Northwest Columbia Plateau PM_{10} Project

Objective #5: ***Identify Alternative Cropping Systems that Reduce Wind Erosion (Wind Erosion and PM_{10} Control Methods)***

Title: ***Developing Sustainable and Profitable Cropping Systems for North-Central, Oregon***

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Abstract of Research Findings
The conventional winter wheat-summer fallow (WW-SF), the predominant cropping system in the Inland Pacific Northwest (PNW), has been shown to deplete soil organic carbon and increase soil erosion. This research evaluates alternative direct seeded cropping systems (DS) designed to reduce these negative impacts on the soil and environment. In this long-term experiment, initiated in 2003-04 crop year, WW-SF is compared to annual winter wheat (WW-WW), annual spring wheat (SW-SW), annual spring barley (SB-SB), winter wheat-chemical fallow (WW-CF), winter wheat-winter pea rotation (WW-WP), and winter wheat-spring barley-chemical fallow rotation (WW-SB-CF), all under direct seeding. Data on grain yield, diseases, weeds, microbial biomass, soil moisture, and crop residue cover were collected in the 2009-10 crop year.

2009-10 Crop-Year. Results show that under continuous annual cropping, spring barley, with the lowest root-lesion nematode (*Pratylenchus* spp) incidences, produced significantly higher yield (42 bu/a) than winter wheat (14.2 bu/a) that had the highest nematode and weed (downy brome) infestations. Annual spring wheat yield (39.8 bu/a) was not significantly different from annual spring barley yield. Yield of spring barley following winter wheat after fallow was not significantly different from yield of annual spring barley. Direct seeded winter wheat after chemical fallow in the three year rotation involving spring barley produced the highest yield (74.4 bu/a) although this yield was not significantly higher than yield from winter wheat after chemical fallow, and conventional fallow. Yield of winter wheat after winter pea was significantly different from yield obtained from winter wheat after fallow treatments. Spring peas (plot reseeded with spring pea after winter pea died) after winter wheat produced 25.8 bu/a. The greatest populations of root-lesion nematode (*Pratylenchus* spp) occurred in annual winter wheat, annual spring wheat, and in the winter wheat-winter pea rotation. Populations were lowest in annual spring barley and in the chemical fallow and winter wheat phases of the 3-year rotation of winter wheat-spring barley-chemical fallow rotation.

Weeds: In the 7th year of this LTE, downy brome infestations continue to be a major weed concern particularly in annual winter wheat, and 2-year crop rotations with alternate years of winter wheat.

Microbial Communities: The managed soils tended to have less microbial biomass and different fungal, and to a lesser degree, bacterial communities when compared to the control (unmanaged grassland) soil. After four years of management, no trends in the composition of bacterial or fungal communities were found, even when just the upper portion of the soil was examined.

Crop Residues: Residue cover was highest under annual cropping systems and lowest following peas and fallow under WW-SF system.

Summary (2003-04 to 2009-10). *Grain Yield*: Based on the 6-yr average (2004-05 to 2009-10 crop-years) the 3-yr rotation produced the highest yield of winter wheat and this was significantly so compared to other rotations except the conventional fallow. The high wheat yield obtained from the 3-yr rotation was partly attributed to low levels of root-lesion nematode incidences and low weed infestation. Conventional fallow and chemical fallow yields were not significantly different from each other. For annual cropping, spring barley has consistently produced the highest yields. These results suggested that direct seeded systems, that tend to increase soil organic matter and maintain surface residues that prevent soil erosion, can replace the conventional tillage wheat fallow system that is prevalent in these low rainfall areas of north-central Oregon and south-central Washington.

Diseases: Lowest population densities occurred in the annual spring barley and in certain phases of winter wheat-chemical fallow rotation and the 3-year rotation. Population densities were particularly high in the annual winter wheat, annual spring wheat and certain phases of the winter wheat-conventional fallow and winter wheat-winter pea rotations.

Weeds: Downy brome infestations have been the major weed concern particularly in annual winter wheat, and 2-year crop rotations with alternate years of winter wheat.

Objective

The main focus of this experiment is to develop profitable and sustainable direct seeding cropping systems for north central Oregon that reduce wind and water erosion.

Methods and Materials

The experiment that compares the following crop rotations (1-8 below) was initiated in 2003-04 crop year at the OSU Columbia Basin Agricultural Research Center near Moro, OR.

1. Winter wheat-conventional fallow: Conventional tillage
2. Winter wheat-chemical fallow: Direct seeding
3. Continuous winter wheat: Direct seeding
4. Continuous spring wheat: Direct seeding
5. Continuous spring barley: Direct seeding
6. Winter wheat-spring barley-chemical fallow: Direct seeding
7. Winter wheat-winter pea: Direct seeding
8. Flex crop (a, b)

Experimental plots measures 48 x 350 ft and the experimental design is a RCB arrangement, with 3 replications. Soil at the site is a Walla Walla silt loam (coarse, silty, mixed, mesic Typic Haploxeroll).

During the 2009-10 crop-year, winter wheat, variety ORCF102, for rotation 1 was seeded at 22 seeds ft^{-2} on October 13, 2009 using the HZ drill (on 16-inch centers) at a depth of 2 to 3.5 inches to reach moisture. The rest of the direct seed treatments (below) were seeded using the Fabro® drill (on 12-inch centers). ORCF102 for rotation 2 and 6 was direct seeded on October 15, 2009 and for rotation 3 on October 30, 2009 and 7 on November 9, 2009 at a depth of 1.5 inches. Winter pea (Austrian Pea) for rotation 7 died and the plot reseeded with spring pea (Universal) at 7 seeds ft^2 on March, 25, 2010 at 1 to 1.75 inch depth. Spring barley (variety Camas) for rotation 5 and 6 was direct-seeded at 22 seeds ft^{-2} in March 25, 2010. Spring wheat (variety Louise) for rotation 4 was seeded at 22 seeds ft^{-2} in March 25, 2010. Spring pea (Universal) for rotation 8 was direct-seeded at the rate of 7 peas ft^{-2} (120 lbs $acre^{-1}$) in March 25, 2010. Granular inoculant was applied with the seed at the rate of 57 grams per 1000 ft. Each phase of each rotation is present each year. Different fertilizer rates were applied to plots of different rotations to bring up the N levels to 80 lbs N $acre^{-1}$ for winter wheat. Nitrogen rates ranged from 10 to 50 lbs $acre^{-1}$.

Data on plant stand, phenology, weeds, diseases and crop residue cover were collected. At maturity, bundle samples were taken from four 3 x3 ft quadrats in each plot. The wheat was cut right at the crown and total bundle weight determined. Wheat heads from bundles were cut off, counted, and threshed and the grain weighed. Harvest index was determined by dividing bundle grain weight by total bundle weight. All plots were then harvested using a commercial combine with an 18-ft header. The 18-ft swath was taken in the center of the 48-ft wide plot. Grain was weighed using a weigh-wagon to determine yield per treatment.

Soil water measurements were taken throughout the growing season using a PR2® probe (Delta-T Devices Ltd. Cambridge, England). The probe senses the soil moisture content at 4-, 8-, 16-, 24-, and 40-inch depths by responding to dielectric properties of the soil. Readings were made on two access tubes in each plot. At each depth, three measurements were taken, each time with the probe rotated to a different direction.

Results and discussion

***Weeds**-Dan Ball and Larry Bennett*

Long-term crop rotation experiments (LTE) were initiated in the 2003-04 crop year at the Columbia Basin Ag Research Center, Moro. Dryland crop rotation treatments (summarized above) are being investigated each crop year for influence on weed population dynamics. Herbicide inputs necessary to maintain weed infestations to prevent yield reductions are also being documented (Table 1). In the 2009-10 crop-year of this LTE, downy brome infestations continue to be a major weed concern. Consequently, significant herbicide inputs have been necessary to maintain downy brome at densities at acceptably low levels in certain crop rotations (Table 1). In particular, continuous winter wheat, and 2-year crop rotations with alternate years of winter wheat have required repeated herbicide treatments for downy brome control (Table 2 and 3), or planted to a CLEARFIELD™ winter wheat and treated with imazamox (Beyond™) herbicide. In general, downy brome infestation levels in this study have been considered to be moderate because of these repeated herbicide applications (Table 3).

In addition to downy brome, other weeds are prevalent depending on crop rotation. Prickly lettuce and tumble mustard are generally present in all rotation treatments, but are controlled with annual broadleaf herbicide treatments (data not shown). Winter pea lacks effective broadleaf herbicide treatment options, but when grown in rotation with winter wheat, broadleaf weeds have only been a sporadic problem. Prostrate knotweed densities were high in winter wheat grown in rotation with pea (data not shown), but the distribution of prostrate knotweed is highly clumped with only minor spread in the study area (personal observation). Rattail fescue was also evident in direct-seeded, continuous spring wheat, and in the winter pea rotations (Table 4). Herbicide options for this species are relatively limited, especially in winter pea, so this weed may be expected to increase in importance as the study continues.

Table 1. Herbicide applications in the Moro LTE study 2008 - 2009.

2009	Herbicide treatments	Dates
1,3,6,7,8,10,13,14	24 oz./acre Glyphos X-TRA with .625% v/v Quest water conditioner and .25% v/v surfactant in 10 gal. water/acre.	4/4/09
11	12 oz./acre Assure II with 19 oz./acre crop oil.	4/24/09
2,4,5,9,12	11 oz./acre Huskie, .5 oz/acre Harmony Extra and 4 oz/acre Sencor with .25% v/v NIS all in 10 gal. water/acre.	4/24/09
3,8	24 oz./acre Glyphos X-TRA, .625% v/v Quest water conditioner and .25% NIS in 10 gal. water/acre.	5/15/09
11	16 oz./acre Chiptox and 16 oz./acre Basagran in 20 gal. water/acre.	5/20/09
6,7,10	11 oz./acre Huskie with 32 oz./acre Sol 32 and .25% v/v NIS in 10 gal. water/acre.	5/21/09
3,8	32 oz./acre Glyphos X-TRA with .25% v/v NIS and .625% v/v Quest water conditioner all in 10 gal. water per acre.	7/9/09
3,8	48 oz./acre Glyphos X-TRA with .625% v/v Quest water conditioner and .25% v/v NIS all in 10 gal. water per acre.	9/15/09
3,5,8,11,12	48 oz./acre Glyphos X-TRA with .625% v/v Quest water conditioner and .25% v/v NIS all in 10 gallon water/acre.	10/12/09
2010	Herbicide treatments	Dates
12	glyphosate+ conditioner+ NIS (0.84 lb ae/a + 0.625% v/v + 0.25% v/v)	3/2/10
2,4,10	glyphosate+ conditioner+ NIS (0.84 lb ae/a + 0.625% v/v + 0.25% v/v)	3/20/10
1,3,5,8,	3.5 oz./acre Powerflex, .5 oz./acre Harmony Extra, 6 oz./acre Barrage HF, a 2,4-D ester, and .25% v/v NIS all in 10 gal. water/acre.	4/7/10
5,11	5 oz. Beyond, 4 oz. Banvel, .25% v/v NIS and 2.5 gal. Sol 32/100 gal. water all in 10 gal. water/acre	5/3/10
12,14	16 oz./acre Basagran and 16 oz./acre Chiptox in 15 gal. water/acre. No surfactant.	5/19/10
6,7,,9,13	11 oz. Huskie/acre with 1# product/acre ammonium sulfate and .64% NIS in 10 gal. water/acre.	5/24/10
2,4,10	32 oz. Gly Star Plus with .625% v/v Quest water conditioner and .50% v/v NIS	5/30/10
12,14	32 oz./acre Basagran, 4 oz/acre Metribuzin 75. 1#/ product/acre spray grade AMS and .25% v/v MSO	5/30/10
4,10	64 oz./acre Gly Star Plus, 16 oz./acre In Place for deposition and drift management with .50% v/v Hel-Fire surfactant/water conditioner in 10 gal. water/acre.	6/10/10
4,10	64 oz./acre Gly Star Plus, 16 oz./acre In Place for deposition and drift management and .50% v/v Hel-Fire surfactant/water conditioner in 10 gal.water/acre	7/11/10
4,10,12,14	64 oz. Gly Star Plus/acre, 16 oz. In Place/acre, .50% v/v Hel-Fire in 10 gal. water/acre.	8/23/10

Table 2. Downy brome density (number per m^2) in early spring prior to herbicide treatments. Moro LTE (2004 – 2010).

Rotation*	Downy brome plant density (plants/m^2)**						
Annual cropping	2004	2005	2006	2007	2008	2009	2010
Continuous *winter wheat* (DS)	0	11	20	19	**1**	**<1**	13
Continuous *spring wheat* (DS)	4	0	36	4	9	7	<1
Continuous *spring barley* (DS)	0	0	2	5	7	<1	0
2-year rotations							
Conventional fallow - *winter wheat*	0	<1	6	13	**6**	**<1**	**<1**
Chemfallow - *winter wheat* (DS)	2	3	12	16	**<1**	**2**	**0**
Winter wheat - *winter pea* (DS)	2	0	32	28	<1	3	<1
Winter pea - *winter wheat* (DS)	<1	<1	7	2	**<1**	**0**	**0**
3-year rotations							
Spring barley - chemfallow - *winter wheat* (DS)	4	5	0	6	<1	2	0
Chemfallow - Winter wheat - *spring barley* (DS)	6	<1	200	9	3	8	300

* Crop name in italics indicates crop for the current year. (DS) = direct seeded crop

** Numbers in (Bold) were from plots previously planted to CLEARFIELD™ wheat and sprayed with Beyond™ herbicide.

Table 3. Downy brome density (number per m^2) in after herbicide treatment in May in Moro LTE plots (2004 – 2009).

Rotation*	Downy brome plant density (plants/m^2)**					
Annual cropping	2004	2005	2006	2007	2008	2009
Continuous *winter wheat*	8	**11**	20	**4**	**2**	4
Continuous *spring wheat*	0	0	0	2	0	<1
Continuous *spring barley*	0	0	2	0	0	0
2-year rotations						
Conventional fallow - *winter wheat*	5	2	6	**0**	**14**	2
Chemfallow - *winter wheat*	4	2	12	41	**6**	3
Winter wheat - *winter pea*	**2**	**1**	**0**	**0**	**0**	**0**
Winter pea - *winter wheat*	8	0	8	2	3	<1
3-year rotations						
Spring barley - chemfallow - *winter wheat*	8	0	0	0	0	8
Chemfallow - Winter wheat - *spring barley*	0	0	0	1	0	2

* Crop name in italics indicates crop for the current year.

** Numbers in (Bold) were from plots previously sprayed with a downy brome control product. Treatments may include ClearMax™ , Beyond™ or Olympus® (winter wheat), or Assure II® (peas).

Table 4. Rattail fescue population density (plants per 5m^2) from Moro LTE experiment 2006-2010. Counts taken before herbicide applications.

		Rattail fescue				
		------------------- # / 5 m^2 --------------------				
Tmt	Rotation*	Feb 06	Mar 07	Mar 08	Mar 09	Mar 10
1a	Winter Wheat-Fallow (conv)	0	0	0	0	0
2a	Winter Wheat-Fallow (DS)	2	0	0	0	0
3	Winter Wheat (cont) (DS)	1	0	0	0	0
4	Spring Wheat (cont) (DS)	23	53	117	109	99
5	Spring Barley (cont) (DS)	0	3	30	12	35
6a	Winter Wheat-SB-F (DS)	14	0	0	0	0
6b	WW-Spring Barley-F (DS)	0	0	1	0	0
7a	Winter Wheat-WP (DS)	1	3	9	92	0
7b	Winter Pea WW (DS)	0	0	0	0	0

* (conv) – conventional tillage. (cont) – continuous cropped. (DS) – direct seeded.

Diseases-*Richard W. Smiley, J.A. Gourlie, and H. Yan*
Plants were collected from 15 winter wheat plots (3 reps of 5 treatments; Rotations 1A, 2A, 3, 6A, 7A) on May 13, 2010. Spring crops were sampled on June 16, including 6 plots each of spring wheat (Rotations 4, 8A), spring barley (Rotations 5, 6B), and spring pea (Rotations 7B, 8B). Plant samples consisted of 20 to 40 plants plus intact roots (to about 4-inch depth) collected over the length of each plot. Soil was washed from the roots, and each root system was scored for incidence (percent plants) and severity (qualitative rating scale of 0 to 4; with 0 = none and 4 = most severe) of the diseases Fusarium crown rot, take-all and Rhizoctonia root rot. Where possible, scores were assigned separately for diseases occurring on seminal roots and crown roots; this was not possible with shallow-planted winter wheat, for which there were almost no subcrown internodes to facilitate rapid distinctions among crown and seminal roots. We also examined plants for the presence or level of damage by other diseases and insect pests.

Soil samples (about 20 cores per plot; 1-inch diameter and 12-inch depth) were collected on April 9 and sent to Western Laboratories (Parma, ID) for quantification of plant-parasitic nematode genera. Nematode data were logarithmically transformed to perform statistical analysis and the logarithmic means were back transformed to report numbers of *Pratylenchus neglectus* per kilogram (2.2 lb) of soil.

Fungal diseases of cereal crops
The late-planted annual winter wheat treatment (Rotation #3) did not have distinguishable subcrown internodes and the roots were therefore rated as crown roots because seminal roots could not be distinguished. Roots systems for all other treatments were rated separately for seminal roots and crown roots.

Only four measures of root disease incidence differed significantly (P=0.05) among treatments; Fusarium crown rot lesions on subcrown internodes and, on seminal roots, the incidences of Rhizoctonia root rot, take-all, and Fusarium crown rot (Table 5). There were no differences among treatments for ratings of disease severity, and of disease incidence on crown roots. While diseases did not differ significantly among tillage treatments in the winter wheat-summer fallow rotations, the incidence of Fusarium crown rot lesions on subcrown internodes and of Rhizoctonia root rot on seminal roots were each numerically at 2-fold higher in the chemical fallow than in the cultivated fallow rotations.

There were significantly fewer Fusarium crown rot lesions on subcrown internodes in the winter wheat-winter pea rotation (7A) than in the winter wheat-chemical fallow (2A) and the 3-year rotation (6A). While the incidence of Fusarium crown rot symptoms on seminal roots was generally higher in the winter wheat rotations (1A, 2A, 6A, 7A) than in the spring crops (4, 5, 6B, 8A), this differed significantly only between the winter wheat in the 3-year rotation (6A) and the spring wheat in the flex-crop rotation (8A).

In general, Rhizoctonia root rot symptoms were most prevalent and more severe on seminal roots of spring barley than on either spring or winter wheat. The incidence of Rhizoctonia root rot on seminal roots was significantly less in the winter wheat-cultivated fallow rotation (1A) than in annual spring wheat (3), annual spring barley (4), and the 3-year rotation (6A).

In general, the incidence of take-all on seminal roots was higher in several of the winter wheat rotations (1A, 2A, 6A) than in the spring crops (3, 4, 6B, 8A). However, the incidence of take-all on seminal roots differed significantly in only a few instances. Take-all was greatest in the 3-year rotation (6A) and least in the annual spring barley (4) and the flex-crop rotation in which spring wheat followed spring pea (8A).

When winter wheat plants were being collected it was apparent that large differences in growth occurred among rotations. We therefore quantified mean plant heights and weights for these rotations. Plants were significantly taller and weighed more in the early-planted wheat-cultivated fallow rotation (1A) than in all later-planted direct drill treatments (2A, 3, 6A, 7A). Also, plant height was greater in the winter wheat-chemical fallow (2A) and 3-year rotation (6A) than in the annual winter wheat (3) and winter wheat-winter pea rotation (7A). Plants were notably least thrifty in the annual winter wheat and winter wheat-winter pea rotations (3, 7A).

Fungal diseases of broadleaf crops

Spring pea was the only broadleaf crop produced during 2010, including peas in the winter wheat-winter pea rotation (7B) and the flex-crop rotation (8B). There were no statistically significant differences for any of the disease comparisons for these rotations (Table 6). In general, the incidence and severity of each disease parameter was higher in the 2-year rotation (7B) than in the flex-crop rotation (8B) where pea is produced infrequently. No attempt was made to associate disease symptoms with specific pathogens or pathogen complexes.

Root-lesion nematodes

As in previous years, *Pratylenchus neglectus* was the primary plant-parasitic nematode species detected. Other nematode genera and species occurred in a few plots but were always at very low populations and there was no pattern of association with a crop rotation or crop management variable. When samples were collected during early spring the winter wheat was well established and the spring crops had been planted only recently. Any differences in nematode population density among rotations therefore mostly reflects an effect of the 2009 crop or land management, particularly for the spring crops planted at about the time the 2010 samples were collected.

As has occurred in previous years, root-lesion nematode populations differed significantly among treatments during 2010 (Table 7). The greatest populations occurred in annual winter wheat (3), annual spring wheat (4), and in the winter wheat-winter pea rotation (7A, 7B). Populations were lowest in annual spring barley (5) and in the chemical fallow and winter wheat phases of the 3-year rotation of winter wheat-spring barley-chemical fallow rotation (6A, 6C), reflecting the long-period between production of a good host crop (winter wheat) and the collection of these samples.

The pattern of lesion nematode populations over the 7-year history of these crop rotations and management sequences were evaluated again, as had been performed previously. Results were similar to the 6-year means calculated during 2009. Lowest population densities occurred in the annual spring barley (5) and in certain phases of winter wheat-chemical fallow rotation (2B) and the 3-year rotation (6A). Population densities were particularly high in the annual winter wheat (3), annual spring wheat (4) and certain phases of the winter wheat-cultivated fallow (1A) and winter wheat-winter pea (7A) rotations.

Since the long-term mean populations in this experiment include several crop management anomalies as the experiments were being established it appeared useful to examine trends only over the most recent five years of the experiment, 2006-2010. Three different analyses were made using this time frame. Population densities were highest in the annual winter wheat (3), annual spring wheat (4) and in both phases of the winter wheat-winter pea rotation (7A, 7B) (Table 7). Likewise, the lowest densities were in the annual spring barley (5) and two phases of the 3-year rotation (6A, 6B) (Table 2). When lesion nematodes were evaluated on the basis of the most recent full-year crop (Table 8), the densities were greater following spring wheat, winter pea, and winter wheat than after chemical fallow, spring barley or spring pea. When lesion nematodes were evaluated on the basis of the basic crop rotation, including all phases of crops and management within those rotations (Table 9), the densities were higher in annual winter wheat (3), annual spring wheat (4), and the winter wheat-winter pea rotation (7) than in all other rotations. Likewise, the lowest densities occurred in the annual spring barley (5) and the 3-year rotation (6).

Table 5. Fungal diseases of wheat and barley roots, and winter wheat metrics during the spring long-term experiment at Moro in 2010.

	Harvest Year	T 1 R 1A WW/CuF	T 3 R 2A WW/ChF	T 5 R 3 Ann WW	T 6 R 4 Ann SW	T 7 R 5 Ann SB	T 8 R 6A 3-yr rot	T 9 R 6B 3-yr rot	T 11 R 7A WW/WP	T 13 R 8A Flex		
		Treatment (‘T’), rotation (‘R’), treatment name, and crop or management treatment histories[1] for 2004 to 2010										
	2010	WW	WW	WW	SW	SB	WW	SB	WW	SW		
	2009	CuF	ChF	WW	SW	SB	ChF	WW	WP	SP		
	2008	WW	WW	WW	SW	SB	SB	ChF	WW	Cam		
	2007	CuF	ChF	WW	SW	SB	WW	SB	WP	SW		
	2006	WW	WW	WW	SW	SB	ChF	WW	WW	Mus		
	2005	CuF	ChF	WW	SW	SB	SB	ChF	WP	SW		
	2004	WW	WW	WW	SW	SB	WW	SB	WW	SB		
Disease or Plant Parameter[2]		*disease and plant data for harvest year 2010*									$LSD_{0.05}$	p>F
Infected crowns:	incidence	2.5 a	3.3 a	-	0.0 a	0.0 a	0.0 a	1.7 a	0.0 a	0.0a	ns	0.17
SCI:	incidence	12.5 abc	38.3 ab	-	8.3 abc	23.3 abc	41.7 a	25.0 abc	0.0c	3.3 c	32.6	0.04
	severity	2.0 a	1.7 a	-	0.8 a	1.6 a	1.8 a	0.9 a	0.0a	1.3 a	ns	0.39
SR – RRR:	incidence	22.5 c	56.7 abc	-	73.3 ab	95.0 a	50.0 abc	90.0 a	60.0 abc	68.7 abc	46.2	<0.01
	severity	1.1 b	1.3 ab	-	1.4 ab	2.2 a	1.5 ab	2.2 a	1.2 b	1.5 ab	1.0	0.02
SR – TA:	incidence	42.5 ab	46.7 ab	-	26.7 abcd	8.3 d	60.0 a	18.3 bcd	15.0 bcd	5.0 d	34.0	<0.01
	severity	1.5 a	1.3 a	-	1.0 a	0.7 a	1.4 a	1.0 a	1.3 a	0.7 a	ns	0.16
SR – FCR:	incidence	32.5 ab	25.0 abc	-	6.7 abc	11.7 abc	36.7 a	6.7 abc	20.0 abc	3.3 bc	30.6	0.02
	severity	1.2 a	1.5 a	-	0.7 a	1.5 a	1.2 a	1.7 a	1.3 a	0.3 a	ns	0.58
CR – RRR:	incidence	45.0 a	41.7 a	23.3 a	33.3 a	55.0 a	38.3 a	48.3 a	18.3 a	42.7 a	ns	0.24
	severity	1.1 a	1.2 a	1.1 a	1.1 a	1.4 a	1.4 a	1.5 a	1.1 a	1.2 a	ns	0.35
CR – TA:	incidence	5.0 a	5.0 a	8.3 a	4.7 a	5.0 a	1.7 a	6.7 a	3.3 a	15.3 a	ns	0.52
	severity	0.8 a	0.7 a	0.7 a	0.7 a	0.7 a	0.3 a	0.3 a	0.7 a	1.0 a	ns	0.91
CR – FCR:	incidence	6.7 a	5.0 a	5.0 a	3.3 a	1.7 a	3.3 a	6.7 a	6.7 a	3.3 a	ns	0.74
	severity	1.5 a	0.7 a	0.7 a	0.3 a	0.3 a	0.7 a	1.3 a	1.0 a	0.7 a	ns	0.20
‘Nubbed roots’:	incidence	1.7 bc	0.0 c	1.7 bc	1.7 bc	3.3 bc	0.0 c	0.0 c	15.0 a	10.3 ab	9.0	0.03
WW height:	centimeter	43.7 a	36.9 b	20.6 c	-	-	36.6 b	-	23.3 c	-	5.4	<0.01
Plant weight:	gram	8.7 a	6.3 b	1.6 c	-	-	5.4 b	-	3.0 c	-	1.8	<0.01

[1] WW = winter wheat, SW = spring wheat, SB = spring barley, WP = winter pea, Cam = camelina, Mus = mustard, ChF = chemical fallow, CuF = cultivated fallow; treatment T1 is managed as a cultivated fallow and all other treatments are managed without tillage (direct-drill).

[2] Infected crowns = plants with a brown rotting of the crown tissue; SCI = lesions on the sub-crown internode, SR = seminal roots, CR = crown roots, RRR = Rhizoctonia root rot, TA = take-all, FCR = Fusarium crown rot, “incidence” = percentage of plants exhibiting the symptom described, “severity” = disease severity rating scale from 0 to 4, with 4 being the most severe.

Table 6. Diseases of spring pea cotyledons and roots in the long-term experiment at Moro during 2010.

Treatment:		12	14
Rotation:		7B	8B
Current crop:		spring pea	spring pea
Previous crop:		winter wheat	spring wheat
		disease data for 2010	
Parameter[1]			
Black cotyledon	incidence	77	57
	severity	1.8	1.2
Root rot lesions on tap root	incidence	91	74
(Rhizoctonia/Pythium complex)	severity	1.6	1.1
Vascular browning (Fusarium wilt)	incidence	24	13

[1] "incidence" = percentage of plants exhibiting the symptom described, "severity" = disease severity rating scale from 0 to 4, with 4 being the most severe. Data did not differ significantly between the two treatments.

Table 7. Density of root-lesion nematodes (*Pratylenchus neglectus*/kg of soil) in the upper soil profile of the long-term experiment at Moro.

Trtmt	Rot	Harvest year and crop or field management[2]								*P. neglectus*/kg of soil [1]								
		2010	*2009*	*2008*	*2007*	*2006*	*2005*	*2004*	*2003*	*2006-2010 (5-yr mean)*	*2004-2010 (7-yr mean)*	*2010*	*2009*	*2008*	*2007*	*2006*	*2005*	*2004*
1	1A	WW	CuF	WW	CuF	WW [3]	CuF	WW	ChF	1,066 bcde	2,057 ab	528 bc	6,120 ab	3,276 ab	3,253 ab	938 abc	4,920 a	1,369 a
2	1B	CuF	WW	CuF	WW [3]	CuF	WW	CuF	ChF	1,909 efg	966 cd	741 abc	1,720 d	2,440 ab	684 cd	984 abc	861 a	604 a
3	2A	WW	ChF	WW	ChF	WW	ChF	WW	ChF	1,150 bcde	1,828 abc	634 abc	2,147 cd	4,706 ab	2,932 ab	1,082 abc	897 a	3,800 a
4	2B	ChF	WW	ChF	WW	ChF	WW	ChF	ChF	1,274 fg	668 de	682 abc	1,387 d	3,663 ab	732 cd	203 d	413 a	422 a
5	3	WW	WW	WW	WW	WW	WW	WW	ChF	4,261 a	3,108 a	2,036 a	7,920 a	5,877 a	4,464 a	3,126 a	2,796 a	573 a
6	4	SW	SW	SW	SW	SW	SW	SW	ChF	3,197 ab	2,181 ab	1,731 ab	5,600 ab	8,641 a	3,617 ab	1,129 abc	2,832 a	247 a
7	5	SB	SB	SB	SB	SB	SB	SB	ChF	334 h	436 e	103 e	347 d	413 b	691 cd	470 bcd	2,409 a	297 a
8	6A	WW	ChF	SB	WW [3]	ChF	SB	WW	ChF	821 gh	660 de	135 de	1,253 d	931 ab	371 d	885 abcd	1,886 a	591 a
9	6B	SB	WW	ChF	SB	WW	ChF	SB	ChF	451 efg	788 de	601 bc	1,133 d	1,886 ab	2,160 abc	342 cd	353 a	709 a
10	6C	ChF	SB	WW	ChF	SB	WW	ChF	ChF	1,173 fg	986 cd	112 e	1,160 d	1,199 ab	1,668 abc	1,632 ab	1,873 a	1,166 a
11	7A	WW	WW	WW	WP	WW	WP	WW	ChF	2,534 abc	2,303 ab	998 abc	2,600 cd	11,052 a	5,401 a	1,187 abc	1,483 a	838 a
12	7B	SP	WP	WP	WW	WP	WW	WP	ChF	3,206 abcd	1,655 abc	1,092 abc	4,680 bc	7,326 a	2,268 abc	1,691 ab	1,356 a	335 a
13	8A	SW	SP	SP	SW	SM	SW	SB	ChF	1,199 def	1,280 bcd	440 cd	1,173 d	7,708 a	1,839 abc	670 bcd	2,322 a	767 a
14	8B	SP	SW	Cam	WW	SM	SB	SW	ChF	1,384 cdef	1,220 bcd	738 abc	1,987 cd	2,803 ab	1,100 bcd	1,542 ab	1,482 a	458 a
	p>F [4]									<0.0001**	<0.0001**	0.0002**	<0.001*	0.006**	0.005**	0.072	0.762	0.313
	CV (%)									14.8	16.7	11.3	61.1	11.3	10.4	12.5	21.2	16.9

[1] CuF = conventional fallow, ChF = chemical fallow, WW = winter wheat, SW = spring wheat, SB = spring barley, WP = winter pea, SP = spring pea, SM = spring mustard, Cam = camelina. Treatments 1 and 2 (Rotations 1A & 1B) are managed as a cultivated fallow and all other treatments are managed without tillage (direct-drill).

[2] Sampling was from the surface 6-inches in spring 2004 and on March 7, 2005, and from the surface 12-inches on April 4, 2006, April 2, 2007, April 14, 2008, and April 8, 2009. The sampling time reflects different stages of plant growth, depending upon plantings made during the fall or spring. Treatments planted to winter crops were planted five months prior to sampling. Treatments planted to spring crops, and the fallow treatments, were sampled immediately after they were planted and before these crops could influence nematode population densities.

[3] Winter wheat plots in rotation 6A were very dry and compact on April 2, 2007. It was impossible to collect manual core samples to the same depth as for other plots. Low numbers of RLN may be somewhat biased by the slightly shallower sampling depth in those three plots.

[4] Data are from back-transformed means of the ln (x+1) transformation used for ANOVA.

Table 8. Density of root-lesion nematodes (*Pratylenchus* spp./kg of soil) during early spring following the previous crop indicated over a five-year period (2006-2010) in the long-term experiment at Moro.

Previous crop or management	RLN/kg [1]	n [2]
Spring wheat	2,444 a	24
Winter pea	2,354 ab	15
Winter wheat	2,101 ab	78
Mustard	1,839 abc	3
Camelina	1,683 abc	3
Cultivated fallow	1,066 bc	15
Chemical fallow	748 c	33
Spring barley	578 c	33
Spring pea	577 c	6
p>F	<0.0001	
CV (%)	15.6	

[1] Data are from back-transformed means of the ln (x+1) transformation used for ANOVA.
[2] n = number of plots for specific previous crop or management during crop years 2006 – 2010.

Table 9. Density of root-lesion nematodes (*Pratylenchus* spp./kg of soil) during early spring following the previous crop indicated over a five-year period (2006-2010) in the long-term experiment at Moro.

Main crop management system		RLN/kg [1]	n [2]
Rotation	*Descriptive Name*		
1	Winter wheat/cultivated fallow	1,426 b	30
2	Winter wheat/chemical fallow (NT)	1,211 bc	30
3	Annual winter wheat (NT)	4,261 a	14
4	Annual spring wheat (NT)	3,197 a	15
5	Annual spring barley (NT)	334 d	15
6	Winter wheat/spring barley/chemical fallow (NT)	757 c	45
7	Winter wheat/winter pea (NT)	2,851 a	31
8	Flexible cropping decisions (NT)	1,288 b	30
p>F		<0.0001	
CV (%)		14.9	

[1] Data are from back-transformed means of the ln (x+1) transformation used for ANOVA.
[2] n = number of plots for all phases of the specific rotation during crop years 2006–2010.

Microbial Communities: *David Myroid*

We measured microbial biomass and the composition of the bacterial and fungal communities 4 years after the establishment of treatments at the Moro long-term experiment. We hypothesized that microbial biomass and community composition would: (1) vary with soil depth; (2) with management treatment; and (3) management effects would be most noticeable in the upper depth intervals.

Fourteen cropping systems were established in Moro, Oregon in 2004. The treatments varied by tillage, chemical usage, and crop choice (spring barley, spring wheat, winter pea, and winter wheat). Samples were collected in April 2008 from each of the 42 plots, plus an additional three plots from a nearby uncropped area to serve as controls. Soils were samples at six different depths (0"-4", 4"-8", 8"-12", 2', 3', and 4'). Soil samples were sieved to 2 mm to remove rocks and plant debris, and stored at -20ºC until June 2008. For this work we used soil samples from only the top four depths.

Microbial biomass C and N were determined for the top four depths using the chloroform fumigation-extraction method (Brookes et al., 1985). Fumigated and nonfumigated samples were extracted with 0.05 M K_2SO_4 and the extracts were measured for total organic C and N using a Shimadzu TOC-V analyzer. We used k_{EC}=0.45 (Joergensen, 1995) and k_{EN}=0.54 (Brookes et al., 1985) to calculate microbial biomass C and N.

DNA was extracted from soil (0.25 g) using a PowerSoil™ DNA isolation kit (MO BIO Laboratories, Carlsbad, CA) according to the manufacturer's instructions, with the modification that a FastPrep instrument was used to lyse cells (Bio 101, Carlsbad, CA). The PowerSoil™ bead beating tubes were shaken for 45 sec using the FastPrep instrument. Extracts were quantified using a ND-1000 UV-Visible Spectrophotometer (Nanodrop Technologies, Wilmington, DE) and diluted to 25 ng^{-1} µl. For each sample 25 ng of extracted DNA was PCR amplified. Bacterial 16S rRNA was amplified with primers 16S 8-F (Edwards et al., 1989) and 16S 907-R (Muyzer et al., 1995) using PCR reactions described by Hackl et al. (2004). The fungal ITS region was amplified using primers ITS1F and ITS4 (Gardes and Bruns, 1993) under previously described conditions (Anderson et al., 2003). ITS1F and 16S 8-F primers used in community profiles contained FAM labels for sequence detection. PCR products were used to generate fungal LH-PCR (uncut) and T-RFLP (HinfI) and bacterial T-RFLP (AluI and MspI) profiles. Restriction products were column purified and T-RFLP and LH-PCR profiles were generated by Oregon State University's Center for Genome Research and Biocomputing using an ABI 3100 capillary DNA sequencer (Applied Biosystems, Foster City, CA).

Microbial biomass C, N, and C:N ratios were analyzed by analysis of variance using PROC GLM (SAS Institute Inc., Cary, NC). A split-plot by depth, randomized complete block model was used with Tukey's to test for significant differences between treatments or depth. T-RFLP and LH-PCR profiles were analyzed using GenoTyper version 3.7 (Applied Biosystems, Foster City, CA). T-RFLP and LH-PCR profiles were further analyzed according to methods described previously (Boyle-Yarwood et al., 2008) using PC-ORD Multivariate Analysis of Ecological Data version 4.06 (MjM software, Gleneden Beach, OR). Non-metric multidimensional scaling (NMS) was used to visualize community composition and blocked multi-response permutation procedures (MRPP) were used to determine treatment differences by calculating p-values (McCune and Grace, 2002). Blocked MRPP analysis was used to compare differences between treatments (accounting for plot variations due to blocks) by comparing the sample distance matrix to a random distribution, resulting in a p-value and an A-statistic. An A-statistic is a measure of within group variability, with values > 0.1 indicative is low variability. The same distance measure was used (i.e., Bray-Curtis) for both NMS and blocked MRPP ensuring agreement between these two analyses.

Microbial Biomass
Microbial biomass C and N, and C:N ratios, showed very similar trends. Across all treatments, microbial biomass C and N was significantly higher in the top four inches of soil than at the other depths. When individual depth increments were examined, only microbial biomass C showed significant differences among treatments (Fig. 1).

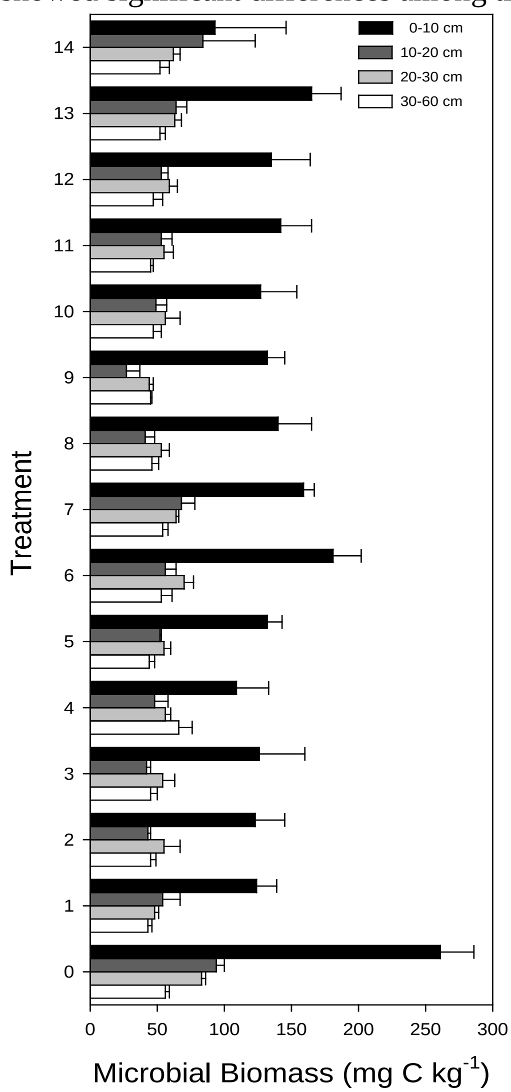

Figure 1. Microbial biomass C as a function of management treatment and depth. Bars are means with standard errors.

For the top three depth increments, microbial biomass C was higher in the uncropped control compared to most of the 14 management treatments; however, there were no significant differences among the 14 management treatments. Microbial biomass C did not differ among any treatments at the lowest depth.

Microbial Community Composition

The composition of the microbial community followed somewhat similar trends to those found for microbial biomass. The composition of the bacterial and fungal communities differed with depth, with communities being significantly different at each of the four depth intervals. The fungal community of the control soil was significantly different from each of the 14 management treatments; however, there were no differences in the fungal community among the 14 management treatments. The bacterial community of the control soil differed from a few of the management treatments, but like the fungal communities, bacterial communities did not differ among the 14 management treatments.

Discussion

Differences in the microbial community, both in terms of biomass and composition, were found with soil depth. The size of the biomass decreased with depth, paralleling similar trends in soil organic matter. Other studies have also found that composition of bacterial and fungal communities changes with depth.

The managed soils tended to have less microbial biomass and different fungal, and to a lesser degree, bacterial communities when compared to the control (unmanaged) soil. After four years of management, no trends in the composition of bacterial or fungal communities were found, even when just the upper portion of the soil was examined.

Grain yield of winter and spring crops under different cropping systems: *Stephen Machado, Larry Pritchett, Erling Jacobsen*

Total precipitation during the 2009-10 crop-year was 13.7 inches, 2.7 inches above the 99-yr average (11 inches) (Fig. 2). Table 10 shows grain yields of all rotations from the 2004-05 to 2009-10 crop years. Under continuous annual cropping, spring barley, with the lowest root-lesion nematode (*Pratylenchus* spp) incidences, produced significantly higher yield (42 bu/a) than winter wheat (14.2 bu/a) with highest nematode and weed (downy brome) infestation. Annual spring wheat yield (39.8 bu/a) was not significantly different from annual spring barley yield. Soil water readings under annual spring barley and annual winter wheat were much lower than under annual spring wheat indicating that spring barley and winter wheat used more water than spring wheat (Fig. 3). Yield of spring barley following winter wheat after fallow was not significantly different from yield of annual spring barley. Direct seeded winter wheat after chemical fallow in the three year rotation involving spring barley produced the highest yield (74.4 bu/a) although this yield was not significantly higher than yield from winter wheat after chemical fallow, and conventional fallow. Yield of winter wheat after winter pea was significantly different from yield obtained from winter wheat after fallow treatments. Spring peas (plot reseeded with spring pea after winter pea died) after winter wheat produced 25.8 bu/a.

Based on the 6-yr average (2004-05 to 2009-10 crop-years) (Table 11) the 3-yr rotation produced the highest yield of winter wheat and this was significantly so compared to other rotations except the conventional fallow. The high wheat yield obtained from the 3-yr rotation was partly attributed to low levels of root-lesion nematode incidences and low weed infestation. Conventional fallow and chemical fallow yields were not significantly different from each other. For annual cropping, spring barley has consistently produced the highest yields. These results suggested that direct seeded systems, that tend to increase soil organic matter and maintain surface residues that prevent soil erosion, can replace the conventional tillage wheat fallow system that is prevalent in these low rainfall areas of north-central Oregon and south-central Washington.

Table 10. Grain yield of winter wheat, spring wheat, spring barley, and winter peas under different cropping systems at CBARC, Moro, 2004-10. The yield shown is for the crop in italics.

Rotation	**Grain yield (bu/ac)**						
Annual cropping	04-05	05-06	06-07	07-08	08-09	**09-10**	04-10
Continuous *winter wheat*	10.6c	18.7d	30.8ef	20.2bc	26.7e	**14.2d**	20.3e
Continuous *spring wheat*	10.1c	37.9bc	32.0e	15.0c	17.0f	**39.8b**	25.4d
Continuous *spring barley*	11.6c	64.8a	39.3d	24.2b	30.7cd	**42.1b**	35.4c
Two-year rotations							
Conventional fallow-*Winter wheat*	58.0a	59.5a	64.5ab	38.9a	34.1bc	**67.3a**	53.7ab
Chemfallow-*Winter wheat*	52.9ab	46.5b	60.6b	41.4a	39.5a	**66.7a**	51.3b
Winter wheat-*winter pea*	9.1c	17.1d	9.5g	-	-	**25.8c**	10.3f
Winter pea-*winter wheat*	40.5ab	33.2c	36.4de	13.2cd	33.7c	**41.1b**	33.0c
Three-year rotations							
Chemfallow-*winter wheat*-spring barley	63.2a	57.9a	65.9a	42.6a	37.8ab	**74.4a**	57.0a
Winter wheat-*spring barley*-chemfallow	12.8c	59.2a	35.7de	9.5d	29.0de	**45.9b**	32.0c
Precipitation (inches)	7.9	16.9	11.1	8.4	9.1	**13.7**	11.2

†All plots are direct seeded except the conventional winter wheat fallow treatments (rotation 1).

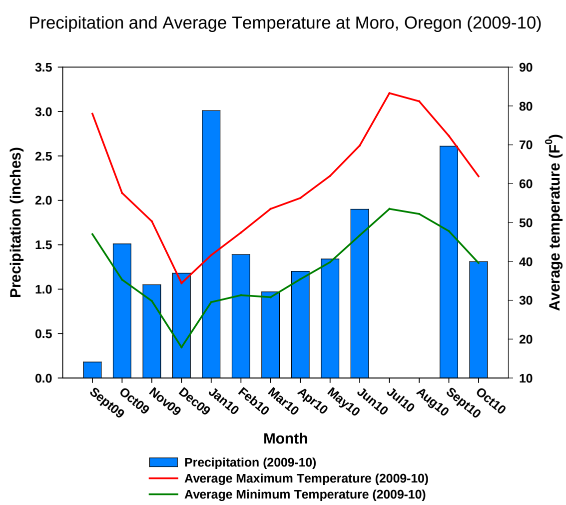

Fig. 2. Precipitation and average maximum and minimum temperatures at CBARC Moro, OR during the 2009-10 crop-year.

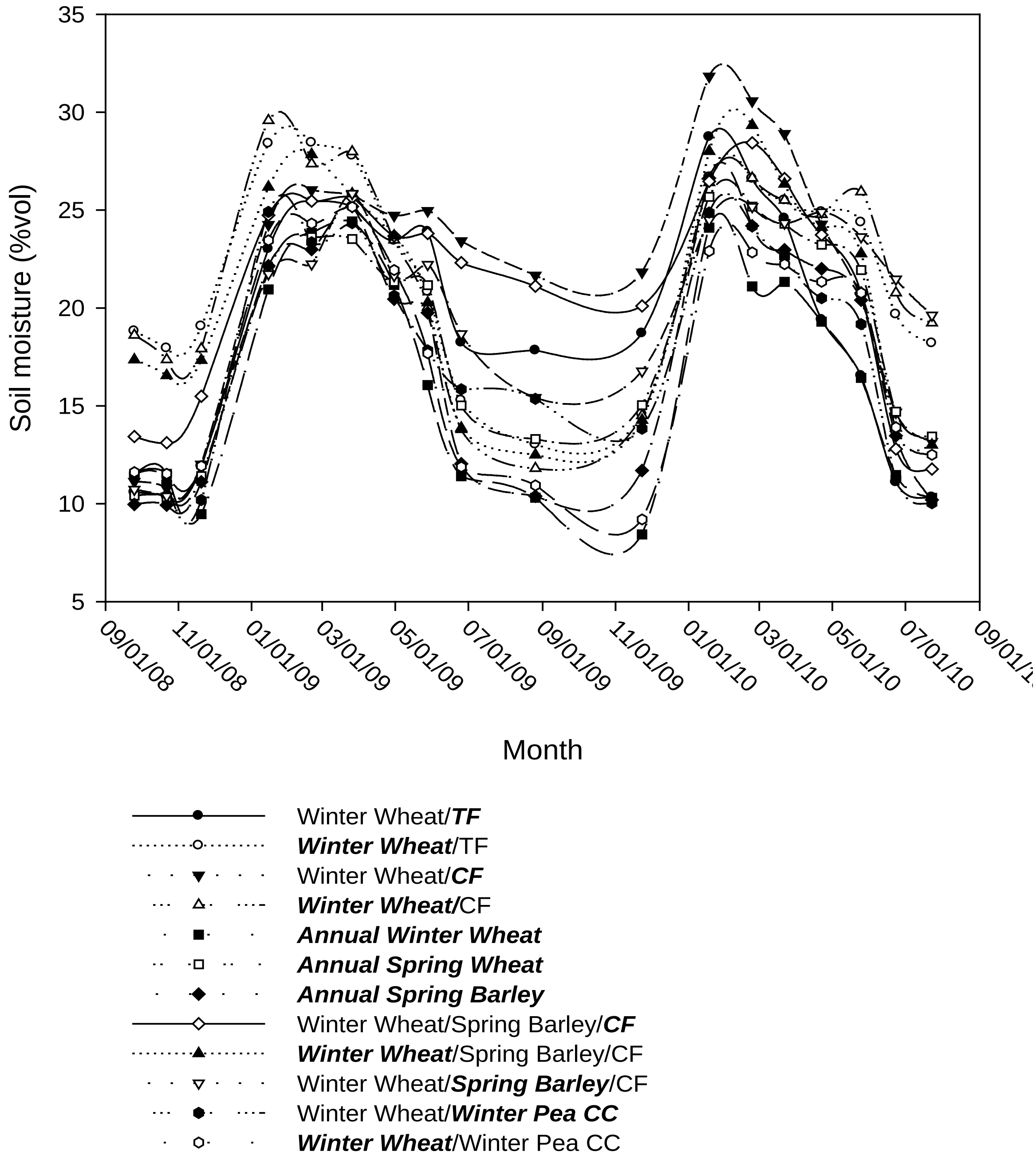

Fig. 3. Average soil water content under all rotations in the 0 to 40-inch depth profile from September 2009 to August, 2010 at CBARC Moro. Data shown is for crop/treatment in boldface and italics of a rotation.

***Crop Residues**: Stephen Machado and Larry Pritchett*

Crop residue cover was measured from a 3ft x 3ft quadrant as shown below (Fig. 4.). A digital image of the residue in the quadrant was taken and then the percent residue cover estimated using the ***grid*** method. Residue weight in about 25% of the quadrants was also determined by collecting and weighing it.

Fig. 4. Residue cover measurement

Residue cover was higher in annual cropping systems than after fallow and pea systems (Fig. 5a, b, and 6). Percent residue cover was highest under continuous winter wheat and the lowest after conventional fallow. This indicated that soil under the annual cropping systems would be better protected from the wind and water erosion than under fallow systems. However, annual winter wheat that had the most cover produced the lowest grain yields and would be uneconomical.

The relationship between residue cover and weight is shown in Figure 6. The correlation between cover and weight was stronger at low residue weights and weaker as residue weight increased. Based on this data estimating residue weight from weight or vice-versa is more accurate when residue weight was below 2000 lbs per acre.

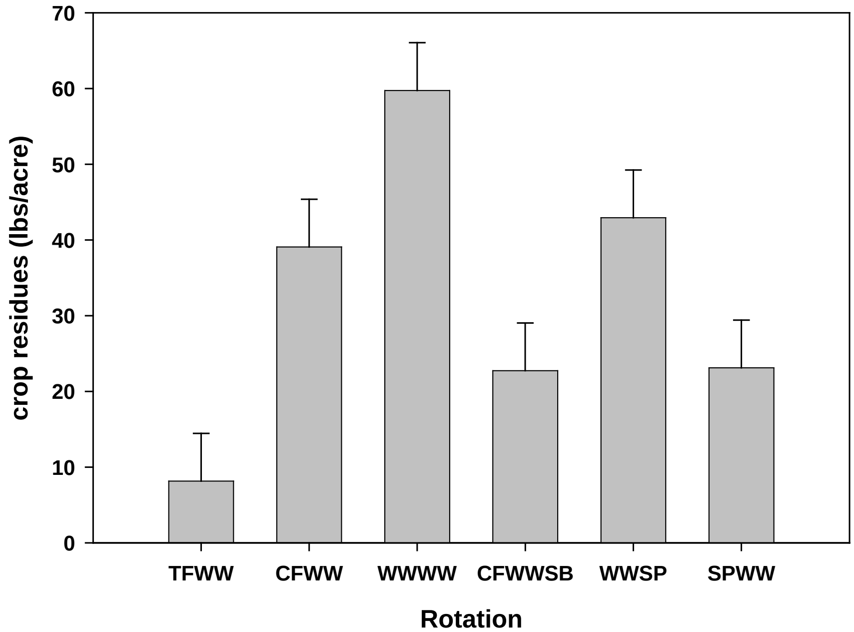

Fig. 5a. Post-plant crop residues (Winter, 2009) of winter crops, CBARC Moro long-term experiment.

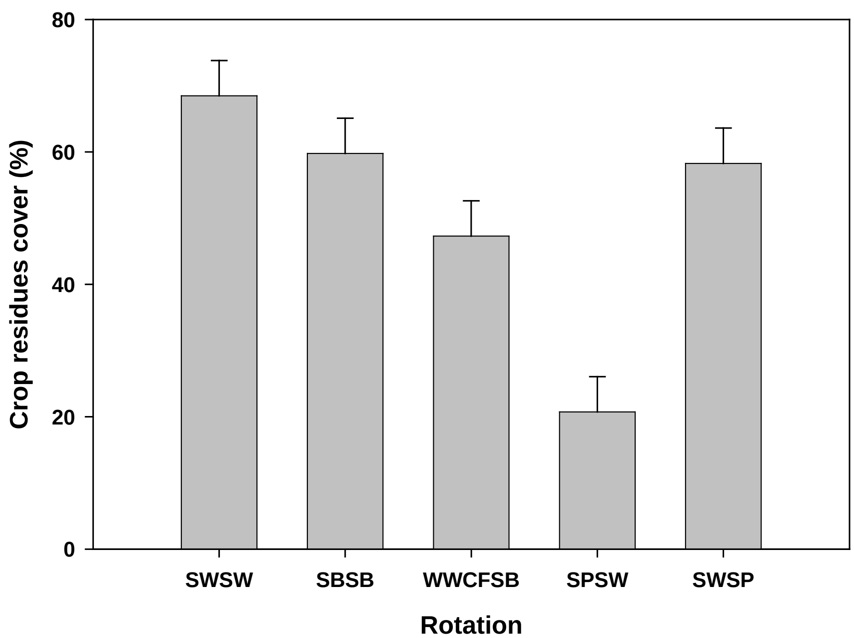

Fig. 5b. Post-plant crop residues (Spring, 2010) of winter crops, CBARC Moro long-term experiment.

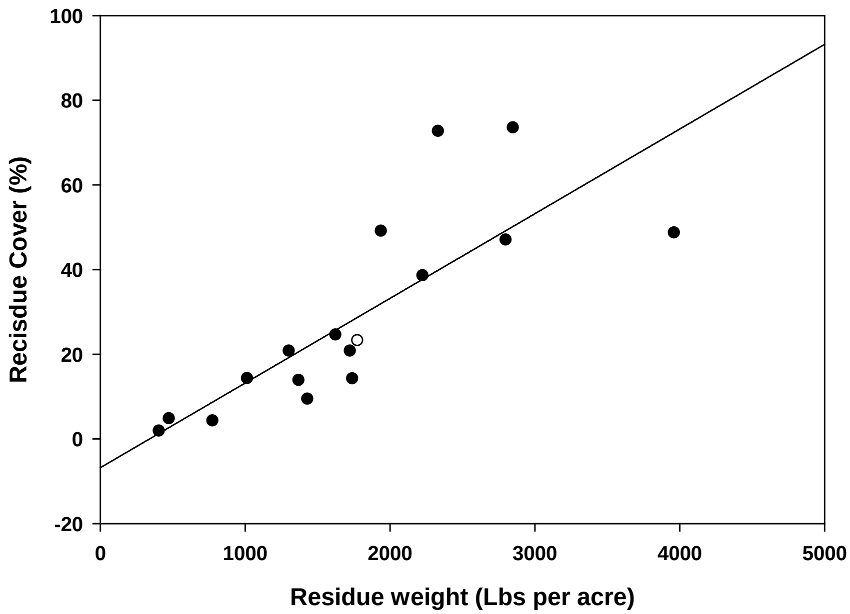

Fig. 6. Relationship between residue cover and weight at CBARC, Moro long-term experiment, 2009-10 crop-year.

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