Project Title: Examine the effect of cropping systems that include canola (*Brassica napus* L.), yellow mustard (*Sinapis alba* L.) or oriental mustard (*B. juncea* L.) on yield of subsequent spring wheat in western Whitman County, Washington State

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Introduction

Small grain cereal crops occupy a high proportion of dryland acreage in the Pacific Northwest (PNW), and very few alternative crop species have shown commercial adaptability in rotation with wheat and barley. Of the potential rotational crops, canola and yellow mustard have shown good rotational effects when grown with small grain cereals. These crops produce a large amount of crop residue that adds to soil organic matter and persists in the soil throughout the winter months reducing soil erosion. Brassicaceae crops have taproots that help break soil panning, improve soil structure and water holding capacity, and reduce nitrate leaching. In addition, these crops can break cereal disease cycles and have shown insecticidal, fungicidal, and herbicidal effects.

Traditionally, winter canola or rapeseed (*Brassica napus* L.) crops were produced only on a small acreage in the high rainfall areas of the PNW. However, over the past 15 years some growers have made an effort to move towards annual cropping systems in the low and intermediate rainfall zones, which has lead them to investigate spring-seeded Brassicaceae crops. The first of these to be considered was spring canola; although growers soon discovered that spring canola was not well adapted to the low rainfall areas of the region. In contrast, yellow mustard (*Sinapis alba* L.) has shown good adaptability to the drier regions of the PNW, and it has shown positive rotational effects when grown prior to wheat. Recently, another mustard species was introduced to the region with the commercialization of 'Pacific Gold' oriental mustard (*B. juncea* L.). Although oriental mustard, also known as Indian mustard, is a close relative of canola and a more distant relative of yellow mustard; it is a new crop to the region, and its yield potential compared to canola or yellow mustard in various rainfall zones has only been examined in small breeder plots. In addition, the rotational effects of oriental mustard crops on the subsequent performance of wheat are not known. This project addresses these issues in order to provide growers in the region with more information regarding crop rotation benefits and options.

Specific Objectives

1. To determine the yield potential of oriental mustard compared to canola and yellow mustard under direct seed systems in western Whitman County, Washington.

2. Determine the rotational effect of oriental mustard compared to spring wheat, canola, and yellow mustard on subsequent spring wheat yield in direct seed systems.

Materials and Methods

Both objectives were investigated using a large-plot study grown on the Stubbs farm near Dusty, Washington over a period of three years beginning in April 2005. In the spring of 2005 and 2006, a rotational crop trial with 'Pacific Gold' oriental mustard, 'IdaGold' yellow mustard, 'Hyola 401' spring canola (*B. napus*), and spring wheat was planted. In 2005, 'Blanca Grande' wheat was used, and 'Tara 2004' was chosen in 2006. The trial design was a randomized complete block with four replications and an individual plot size of 20 x 56 feet. The following years, 2006 and 2007, a solid block of spring wheat was seeded on the site of the previous rotational crop trial to determine the effect of the previous crop on a subsequent wheat crop. Tara 2004 wheat was used in recrop trial in 2006, and 'Buck Pronto' was used in 2007. Progress made during the first two years was described in previous reports and will be summarize here as well.

The first year of the rotational crop trials was planted on April 5, 2005 and the second year was planted on March 29, 2006. Seeding rates used were 90 lbs. per acre for spring wheat, 7 lbs. per acre for spring canola, 8 lbs. per acre for yellow mustard, and 5 lbs. per acre for oriental mustard. The canola and mustard seed was treated with thiamethoxam insecticide (HelixXtra or Crusier) to protect seedlings from flea beetle damage. The wheat seed was treated with a fungicide-insecticide package that included Raxil XT, Allegience, Cruiser, and Seed Life in 2005 and Dividend Xtreme, Apron, Gaucho, and Seed Life in 2006. A small-plot planter equipped with Flexi-Coil Stealth paired-row shank openers was used to seed and fertilize the trials in a single pass. A granular urea plus ammonium phosphate sulfate blend (31-10-0-7.5) was banded below the seed at 260 lbs. per acre in 2005 and at a 291 lbs. per acre in 2006. Soil test data provided in 2005 by Dennis Roe of USDA-NRS showed 67 lbs of available nitrate nitrogen in the top 5 feet of soil and 29 lbs of ammonium nitrogen in the top 1 foot of soil. Stand establishment was evaluated by counting the number of plants in 1 meter of two rows in each plot on May 30, 2005 and May 24, 2006.

The wheat recrop trial was planted over the first rotational crop site on March 28, 2006, and the second year of the wheat recrop study was planted on April 3, 2007. The areas planted to previous crop treatments were used to delineate the area into experimental plots. The seed treatment used was as described for 2006 above. Liquid fertilizers were applied at the time of planting at a rate to achieve 90 lbs. of nitrogen per acre, 10 lbs of phosphorous (as P_2O_5) per acre, and 15 lbs of sulfur per acre. Stand establishment was evaluated by counting the number of plants in 1 meter of two rows in each plot. Counts were taken on May 24, 2006, and May 17, 2007.

Weed control in the rotational crop trial was initiated with a fall application of glyphosate, which was followed by a second, pre-plant application of glyphosate in the spring. In first year of the rotation crop trial, no additional herbicides were applied to the mustard or canola plots, but the wheat plots were hand-weeded to control broadleaf weeds. Hand-weeding was used due to its expediency, to avoid herbicide drift on the adjacent plots and surrounding field, and to avoid driving in the adjacent crop. An application of a broadleaf herbicide such as bromoxynil, described below, could have been substituted for the hand-weeding. During the second year of the study, herbicides were applied to all crops on May 25, 2006 with a shielded plot sprayer to prevent off-target drift. Grassy weeds were controlled in the canola and mustard plots with an application of Select herbicide (clethodim) at 6 fl. oz. of product per acre, and broadleaf weeds were controlled in the canola plots with an application of Stinger herbicide (clopyralid) at 4 fl. oz. per acre. A tank mix of Rhino (bromoxynil and MCP ester) and Puma 1EC (fenoxaprop-p-ethyl) herbicides at a rate of 16 fl. oz. and 10 fl. oz. per acre, respectively, was applied to the spring wheat in the rotational crop trial to control broadleaf and grassy weeds. While not applied as part of this study, a post-harvest treatment of Surefire herbicide (diuron and paraquat dichloride) is typically used to control Russian thistle after a yellow mustard crop on the Stubbs Farm. This treatment is usually necessary on approximately half the yellow mustard acreage.

Weeds were controlled in the recrop trial during both years with the same herbicide regime used in the surrounding commercial field. Weed control began with a fall application of glyphosate, followed by a second, pre-plant application of glyphosate in the spring. A post-emergence application of Bronate (bromoxynil and MCPA) was used to control broadleaf weeds in the crop.

The first year of the rotational crop study was harvested on August 8, 2005. In the second year of the study, the mustard and canola plots were harvested on August 3, 2006, and the wheat plots in both the recrop and rotation trial were harvested on August 7, 2006. All plots were harvested with a small plot combine that was appropriately adjusted for each crop. After weighing, test weight was determined on the wheat samples. Subsamples of seed were taken from the mustard and canola plots for seed weight and total oil determination. Soil samples were taken from the oriental mustard and wheat plots in the crop rotation trial on July 11, 2005 and August 30, 2006 by USDA-NRCS personnel. During the winter months, the total oil content and seed weight were measured in the University of Idaho oilseed chemistry laboratory.

Results

Rotational Crop Trial. Stand counts of the mustard and canola treatments did not differ from each other; however, the wheat stand count was significantly higher than those of the other crops in 2006 (Table 1). These stand counts are within typical plant populations for these crops. Weed populations in the trial were moderate, and the primary weeds noted were wild oats, common lambsquarters, and Russian thistle. The herbicide treatments and crop competition were sufficient to limit weed growth, especially in the wheat and canola plots where broadleaf herbicides were available. Only limited insect damage in the canola and mustard plots was noted; however the 2005 wheat plots were damaged by a Hessian fly infestation. We observed no disease problems in the study.

The spring wheat plots produced significantly higher yields by weight than the canola in both years of the rotational crop trial (Table 1). The average test weight of the wheat plots was 59.1 lbs. per bushel in 2005 and 55.6 lbs. per bushel in 2006, which resulted in yield of 38.4 and 47 bushels per acre, respectively. Higher wheat yield in 2006 is attributable in part to the change from Blanca Grande to Tara 2004. In 2005, Pacific Gold oriental mustard yielded significantly more than IdaGold and Hyola 401, but in 2006, Pacific Gold had the lowest yield in the trial, while Hyola 401 canola and IdaGold yellow mustard had similar, intermediate yields (Table 1). In addition to the change in ranking, yields of the mustard and canola plots were reduced in 2006 as compared to 2005. These differences between years are likely due in part to increased stress caused by less early spring rainfall in 2006 and unseasonable high temperatures during May 2006. Lower seed oil content in 2006 also suggests that this year had higher levels of stress than 2005.

Table 1. Stand counts, yield and percent oil of rotational crops grown near Dusty, Washington during 2005 and 2006.

CROP	STAND		YIELD		OIL CONTENT	
	2005	2006	2005	2006	2005	2006
	plants/ ft of row		*lbs/acre*		*percent*	
Wheat	7.0	10.6 a	2271 a	2615 a	*	*
Oriental Mustard	5.3	6.4 b	1737 b	624 c	33.5 b	27.8 b
Yellow Mustard	5.8	5.4 b	1433 c	964 b	23.3 c	21.7 c
Canola	4.1	4.8 b	1036 d	999 b	34.6 a	32.4 a

Means with different letter suffixes are different at p=0.05 by Fisher's protected LSD.

When the data from both years is combined, spring wheat had the highest yield of all crops tested, the two mustards had similar yields, and spring canola had the lowest yield (Table 2.) Seed weight of the mustard and canola crops was distributed as expected, with yellow mustard having the largest seed and oriental mustard having the smallest seed. The seed weights found in this trial are typical for the drier areas of the Palouse region, and are in the low end of the acceptable range for commercial production. The oil content rank of the canola and mustards was also as expected, with canola having the highest percent oil and yellow mustard having the lowest. The oil content of the mustards is typical for those crops, but the oil content of canola was lower than ideal. This is not unexpected; western Whitman County is generally not considered an ideal environment for *B. napus*-type spring canola, and the environmental stresses seen in the region typically result in lower oil content in spring canola seed.

Table 2. Two year means of stand counts, yield, seed weight and percent oil of rotational crops grown near Dusty, Washington during 2005 and 2006.

CROP	STAND	YIELD	SEED WEIGHT	OIL CONTENT
	plants/ ft of row	*lbs/acre*	*oz/1000 seed*	*percent*
Wheat	8.8 a	2443 a	*	*
Oriental Mustard	5.8 b	1198 b	0.10 c	30.6 b
Yellow Mustard	5.6 b	1181 b	0.19 a	22.6 c
Canola	4.5 b	1017 c	0.13 b	33.5 a

Means with different letter suffixes are different at p=0.05 by Fisher's protected LSD.

In 2005, more moisture remained after the wheat crop than after the oriental mustard crop, 7.7 inches and 5.6 inches in the top 5 feet, respectively. In contrast to the results of 2005, in 2006 more moisture remained in the soil after the oriental mustard plots than in the spring wheat plots; total moisture remaining in 5 feet of soil after oriental mustard was 8.2 inches, with 5.9 inches of moisture remaining in the spring wheat plots. The difference in soil moisture contents found in 2006 was at 4 and 5 feet; the moisture remaining in the top three feet were similar between crops. The reasons for this are unclear, but perhaps root growth in the oriental mustard was limited the early season stress mentioned above, resulting in the lower moisture use and lower yield that was observed in 2006.

Recrop Trial. Results of the recrop trial indicate that the previous crop did not have an effect on a subsequent spring wheat crop yield or test weight averaged over both years (Table 3); although a previous crop of oriental mustard or canola did result in a gain in test weight versus growing wheat on wheat in 2006. (See previous report.) Stand counts of wheat were statistically similar across previous crop treatments.

Table 3. Spring wheat stand counts, yields and test weights when grown after different rotational crops near Dusty, Washington during 2006 and 2007.

PREVIOUS CROP	STAND	YIELD	TEST WEIGHT
	plant / ft of row	*bushels/acre*	*lbs/bushel*
Wheat	15.8	39.7	56.3
Oriental Mustard	14.6	38.6	57.0
Yellow Mustard	18.1	38.0	56.7
Canola	17.0	39.3	57.3

Means with different letter suffixes are different at p=0.05 by Fisher's protected LSD.

Economic Analysis

Even though the absolute yields of the canola and mustard crops were lower than the spring wheat yields, the commodity prices during the years of the study reduce the economic difference between mustard and wheat. DNS wheat sold for over $5.00 per bushel in 2006, and yellow mustard was being contracted at 20 cents per pound (FOB Great Falls, MT) in early 2007. Prices in the region for Pacific Gold oriental mustard have ranged from 12 cents to 16 cents per pound If returns for wheat and mustard are calculated using the mean yields from 2005 and 2006 and a price of $5.25 per bushel for wheat, 18 cents per pound for yellow mustard, and 15 cents per pound for oriental mustard, which would be representative of those years, the gross return for the wheat is $224.18 per acre, the gross return for yellow mustard is $212.58 acre, and the gross return for oriental mustard is $ 179.70 per acre. Canola prices have been lower than mustard prices for a number of years. If a representative figure of 12 cents per pound is used for canola, the gross return for the spring canola crops is only $122.04 per acre.

Recently the prices of most farm commodities have increased substantially. At the time of writing, DNS wheat is $11.78 per bushel and yellow mustard has been contracted at 48 cents per pound, giving a return of and $503.02 and $566.88, respectively. Contract prices for oriental mustard are 38 cents per pound, for a return of $467.22. Current contracts for canola are offering prices around 25 cents per pound, which would increase the return to $254.25, still well below returns for mustard and spring wheat in today's market.

To calculate gross returns after differential costs of production (Table 4), only the variable costs that differ between the crops are considered. These include seed cost and the cost of post-emergent herbicides. Growers should examine the situation on their own farms and make adjustments to adapt these assumptions to their own production systems.

Seeding rates used on the Stubbs' Farm, the grower-cooperator in this trial, were used in the calculations; 6 lbs per acre for yellow mustard, 4 lbs per acre for oriental mustard, 5 lbs. per acre for canola, and 90 lbs. per acre for spring wheat. The grower cooperator reported that they typically apply 5 lbs. more nitrogen per acre for a spring wheat crop than for a mustard crop, but that they also apply about 3 lbs. more sulfur per acre for a mustard crop. For the purposes of this report however, the fertilizer costs are assumed to be equal. In addition to the different selective herbicides used in the crops, a yellow mustard crop on the Stubbs' Farm often receives a post-harvest application of a broad spectrum herbicide such as Surefire, to control Russian thistle. A value of $6.60 per acre was used for post-harvest application cost. On average, this is done to about half the mustard acreage, so half of the per-acre cost was used in the calculation. Application costs of the in-crop herbicides are assumed to be equal for the different crops.

The estimated cost to grow RoundupReady canola, $43.60 per acre, is also included for comparison even though a RoundupReady cultivar was not used in the trial. This cost is considerably higher than the differential cost of a non-herbicide resistant canola, which is estimated to be $26.36 per acre. RoundupReady cultivars may offer a yield advantage over other cultivars in high rainfall areas when high weed pressure is encountered. In recent years, new RoundupReady cultivars have yielded approximately equivalent to 10% higher than Hyola 401 in regional trials conducted by the University of Idaho.

Table 4. Estimated gross returns, differential production costs, and gross returns after differential costs for yellow mustard, oriental mustard, and spring canola, and spring wheat based on yields obtained near Dusty, Washington in 2006 and 2007.

	Yellow Mustard	Oriental Mustard	RoundupReady Canola	Spring Canola	Spring Wheat
Gross return (2006 prices)	$212.58	$179.70	*	$122.04	$224.18
Gross return (2008 prices)	566.88	467.22	*	254.25	503.02
Seed cost	7.50	6.00	27.50	12.50	18.00
Herbicide	13.86	13.86	16.00	13.86	9.63
Post harvest herbicide	8.55	-	-	-	-
Total costs	29.91	19.86	43.60	26.36	27.63
Return after differential costs 2006	182.72	159.84	*	95.68	196.55
Return after differential costs 2008	536.97	447.36	*	227.89	475.39

Discussion

The economic analysis of the rotational crops suggests that yellow mustard can economically competitive with spring wheat in western Whitman County. Yellow mustard prices sometimes peak at levels higher than contract prices during the winter months, so if a grower is positioned to take advantage of those price peaks, the economic return of yellow mustard could easily equal or perhaps exceed that of spring wheat in western Whitman County. At current wheat prices ($11.78 per bushel), yellow mustard must be approximately $0.38 per pound for an equivalent return based on the yields achieved in this trial.

In this study, oriental mustard was not as economically competitive with spring wheat as yellow mustard, but this is primarily a function of current prices, because oriental mustard yielded as well as yellow mustard averaged over both years, and it has a lower differential production cost. Growers in western Whitman County should watch mustard prices and contracts carefully when choosing which mustard species to grow on their farms, since both are viable crops. Of course, growers need to consider commodity prices and production costs on at least an annual basis when choosing rotational crops.

Even though the cost of production of non-herbicide resistant canola was less than that of yellow mustard and spring wheat, canola was not economically competitive with spring wheat or either mustard species. This is primarily due to the low yields of spring canola seen in the trials, which were not unexpected for the region. Western Whitman County is typically considered to be a poor environment for growing *B. napus*-type spring canola cultivars due to the low rainfall and high summer temperatures. *B. rapa*-type spring canola cultivars are earlier and somewhat more resistant to high temperatures and might be an option for region.

No significant differences were seen in subsequent wheat yields. Even though the mean wheat yields were not exactly the same based the previous crops, the statistical analysis of the data indicates the small differences observed are due to error and/or random environmental effects. This is contrary to previous research and experience that has shown that wheat often performs better after a rotational crop such as mustard or canola, in part due to reduced disease pressure. The lack of differences in this project could be a caused by a number of factors; perhaps disease pressures were low across the entire experiment due to the environmental conditions, or perhaps the disease resistance package of the wheat varieties used was ideal for the conditions encountered. The fact that the mustard and canola crops did not reduce the yield of a subsequent wheat crop is also important. One of the reasons that this experiment was undertaken was to determine if the potential for mustard crops to use more soil water than other crops would be a detriment in western Whitman County. That was not the case in the experiment, suggesting that these crops will not have a detrimental effect on subsequent wheat crops.