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Comparison of Spring, Summer, and Fall-planted Cover Crops for Use in Organic Potato Production

Rob Wilson, Center Director/Farm Advisor[1]; Daniel Geisseler, UC Davis CE Nutrient Management Specialist; Darrin Culp, IREC Superintendent of Agriculture; Kevin Nicholson & Skyler Peterson, IREC Staff Research Associates. University of California Intermountain Research & Extension Center[1], 2816 Havlina Rd. Tulelake, CA. 96134 Phone: 530/667-5117 Fax: 530/667-5265 Email: rgwilson@ucdavis.edu

Introduction: The Klamath Basin has experienced a large increase in organic agriculture in recent years. Last year there were over 10,000 acres of alfalfa, 10,000 acres of wheat and barley, and 2,000 acres of potatoes produced organically on the California side of the Klamath Basin. Organic production offers growers a niche market and price premiums. Conversely, organic production has limited pest management and fertilization options compared to conventional production. Organic producers are pursuing multiple approaches to increase soil fertility and manage pests, but research and data verifying the effectiveness of these practices is limited at the local level. Organic practices of most interest to potato growers include the use of certified amendments such as composted manures, application of organically approved pesticides (copper, Serenade, Actinovate, etc.) and cover crops/green manure.

A two-year study was established in 2016 to evaluate cover crops managed as a green manure, amendments, and combinations of cover crops and amendments for organic potato production. Cover crops were grown in 2016 and potatoes will be grown in 2017. Cover crop trials included a spring planted dryland trial with 9 treatments, a spring planted irrigated trial with 18 treatments, a mid-summer planted irrigated trial with 18 treatments, and a fall planted irrigated trial with 9 treatments. A spring dryland trial was added to gauge if cover crops can be grown effectively without irrigation and to evaluate the effects of irrigation on soil fertility, weeds, and diseases in potatoes grown the following year. Mid-summer planted cover crop treatments included cool-season and warm-season cover crops grown alone, grown in mixes, and grown in combination with fall-applied amendments. Fall planted cover crops were grown at the request of several growers wanting an option to use cover crops after harvesting spring wheat/barley for grain. All trials include conventional fertilizer controls to compare cover crop and amendment results to conventional fertilizer results.

This progress report summarizes results for spring-planted and mid-summer planted cover crops grown in 2016. Production data for fall-planted cover crops, and data on the effects of cover crops and amendments will be available in 2017 when potato are grown on the site.

Methods: Five trials are being conducted at IREC in a 4.5 acre field with low residual soil nitrate. The field was planted to wheat in 2014 and sudangrass in 2015. The sudangrass did not receive fertilizer in 2015 to reduce soil nitrogen levels. Herbicides were applied in 2014 and 2015 to control weeds; No pesticides were applied in 2016. On April 1 2016, soil properties (0-10 inch soil depth) in the trials were: pH=6.4-6.8; EC=0.33-0.43mmho/cm; OM%=5.7-5.8; Olsen phosphorus= 51-62 ppm; potassium= 170-226 ppm; sulfate sulfur= 22-23 ppm; nitrate nitrogen= 7.5-11.2 ppm; ammonium nitrogen= 2.7-4.2 ppm. Treatments were arranged in a randomized complete block with four replications. Plot size is 12 ft by 40 ft.

Planting date, harvest dates, and applied water for the cover crop trials are shown in Table 1. Cover crop seeding rates are shown in Table 2. Cover crops were drill seeded at ½ - ¾ inch depth using a research cone planter with 6-inch row spacing. This depth worked well for all cover crops except arugula. The spring seeding of arugula was too deep for uniform emergence and spring arugula plots were reseeded at ¼ inch. Arugula was seeded in the fall trial at ¼ inch using the cone planter. Cover crops were grown until plants reached 50% to 100% flowering. They were then chopped with a flail mower and disked into the soil (green manure). Cover crop biomass yield was estimated in each plot by harvesting a 5ft by 10ft quadrat shortly before incorporation. Sub-samples were pulled from harvested biomass to estimate total nitrogen content and moisture content. Other data on cover crops included % stand, visual early- and mid-season vigor, visual weed suppression, and plant height. Soil samples were collected from select cover crop treatments at the time of planting and in fall 2016 to estimate plant available nitrogen at 0-10 inches and 10-20 inches.

Potatoes will be planted in May 2017 and harvested in early October 2017. Data collected in 2017 will assess treatment effects on potato yield, potato quality, soil nutrients, and potato petiole nitrate. Differences in weed, insect, and disease pressure will also be evaluated.

Table 1. Planting and Harvest Dates and Applied Water for Spring Dryland (SD), Spring Irrigated (SI), and Mid-summer irrigated (MSI) trials.

	Spring Dryland (SD)	Spring irrigated (SI)	Mid-summer irrigated (MSI)[1]
Planting Date:	4/8/16	4/20/16	7/27/16
Total Applied Water (precipitation + irrigation)	4.38 inches	11.74 inches	6.2 inches
Harvest Date:	6/21/16	6/30/16 & 7-6-16	10/11/16
Days to harvest:	74	71 [1] or 77	76

[1] Vetch, mustard, radish , arugula and all mixes were harvested 71 days after planting. Field pea and wheat were harvested 77 days after planting

Table 2. Cover Crop Seeding Rates

Cover Crop	Seeding Rate
Grasses	
Twin spring wheat	70 lbs/a
SX 17 sorghum sudangrass	30 lbs/a
Trical 141 spring triticale	90 lbs/a
Legumes	
Cowpea	40 lbs/a
Flex spring field pea	10 seed/ft^2
Lana woollypod vetch	60 lbs/a
Nutrigreen winter field pea	10 seed/ft^2
Mustards	
Caliente 199 mustard	10 lbs/a
Nemat arugula	6 lbs/a
Radish	
Defender oilseed radish	15 lbs/a

Cover Crop	Seeding Rate
50/50 Mixes	
Arugula & spring field pea	
Nemat arugula	3 lbs/a
Flex spring field pea	5 seed/ft^2
Mustard & spring field pea	
Caliente 199 mustard	5 lbs/a
Flex spring field pea	5 seed/ft^2
Radish & spring field pea	
Defender oilseed radish	7.5 lbs/a
Flex spring field pea	5 seed/ft^2
Mustard & woolypod vetch	
Caliente 199 mustard	5 lbs/a
Lana woollypod vetch	30 lbs/a

2016 Cover Crop and Nitrogen Contribution Results: Cover crop stand, early and late season vigor, and weed suppression results are presented in Table 3. Stand for all grass species was over 85% in all trials. Stand for legumes was at or above 79% in all trials except for cowpeas seeded in mid-summer which averaged 73%. Stand for mustards and radish was above 80% in all trials except for arugula. Arugula stands were less than 50% because the initial seeding depth was too deep. Arugula in spring trials reached the rosette stage by the time the initial seeding reached the flowering stage.

Spring wheat, woollypod vetch, and spring field pea had high early- and late- season vigor and weed suppression in the spring dryland trial. Spring wheat, woollypod vetch, and oilseed radish had the highest vigor in the irrigated trial. Spring field pea, mustard, and a 50/50 mix of mustard and spring field pea had slightly lower vigor in some cases compared to the top-performing cover crop in the spring irrigated trial, but their vigor and competition with weeds was sufficient to provide similar weed suppression compared to the most vigorous cover crops. Arugula had lower vigor and weed suppression compared to the other spring cover crops likely due to the stand problems associated with seeding it too deep.

50/50 mixes of mustards and legumes and oilseed radish had the highest early season vigor in the mid-summer trial. The 50/50 mixes, spring field pea, and woollypod vetch had the highest late season vigor. Oilseed radish and mustards seeded alone had low late season vigor due to nitrogen deficiency as the mid-summer trial had very little nitrogen available at planting (results described below). Cowpeas and sorghum-sudangrass died at the first-killing frost in early

September and failed to produce a viable crop in the mid-summer trial. Treatments with spring field peas, woollypod vetch, Caliente 199 mustard, oilseed radish, and 50/50 mixes had the highest weed suppression in the mid-summer trial. Flex spring field pea had higher vigor and weed suppression compared to Nutrigreen winter field pea in the mid-summer trial. Triticale had low late season vigor and weed suppression due to low soil nitrogen and disease problems.

Cover crop height, biomass, nitrogen content, and incorporated nitrogen in green manure results are presented in Table 4. Spring wheat, spring field pea, woollypod vetch, and the 50/50 mix of arugula and spring field pea had the highest biomass in the spring dryland trial. Spring wheat, spring field peas, and oilseed radish had the highest biomass in the spring-irrigated trial. Spring field peas, woollypod vetch, and the 50/50 mixes with mustard and field pea or vetch had the highest biomass in the mid-summer trial. Flex spring field pea contributed the most total nitrogen as a green manure in both the spring dryland and spring irrigated trials at 243 lb N/A and 306 lb N/A respectively. Woollypod vetch contributed the most total nitrogen as green manure in the mid-summer trial at 222 lb N/A.

Soil in fallow plots in the spring and mid-summer trials was sampled at 0-10 inches immediately before planting to estimate soil nitrogen. In the spring trials nitrate nitrogen averaged 17.03 ppm and ammonium averaged 0.44 ppm at planting. In the mid-summer trial nitrate nitrogen averaged 4.4 ppm. The difference in mineralized nitrogen at planting between spring and mid-summer is the primary reason mustards and grasses were nitrogen deficient in the mid-summer trial. Many producers have expressed interest in growing a spring grass hay crop and mid-summer cover crop, but this study clearly shows adequate mineralized soil nitrogen is needed in midsummer for non-legume cover crops to flourish.

In October 2016, soil in select cover crop treatments in spring and mid-summer trials were sampled for mineralized nitrogen at 0-10 inch and 10-20 inch depths. Results are presented in Table 5 and calculated lbs of mineralized nitrogen per acre are presented in Table 6. Similar to the trend at planting, the mid-summer trial had less than half the amount of mineralized nitrogen compared to spring trials in fall 2016. The spring fallow treatments had 286 and 290 lbs N/A available in the top 20 inches, and mid-summer fallow treatment had 125 lbs N/A. When looking woollypod vetch, the spring irrigated trial had 399 lbs N/A available in the top 20 inches while the mid-summer trial had 45 lbs N/A. The large differences in spring and mid-summer soil nitrate in fall 2016 incite a lot of questions going into 2017. The spring trial clearly has more plant available nitrogen going into 2017, but whether this nitrogen will be leached or lost over the winter is yet to be determined. Stay tuned to results in 2017.

Figures 1, 2, and 3 include pictures of different cover crop treatments at the time of incorporation.

Table 3. Cover Crop Stand, Vigor, and Weed Suppression.

Cover crop	Stand[1]			Early Season Vigor[2]			Late Season Vigor			Weed Suppression[3]		
	SD	SI	MSI	SD	SI	MSI	SD	SI	MSI	SD	SI	MSI
	%			1-10; 10=most vigorous						1-10; 10=best		
Grasses												
Twin" spring wheat	86	90	-[4]	8.9a[5]	8.4a	-	8.4ab	7.9a	-	8.0ab	7.0a	-
SX17 sorghum sudangrass	-	-	89	-	-	7.6bc	-	-	0.0g	-	-	5.0c
Trical 141 spring triticale	-	-	90	-	-	7.0cd	-	-	5.8ef	-	-	4.8c
Legumes												
Cowpea	-	-	73	-	-	5.0e	-	-	0.0g	-	-	2.8d
Flex spring field pea	80	81	83	8.4a	7.0b	7.4bc	8.9ab	7.1bc	8.6a	8.0ab	7.0a	8.5a
Lana woollypod vetch	79	89	89	8.5a	8.0a	7.0cd	9.0ab	8.0ab	7.5bc	8.5ab	7.3a	8.0ab
Nutrigreen winter field pea	-	-	79	-	-	6.3d	-	-	7.0cd	-	-	7.0b
Mustards												
Caliente 199 mustard	80	89	94	7.0b	6.6b	7.1bcd	8.1bc	7.1c	6.5de	7.5b	7.0a	8.8a
Nemat arugula	49	31	-	5.8c	4.8c	-	6.3d	5.8d	-	6.5c	5.0c	-
Radish												
Defender oilseed radish	-	89	93	-	8.0a	8.1ab	-	7.9abc	5.0f	-	7.3a	8.5a
50/50 Mixes												
Arugula & spring field pea	40 & 30	38 & 21	-	6.9b	6.8b	-	7.6c	6.0d	-	7.8ab	6.0b	-
Mustard & spring field pea	-	35 & 45	70 & 50	-	7.0b	7.9abc	-	7.3abc	8.3ab	-	6.9a	9.0a
Radish & spring field pea	-	-	73 & 54	-	-	8.6a	-	-	7.8bc	-	-	8.8a
Mustard & woolypod vetch	-	-	73 & 61	-	-	7.6abc	-	-	7.8bc	-	-	9.0a

[1] % Stand was a visual estimation of plant density in drill rows in the plot.

[2] Vigor was a visual estimation of plant growth in the plot. Taken roughly 1 month after planting for early season, and 2 weeks prior to harvest for late season.

[3] Weed suppression was a visual estimation of weed denisty and growth in the plot. 10= best suppression and lowest weed density.

[4] - = species were not included in the trial

[5] Means were compared using Tukey's HSD test. Means with the same letter are not statistically different. Means can be compared within columns.

Table 4. Cover Crop Height, Biomass, Nitrogen content, and Incorporated Nitrogen in Green Manure at the Time of Incorporation.

Cover crop	Plant height			Crop biomass			Nitrogen content in green manure			Incorporated nitrogen in green manure		
	SD	SI	MSI	SD	SI	MSI	SD	SI	MSI	SD	SI	MSI
	inches			ton/acre[1]			% total N			lbs N/acre[2]		
Grasses												
Twin spring wheat	31	34	-[3]	2.6a[4]	2.9ab	-	1.7c	1.6e	-	88c	93d	-
SX17 sorghum sudangrass	-	-	17	-	-	0.6de	-	-	2.2ef	-	-	24d
Trical 141 spring triticale	-	-	13	-	-	0.4de	-	-	1.7fg	-	-	14d
Legumes												
Cowpea	-	-	4	-	-	0.1e	-	-	3.4bc	-	-	4d
Flex spring field pea	40	48	28	2.6a	3.4a	2.2ab	4.6a	4.5ab	4.1ab	243a	306a	176b
Lana woollypod vetch	34	43	26	2.1ab	1.9cd	2.4a	4.7a	5.3a	4.6a	196b	205b	222a
Nutrigreen winter field pea	-	-	21	-	-	1.6c	-	-	4.5a	-	-	148bc
Mustards												
Caliente 199 mustard	48	57	27	2.0b	2.3bcd	0.8de	2.3bc	2.1de	1.2g	93c	95d	19d
Nemat arugula	32	40	-	1.8b	1.6d	-	2.9b	3.2cd	-	108c	98d	-
Radish												
Defender oilseed radish	-	55	5	-	2.7abc	0.4de	-	2.1e	1.6fg	-	110cd	12d
50/50 Mixes												
Arugula & spring field pea	38*	39 & 42	N/A	2.6a	1.8d	-	4.4a	5.0ab	-	205ab	178bc	-
Mustard & spring field pea	-	57 & 45	38 & 29	-	2.2bcd	2.0abc	-	4.2bc	2.6de	-	187b	99c
Radish & spring field pea	-	-	10 & 26	-	-	1.7bc	-	-	3.2cd	-	-	112c
Mustard & woolypod vetch	-	-	37 & 28	-	-	2.3ab	-	-	3.3cd	-	-	150bc

[1] Biomass yield was determined by harvesting a 5ft by 10ft quadrat in each plot.

[2] Added lbs N/A was calculated by multiplying the above ground biomass yield by the % nitrogen of the biomass. The calculation does not take into account the small amount of nitrogen in below ground cover crop roots.

[3] - = species were not included in the trial

[4] Means were compared using Tukey's HSD test. Means with the same letter are not statistically different. Means can be compared within columns.

Table 5. Mineralized Nitrogen in the Soil on October 10th for Select Cover Crops

Cover crop	0 to 10 inch soil depth									10 to 20 inch soil depth								
	SD	SI	MSI	SD	SI	MSI	SD	SI	MSI	SD	SI	MSI	SD	SI	MSI	SD	SI	MSI
	NH_4-N			NO_3-N			Total mineral N[1]			NH_4-N			NO_3-N			Total mineral N[1]		
	ppm			ppm			ppm			ppm			ppm			ppm		
Trical 141 spring triticale	-[2]	-	.33b[3]	-		3.56b	-	-	3.89b	-	-	1.4	-	-	3.6b	-	-	4.9b
Lana woollypod vetch	-	0.4	1.07a	-	64.6a	4.49b	-	65a	5.56b	-	1.1	1.5	-	30.1a	3.7b	-	31.2a	5.2b
Caliente 199 mustard	-	0.2	.11b	-	27.6c	3.29b	-	27.8c	3.4b	-	0.5	1.4	-	15.2c	2.9b	-	15.8c	4.2b
50/50 mix mustard & spring field pea	-	0.2	.34b	-	44.6b	2.55b	-	44.8b	2.89b	-	0.5	0.8	-	22.8b	2.8b	-	23.3b	3.6b
Fallow	0.21	0.1	.63ab	34.38	39.7b	14.36a	34.59	39.9b	14.99a	0.8	0.6	1.3	33.5	29.3a	13.9a	34.3	29.8a	15.2a

[1] Total mineral N = ammonium + nitrate.

[2] - = Species was not included in the trial.

[3] Means comparsions used Tukey's HSD test. Means with the same letter are not significantly different. Means can be compared within columns.

Table 6. Calculated Pounds of Mineralized Nitrogen Per Acre on October 10th for Select Cover Crops.

Cover crop	Mineralized nitrogen 0 to 20 inch soil depth		
	SD	SI	MSI
	lbs N/acre		
Trical 141 spring triticale	-[1]	-	37b[2]
Lana woollypod vetch	-	399a	45b
Caliente 199 mustard	-	181c	32b
50/50 mix mustard & spring field pea	-	283b	27b
Fallow	286	290b	125a

[1] - = Species was not included in the trial.

[2] Means comparsions used Tukey's HSD test. Means with the same letter are not significantly different. Means can be compared within columns.

Figure 1: 2016 Spring Dryland Cover Crops at Time of Incorporation

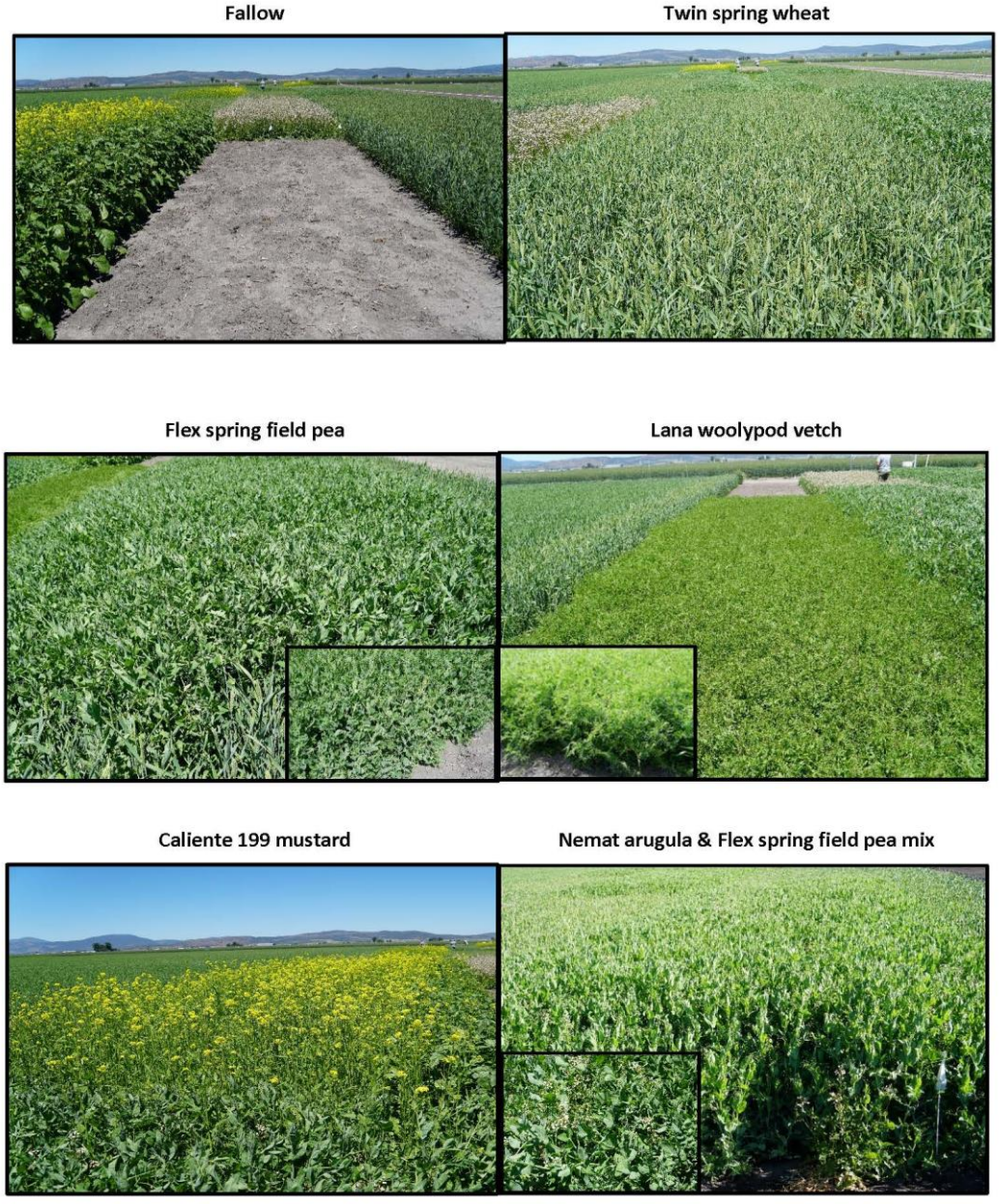


Figure 2: 2016 Spring Irrigated Cover Crops at Time of Incorporation

Fallow

Twin Wheat

Flex Field Pea

Lana Woolypod Vetch

Caliente Mustard 199

Nemat Arugula

Figure 2 (continued): 2016 Spring Irrigated Cover Crops at Time of Incorporation

Caliente Mustard & Flex Pea Mix

Defender Oilseed Radish

Nemat Arugula & Flex Pea Mix

Flea Beetle Damage

Chopping a plot

Incorporating the plots

Figure 3: 2016 Mid Summer Irrigated Cover Crops at Time of Incorporation

Fallow

Trical 141 spring triticale

SX17 sorghum sudangrass

Lana woolypod vetch

Caliente 199 mustard

Flex spring field pea

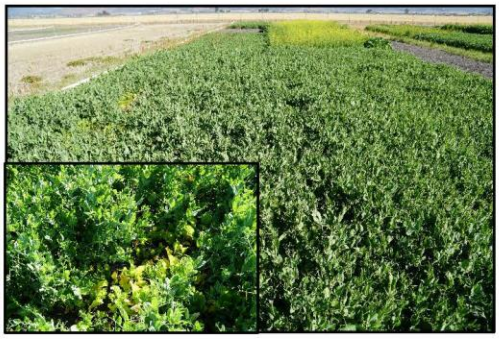
Figure 3 (continued): 2016 Mid Summer Irrigated Cover Crops at Time of Incorporation

Nutrigreen winter field pea

Defender oilseed radish

Mustard and spring pea mix

Radish and spring pea mix



Mustard and vetch mix

Cowpea