OILSEED CROPS AND VALUE CHAINS IN PARTNERSHIP WITH ORGANIC VALLEY

Final Report

The Ohio State University Agroecosystem Management Program

SUMMARY

Biofuels produced from oilseed crops offer a promising alternative to increasingly scarce and environmentally costly fossil fuels. However, our capacity to grow sufficient quantities of oil – and the environmental impact of transferring a portion of production to oilseeds – is still unclear, and is the subject of current research. One strategy is for farmers to incorporate oilseed crops into current crop rotations to produce their own fuel on-farm. This approach not only presents an alternative to ecologically fragile and environmentally costly oilseed monocultures, but potentially offers an array of biological and economic benefits. In addition to providing fuel, this strategy diversifies crop rotations, allowing farmers to access a number of ecosystem services and value-chains that could reduce expensive inputs and diversify economic output. In this report, we take a whole system approach to comparing the internal and external value-chains resulting from four different oilseed crops on a small to mid-sized farming system in Northeast Ohio. Spring canola, flax, camelina and sunflowers were planted in one-acre demonstration plots and monitored for growth characteristics and key ecosystem services, as well as the nutritional content of the resulting oil and meal. The project brought together experts from a range of disciplines, from entomology to soil science, animal science, engineering and nutrition. This preliminary interdisciplinary study provides valuable information for future integrated oilseed research, and for area farmers interested in adding these multifunctional crops to their farming systems.

1. INTRODUCTION

Incorporating oilseed crops like canola, flax, camelina or sunflowers into crop rotations may offer a number of benefits to operators of small and mid-sized farms in the Midwest. These potential benefits are both internal (ie. ecosystem services and on-farm value streams that reduce costly inputs) and external (diverse high-value products that can be marketed off-farm). A whole system comparison of the value – internal and external, biological, agronomical and economic – of popular oilseed crops is essential as biofuels take center stage and integrated, low-input agriculture becomes an important ecological and economic alternative.

Because biofuels could require a significant portion of agricultural land, resources and dollars, there have been numerous studies examining not only their potential as fuel, but also their impact on ecosystems and natural resources (Chatskikh et al. 2013; Fieldsend and Singh 2013). They have been examined for their impact on erosion (Chatskikh et al. 2013), ecosystem services (Holzschuh et al. 2012; Fieldsend and Singh 2013), and water use (Nielson 1998; Eynchk et al. 2013). Others have considered their potential to diversify grain crop rotations (Eynchk et al. 2013) and to provide a source of organic protein supplements for livestock in the form of pressed meal (Herikson et al. 2009, Kirkhus et al. 2013). For an excellent summary of biofuel production and sustainability, see *Biofuel Crop Sustainability*, especially chapter 5, "Sustainable Oil Crops Production" (Eynck et al. 2013; Singh 2013). However, few of these studies have compared these crops across ecological and production variables simultaneously and none have taken place in the Eastern Midwest, one of the most important agricultural regions on the planet.

Canola, camelina, flax and sunflowers each have a different history in Northeast Ohio. Currently, US production of all four oilseeds is concentrated in Montana and the Dakotas. Sunflower and winter canola are occasionally grown in Ohio, and canola was planted in trial plots in the Northwest part of the state in the early 1990s (Ed Lentz, Schmidt 1990). Pennsylvania State University is currently conducting research on canola and camelina (Hunter and Roth 2010 and 2013), and further east, the University of Vermont launched a project centered on integrated oilseed production in a temperate climate. No studies were found investigating flax production in the region. However, many early Ohio settlers grew flax for fiber, including the pioneer family that originally farmed the site of the current research plots.

These four crops have been associated with a number of valuable ecosystem services. Canola and sunflowers, for instance, have been shown to open up compacted soils (Nielson 1998, Chatskikh et al. 2013), and winter canola is sometimes planted as a cover crop for that purpose. Canola and sunflowers are also known to attract and support pollinators, including wild bee species (FAO-Animal Feed Resources Information System; Holzschuh et al. 2013; Westphal 2003). Researchers in North Carolina are even exploring the use of sunflowers as a trap crop for brown marmorated stink bug in instances where it is not the major cash crop (Mathews and Hallack 2012). Camelina has received attention for its ability to grow in poor soils and to thrive with little water or fertilizer (Eynchk et al. 2013). This is not an ecosystem service per se, but means that camelina grows at little ecological cost and with few synthetic inputs, potentially benefiting organic growers, regions expecting or experiencing drought, and farmers who need to conserve resources for other crops or future years.

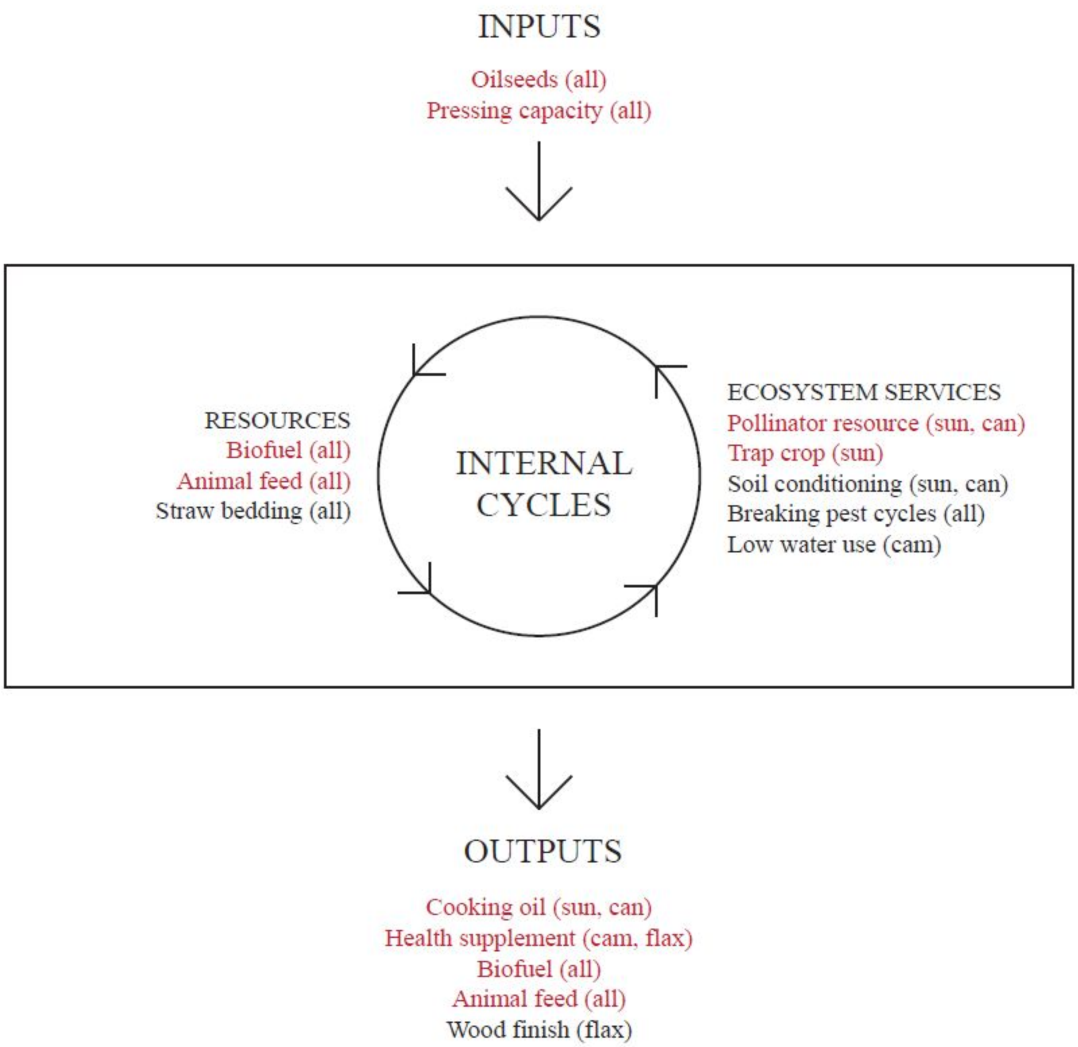
In addition to these potential biological benefits, oilseed crops result in two valuable end-products: the oil itself and the leftover seed pulp, or pressed meal. The latter can be fed to poultry and ruminants on or off-farm as a protein supplement. Indeed, canola is the second most common protein supplement added to livestock feed in the United States, and sunflower is the fourth most common worldwide (Ash 2012; Anderson 2013). Canola meal is fed to all livestock, while sunflower meal is limited to ruminants due to high fiber (Anderson 2013). Flax meal and flax seeds are also a common feed supplement, and are especially valuable for their high levels of polyunsaturated fatty acids. In fact, chickens whose diets include flax have been shown to produce eggs with higher levels of omega-3 fatty acids (Maddock 2005; Kakani et al. 2012). Camelina meal is approved in amounts up to 10% in livestock feed (Eynchk et al. 2013), and has also been shown to improve the fatty acid composition of chicken eggs (Maddock 2005; Kakani et al. 2012).

The oil itself can contribute to several potential value-streams. Canola and sunflower oil are common cooking oils. Flax and camelina oils are notably high in omega-3 fatty acids, which have been scarce in contemporary western diets and popular for their health benefits (Maddock 2005; Zubr 2009; Laux 2013). Both oils are being marketed as health supplements. In addition, linseed (flax) oil can be processed into a natural wood finish (Laux 2013). Most notably, all four crops are potential sources of biofuel. All four can be transformed into biodiesel, and in some cases can even be used as straight vegetable oil. For instance, mixtures of canola and camelina vegetable oil have been shown to be a safe and effective fuel

(Paulsen et al. 2011). Biodiesel produced from camelina oil is even being explored as fuel for jet airplanes (Cline 2011).

Our goal was to compare the range of benefits that these crops could offer if integrated into a diversified farming system in the Midwest. We chose a number of potential on and off-farm value streams to evaluate, which are highlighted in Figure 1. Four plots in Northeast Ohio were planted and monitored for growth characteristics, pollinator attraction, trap crop potential and yield, and the resulting oil and meal were analyzed for fat and protein composition. We expected the crops to display different strengths and weaknesses across variables, and compiled the data to create an easy comparison. This information could be of use to researchers interested in the role of oilseeds in integrated farming systems, and farmers hoping to incorporate these multifunctional crops into a small to mid-sized farm.

Figure 1. Model of the on and off-farm benefits of oilseed crops in an integrated farming system. Services highlighted in red were included in the present study.



2. MATERIALS AND METHODS

The plots were established at a research station called the Mellinger Farm, in Wayne County, Ohio. The Mellinger Farm is located at 40.8 degrees north and 81.9 degrees west. The location of the plots had previously been in a conventional pasture mix, and was plowed in early spring, prior to planting. Though the land is not certified organic, no pesticides or herbicides were used during the trial. Flax (cv. 'Omega' developed by North Dakota State), spring canola (cv. '30120B6 non-GM' variety from Rubisco), camelina (cv's. 'Suneson' and 'Blaine creek' developed by Montana State) and sunflower (cv. 'Daytona') were planted in a randomized block design, with each block comprising four quarter-acre replicates of each crop. The two varieties of camelina were planted in alternating strips (7.5ft wide) within each camelina plot.

The flax, canola and camelina were planted on April 22. They were planted at 45, 7.5 and 10 pounds per acre respectively, with 7" row spacing, at a depth of ¼ in. The canola and flax were inter-seeded with red clover for weed suppression and nutrient management. The sunflowers were planted on June 21st, at 30" row spacing. An extra ¼ acre of sunflowers was planted to the west of the final plot, as a buffer between the fields and the woods. To avoid a large wet spot in the field, one plot of canola had to be enlarged to over ¼ acre to ensure that at least ¼ acre would be harvestable. All yield values were adjusted accordingly. The sunflowers were mechanically cultivated July 27 for weed control.

The plots were bordered by conventional no-till corn and soybeans to the south, orchard grass/clover pasture to the north, woodlands to the west and a barn and outbuildings to the east. They were situated on a slight incline, with lower ground toward the east and higher ground toward the west. The prevailing winds blew from west to east. A set of beehives managed by the bee lab at OSU are located about half a mile to the south of the plots, in a strip of woods beyond the corn and soybeans.

2.1 Height and Stand Density

The height of the flax, canola, and camelina was recorded twice between flowering and harvest. Sunflower height was measured four times from emergence to maturity. To gauge the overall height in each plot, eight plants in a row were measured at three random points on the perimeter of each plot. The measurement represented the length of the stalk of the plant, not the vertical distance from the top of the plant to the ground. The mean was found for each plot, and compared among plots.

Stand density was measured after harvest for all crops. At four randomly selected points within each plot, the number of stalks along a 50cm stretch of one row was counted. Stand density per square meter was calculated using the known length of the plots, and known number of rows per plot. Again, the mean was found for each plot, and compared among plots.

For both height and stand density, separate measurements were taken for the two camelina varieties within each camelina plot. However, for comparisons among crops, the mean was determined per camelina plot using all the measurements, without regard to variety.

2.2 Pollinator Activity

Pollinator activity was assessed for flax, canola and sunflowers by counting the number of flower visitors within a meter-square quadrant during a 20 minute window, and by photographing all observed pollinating insects and birds.

Image 1. Observation quadrant, 1 m x 1 m

The flax and canola bloomed during the last two weeks in June. Pollinator observations took place June 25 and 26 during late flower. During each 20-minute observation window, a square-meter quadrant was placed within the plot at an arms-length from the perimeter, and the number of flower visitors within the quadrat was recorded. Because there were so many honeybees in the canola, we only counted honeybees for two two-minute windows within the 20-minute observation period. Four morning observations (before 11am) and four afternoon observations (after 11am), were taken on each day. The observations were grouped to compare changes between morning and afternoon and between flax and canola: two plots of each crop were observed both morning and afternoon on the first day, and the other two plots of each crop were observed morning and afternoon on the second day.

The sunflowers bloomed during the last week in August. Pollinator observations were made during early flower (August 26) and late flower (August 30). On each day, both morning and afternoon observations were made for each of the four sunflower plots. Because the numbers varied among the observation quadrants, large and small flowers within the meter quadrants were counted.

To assess the total pollinator population for the crops, all observed pollinator species were photographed. For the flax and canola, pollinator species were captured by walking around the crop with a net and catching all observed flower-visitors. These were chilled, sorted, and photographed using a high-resolution camera. The pollinators visiting the sunflowers were generally larger, more noticeable, and more infrequent. To generate a comprehensive list of sunflower visitors, pollinators were photographed or recorded on site throughout bloom. The pollinators in the photographs were identified to genus (or family) and combined with frequency data to estimate diversity indices for pollinating insects and birds that were attracted to the crops.

2.3 Sunflower Trap Crop Potential

To assess the ability of the sunflower crop to attract brown marmorated stink bug (BMSB) away from other crops, the sunflowers were surveyed weekly for BMSB eggs, larvae and adults. Surveys took place late morning or early afternoon. Along a five foot stretch on each side of the perimeter of each plot, BMSB evidence was recorded, along with evidence of native stink bugs.

2.4 Harvest, Yield and Biomass

The camelina and canola were combined on July 18 and August 6, respectively. Due to weather constraints, the flax was harvested over three days: August 6, August 7 and August 12. The moisture at harvest was around 12% (camelina), 11% (canola) and 14% (flax) and the seed was dried to 5-8% moisture in heated grain drying closets and cleaned using a small seed-cleaner. The seed was then weighed. To compare the yield of the two camelina varieties, all of the seed from one combine pass through each variety in each plot was saved and weighed separately. The camelina, canola and flax seeds were expeller pressed September 23 and 24 using the Organic Valley mobile Kern Kraft cold screw press. The oil was poured into air-tight food-grade buckets, and the meal was placed in polyester bags. Both were weighed and stored.

The sunflowers were combined October 29 and October 30, at a moisture that registered "out of range" (15-20%). They were dried to 5-7% moisture, weighed and stored.

After harvest, biomass was estimated by collecting all stalks on the ground along a pass of the combine for a 6 meter stretch. Two samples were collected per plot, and the samples were weighed. To account for the stalk residues that remained in the ground, stalk residues were cut from each plot and weighed (50 for camelina and flax, 25 for canola and 10 for sunflowers). This information was combined with stand density data to estimate the total biomass left on the ground for each plot.

The sunflowers were pressed using an expeller press February 9th. The oil was placed in food-grade buckets and the meal was returned to the grain bags. Both were weighed and stored.

2.5 Analysis – Oil and Meal

Oil samples from each crop were analyzed using a GC Mass Spectrophotometer to provide a standard lipid profile. That lipid profile was used to compare omega-3 and omega-6 fatty acid compositions among crops. The profile was also used to determine cetane number (ignition delay, the primary characteristic for judging fuel quality) (Piloto-Rodriguez et al. 2011).

Meal samples were analyzed for crude protein and amino acid composition at the University of Missouri-Columbia Agricultural Experimental Station Chemical Laboratories.

2.6 Statistical Analysis

Results were assembled into a table and analyzed using two-way analysis of variance for statistical difference among the crops. The blocking factor was dropped from the model in cases where it did not reduce the MSE. Mean and standard error of the mean values were also determined for each crop. Any percentages were transformed using an arcsine square root transformation before conducting analysis.

3. RESULTS

3.1 Agronomic Performance

Challenging weather most likely impacted yield. The flax lodged as a result of heavy rains during bloom (in late June and early July), and was overtaken by weeds in at least some areas of some replicates. The canola experienced premature shattering due to white mold (sclerotinia), presumably caused by the wet conditions.

The sunflower plots yielded the most seed, at 1089 (+/-45) lbs per acre, followed by the camelina at 699 (+/-60) lbs per acre. Canola and flax had lower yields, at 423 (+/-74) and 145 (+/-8) lbs per acre respectively.

Similarly, the sunflower and the camelina plots resulted in the greatest oil quantity, at 49.14 (+/- 2.83) and 13.69 (+/- 1.61) gallons per acre respectively, as compared with canola (10.07 (+/- 2.14)) and flax (3.34 (+/- 0.21)). The sunflower seeds contained approximately twice the oil content by weight of the other crop seeds; they yielded 35% oil, compared with 15, 18 and 19% for camelina, canola and flax respectively.

3.2 Ecosystem Services

The canola and sunflower attracted the largest numbers of pollinators. The canola attracted the greatest numbers of honeybees and flies, but the sunflowers attracted the widest variety of pollinators, including butterflies, hummingbirds, and carpenter bees (Table 2).

Due to weather, the afternoon data for flax and canola was incomplete (flax flowers close in the afternoon; and on one day it began to rain), so we only included the morning data for those two crops. Weather also introduced a degree of uncertainty into the flax and canola pollinator data in general. The first day of pollinator observations was bright, sunny and hot. It rained heavily that evening and the following morning, and let up only briefly during the morning. This led to a noticeable increase in honeybee and fly activity (given that they only had a small window for flight during the day). This began a 17-day period of frequent rain, which made further observations impossible. (See Appendix for more detailed information on rainfall, temperature and wind speeds near Wooster Ohio for the weeks between April 22 and October 30, 2013.)

Two brown marmorated stink bugs were observed over the course of the entire observation period, and no eggs or nymphs were found. We also encountered 12 adult native stink bugs dispersed throughout the fields over the course of the total observation period. Based on these small numbers we were unable to test the value of sunflower as a trap crop.

			CANOLA			FLAX			CAMELINA			SUNFLOWER			
			Mean	*SEM*	Lit Values	Mean	*SEM*	Lit Values	Mean	*SEM*	Lit Values	Mean	*SEM*	Lit Values	**Source**
GROWTH	Seed yield (6-8% moist.)**	*lbs/acre*	**423.44**	*73.94*	1,000-3,000	**145.19**	*8.28*	2,000-3,000	**699.08**	*59.52*	1000-1500	**1088.72**	*45.02*	1000-3000	1 (can, flax, sun); 2 (cam)
	Oil yield**	*gal/acre*	**10.07**	*2.14*	53	**3.34**	*0.21*	112	**13.69**	*1.61*	58	**49.14**	*2.83*	80	1
	Meal yield**	*lbs/acre*	**312.73**	*48.25*	NA	**115.94**	*7.86*	NA	**581.27**	*50.42*	NA	**593.56**	*30.87*	NA	
	Height**	*inches*	**52.37**	*0.88*	20-50	**29.00**	*0.24*	12-36	**34.08**	*0.55*	12-36	**51.01**	*0.64*	42-56	2 (cam); 3 (flax); 4 (can)
	Stand Density**	*plants/ft2*	**6.21**	*0.35*	6-8	**42.20**	*3.64*	NA	**36.95**	*2.20*	NA	**0.81**	*0.02*	0.41	5 (can); 6 (sun)
	Biomass	*tons/acre*	**1.78**	*0.20*	NA	**1.40**	*0.11*	NA	**1.63**	*0.23*	NA	**2.01**	*0.26*	NA	
OIL	Seed Oil Content**	*% (weight)*	**18.17**	*1.50*	26-42	**18.28**	*1.50*	40-45	**15.29**	*0.68*	29-41	**35.44**	*1.15*	39-43	1 (can, flax, cam); 6 (sun)
	Omega-3**	*%*	**7.54**	*0.15*	9.9	**25.63**	*9.23*	55.0	**24.33**	*1.52*	38.1	**7.48**	*0.09*	0.5	7
	Omega-6**	*%*	**18.07**	*0.24*	21.5	**21.04**	*2.89*	14.9	**20.49**	*0.76*	16.0	**0.11**	*0.04*	65.6	7
	Oleic Acid**	*%*	**62.02**	*0.39*	60.1	**34.38**	*4.04*	18.4	**16.81**	*0.36*	18.7	**82.48**	*0.44*	22.1	7
	Total SFA**	*%*	**10.04**	*0.31*	8.0	**17.40**	*2.13*	10.0	**15.52**	*0.25*	9.7	**9.00**	*0.38*	12.8	7
	Total MUFA**	*%*	**64.30**	*0.33*	62.4	**35.88**	*4.36*	18.5	**36.04**	*0.49*	32.8	**83.41**	*0.41*	22.4	7
	Total PUFA**	*%*	**25.66**	*0.37*	31.5	**46.72**	*6.37*	69.9	**48.44**	*0.67*	54.1	**7.59**	*0.11*	66.0	7
	Ignition Delay**	*Cetane #*	**50.07**	*0.13*	55	**46.21**	*2.56*	52	**47.60**	*0.44*	NA	**53.59**	*0.06*	49	8
PRESSED MEAL	Crude Protein**	*%*	**1.70**	*0.05*	1.89	**1.07**	*0.01*	1.18	**1.53**	*0.01*	1.59	**1.03**	*0.02*	1.01	9 (can, sun); 10 (cam); 11 (flax)
	Lysine**	*%*	**0.50**	*0.01*	0.69	**0.45**	*0.01*	0.58	**0.52**	*0.00*	0.59	**0.56**	*0.01*	0.58	9 (can, sun); 10 (cam); 11 (flax)
	Methionine**	*%*	**0.63**	*0.02*	0.83	**0.41**	*0.00*	0.61	**0.65**	*0.01*	0.74	**0.40**	*0.00*	0.44	9 (can, sun); 10 (cam); 11 (flax)
	Cysteine**	*%*	**1.12**	*0.03*	1.52	**0.86**	*0.01*	1.19	**1.17**	*0.02*	1.33	**0.95**	*0.01*	1.02	9 (can, sun); 10 (cam); 11 (flax)
	Meth + Cys (TSAA)**	*%*	**1.18**	*0.03*	1.44	**0.96**	*0.01*	1.14	**1.18**	*0.00*	1.34	**0.93**	*0.01*	0.92	9 (can, sun); 10 (cam); 11 (flax)
	Threonine**	*%*	**1.66**	*0.03*	2.12	**2.21**	*0.02*	2.81	**2.32**	*0.03*	2.86	**1.78**	*0.04*	2.08	9 (can, sun); 10 (cam); 11 (flax)
	Arginine**	*%*	**1.44**	*0.03*	1.94	**1.31**	*0.02*	1.61	**1.47**	*0.01*	1.75	**1.15**	*0.02*	1.43	9 (can, sun); 10 (cam); 11 (flax)
	Valine**	*%*	**0.69**	*0.02*	1.01	**0.51**	*0.01*	0.65	**0.65**	*0.01*	0.83	**0.59**	*0.01*	0.68	9 (can, sun); 10 (cam); 11 (flax)
	Histidine**	*%*	**26.85**	*0.55*	39.0	**25.25**	*0.17*	34.3	**28.93**	*0.25*	35.0	**23.26**	*0.27*	29.4	9 (can, sun); 10 (cam); 11 (flax)
POLLINATOR	Honeybee**	^	**142.50**	*26.18*	NA	**0.00**	*0.00*	NA	**NA**	*NA*	NA	**23.75**	*6.12*	NA	
DIVERSITY	Bumblebee	^	**0.00**	*0.00*	NA	**2.25**	*0.75*	NA	**NA**	*NA*	NA	**4.25**	*1.97*	NA	
	Syrphid Fly*	^	**22.00**	*7.15*	NA	**14.25**	*3.99*	NA	**NA**	*NA*	NA	**3.25**	*1.11*	NA	
	Sweat Bee	^	**0.50**	*0.29*	NA	**0.25**	*0.25*	NA	**NA**	*NA*	NA	**0.00**	*0.00*	NA	

*p<0.05

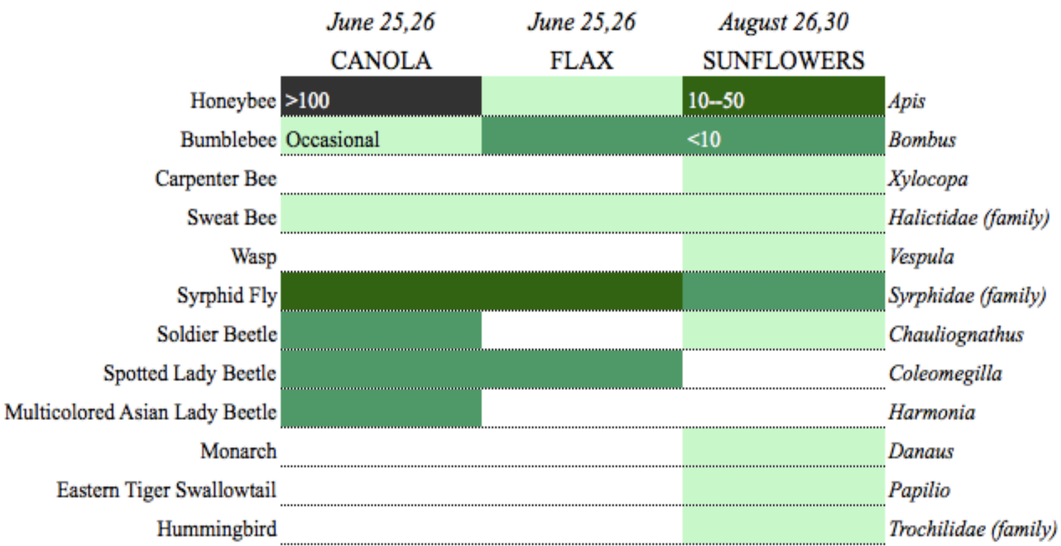
**p<0.01

^observed during a 20min observation window, in a 1m x 1m meter quadrant

1. Jaeger 2008
2. Hunter and Roth 2010
3. Delate
4. Canola Council of Canada
5. Frier and Roth
6. Kandel et al. 2012
7. Dubois et al. 2007
8. Piloto-Rodriguez et al. 2013
9. Gonzalez-Vega and Stein 2002
10. Pekel et al. 2009
11. Kratzer and Vohra 1996

Table 1. Combined Results for Yield, Oil Content, Meal Content and Pollinator Activity

Figure 2. Pollinator Frequency. Numbers refer to the number of pollinators entering a meter quadrant during a 20-minute observation window.



3.3 Value Added Products

3.3.1 Fatty Acid Composition, Oil

Concentrations of omega-3 fatty acids differed significantly among crops (F=10.5; df=3,3; p=0.003), with the highest concentrations observed in camelina and flax, each at just over 20%. Omega-6 fatty acids also differed significantly among crops (F=32.12; df=3,3; p=0.000) and the camelina, flax and canola oils contained higher proportions than the sunflower oil. However, the sunflower oil had the highest percentage, more than 60%, of oleic acid, which also differed significantly among crops (F=210.10; df=3,12; p=0.000). Overall, the sunflower oil had a greater percentage of monounsaturated fatty acids (64%), while flax and camelina had a higher proportion of polyunsaturated fatty acids (at 44 and 47% respectively), both of which differed significantly among crops (F≥50.61; df = 3,3; p<0.01)

3.3.2 Amino Acid Profile, Meal

Camelina had the highest crude protein composition at 29%, compared with 25% for flax and 27% for sunflower, and differences among crops were statistically significant (F=60.61; df=3,3; p=0.000). Individual amino acid composition also varied significantly among crops (F≥22.36, df=3,3, p<0.01). Sunflower was highest in lysine, whereas camelina was highest in cysteine and methionine.

3.4 Biofuel

Statistically significant differences in cetane number were observed among crops (F=6.20, df=3,21, p=0.009); sunflower oil had the highest cetane number, at 54, followed by canola oil (50), camelina oil (48) and flaxseed oil (46).

4. DISCUSSION

4.1 Challenges in Production

Compared with yields recorded in the literature, our yields for flax and canola were relatively low (Table 1). Our sunflower yield was within a typical range, and our camelina yield was slightly below what has typically been reported.

Several factors account for this difference. First, the comparison yield values were largely taken from conventional trials in typical growing locations. Because we did not use synthetic fertilizers, and were growing the crops in a less typical location, we might have expected reduced yields. Where possible, the literature comparison was made with values that shared at least one characteristic: lack of synthetic amendments, location or variety. For example, the sunflower comparisons were with trials of *cv. 'Daytona'* sunflowers, although they were grown with fertilizer and pesticide inputs in North and South Dakota in the comparison trials. The camelina values come from trials in Northwest Pennsylvania, and the flax values refer to organically grown flax. However, it was not always possible to find this type of data, and the literature values rarely share more than one characteristic in common with our trial.

Even more importantly, several severe weather events during the growing season impacted crop performance. During the last two weeks of June, Northeast Ohio experienced a series of violent thunderstorms (see Appendix). At this time, the sunflower plants were still small and the camelina had just completed blooming. The flax and canola plots, however, were at mid-bloom. As a result of the damp conditions, our canola developed white mold, *Sclerotinia sp.*, which caused premature shattering and reduced yields. The flax lodged severely during the storms – almost three quarters of the plot areas were lodged by July – and did not fully recover. Much of the crop rotted on the ground, and weed competition increased for the rest.

Weed density is a common problem in organic flax production. Flax should be planted very early because it germinates at very low temperatures and early germination of flax will suppress weed germination and establishment by shading and crowding weed seedlings. In addition to competition for water and nutrients, weeds that do not senesce and dry before the flax is combined will lead to contamination with moist green weed plant parts in the harvested flax seed, which should be as dry as possible. A common solution is to windrow the crop before harvest and let it dry in the field. However, windrowing equipment was not available in the region. In the end, we combined the plots without windrowing. All together, the lodging and weed growth led to very low flax yields.

On a more positive note, we found that the camelina was resilient in the face of the extreme rain events. We had a dense, relatively weed-free stand of camelina, with a yield that was close to that observed in other regions. As may be common for this crop, we found it challenging to adjust our equipment for the very small camelina seeds, and some seed was certainly lost during harvest, particularly before but even after we found settings that balanced seed loss with husk and stem removal. Our sunflowers performed the best of all of the crops, with good yield from consistent stands that remained relatively weed free after a single cultivation.

Image 2. A strong stand of camelina July 17

4.2 On-farm Value Chain Potential

These four crops offer a number of potential benefits in on-farm value chains – products and ecosystem services that could substitute for purchased inputs.

For instance, the feed from all four oilseeds can be fed to livestock as a protein supplement. All four are suitable for ruminants, and all except the un-hulled sunflowers are recommended for poultry. Our yields on one acre could provide protein for 104 (canola), 39 (flax) or 194 (camelina) layer hens for 20 weeks (assuming an inclusion rate of 10%, and a consumption rate of 1.5 pounds of feed per week per chicken). Alternatively, these crops could have provided the protein to raise 284 (canola), 105 (flax) or 529 (camelina) broiler chickens to slaughter (at 5.5 lb live weight, assuming 10% inclusion and 2 pounds of feed per pound of body weight).

Another valuable on-farm product is fuel. The oil could be converted to biodiesel, a process that removes glycerin from the oil, or used in diesel engines as straight vegetable oil (SVO). Many times, the most effective use of SVO is with combinations of vegetable oils, or in combination with diesel fuel. For example, camelina oil is not suitable on its own for use as SVO, but has been used successfully when mixed with canola oil (Paulsen 2011). Farmers may want to find suitable oil combinations, and then grow multiple oilseed crops simultaneously for fuel. Our plots yielded 49.14 (+/- 2.83), 10.07 (+/- 2.14), 13.69 (+/- 1.61) and 3.34 (+/- 0.21) gallons per acre of sunflower, canola, camelina and flax oil respectively. However, the literature suggests that a farmer could expect yields up to 80, 53, 58 and 112 gallons per acre (Jaeger 2008).

To gauge fuel potential, we calculated cetane number from the fatty acid composition for each oil. Cetane number is the measure of ignition delay, and is one of the most important parameters for testing oil quality. Higher cetane numbers correlate with higher quality fuel. Typical cetane numbers for fuel range from 40 to 55. US biodiesel standards prescribe a minimum cetane number of 47 (Knothe 2003). The calculated cetane numbers for sunflower (54), canola (50), camelina (48), and flax (46) fall comfortably within this average range, and approach or exceed US standards. While cetane value alone does not determine fuel suitability (there are many other factors including viscosity, melting point, vapor point, etc.), it does confirm strong potential as a biofuel.

Regarding ecosystem services, sunflower and canola drew in the largest numbers and variety of pollinators. These crops alone could not support farm pollinator populations because they bloom over a short time-frame, but they could play a valuable part in a full-season pollinator management strategy. The literature contains reports that identify both crops as pollinator favorites (FAO-Animal Feed Resources Information System; Westphal 2003; Holzschuh et al. 2013).

Further research on the impact of these crops on soils could help farmers decide which crop would be most effective in improving soil quality in a particular location and rotation. These impacts might include nutrient use, water use, and effect on pore space (in particular, with respect to canola and sunflower). Similarly, other internal services that could be explored include the value of the fiber for animal bedding, and the ability of oilseed crops to break pest cycles associated with grains.

4.3 Off-farm Value Chain Potential

Both the oil and the meal are potential high-value products that could be sold off-farm. Omega-3 fatty acids have a number of nutritional benefits, and both flax and camelina oil could be sold as a high-value health product. Our data included omega-3 levels of 26% in flax and 24% in camelina, which are still higher than most cooking oils, if well below literature values of 55% and 38% respectively (Dubois et al. 2007). At the same time, all four oils are low in saturated fats, making them attractive as cooking oil in niche markets. It is important to keep in mind that selling food-grade oil requires specialized processing equipment, including a bulk tank for settling and a centrifuge for separating out sediment. Some have proposed the idea of selling the oil to restaurants and then re-claiming the used oil as biofuel, thereby recovering both values. Raw linseed oil could also be sold for processing into a natural wood finish, or used for this on farms that produce furniture and other wood products as a value added agroforestry enterprise.

The meal could be sold off-farm as a natural protein supplement for livestock. Indeed, the US market for organic protein supplements is growing, fueled by consumer demand for organic animal products. For example, organic poultry supplements have seen an increase in demand due to the popularity of organic eggs (Charles 2014). Most poultry growers turn to soybeans as a protein supplement, but there are few domestic organic soybean growers. Camelina is particularly suitable as an organic supplement because it grows well without synthetic fertilizers, and is naturally weed resistant. Camelina and flax have the added advantage that they increase the omega-3 fatty acid composition of the resulting eggs.

4.4 Conclusions

Although we experienced unfavorable growing conditions, we were able to produce seed from each crop to evaluate their potential across multiple value chains. Our integrated approach – based in assessing crops on a suite of parameters which are rarely combined and yet are all highly relevant to growers – will be pursued in future research. The character and potential value of these oilseeds within a crop rotation becomes more complex and varied when one takes into account both product-oriented and systems-oriented effects. Ultimately, an integrated understanding of oilseed crops would allow farmers to incorporate them most effectively into a farming system, particularly a diversified farming system that benefits both from internal value-chains and new sources of profit.

Recommended considerations for farmers, based on our study, are: 1. *Think beyond oil.* We tested and confirmed that the value chains accruing from these crops vary considerably, so match your choices with the other enterprises on your farm. 2. *For Northeast Ohio spring planting, consider camelina and sunflower* as the two crops that performed relatively well in our area, although in each case having the appropriate combine equipment and settings will take some experience. 3. *Plant early and be proactive about weed management* for organic flax in particular. Planting flax earlier in the spring allows the crop to get a head start over the weeds, and reduces weed problems, and securing windrowing equipment for harvest can help with achieving consistent moisture levels and avoiding plant material contamination when combining the crop. 4. *Be aware* of potential for white mold in spring-planted canola, which becomes a particular risk with standing water and moisture during bloom. Because of disease problems, most growers in this region plant winter rather than spring canola. 5. *Evaluate your market.* Camelina oil in particular could play a part in emerging local markets for cooking oil or biodiesel. During the study, the camelina received the most attention from growers, researchers and processors, who were curious about both its culinary and fuel potential. For growers eager to establish new markets for value added products, this low-input crop could afford a niche high-value opportunity. By considering your markets, your farm enterprises, and the values that different oilseed crops provide, you may find an ideal opportunity for diversifying your rotations.

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APPENDIX – Weather Data from OARDC Weather Station, Wooster Location

Date	Precip	MaxAirTem	MinAirTem	AvgAirTem	MaxAirTempTim	MinAirTempTim	MaxRel.Hum	MinRel.Hum	Avg.Rel.Hum	MaxWindSpeed
22-Apr-2013	0	65.9	29.3	49.3	6:15 PM	6:50 AM	90	37	61	7.2
23-Apr-2013	0	71.5	38.2	56.8	4:20 PM	6:35 AM	77	36	52	12.7
24-Apr-2013	0.59	59.9	35.1	48.2	2:35 AM	11:55 PM	96	59	86	14.8
25-Apr-2013	0.06	52	30.2	41.3	3:20 PM	6:40 AM	95	53	79	20.3
26-Apr-2013	0	58.8	28.1	44.2	5:45 PM	7:00 AM	97	37	69	6.8
27-Apr-2013	0	70.9	33.2	53.1	4:30 PM	6:10 AM	94	30	60	7.1
28-Apr-2013	0.41	58	46.3	53.9	5:35 PM	2:40 AM	95	55	86	6.6
29-Apr-2013	0.19	66.3	53.4	59.1	2:10 PM	11:45 PM	97	70	88	9.6
30-Apr-2013	0	75.8	45.4	61.9	6:25 PM	7:00 AM	99	51	77	7.1
1-May-2013	0	78.8	49.8	65.4	3:55 PM	5:10 AM	96	47	70	7.3
2-May-2013	0	78.2	51.9	65.4	4:50 PM	4:35 AM	72	40	56	7.9
3-May-2013	0	76.2	53.5	65	5:05 PM	5:35 AM	66	29	47	9
4-May-2013	0	70.8	50.7	60.7	5:15 PM	6:35 AM	70	31	51	9.9
5-May-2013	0	73.6	50.1	61.4	4:50 PM	6:30 AM	71	24	47	12.6
6-May-2013	0	73.2	50.4	61.7	3:30 PM	5:00 AM	87	33	58	8.7
7-May-2013	0	70.4	54.6	62.3	6:05 PM	12:05 AM	87	61	77	11.2
8-May-2013	0.17	72.4	55.3	61.4	3:50 PM	5:15 AM	98	52	81	12.7
9-May-2013	0	79.1	51.4	65.3	5:20 PM	5:50 AM	99	37	72	9.9
10-May-2013	0.65	73.4	58	63.3	1:45 PM	6:35 AM	97	71	88	16.1
11-May-2013	0.18	61.3	45.3	51	12:20 AM	11:55 PM	97	80	91	16.5
12-May-2013	0	50.3	34.9	43.5	2:55 PM	6:40 AM	93	49	69	18.3
13-May-2013	0	52.8	30.6	42.1	6:00 PM	6:30 AM	91	40	64	14.2
14-May-2013	0	70.2	32.2	51.6	6:10 PM	3:00 AM	89	43	64	9.7
15-May-2013	0	83.9	52.4	70.1	4:40 PM	1:25 AM	91	39	65	18.6
16-May-2013	0.08	79.6	54.3	67.5	4:30 PM	6:25 AM	97	34	63	9.1
17-May-2013	0	80.7	48.8	63.5	4:30 PM	6:30 AM	98	48	78	6.9
18-May-2013	0	83	51.2	67.6	4:50 PM	5:55 AM	86	44	63	6
19-May-2013	0	81.1	59.1	70.7	4:40 PM	6:10 AM	97	61	80	8.3
20-May-2013	0	81.4	61.1	71.5	6:25 PM	6:35 AM	99	70	87	9.6
21-May-2013	0	84.6	68.6	75.8	3:20 PM	5:05 AM	97	52	77	10
22-May-2013	0.01	82.5	64.4	73.9	5:10 PM	11:55 PM	88	55	70	13.7
23-May-2013	0.14	72.2	43	61.4	1:55 PM	11:40 PM	95	66	87	14.6
24-May-2013	0	49.5	34.2	43.2	6:45 PM	11:20 PM	95	61	77	12.8
25-May-2013	0	60.7	30.2	46.5	4:15 PM	5:55 AM	97	38	70	10.8
26-May-2013	0	65.5	31.9	50.9	3:50 PM	5:35 AM	97	32	62	10.4
27-May-2013	0.06	61.3	38.2	51.9	3:00 PM	3:55 AM	93	61	77	7.1
28-May-2013	0.23	83.4	54.1	68.6	5:50 PM	2:00 AM	97	55	78	13
29-May-2013	0.01	87.2	67.8	77.3	3:50 PM	11:35 PM	83	44	61	13.8
30-May-2013	0	88.8	61.7	76	4:30 PM	6:25 AM	96	43	69	8.4
31-May-2013	0.5	86.3	63	74	2:10 PM	4:45 AM	97	55	77	17.9
1-Jun-2013	0.02	83	65.2	74.4	5:30 PM	4:45 AM	97	62	80	12.5
2-Jun-2013	0.53	75.8	64.6	69.6	2:55 PM	11:55 PM	98	61	79	16.6
3-Jun-2013	0	66.1	43.7	58.2	4:10 PM	11:55 PM	90	48	72	10
4-Jun-2013	0	70.8	39	56.4	4:25 PM	6:05 AM	98	46	69	8.9
5-Jun-2013	0	78.9	45.9	63.6	6:35 PM	6:00 AM	94	40	65	8.6
6-Jun-2013	0.71	64.2	55	59.9	1:45 PM	10:50 PM	99	67	94	9.2
7-Jun-2013	0	62.2	54.8	57.6	3:30 PM	3:40 AM	99	86	94	8.7
8-Jun-2013	0	75.4	55.3	62.6	7:15 PM	6:15 AM	97	52	80	6.4
9-Jun-2013	0	80.8	55.5	69	5:20 PM	12:00 AM	96	61	78	7.6
10-Jun-2013	0.4	75.1	62.6	68.3	2:35 PM	11:55 PM	98	78	90	13.1
11-Jun-2013	0.04	79.6	61.7	70	5:25 PM	12:25 AM	97	63	84	12.6
12-Jun-2013	0.26	83.2	63.2	73.3	5:40 PM	4:50 AM	96	65	83	15.6
13-Jun-2013	0.4	72.9	61.4	66.7	5:10 PM	11:55 PM	96	59	82	14
14-Jun-2013	0	71.9	53.9	63.3	6:30 PM	11:55 PM	95	63	80	10.6
15-Jun-2013	0	78.8	48.1	63.6	4:20 PM	6:05 AM	99	46	77	8.3
16-Jun-2013	0.83	77.3	63.1	68.4	5:25 PM	2:15 AM	98	75	88	15.6
17-Jun-2013	0.16	83.4	63.6	70.2	3:15 PM	10:30 PM	99	48	85	12.7

18-Jul-2013	0	91	72.5	82	4:40 PM	5:55 AM	99	60	81	8.3
19-Jul-2013	0.06	89.2	74	79.5	1:25 PM	6:30 AM	94	65	83	14.3
20-Jul-2013	0.44	79.6	67.5	73.2	5:25 PM	8:20 AM	97	77	91	10.5
21-Jul-2013	0	83.4	68.6	74.7	3:45 PM	6:15 AM	99	63	86	9.1
22-Jul-2013	0.17	74.1	65.2	68.9	2:55 PM	9:55 PM	99	87	95	7.3
23-Jul-2013	0.06	84.6	62.9	72.6	5:40 PM	3:45 AM	100	64	88	13.2
24-Jul-2013	0.02	70.6	54.5	65.7	4:10 PM	11:55 PM	91	62	75	11.4
25-Jul-2013	0	75.9	49.2	63	5:50 PM	6:35 AM	98	46	74	8.4
26-Jul-2013	0	80.1	50.9	66.2	6:00 PM	6:35 AM	99	49	77	8.3
27-Jul-2013	0.22	72.3	61.5	66	7:30 PM	2:55 AM	96	83	92	7.5
28-Jul-2013	0.01	70.1	52.9	62.7	5:15 PM	6:40 AM	98	56	78	12.4
29-Jul-2013	0	70.3	53.7	63.2	3:05 PM	4:10 AM	97	57	77	11.3
30-Jul-2013	0	79.5	50.5	64.7	5:20 PM	6:15 AM	99	53	81	7.8
31-Jul-2013	0.08	76.5	58.5	66.6	2:40 PM	3:35 AM	99	65	90	7.7
1-Aug-2013	0.06	78.9	62	70.2	3:20 PM	11:30 PM	99	57	82	11.2
2-Aug-2013	0.12	73.4	56.3	66	6:05 PM	6:45 AM	96	62	83	9.3
3-Aug-2013	0.24	78	59.2	69.5	1:50 PM	11:55 PM	98	47	79	9.9
4-Aug-2013	0	72	55.4	64.2	2:55 PM	11:45 PM	99	58	79	10.7
5-Aug-2013	0	75.1	50.1	62.8	2:10 PM	6:55 AM	99	50	80	6.9
6-Aug-2013	0	81.6	56	69.5	6:05 PM	2:40 AM	98	51	75	7.4
7-Aug-2013	0.37	78.9	60.9	69.9	1:45 PM	4:05 AM	98	81	91	12
8-Aug-2013	0.41	82.5	71.2	75.4	1:40 PM	11:55 PM	98	77	92	7.6
9-Aug-2013	0.01	79.2	60.3	70.4	4:40 PM	11:20 PM	96	54	82	8.3
10-Aug-2013	0	81.3	58.9	69.6	4:10 PM	5:55 AM	99	63	82	9
11-Aug-2013	0.01	81.3	60.2	70.1	3:45 PM	5:45 AM	97	62	77	8.2
12-Aug-2013	0	83.6	59.3	71.5	4:30 PM	6:15 AM	100	58	82	8.6
13-Aug-2013	0	74.7	52.6	67.3	2:10 PM	11:35 PM	98	63	83	12.3
14-Aug-2013	0	68.7	49.9	58.4	5:45 PM	5:00 AM	97	55	82	10.2
15-Aug-2013	0	73.6	43.9	58.8	5:35 PM	6:35 AM	99	48	79	6
16-Aug-2013	0.01	75.4	51.1	63.3	4:25 PM	3:55 AM	99	46	75	8.7
17-Aug-2013	0	79.7	53.1	65.8	4:45 PM	6:20 AM	99	49	78	8.5
18-Aug-2013	0	77.1	54.5	64.8	3:55 PM	3:20 AM	99	71	89	5.1
19-Aug-2013	0	80.2	60.8	69.3	5:45 PM	1:25 AM	100	54	82	7.5
20-Aug-2013	0	85.3	55.7	69.9	4:05 PM	5:45 AM	100	50	81	7.8
21-Aug-2013	0	84.9	57.7	71.4	3:20 PM	6:40 AM	100	56	82	6.3
22-Aug-2013	0.09	83	64.6	72.6	4:20 PM	6:45 AM	96	74	89	10.3
23-Aug-2013	0.44	81.7	56.1	71.4	2:15 PM	11:55 PM	99	48	79	10
24-Aug-2013	0	85	51	66.2	7:00 PM	5:45 AM	99	37	72	7.8
25-Aug-2013	0	83.9	52	68.2	5:10 PM	6:45 AM	99	48	77	8.3
26-Aug-2013	0	85	59.8	73.8	1:50 PM	6:15 AM	94	54	75	10.2
27-Aug-2013	0.13	81.6	71.5	74.9	6:10 PM	7:20 AM	96	80	89	9.2
28-Aug-2013	0	82.4	69.6	76.5	12:40 PM	11:45 PM	97	77	88	13.1
29-Aug-2013	0	86.1	66.8	75	5:10 PM	11:55 PM	99	58	85	6.7
30-Aug-2013	0	87.3	61.7	74.2	4:05 PM	7:20 AM	100	60	85	9.3
31-Aug-2013	0.06	85	69	76	4:35 PM	7:10 AM	97	70	84	12.4
1-Sep-2013	0	84.3	69.1	75.5	3:30 PM	2:35 AM	100	69	86	7.6
2-Sep-2013	0.07	81.6	62.1	71.5	2:10 PM	11:55 PM	99	68	89	10.7
3-Sep-2013	0	64.5	53.2	60.2	6:30 PM	10:55 PM	99	76	90	9.6
4-Sep-2013	0.01	78.5	47.6	63.2	4:45 PM	5:40 AM	100	51	81	11
5-Sep-2013	0	74.3	52.2	64.9	1:50 PM	11:05 PM	98	41	75	10.5
6-Sep-2013	0	75.9	42.5	58.7	5:30 PM	7:20 AM	99	32	73	6.3
7-Sep-2013	0	81.6	46.8	64.9	5:25 PM	7:00 AM	99	52	79	9
8-Sep-2013	0	76.2	58.6	68.9	4:10 PM	11:35 PM	98	68	85	10.9

9-Sep-2013	0.04	85.4	52	68.2	2:40 PM	3:05 AM	98	65	86	9.2
10-Sep-2013	0	94.1	71.9	81.8	4:00 PM	7:10 AM	91	56	78	10
11-Sep-2013	0	90.7	72.6	80.1	2:05 PM	7:05 AM	96	60	81	8.8
12-Sep-2013	0.85	74.8	60.2	69	12:00 AM	11:55 PM	99	74	94	10.4
13-Sep-2013	0.24	61.1	51.2	56.6	1:40 PM	11:55 PM	99	71	87	12.1
14-Sep-2013	0	69.1	41	54.2	6:00 PM	7:15 AM	98	48	76	8
15-Sep-2013	0	68.7	41.5	55.7	5:50 PM	6:50 AM	99	59	84	6.7
16-Sep-2013	0.03	69.6	48.2	59.7	2:20 PM	11:35 PM	99	59	85	13.3
17-Sep-2013	0	71	42.4	54.7	5:35 PM	4:45 AM	99	52	84	7.4
18-Sep-2013	0	76.1	46.1	60.8	4:35 PM	6:50 AM	98	63	84	6.1
19-Sep-2013	0	73.5	62.5	67.4	12:00 PM	12:00 AM	96	81	91	8.7
20-Sep-2013	0.14	83.7	66.5	73.2	3:05 PM	6:20 AM	98	69	88	13.3
21-Sep-2013	1.5	69.9	53.8	64.5	4:25 PM	11:25 PM	99	64	90	10.6
22-Sep-2013	0.01	59.5	48.4	53.4	1:00 PM	8:25 PM	98	63	83	9.6
23-Sep-2013	0	59	42	52.7	4:00 PM	11:40 PM	97	65	84	6.7
24-Sep-2013	0	68.6	37.9	51.6	5:30 PM	6:15 AM	99	52	82	7.7
25-Sep-2013	0	72.3	41.4	57.4	4:45 PM	6:20 AM	99	51	80	9.1
26-Sep-2013	0	75.6	44	59.2	3:45 PM	7:15 AM	99	39	76	7.7
27-Sep-2013	0.01	72.7	43.2	58.1	3:15 PM	7:45 AM	99	48	79	10
28-Sep-2013	0	77.2	47.2	61.5	4:25 PM	7:50 AM	99	50	80	5.6
29-Sep-2013	0	73.2	53.8	63.3	2:40 PM	4:30 AM	95	68	84	8.5
30-Sep-2013	0	68.8	57.1	62.8	4:55 PM	11:40 PM	99	82	91	6.4
1-Oct-2013	0.02	78.3	54.8	65.4	3:45 PM	3:45 AM	100	58	85	10.8
2-Oct-2013	0	81.3	59.6	68.3	4:00 PM	3:40 AM	98	61	85	8.1
3-Oct-2013	0.27	80	61.7	68.9	3:35 PM	1:35 AM	99	66	90	13.9
4-Oct-2013	0.03	78.4	64	70	1:05 PM	7:45 AM	99	72	91	10.5
5-Oct-2013	0.77	75.1	62.1	68.7	4:25 PM	4:30 AM	100	87	96	9.9
6-Oct-2013	0.57	80.8	56.2	70.3	4:40 PM	11:55 PM	99	66	90	16.1
7-Oct-2013	0.66	59.5	46	53	4:25 PM	8:05 AM	98	61	84	12.9
8-Oct-2013	0	67.2	40.7	53.4	4:20 PM	7:30 AM	99	49	80	7.7
9-Oct-2013	0	69.1	40.7	53.7	4:20 PM	5:15 AM	99	42	77	7.4
10-Oct-2013	0	70.8	39.8	53.4	4:40 PM	6:25 AM	99	38	75	7
12-Oct-2013	0	76.7	48.8	64.5	5:35 PM	7:50 AM	98	65	82	6.3
13-Oct-2013	0	68.8	58.3	62.6	11:05 AM	11:55 PM	99	75	89	7.2
14-Oct-2013	0	67.6	49.1	57.4	5:10 PM	11:45 PM	96	59	79	10.7
15-Oct-2013	0	65.1	41.5	55.2	5:50 PM	4:55 AM	99	84	93	5.6
16-Oct-2013	0.14	66	49.1	61.6	3:25 PM	11:55 PM	97	81	93	11.9
17-Oct-2013	0.18	57.1	39.8	48.7	12:45 PM	8:05 AM	99	72	91	13
18-Oct-2013	0	62.5	41.2	51.3	4:40 PM	7:50 AM	97	56	79	12.6
19-Oct-2013	0.22	50.1	40.2	45.4	12:00 AM	10:35 PM	96	79	91	11.5
20-Oct-2013	0	60.1	38	47.7	5:25 PM	6:20 AM	95	54	77	15.3
21-Oct-2013	0.06	65.1	43.9	53.7	4:20 PM	5:45 AM	94	45	68	12.5
22-Oct-2013	0.1	50.3	33.9	43	12:25 AM	8:10 AM	95	49	72	11.5
23-Oct-2013	0.09	44.4	35.7	38.9	4:05 PM	5:45 AM	97	71	89	15.2
24-Oct-2013	0	44.1	31.6	37.2	2:20 PM	8:05 AM	94	63	83	14
25-Oct-2013	0	47.4	29.8	37.3	3:20 PM	8:05 AM	96	56	81	11.8
26-Oct-2013	0.01	46.5	33	40	3:10 PM	4:45 AM	94	54	70	13.8
27-Oct-2013	0	53.7	29.1	40.6	4:40 PM	7:25 AM	97	51	80	10.2
28-Oct-2013	0	58.8	27.2	41.9	4:20 PM	8:00 AM	98	42	79	8
29-Oct-2013	0	57.1	30.2	43.3	3:45 PM	7:10 AM	99	58	85	5.9
30-Oct-2013	0.01	64.9	38.8	52.7	2:05 PM	6:35 AM	96	60	83	5.8