesota Crop Improvement, St. Paul, MN). We experienced unfavorable environmental conditions in Clinton, MN, and could not fulfill the three-year rotation. The 3-year rotations were initiated in 2011 at Lamberton, in 2012 at Madison and a 2nd site in Lamberton, and in 2013 at a 3rd site in Lamberton.

Measurements in addition to yield that were collected include soil nutrients and weed biomass. The soil samples, taken at 0-1' and 1-2' were used to identify the nutrient needs of each replicate per site. In early spring of Year 3, soil samples for nutrient status and soil health were taken on a plot basis to assess the effects of any nitrogen carryover from the beans in Year 2. Weed samples were taken from 4 ¼ m^2 quadrats at bean and wheat harvests of each year. Weed dry matter yields were measured and identified as either broadleaf or grass.

Results and Discussion

Bean Yield

The previous crop of corn or alfalfa in rotations had inconsistent effects on yields of bean cultivars across locations (Table 2). At Lamberton in all three years, the mean yield of the beans was greater after corn, while in Madison, the mean yield was greater after alfalfa; however only the mean yields in Lamberton 2014 were found to be significantly different. Because dry beans generally require supplemental nitrogen, existing site fertility would be expected to have an effect on their yields. The lack of significantly greater yields from the nitrogen provided by alfalfa as compared to corn may be due to the residual effects of application of N through composted dairy manure on corn. Low yields for the 2014 Lamberton site were related to delays in weed control due to inclement weather.

Table 2. Dry bean and soybean yields (lbs ac^{-1}) from Year 2 of rotation experiments on organic soils in 2012-2014 at Lamberton and Madison, MN. All cultivars are dry beans except MN1505, a food grade soybean.

	Lamberton, 2012		**Lamberton, 2013**	
Bean Cultivar	**Alfalfa**	**Corn**	**Alfalfa**	**Corn**
Eclipse	1645	1717	1225	1250
Lariat	1776	1978	1356	1592
MN1505SP	1554	1903	1904	2583
Red Hawk	1540	1657	1123	744
OAC Rex	1202	1361	1259	1236
Peregion	1342	1274	838	1295
Mean	1510	1648	1284	1450

	Madison, 2013		**Lamberton, 2014**	
Bean Cultivar	**Alfalfa**	**Corn**	**Alfalfa**	**Corn**
Eclipse	2116	1359	182	639
Lariat	2403	2162	232	1066
MN1505SP	2166	1628	1929	2683
Red Hawk	1377	867	91	380
OAC Rex	2007	1657	15	125
Peregion	1991	1729	185	456
Mean	2010	1567	439	892

Wheat yield

Wheat yields following dry beans did not vary significantly as a result of the previous bean cultivar from the three sites (Table 3). The alfalfa and corn treatments did not have an effect on wheat yields at Lamberton. However, at the Madison site, the mean wheat yields were significantly higher in the rotation that had corn prior to the dry beans. Wheat yields from 2015 will be recorded and analyzed following harvest this year.

Table 3. Wheat yields (bu/ac^{-1}) following dry beans and soybean from Year 3 of rotation experiments in 2013 and 2014.

	Lamberton, 2013		**Lamberton, 2014**		**Madison, 2014**	
Bean Cultivar	**Alfalfa**	**Corn**	**Alfalfa**	**Corn**	**Alfalfa**	**Corn**
Eclipse	41	49	49	45	13	24
Lariat	45	52	45	46	9	22
MN1505SP	41	48	47	43	17	29
Red Hawk	42	50	52	42	16	20
OAC Rex	47	49	53	47	17	26
Peregion	39	51	42	43	23	23
Mean	43	50	49	45	16	24

Weed measurements

Table 4. Weed biomass in wheat and beans in lbs/acre.

	Lamberton, 2012-13		**Lamberton, 2013-14**		**Madison, 2013-14**		**Lamberton, 2014-*15***	
Previous Crop	**Beans**	**Wheat**	**Beans**	**Wheat**	**Beans**	**Wheat**	**Beans**	**Wheat**
Alfalfa	*NA*	1200	1737	1528	920	3214	6419	*NA*
Corn		1334	2112	768	1530	2780	6945	
Mean	*NA*	1267	1925	1148	1225	2997	6682	*NA*
Eclipse	*NA*	1244	2054	1275	1327	3184	6693	*NA*
Lariat		1320	2009	1250	1843	3291	6327	
MN1505SP		1231	599	848	1148	2514	4445	
Red Hawk		1232	2139	890	545	2803	8150	
OAC Rex		1298	2671	143	1035	3100	9064	
Peregion		1372	1559	1185	996	3090	5368	
Mean	*NA*	1283	1839	932	1149	2997	6674	*NA*

Weed biomass in the beans overall was greater following corn than alfalfa at three sites, but this was not statistically significant (Table 4). At two sites, Lamberton 2013 and Lamberton 2014, bean cultivars differed significantly in weed biomass indicating differences in competitiveness. Individual bean cultivars did not show an effect on weed biomass in the subsequent wheat crop.

Soil nutrient assessments

For two of the sites for which we have data, soil nitrate levels were not different for the bean cultivars (Table 5). However, there were significantly different nitrate levels due to the preceding crops of alfalfa and corn. In Lamberton, alfalfa had higher nitrates, while at Madison, corn treatments had higher nitrates. As discussed previously, the wheat yields in the Madison corn treatment were higher than the in alfalfa, which corresponds to the soil data. Soil samples are in the process of being analyzed for 2015.

Table 5. Soil nitrate levels (lbs/ac-1) before wheat planting in the spring of Year 3 at Lamberton and Madison, MN in 2014.

	Lamberton, 2014		**Madison, 2014**	
Bean Cultivar	**Alfalfa**	**Corn**	**Alfalfa**	**Corn**
Eclipse	166	135	132	162
Lariat	172	100	116	190
MN1505SP	128	80	127	179
Red Hawk	207	106	145	197
OAC Rex	169	104	120	138
Peregion	142	95	133	149
Mean	155	103	125	163

Economic Analysis

The economics of dry bean production are difficult to estimate due to widely fluctuating bean prices and varying production costs, resulting in profits that are highly variable. Conventionally grown dry beans could potentially return \$180 to \$270 to land and management per acre at the average expected price for 2013 (\$40 per hundredweight) and with a yield averaging 2,000 pounds per acre (Lee, 2013). Further, organic bean economics are even more difficult to estimate, as seed is often unavailable, especially in large quantities. Nevertheless, many large-scale bean producers are considering organic production because of the organic premiums (~150%) for the organic crop (Michigan State University, 2015). While this may be a high estimate, personal communication with local seed suppliers estimate 30-40% higher costs in price received for organic dry beans, but that is coupled with lower yields and potentially higher production costs.

In the following analysis using average yields over the sites from our experiments, both direct and indirect costs and benefits are integrated into our economic comparisons among bean cultivars. Production costs include seed, weed management, fuel, labor, harvest, and other machinery costs (Table 6). Gross income from each crop was estimated based on crop yield and current market prices (Table 7). Organic market prices were estimated with figures provided by regional conventional grain buyers and adding a 40% organic premium.

Table 6. Predicted total yearly costs (seed cost per acre + production costs per acre) of organic soybean and dry bean cultivars per acre. Production costs include field preparation, weed control operations, planting and harvesting costs.

Cultivar	***Seeding Rate/ac***	***Seeds/lb***	***Seed Cost/lb***	**Seed Cost/ac**	**Production Cost/ac**	**Total Cost per Cultivar / ac**
Eclipse	*100,000*	*2500*	*$0.60*	$24.00	$78.65	**$102.65**
Lariat	*70,000*	*1350*	*$0.60*	$31.11	$78.65	**$109.76**
MN15055P	*150,000*	*2800*	*$0.60*	$32.14	$78.65	**$110.79**
Red Hawk	*70,000*	*900*	*$0.60*	$46.67	$78.65	**$125.32**
OAC Rex	*100,000*	*2500*	*$0.60*	$24.00	$78.65	**$102.65**

Table 7. Estimated total returns received (revenue minus total costs from Table 6) for organic soybean and dry bean cultivars using average yields from our experiment.

	Yield (lbs ac-1)		**Revenue / ac**		**Total Returns / ac**	
Cultivar	**Alfalfa**	**Corn**	**Alfalfa**	**Corn**	**Alfalfa**	**Corn**
Eclipse	1292	1241	$542.56	$521.35	**$439.91**	**$418.70**
Lariat	1442	1699	$605.53	$713.66	**$495.77**	**$603.90**
MN15055P	1888	2199	$705.76	$822.11	**$594.97**	**$711.32**
Red Hawk	1033	912	$751.75	$797.12	**$626.43**	**$671.80**
OAC Rex	1121	1095	$376.54	$367.90	**$273.89**	**$265.25**

Soybean (MN1505SP) has the highest returns after corn, while kidney bean (Red Hawk) had the highest returns after alfalfa. Lariat pinto beans were also competitive in price relative to soybean.

Dissemination of Results/Outreach

Preliminary results from this research were presented in poster form to a primarily grower audience at the MOSES Organic Farming Conference in February 2015. Presentations included “Dry Edible Beans,” at the Minnesota Organic Conference in St. Cloud, MN in January 2014, and “Dry Beans in Organic Production Systems” at MOSES Organic Farming

Conference in La Crosse, WI in February 2014. Researchers also presented a webinar on eOrganic titled, “Organic Dry Bean Production Systems and Cultivar Choices” in November 2014. Final results from the rotation experiment will be presented at the upcoming ASA-CSSSA-SSSA Annual Meeting in Minneapolis, MN on November 18, 2015.

We participated in field days held at the University of Minnesota Research and Outreach Center in Lamberton in July 2013, 2014 and 2015, as well as the Organic Field Day for North Dakota State University in July 2014, where we shared research results and gave research plot tours. Graduate students gave an on-farm field tour to agritourists from Fargo, ND in Clinton, MN in September 2013. A field day demonstration was also held on-farm in Madison, MN, where our research was being conducted in September 2014.

To involve our immediate community within the University, graduate students presented research posters during the Production Ag Symposium in February 2014, and presented a seminar titled “The Bean Dream” to the What’s Up in Sustainable Agriculture series at the University of Minnesota in April 2014. In collaboration with the Regional Sustainable Development Partnerships and UMN School of Design, 25-lb. paper bags were designed to market local, organic dry beans which have been displayed at conferences.

The information gathered from this project will be incorporated into Extension publications and published on a University of Minnesota website focused on sustainable agriculture. A paper for academic journal publication is under development using the results of this experiment, and will be submitted for peer review in the fall of 2015. Our overall plan is to release this information, combined with our other dry bean research on tillage and row-spacing, organic nitrogen applications, yield trials, and planting dry beans into cover crops, in an accessible format to provide grower recommendations for organic dry bean production in the Upper Midwest.

Summary

Unlike soybean, dry beans usually require supplemental nitrogen and providing nitrogen can be an issue in organic systems without livestock. Because alfalfa can provide large amounts of nitrogen to a subsequent crop, we had expected dry bean yields to be consistently higher following alfalfa than corn, but this was not the case in our results. Additionally, the soil nitrate levels were not consistently higher after alfalfa compared to corn, at least in the two sites for which we show data. We believe both of these results are due to the residual effects of composted manure application in the corn treatment. The bean cultivars and alfalfa or corn treatments did not appear to affect the subsequent wheat yields consistently. Based on our results, we recommend that either alfalfa or corn prior to dry beans is acceptable in rotations if there is adequate existing soil fertility, but in cases where there is not adequate nitrogen, we would expect that alfalfa prior to dry beans would increase yields. Despite our inconsistent results in this experiment, we believe that diverse crop rotations including perennials such as alfalfa are essential to the function of successful organic cropping systems. Longer term studies on rotations need to be done to discover the effects of previous and subsequent crops on dry beans.

In our preliminary economic analysis, with the exception of kidney bean, dry beans tended to have lower returns as compared to soybean. However, as demand for local organic dry beans grows, premiums for organic dry beans may increase, which could help narrow the gap. Additionally, production refinements and breeding beans for organic systems (research that is currently being conducted by our project team) may lead to organic dry bean yield increases and the greater inclusion of dry beans in local organic cropping systems in the future.

References

Lee, C. 2014. Dry Beans. Cooperative Extension Service, University of Kentucky College of Agriculture, Food and Environment, Lexington, KY. <http://www.uky.edu/Ag/CCD/introsheets/drybeans.pdf>

Michigan State University. 2015. Dry Beans. Michigan State University, East Lansing, MI. < http://bean.css.msu.edu/Organic.cfm>

Northarvest Bean Growers Association. 2015. Elevator shippers and marketing firms. 06 March 2015. <http://www.northarvestbean.org/html/directory.cfm>.

U.S. Department of Agriculture. 2011a. Table 54 - World dry edible (round) bean area harvested, 1961-2009. Economic Research Service (ERS), Washington, DC. November 2013. <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1394>.

U.S. Department of Agriculture. 2011b. Table 01b - U.S. dry edible beans, Harvested acres, 1950-2010. Economic Research Service (ERS), Washington, DC. November 2013. <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1394>.

U.S. Department of Agriculture. 2011c. Table 27 - Minnesota dry bean production by commercial class, 1964-2010. Economic Research Service (ERS), Washington, DC. November 2013. <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1394>.

U.S. Department of Agriculture. 2011d. Table 07 - U.S. certified organic beans, by State, 2011. Economic Research Service (ERS), Washington, DC. November 2013. <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1394>.

U.S. Department of Agriculture. 2012a. Nutrition standards in the national school lunch and school breakfast programs, Final Rule 7 CFR Parts 210 and 220. Food and Nutrition Service, Washington, DC. 28 April 2015. <http://www.gpo.gov/fdsys/pkg/FR-2012-01-26/pdf/2012-1010.pdf>.

U.S. Department of Agriculture. 2012b. 2012 Minnesota Agricultural Statistics. National Agricultural Statistics Service (NASS), Washington, DC. <http://www.nass.usda.gov/Statistics_by_State/Minnesota/Publications/Annual_Statistical_Bulletin/2012/Whole%20Book.pdf>

U.S. Department of Agriculture. 2015. Quick Stats by Commodity. National Agricultural Statistics Service (NASS), Washington, DC. <http://quickstats.nass.usda.gov/>

Wilson, G.L. 1987. Buffalo Bird Woman's Garden. St. Paul, MN: Minnesota Historical Society Press.

Zahniser, S. and H.F. Wells. 2014. Commodity highlight: Dry beans. United States Department of Agriculture, Economic Research Service, Vegetables and Pulses Outlook Report Vegetables and Specialties Situation and Outlook. VGDS-354-SA1. Accessed 10 November 2014. <http://www.ers.usda.gov/media/1680744/vgs-354-sa1.pdf>.