Results

In this summary we are attempting to pool data from the 4 years of the project and do statistical analysis where possible. Because of the nature of the project, some statistical analysis is not acceptable. In these cases, averages and non-statistical data are presented and should be recognized as such. Because each cooperator only had 1 rotation on the farm, no comparisons among farms can be made, only within a farm. In some cases, data from cooperator farms are pooled together. Where statistical inferences are made, fields, years, or multiple sampling data were used as replications. The project began with 6 farmer cooperators, but only 3 of these cooperators completed the whole 4-year project.

Climatic Conditions

Precipitation was above the long-term average at both Davenport and Harrington in 1998 and 2000 and below average in 1999 and 2001 (Table 1). Because crop production in the Pacific Northwest relies heavily on stored soil moisture, dry fall and spring precipitation for the last 2 years of the study limited crop yield and profitability in 2000 and 2001. For example, during the soil recharge months, October through April, Davenport received 70% and Harrington received 59% of the historic precipitation for the 2001 growing season. The effects of this reduced precipitation will be discussed below.

Table 1. Total monthly precipitation for Davenport (Dav) and Harrington (Har) for study period.

	1998		1999		2000		2001		Long-term average	
Month	Dav	Har	Dav	Har	Dav	Har	Dav	Har	Dav	Har
	---- inches ----									
Jan.	2.94	2.11	1.23	1.14	1.71	1.65	0.63	0.61	1.78	1.40
Feb.	1.53	1.70	2.03	2.10	1.52	1.40	0.41	0.36	1.29	1.10
Mar.	1.14	0.86	0.19	.025	2.39	2.00	1.37	1.34	1.42	1.16
Apr.	0.46	0.43	0.20	0.45	1.72	1.61	0.98	1.10	1.06	1.00
May	2.71	2.06	0.86	0.58	1.63	1.23	0.95	0.58	1.34	1.16
Jun.	0.81	0.68	1.23	1.54	1.40	1.39	1.21	0.79	1.03	0.90
Jul.	0.92	0.64	0.41	0.20	0.32	0.11	0.10	0.23	0.66	0.56
Aug.	0.33	0.13	0.49	0.61	0	0	0.28	0.33	0.56	0.46
Sept.	0.12	0.63	0.05	0	0.95	1.17	0.13	0.15	0.68	0.57
Oct.	0.29	0.21	0.55	0.70	0.99	0.77	1.35	1.41	1.03	0.89
Nov.	2.54	2.57	1.79	1.88	2.13	1.05	2.23	2.32	1.93	1.70
Dec.	3.04	2.92	1.57	1.81	0.93	0.88	1.83	1.74	2.08	1.89
Total	**16.83**	**14.94**	**10.6**	**11.26**	**15.69**	**13.26**	**11.47**	**10.96**	**14.86**	**12.78**

Weed Population Changes

Weed management is a major concern in transition to direct seeding and one of the most costly operations to consider. One of the theories behind intensive cropping is, with a mixture of winter and spring crops, certain weed species are selected against and should be less of a problem. For example, winter annual grasses such as jointed goatgrass or downy brome (cheat grass) should be less of a problem in a spring cropping system. Likewise, wild oats should be less of an issue during winter cropping. Also, adding warm season crops that can be planted later should aid in management of early germinating weeds and multiple weed flushes. In this project, we observed a portion of this theory with some weed populations decreasing in number while direct seeding or management has favored other species.

On the Wilke farm, when comparing the 3- and 4-year rotations, wild oats were the only weed species that showed a significant difference between the 2 rotations. Averaged over years, wild oat populations were on average 8.9 and 0.25 plants/yd^2 in the 3- and 4-year rotations, respectively. In the 4-year rotation, 2 years out of a spring cereal reduced wild oat populations (Table 2.) cereals are grown, wild oat populations can be reduced. Averaged over rotations, prickly lettuce, knotweed, and wild oat populations decreased over time, while cone catchfly and downy brome populations increased (Table 2). Weeds, in particular wild oats, contributed to lower than expected yields for many crops and was one of the most expensive crop inputs. The method of recording weed populations when dealing with a "resident" population may not accurately describe these populations because of the special variability of weeds in a field. Some sampling points or field areas had high weed populations while others had very few weeds. One such case is Russian thistle in the plot area, but not in the area sampled.

Within a rotation, weed populations varied by crop (Table 3). In the 3-year rotation, wild oat population was greater in spring cereal than in winter wheat or the broadleaf crop while downy brome populations were greater in winter wheat crops. In general, broadleaf weed populations deceased in both rotations except for Canada thistle (Figures 1 and 2). Wild oat populations decreased in both rotations while downy brome populations increased in the 3-year rotation (Figure 3).

Cooperator fields also had changes in weed populations. Downy brome populations generally decreased, but populations of kochia, prickly lettuce, and Russian thistle increased in some cases. Other shifts in weed populations based on observations are a reduction in field bindweed (morning glory), which does well in tilled systems. Based on ours and other grower observations, other perennial weeds such as Canada thistle, dalmation toadflax, and mullein have increased in area. (Data not shown.)

Weed management is also critical in crop selection. Growing a crop with limited weed control options needs to be considered. If weeds are allowed to grow and not controlled because there are no registered herbicides, not only can yield be reduced because of competition, but it can be the cause of future weed problems. (See the section at the end of the agronomic results that describe some of the observations not shown in the data.)

1. Weed management was one of the most costly operations in transitioning to direct seeding.
2. Annual broadleaf weed populations generally decreased over time in both 3- and 4-year crop rotations.
3. Canada thistle populations increased during the study and increases were greater in the 4-year rotation.
4. Wild oat populations decreased in both rotations, but the decrease was less in the 4-year rotation due to poor control in proso millet.
5. Downy brome decreased in the 4-year rotation, but increased in the 3-year rotation due to the

shortness of rotation to deplete the seedbed and poor completive ability of winter wheat in a re-crop situation.

6. Total crop yield was greater in the 3-year rotation compared with the 4-year because of the poor yield of proso millet in the rotation.
7. More research is needed to identify more profitable crop rotations and address weed and other management practices in a direct seed system.

Table 2. Change in cone catchfly, prickly lettuce, Shepherd's purse, knotweed, wild oat, and downy brome populations over time in direct seeded rotations at the WSU Wilke farm†.

Year	Cone catchfly	Prickly lettuce	Shepherd's purse	Knot-weed	Wild oat	Downy brome
	----------------------------------	plants/yard^2	----------------------------------			
1999	0.6 c	9.2 a	0.8 b	2.0 a	136.9 a	0.8 b
2000	8.4 b	3.0 b	4.8 a	0.4 b	41.0 b	9.0 a
2001	20.9 a	0.9 c	0.7 c	0.1 b	13.0 b	11.7 a
LSD (0.05)	4.0	3.5	3.5	0.5	16.0	7.8

† Means within columns followed by the same letter are not significantly different according to test at the 5% level of probability.

Table 3. Wild oat, downy brome, and prickly lettuce populations in Wilke 3- and 4-year crop rotations, averaged over years†.

Rotation and Crop	Weed species		
	Wild oat	Downy brome	Prickly lettuce
	----------------------------	plants/yard^2	----------------------------
3-year			
W. wheat	1.7 b	4.2 a	0.01 ab
Sp. cereal	4.3 a	0.1 b	0 b
Broadleaf	1.9 b	0.1 b	0.03 a
4-year			
W. wheat	2.8 b	0.5 a	0.08 b
Sp. cereal	2.7 b	0 b	0.1 ab
WS grass	6.4 a	0.1 ab	0.1 ab
Broadleaf	2.5 b	0.3 a	0.2 a

†Means within a rotation and species followed by the same letter are not significantly different at the 5% level of probability using LSD procedure.

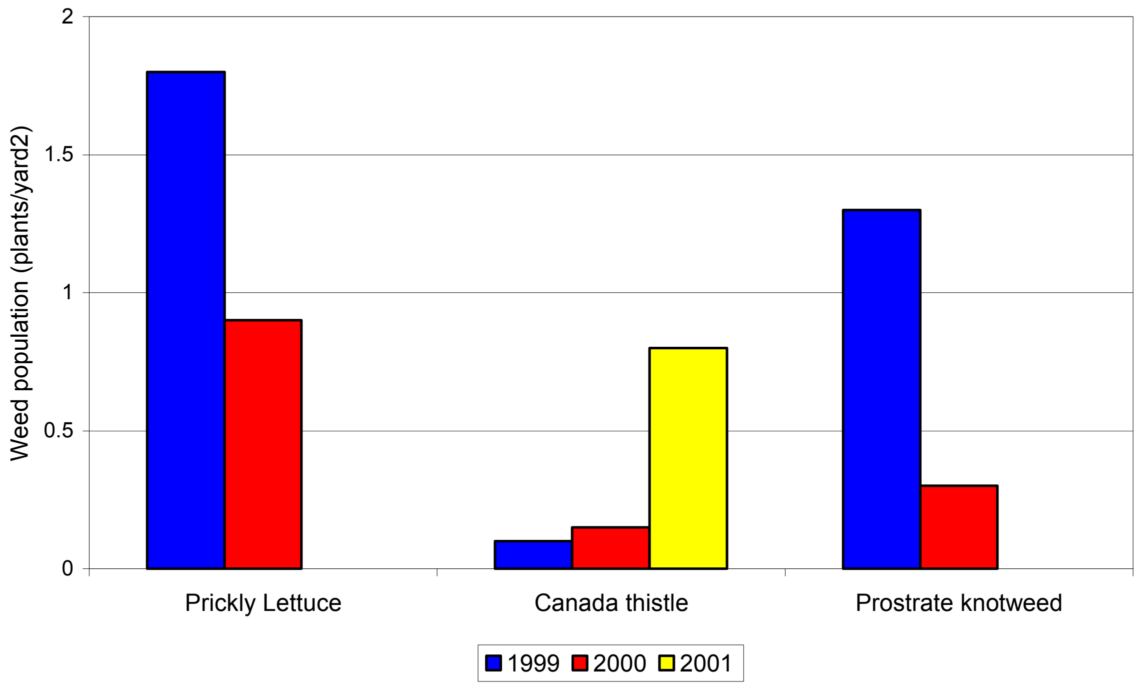

Figure 1. Change in broadleaf weed populations over years in Wilke 3-year crop rotation. Means with the same letter within a species are not significantly different using LSD procedure (p=0.05).

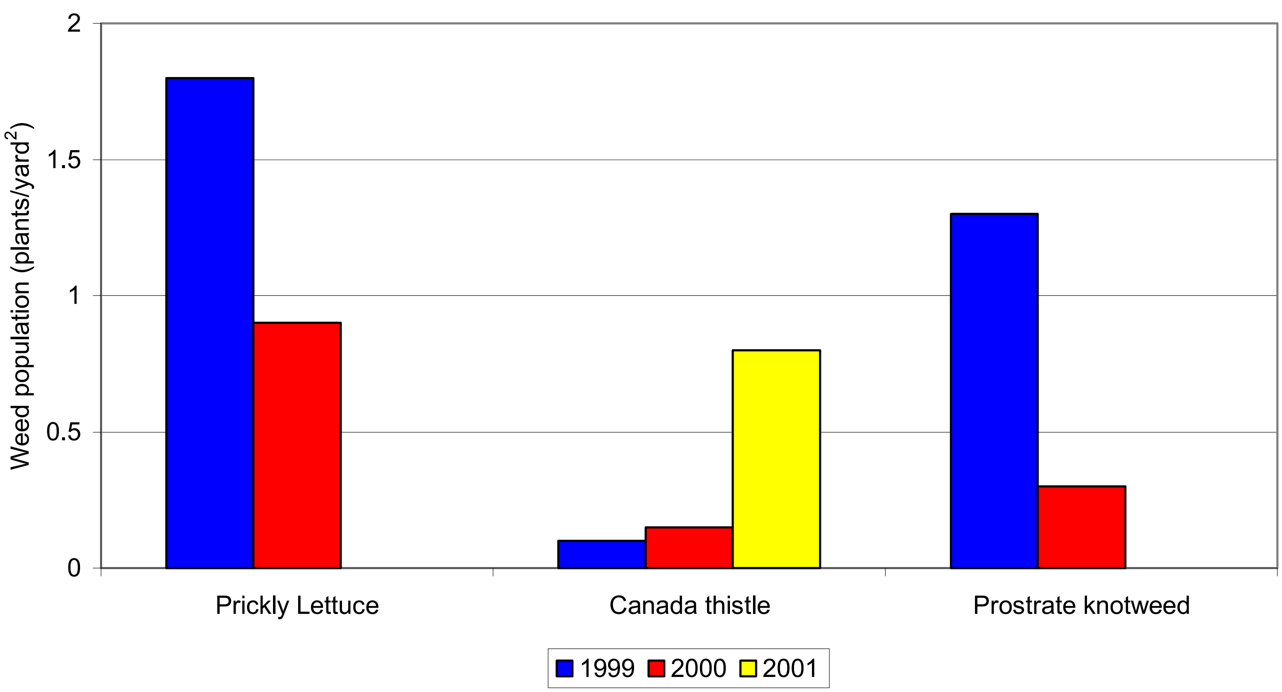

Figure 2. Change in broadleaf weed populations over years in Wilke 4-year crop rotation. Means with the same letter within a species are not significantly different using LSD procedure (p=0.05).

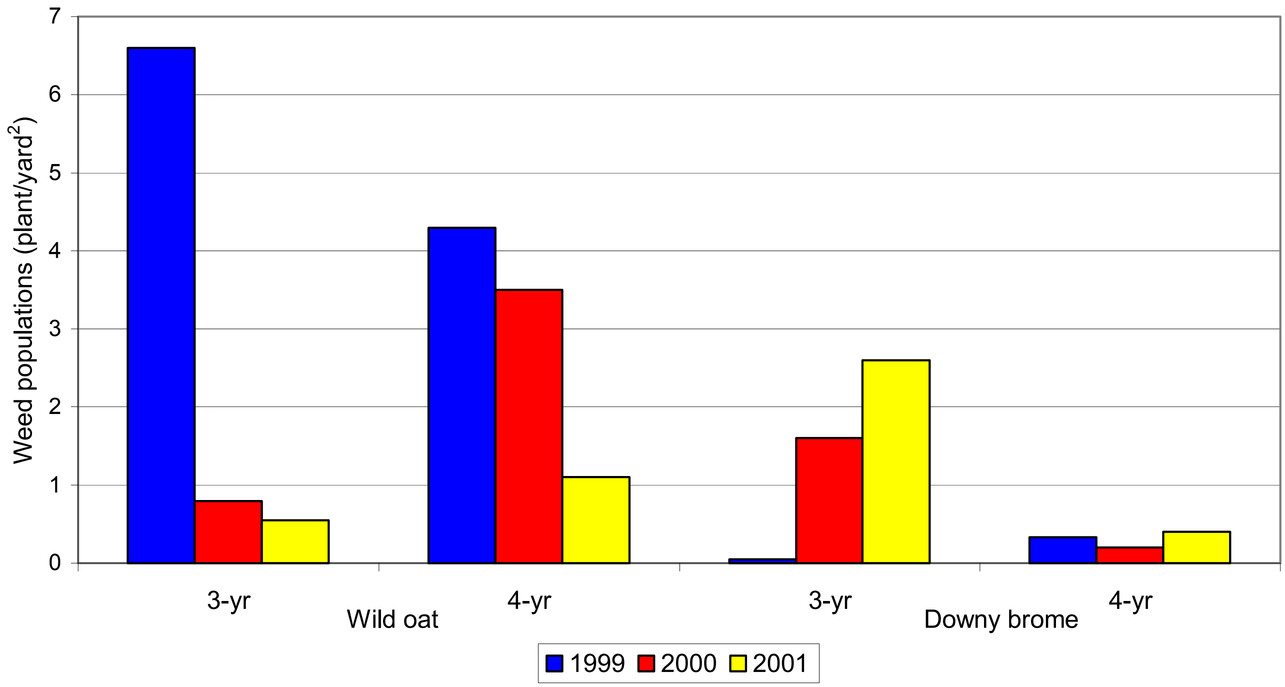

Figure 3. Change in wild oat and downy brome populations over years in Wilke 3- and 4-year rotations. Means followed by the same letter within a rotation and species are not significantly different using LSD procedure (p=0.05)

Insects

We collected both pest (aphids, leafhoppers, thrips) and beneficial insects (lady beetles, parasitic wasps, damsel bugs, soft winged flower beetles). The following comments are based on our observations.

Insect populations varied from year to year of the study period, but have shown a general trend of pest insects peaking in early July and outnumbering beneficial predators that increased soon afterwards (Figure 4).

Small grain fields that had been in canola the previous year demonstrated higher aphid populations than did fields of small grains following small grains. This was noted in 2 out of the 4 years of the study, at 2 different cooperator farms, suggesting a carryover in populations (data not shown).

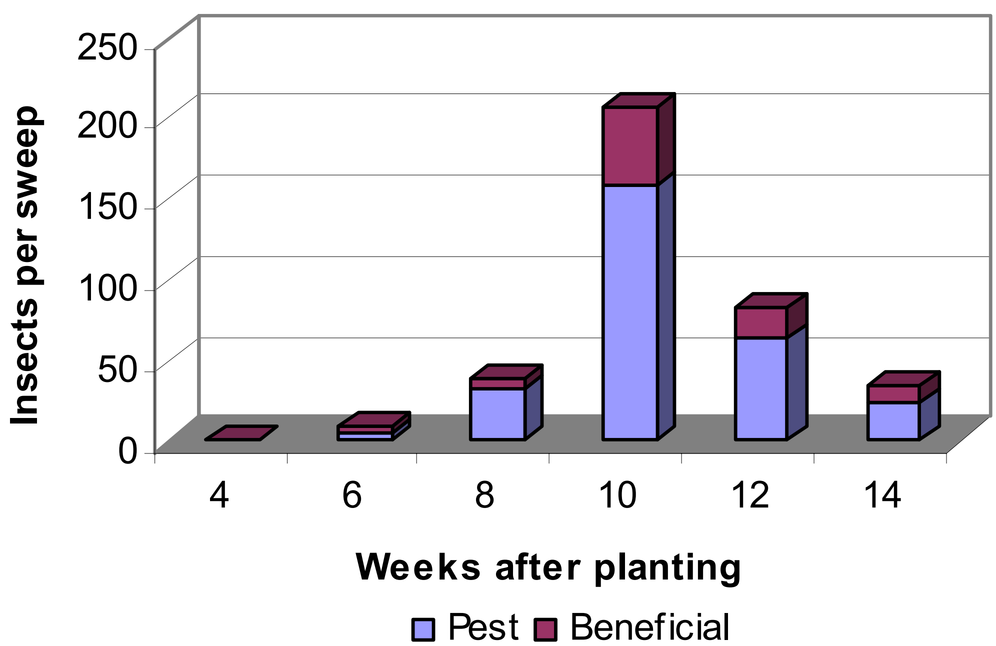

Figure 4. Insect population change during cropping season, averaged over years and crops.

Crop Disease

The only incidence of disease we observed was take-all in 2000 in a winter wheat field following safflower planted in 1998. Otherwise, fields have been disease free.

Crop Yield and Residue

Crop yield is generally reported as pounds of crops produced per acre (lb/a) in order to average and add together cereals and broadleaf crops for comparison of yields between rotations. Crop yield varied from year to year averaged over rotations and crops. In most cases, crop yield was greatest in 2000, while lowest average yield was in 2001, due to dry growing conditions (Table 2). Averaged over rotations and crops, crop yield ranged from 1441 to 1638 lbs/a at the Wilke farm. Cooperator crop yield ranged from 1115 to 2544 lbs/a during the study period (Table 5). During the same period, the conventional cooperator yield was 2311 lbs/a, averaged over years, crops, and fallow. On the Wilke farm, the 3-year rotation produced 22% more crop than the 4-year rotation, averaged over crops (Table 3). This is mainly due to the poor performance of the warm season grass (proso millet) in the 4-year rotation (Table 4).

At the Wilke farm beginning in 2000, winter wheat replaced spring wheat following the broadleaf crop in the 3-year rotation. In the 4-year rotation, winter wheat was planted as the second small grain in the rotation sequence. During the last 2 years of the study, winter wheat out-produced spring wheat by an average of 18 bu/a (data not shown). During this period, winter wheat yield ranged from 2580 to 3660 lbs/a (43 to 61 bu/a) while spring wheat yielded from 1800 to 3060 lbs/a (30 to 51 bu/a). In the 3-year rotation, barley followed wheat in the rotation and averaged 2489 lbs/a (1.25 T/a) and ranged from 1500 to 3000 lbs/a (0.75 T/a to 1.5 T/a) (Tables 4 and 5).

Alternative crops grown in the project included yellow mustard, canola, safflower, sunflowers, peas, buckwheat, flax for broadleaf crops, and proso millet and corn for warm season grasses (see Tables A1 through A5 for specific crops and varieties). One cooperator grew corn and sudangrass that was harvested for forage. These crops were grown with varying degrees of success. Several of the alternative crops were sensitive to frost, heat, and generally not well adapted to the climate. For example, sunflowers or corn may require too long a growing season or require more summer rainfall than is customary in the area. More work is required to select crops and varieties that may be suitable for the climate. Cool season broadleaf crops may be better suited to the area.

Crop residue ranged from 5400 to 7635 lbs/a during the study period (Table 2). On the Wilke farm, the greatest amount of residue was produced during the year with the lowest yields. While the 3-year rotation produced greatest yields overall, the 4-year rotation produced slightly greater residue levels (Table 3). This is likely due to inclusion of proso millet in the rotation that produced residue amounts nearly equal to small grains and may decay at a slower rate. Overall, residue levels did not increase over the study period indicating residue is breaking down at a rate nearly equal to what is being produced. Cooperator residue levels varied by location (Table 5).

Because of the poor yield of the warm season grass, it has been eliminated from the 4-year rotation on the Wilke farm and replaced with barley in an attempt to make the rotation more profitable. We are also attempting to make the rotations more rigid, planting the same broadleaf crop and wheat varieties in both rotations to allow streamlining of operations and more accurate analysis of the data.

Table 3. Average crop yield and residue levels for the Wilke farm from 1998 to 2001 averaged over rotations and crops[†].

Year	Yield	Residue
	lb/a	lb/a
1998	1638 a	5400 b
1999	1569 b	5401 b
2000	2069 b	5186 b
2001	1441 c	7635 a
LSD (0.05)	84	663

[†] Means within columns followed by the same letter are not significantly different according to test at the 5% level of probability.

Table 4. Wilke farm crop yield and residue averaged over crops and years[†].

Rotation	Yield	Crop Residue
	lb/a	lb/a
3-year	1926 a	5787 b
4-year	1507 b	5902 a

[†] Means within columns followed by the same letter are not significantly different according to test at the 5% level of probability.

Table 5. Crop type yield in Wilke 3- and 4-year rotations averaged over years[†].

	Yield[b]		Crop residue	
Crop type	3-year	4-year	3-year	4-year
	--------lb/a--------		--------lb/a--------	
Sm. grain 1[‡]	2567 a	2143 a	6394 a	5942
Sm. grain 2	2489 a	2656 a	6150 a	6319
Warm season grass	NA	403 c	--	5816
Broadleaf	663 b	824 b	4760 b	5510
LSD (0.05)	174	134	1195	NS

[†]Means within columns followed by the same letter are not significantly different according to LSD procedure at the 5% level of probability.
[‡]Crop type within a rotation - 3-year: Sm. grain, 1 (winter or spring cereal); Sm. grain 2 (spring cereal); 4-year: Sm. grain 1, (spring cereal); Sm. grain 2, (winter or spring cereal).

Table 6. Wilke project cooperator yields and crop residues averaged over years†.

Cooperator (rotation)	Crop Type	Yield	Crop Residue
		lb/a	lb/a
3-1 (3-yr)	Sm. grain‡	2977 a	8677
	Sm. grain	2812 a	5858
	Broadleaf	455 b	5225
	LSD	1769	NS
3-2 (3-yr)	Sm. grain	1977 b	4303
	Broadleaf	759 c	4516
	Sm. grain	2370 a	5489
	LSD	121	NS
4-1 (4-yr)	Sm. grain	3048 a	5588
	Sm. grain	3535 a	5669
	Warm season grass	875 b	4910
	Broadleaf	906 b	7413
	LSD	1010	NS
4-2 (4-yr)	Sm. grain	2183 a	7244
	Sm. grain	2018 a	7481
	Warm season grass	620 b	6580
	Broadleaf	865 b	6412
	LSD	610	NS

†Means within columns and sites followed by the same letter are not significantly different according to LSD procedure at the 5% level of probability.
‡Crop type within a rotation: 3-year Sm. grain 1 (winter or spring cereal), Sm. grain 2 (spring cereal): 4-year Sm. grain 1 (spring cereal), Sm. grain 2 (winter or spring cereal).

Soil Quality

Organic matter. Organic matter is a key component in improving soil physical properties. It contributes to increased water holding capacity, increases available plant nutrients, and holds soil particles together. Crop rotation and incorporation of crop residue are important for maintaining organic matter (Kennedy 1999). Increased organic matter should reduce wind and water erosion by holding the soils together. This will make soil less available to be blown away by wind, and water to be captured in the soil, rather than running off soils.

In 1998, we measured baseline soil organic matter at 0 to 2", 2 to 4", and 4 to 12" depths. In the spring of 2002, these measurements were repeated in approximately the same locations in each field. There was a trend for increased soil organic matter (carbon) in the top 1 foot of soil, especially in the to 0-2" range (Tables 6 and 7). The only statistical difference in organic matter was at the 0–2" range on the Wilke farm although in some cases, cooperator organic matter increased by as much as 1%. This is likely due to the small number of samples collected and analyzed. Greater depths also showed a trend for increase, but these were more moderate. The conventional cooperators' fields also showed a trend for increased organic matter likely due to adopted conservation practices.

Table 7. Soil pH and organic carbon in 1998 and 2002 in the top foot of soil after 4 years of direct seeding on the Wilke farm, averaged over 3- and 4-year rotations†.

	Organic carbon		pH	
Soil depth	1998	2002	1998	2002
(in)	------(%)-------			
0-2	3.1	3.9*	6.0	6.1
2-4	2.8	2.9	5.7	5.7
4-12	2.1	2.1	6.3	6.1

†Pairs within a depth range followed by an asterisk(*) are significantly different at the 5% level of probability.

Table 8. Comparison of Wilke cooperator soil organic matter content and pH measured at 0-2, 2-4, and 4-12 inches in 1998 and in 2002 averaged across fields†.

		Organic matter			pH		
Cooperator	year	0-2	2-4	4-12	0-2	2-4	4-12
		(depth in inches)					
		-------%-------					
Conv. 1	1998	2.6	2.5	1.9	6.1	5.8	6.2
	2002	2.9	2.7	2.2	6.3	5.9	5.9
Conv. 2	1998	3.1	2.5	1.9	5.7	5.4	6.0
	2002	3.8	3.1	2.3	6.2	5.3	5.9
3-year	1998	3.3	3.1	2.1	6.1	5.7	6.4
	2002	4.3	3.3	2.3	6.2	5.4	6.0
4-year 1	1998	3.7	3.2	2.4	6.1	5.7	6.6
	2002	4.4	3.8	2.7	6.5	5.9	6.4
4-year 2	1998	3.0	2.3	1.9	5.4	5.3	6.0
	2002	3.9	2.3	1.7	6.2	5.5	6.1

†Means for years within a depth range were not significantly different at the 0.05% probability level.

Soil pH. Acidification of direct seeded soils has been a concern in the higher rainfall areas of the Palouse. Data collected in 1998 and again in 2002 indicate that soil pH is not decreasing under direct seeded systems (Tables 6 and 7).

Nitrate movement. Baseline information for nitrate levels was obtained in 1998 to monitor the movement of nitrogen fertilizer in the soil in a more intensively cropped system. Results indicate that there was a slight increase in nitrate levels in the 3- and 4-foot levels in 2002 compared with 1998 (Figure 5). This indicates that care needs to be taken to ensure that nitrate movement is minimized in the profile. There was no statistical difference between nitrate levels in the soil profile, although there is a trend for less nitrate in the 5th and 6th foot of the 4-year compared with the 3-year rotation, possibly due to growing deep-rooted crops like sunflowers in the rotation (Figure 6). Cooperator fields did not show a significant increase in nitrate levels in the soil profile. In fact, 2 farms showed a decrease in nitrate levels over all (data not shown).

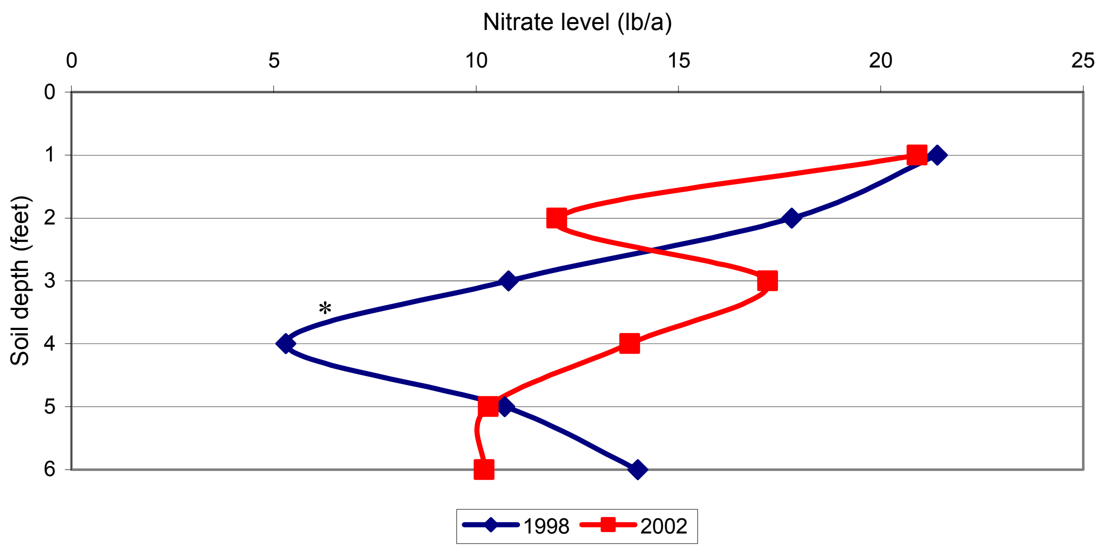

Figure 5. Soil nitrate levels in 1998 and 2002 for direct seeded fields on the Wilke farm. * indicates significant difference within depth level (p=0.05).

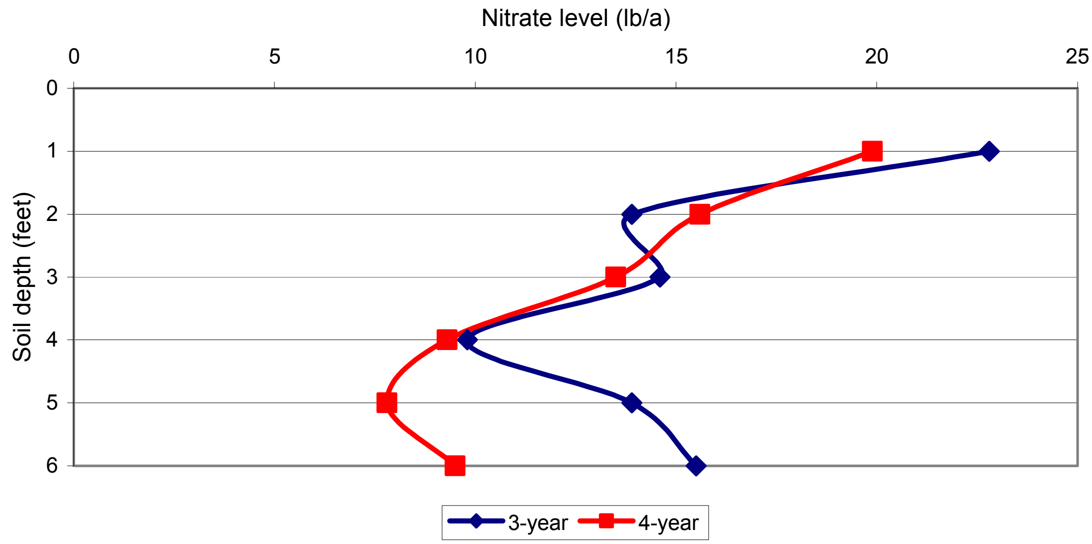

Figure 6 . Soil nitrate levels comparing 3- and 4-year crop rotations on the Wilke farm averaged over years.

Water infiltration. Water infiltration is the rate at which water enters the soil and depends on soil type, soil structure, or amount of aggregation, and water content (USDA 1999). Tillage affects water infiltration rate by temporarily loosening the soil, causing rapid water infiltration. However, tillage also disrupts aggregation and soil structure, creating compaction. Soils that are not disturbed will enhance water infiltration because of larger pore size and soil aggregation. Root and earthworm channels can create continuous pores into the profile. Compacted or disrupted soils have less pore space resulting in lower infiltration rates. The infiltration rates in inches per hour that have historically been used in soil survey classes are as follows: 0.6 to 2 inches/hour (moderate), 2 to 6 inches/hour (moderately rapid), and 6 to 20 inches/hour (rapid).

Average infiltration rates increased from 2.8 to 10.0 inches per hour comparing data from 2000 with the 2001 data. Infiltration rates ranged from 1.1 to 6.3 in 2000 to 3.6 to 20.2 inches per hour in 2001. Infiltration rates in the cooperator fields have also increased from 3.0 to 4.8 to 3.2 to 11.4 inches per hour, depending on location, in 2000 and 2001, respectively. This dramatic increase helps avoid runoff from rainfall and rapid snowmelt.

Erosion. We observed slight water erosion at the Wilke farm in the spring of 2000 after several rains on frozen soil. In the spring of 2002, there was some soil movement in a waterway, but it would have been much worse if the soil was left bare.

Earthworms. Earthworms can be very beneficial in direct seed systems. In direct seeded fields they become the primary source of nutrient cycling by ingesting and recycling soil organic matter. As the surface residue increases and soil disturbance decreases, it creates a habitat suitable for earthworm growth. We have sampled intensively for earthworms both on the Wilke farm and at one of the cooperators' farms. As yet, no earthworms have been found, although worms were found at the old home site at the Wilke farm. Earthworm populations will need to be monitored over time.

General Observations

Following are some of the empirical observations from researchers and cooperators.

Weeds

- Weeds are one of the major problems in direct seeding.
- Growers are seeing shifts in weed species with new cropping systems.
- Wild oat populations tend to increase with spring cropping and will continue to germinate with moisture; up to six flushes were seen in 2000.
- On the Wilke farm, growing safflower for 1 year without being able to apply any herbicides greatly increased the wild oat problem on the farm.
- Spring wheat is also a weak link in wild oat control.
- Field bindweed tends to decrease with direct seeding. One grower who had a substantial infestation on some new ground now has to search for bindweed plants after 3 seasons of direct seeding.
- Dalmatian toadflax and mullein are both very susceptible to tillage and are increasing with direct seeding.
- Canada thistle seems to be increasing both in conventional tillage and with direct seeding; it does well in low disturbance systems.
- We also need a good tool for Russian thistle management.
- In 2000, an early frost the first week of September stunted Russian thistle plants and eliminated their usual post harvest flush.
- Keep in mind crop rotational restrictions, i.e., don't get caught with long plant-back restrictions.

Soil Fertility

- Soil fertility is still a key issue – precision, timing, and amount.
- One cooperator, who had not direct seeded as long, applied 40-50 lbs N in the fall of 1999. He was encouraged to see it evenly distributed in the top 2-3 feet in the spring of 2000.
- A third cooperator used all Solution 32 in the spring of 2000, and his malt barley was too high in protein.

Crops

- Rotation, diversity, and crop selection continue to be an issue.
- A warm season grass is probably not a viable option in this area.
- With consistent direct seeding, one grower cooperator has noticed that crops can germinate quicker and from greater depths than normally recommended for that seed size.
- Seed can emerge quite easily through the duff layer, so small seeds can still emerge when placed deeper to make good contact with soil and moisture. Things to be aware of: (1) For example, if you are planning to apply glyphosate post-seeding and prior to crop

emergence, you may have a shorter spray window than anticipated. (2) Frost-sensitive crops that germinate quicker than normal may need to be seeded later so that the danger of frost is less as they emerge.

- If you are choosing a crop variety to obtain a premium in a niche market, especially an alternative crop with limited yield data from our area, be sure you know its yield potential. In 1998, red proso millet had a higher price than white proso millet on the birdseed market. It may have been possible to harvest it direct without swathing. However, the yield potential was lower than for the white millet so the price premium was not advantageous.
- Weather affects crops. This statement is too obvious. However, it underscores the value we have obtained from a hundred years of breeding cereals (wheat and barley) that are well adapted and stable in our Pacific Northwest environment. Alternative crops that have not benefited from this research investment are far more susceptible to weather fluctuations. Unseasonably hot weather in 1998 and drought in 2000 reduced yields of most of the alternative crops. Mustard at the Wilke farm was affected more than an early maturing canola variety grown 3 miles away, even though mustard is supposedly less heat sensitive than canola. In 1999, frost after emergence damaged mustard and canola stands. Seedlings emerging through heavy residue were actually more susceptible to frost than in areas where the ground was clear of residue and heated more quickly.
- If a crop has a rotational benefit in the system, don't cancel this out with other management decisions (e.g., losing patience). One of the Wilke crop rotations includes a warm season grass to allow a wider window in the spring for managing weeds prior to seeding. In 1998, we seeded millet on June 6, which allowed for 3 glyphosate applications beforehand and greatly reduced wild oat populations. In 1999, we followed a recommendation from the Midwest and seeded the millet earlier (May 24). The spring was unusually cool, and although there were 2 glyphosate applications, a lot of wild oats germinated after seeding. Consequently, we missed a major rotational benefit of this crop.
- Watch nature (soil temperature and moisture) more than traditional dates to determine optimum seeding time. In 1999, the Wilke farm was sprayed with Roundup™ prior to seeding in mid-April. However, with a cold, dry spring, very few weeds emerged. A second, post-seeding pre-emergence glyphosate application was necessary, as there was a sudden flush of weeds.
- Make sure that a new alternative crop has pesticides registered for weeds and other potential problems. Safflower in 1998 had one of the better returns of alternative crops on the Wilke farm. However, lack of registered herbicides for grassy weed control makes it a risky rotational crop.
- Pick rotational crops based on potential for marketability, pest and weed management, and rotational benefits.

<u>Miscellaneous</u>

- Chaff spreaders on combines are a must. Chaff spreading reduces problems with seed germination and nutrient tie-up that may be associated with chaff rows.
- Getting good seed to soil contact is crucial to obtaining a good stand. It requires extra time to achieve this.
- Seeding depth control and fertilizer placement are important criteria in drill choice.