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The Spokane County Direct Seeding Project (2001 to 2003): An On-Farm Project To Answer Grower Questions About Transitioning To Direct Seeding

By
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Introduction

The Spokane County Direct Seeding Project was a 3-year project (2001–2003) funded by a grant from USDA-SARE (Sustainable Agriculture Research and Education).

Southern Spokane County is a unique part of eastern Washington; it is part of the Palouse, yet colder than the Pullman area and with a climate suitable for Kentucky bluegrass production. Growers in the annual cropping region (18 to 22 inches precipitation) identified residue management as a primary challenge to successfully adopting direct seeding. Seeding through heavy residue can be tough in the fall, and especially in the spring when thick winter wheat residue tends to keep the soil cold and wet.

The Spokane County growers participating in this direct seeding project decided to identify specific questions they wanted answered, and designed their own trials to solve them. Not surprisingly, most of the questions related to residue management.

1. Larry Tee (Latah) compared different stubble heights for direct seeding into heavy residue. He was working on the theory that one should not have seeding problems if the height of the standing stubble was less than the distance between the rows (determined by one's drill).
2. David Ostheller (Fairfield) tested 3 residue management treatments on winter wheat stubble in preparation for direct seeding the following spring: (1) mowing, (2) fall chisel rip plus spring harrowing, and (3) standing stubble.
3. Randy and Jeff Emtman (Rockford) had been successful at taking out bluegrass stands by direct seeding oats into them after applying Roundup™. However, they weren't always able to achieve an acceptable test weight on the oats, so they were looking at a fall fertilizer regime that would enable them to achieve adequate oat test weight while allowing them the flexibility to keep the grass stand in if it looked good in the spring.
4. Glenn and Bryan Dobbins (Four Lakes) tested a commercial residue digester called Biocat™, made by Bioburst 'n Grow. The product was not a microbial solution, but a nutrient mix that stimulates the growth of microbes found naturally in the soil. They applied Biocat™ to residue following harvest,

and studied its effect on stand establishment and yield of direct seeded fall and spring cereal crops. This study was funded in part by Bioburst ‘n Grow.

5. Paul and Jake Gross (Deep Creek) tested a late fall rotary subsoil treatment for its potential to improve water infiltration into the soil and boost winter wheat yield under direct seeding.

Cooperators on the project were WSU Extension, NRCS, and the Spokane County Conservation District. The farmers designed the trials to answer a specific question, with aid from Extension. They used their own farm equipment to seed, spray, and harvest the trials, which were all in on-farm testing dimensions; each plot was about 40 feet by 300 to 1,000 feet long. There were 3 to 4 replications of each treatment in a trial, and the growers repeated the trials for 3 seasons.

We gratefully acknowledge the project statistician, J. Richard Alldredge, Department of Statistics, WSU, for his help and patience in assisting with the data analyses.

Residue Management for Direct Seeded Wheat (Latah)

Goal

To determine whether reducing stubble height of the previous crop to less than the drill row width improved plant stand and yield of direct seeded wheat.

Seeding into heavy residue can be extremely challenging with direct seeding, especially if the straw has lodged and the ground is very moist. “Hairpinning” or tucking of residue from the previous crop may occur with disk-type drills, resulting in poor seed-to-soil contact and reduced germination. Hoe drills tend to act like a hay rake, leaving clumps of straw across the field. Reduced plant stand may cause a loss in yield.

The grower wanted to test a theory he had heard that if the stubble height of the previous crop is less than the drill row spacing, then these problems should not occur.

Methods

Immediately following harvest in the test field, the grower used his combine to cut the test strips. He harvested the field at a normal 20-in height, and then lowered the combine header to cut test strips that left the stubble 6 inches high. The grower seeded the strips using a Great Plains chisel drill with double disk openers that was set with paired 4-inch rows on 7-in center spacing.

In the 2001 season, he tested Madsen winter wheat that he seeded into 45 bu Wawawaii spring wheat stubble; in 2002, he seeded Zak spring wheat into 86 bu Madsen winter wheat stubble; and in 2003, he seeded Wawawaii spring wheat into 79 bu Madsen stubble. The 2 treatments were tall stubble (20 inches) and short stubble (6 inches). There were 3 replications of the treatments in 2001, 5 replications in 2002, and 6 replications in 2003. He did no other residue management prior to seeding, and he planted the whole field at the same time, treating the plots similarly in every other management practice.

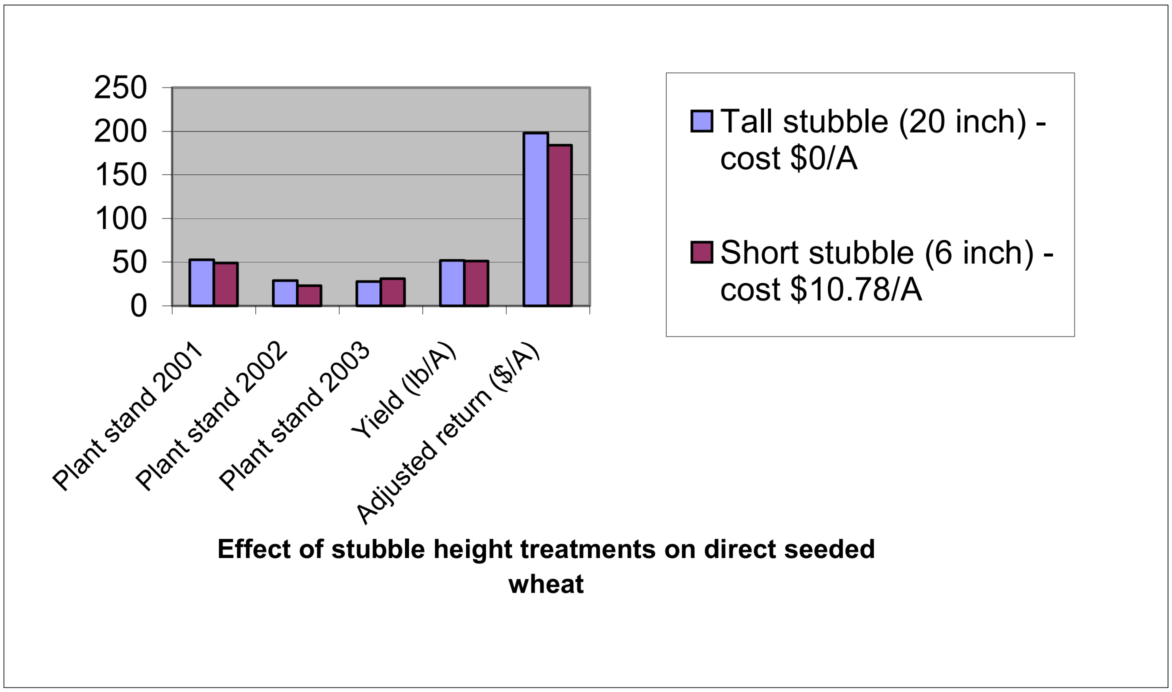
Each season we collected data on stand counts and weed populations in the plots about a month after emergence. Stand counts were the average number of plants in a 3-ft length of 2 drill rows (paired), and we took 6 random samples per plot. Weed counts were the total number of weeds in a random 100-ft strip, counted as the number of weeds intersecting with knots on two 50-ft residue ropes. We harvested each plot separately using the grower’s combine, and took a single test weight sample of the grain from each plot.

Results and Discussion

The summary of the combined 3-year data is shown in Figure 1, and features the variables of primary interest. The complete results of the analysis are in Table 1 in the Appendix section.

In 2001, contrary to expectation, the stand counts were higher in the tall stubble (53 plants/yd) than in the short stubble (49 plants/yd), as shown in Figure 1. An early snow precluded our taking these counts in the fall, and as all spring wheat volunteer did not winterkill, it is possible that increased survival of spring wheat in the tall stubble affected the results. In 2002, plant stands were also higher in the tall stubble (29 vs. 23 plants/yd). It is possible that the combine did not spread the chaff and straw adequately, so more tucking occurred in the short stubble plots. The cooperator had a factory John Deere straw chopper on the combine, plus a Kary chaff spreader. This was hydraulic with variable speeds, and spread the chaff wider than the width of the header. However, on hillsides the distribution of the chaff was inadequate due to the slope, as the combine remained level. With a tractor-drawn mower this situation should not arise. In 2003, however, the trend was reversed with an average of 28 plants/yd in the tall stubble vs. 31 plants/yd in the short stubble. As the farmer seeded the field when the cultivated ground around the plots was ready, and because the stubble ground dried out slower, the plots tended to be too wet at seeding in the spring (2002 and 2003). Some of the seed tended to bounce out of the drill row, and this may have contributed to the stand establishment differences.

Figure 1. Effect of 2 stubble height treatments (20 inches and 6 inches) on subsequent direct seeded spring and winter wheat at Latah, WA, from 2001 to 2003.



Despite differences in stand establishment, in each year of the project there were no visible differences between the treatments by harvest, and there were no appreciable yield differences in any season (Figure 1). We calculated an adjusted return ($/A) to compare the economics of the treatments. Adjusted return was the gross economic return on a treatment less the cost of the residue management treatment *only* (no seeding, herbicide, fertilizer, harvest costs). We used *total costs* that included ownership, depreciation, fuel, maintenance, and wear and tear on the equipment. We used the costs for a mower, assuming the farmer would not use his combine for mowing a whole field. The costs for the treatments were: mowing - $10.78/A, standing stubble - $0/A. The grain price ($3.80/bu) was the target price for 2001 to 2003.

Over the 3 years there was a consistent trend (Figure 1) of the short stubble treatment providing a lower adjusted return ($183.93/A) than did the tall stubble treatment ($197.91/A). From this it was evident that the extra cost of mowing ($10.78/A) was not warranted. If there were stand differences due to seeding conditions, the crop consistently compensated in yield.

Observations

The farmer noted during the winter of 2001-2002, the tall stubble plots held drifting snow in place better than the short stubble plots. This is consistent with direct seeding principles, and in a low-moisture year or region it would be beneficial. However, every year that we conducted the trials, we took 4-ft soil tests in each plot in the spring and both treatments were consistently at field capacity (13 inches).

In 2003, the direct seeded plots yielded 10 to 15 bu/A less than the rest of the field. The farmer attributed this to the timing of seeding, which was good for the tilled ground, but too wet and cold for direct seeding.

Fall Residue Management for Direct Seeding Spring Crops (Fairfield)

Goal

To determine the optimal level of fall residue management prior to seeding spring crops.

In the annual cropping region of Spokane County, direct seeding into heavy residue can be challenging, especially in the spring when the soil is cold and wet. Stubble ground warms slower than cultivated ground, and in some seasons this can be an apparent detriment to the farmer who wishes to transition to direct seeding.

The farmer wanted to compare how 3 fall residue management treatments on winter wheat stubble impacted the spring crops in the rotation.

Methods

The 3 residue management treatments he compared were:

- Mowing
- Fall disk rip plus a spring harrow
- Standing stubble (check treatment)

We laid out the plots in the fall after winter wheat harvest. There were 2 replications of each treatment in 2001, 3 in 2002, and 4 in 2004. The farmer used a Schulte mower (28 feet wide) for the mowing treatment and a John Deere (17.5-ft) disk ripper. In the spring, he harrowed the disk rip plots only using a 10-bar flex harrow. He did no residue management operations on the standing stubble (check plots).

The farmer used a Great Plains 3010 double disk drill with 8-inch row spacing to seed all the plots. In 2001, he grew Harrington spring barley seeded into 80 bu Madsen; and in 2003, he grew Brewer lentils following 60 bu Zak spring wheat.

Results and Discussion

The summary of the 3-year yield data is shown in Figure 2 and the adjusted returns are in Figure 3. In order to have all results on the same scale, all crop yields are in lb/A. The complete results of the analysis are in Table 2 in the Appendix section. Because the differences between treatments were not consistent from year to year, we have shown the results for each year rather than combining them.

Adjusted return was the gross economic return on a treatment less the cost of the residue management treatment *only* (no seeding, herbicide, fertilizer, harvest costs). We used *total costs* that included ownership, depreciation, fuel, maintenance, and wear and tear on the equipment. The costs for the treatments were: standing stubble - $0/A, mowing - $10.78/A, fall disk rip - $10.00/A (grower estimate), and $14.04/A (WSU estimate) plus spring harrow - $2.25. We used target grain prices of $3.80/bu for wheat, $2.21/bu for barley, and $11.94/cwt (loan rate) for lentils.

In 2001, for Harrington barley, the disk rip and harrow treatment (2,729 lb/A) statistically outyielded the mowed (2,285 lb/A) and standing stubble (2,086 lb/A) treatments (Figure 2). The disk rip treatment ($10/A) also had the highest adjusted return ($116.33/A) in this season (Figure 3 and Appendix Table 2) compared with $98.96/A for direct seeding and $97.32/A for mowing. However, due to statistical nonsignificance, the disk ripping treatment would not necessarily always return more than direct seeding. This trend was re-emphasized when we analyzed the data using $14.04 for the cost of disk ripping (Appendix Table 2).

Figure 2. Effect of 3 fall residue management treatments on yield of subsequent spring crops at Fairfield, WA, from 2001 to 2003.

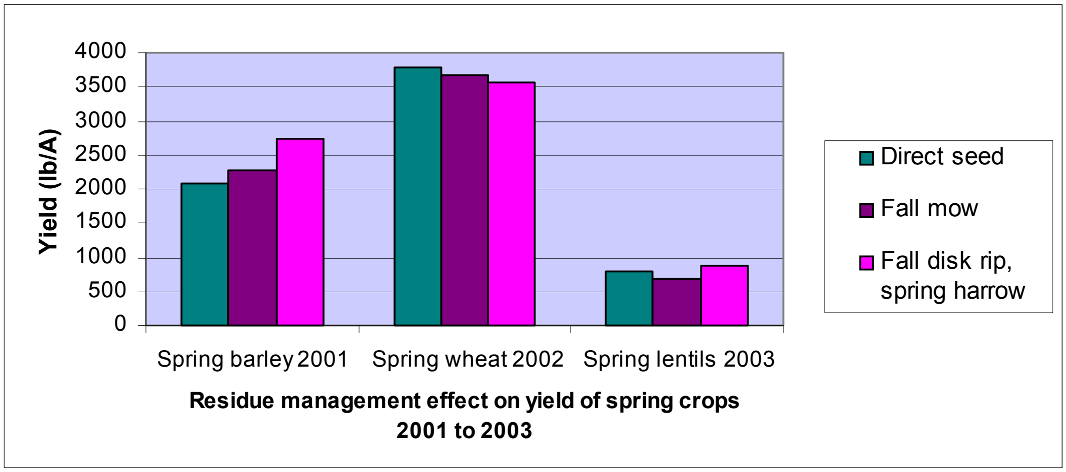
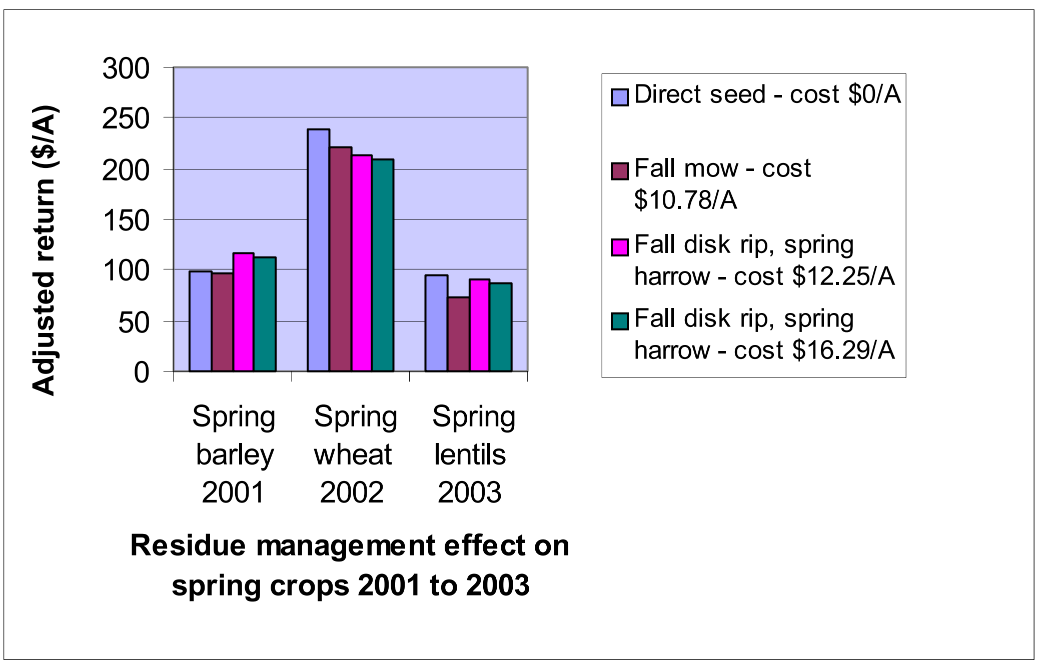


Figure 3. Effect of 3 fall residue management treatments on adjusted return of subsequent spring crops at Fairfield, WA, from 2001 to 2003.



With the Zak spring wheat crop in 2002, the direct seeding treatment outyielded (Figure 2) the disk ripping, but not the mowing treatment. It had higher adjusted return (Figure 3) than did both other treatments when we used both the $10/A and the $14.04/A cost for disk ripping. The farmer noted that although he seeded the test plots 10 days later than the rest of the field, the yields in these plots were not depressed. This indicated that waiting for the soil to dry prior to direct seeding was not necessarily negative.

In 2003, the lentil crop in all the plots yielded poorly due to drought conditions. The disk rip treatment significantly outyielded the mowing, but not the direct seed treatment (Figure 2), and the results were similar for adjusted returns (Figure 3).

From the data obtained we were unable to draw broad conclusions about the success of different residue management treatments. Across the 3 years of the project, direct seeding equaled or exceeded the tillage treatment in 2 years. Also, in 2 of the 3 years it tended toward or demonstrated being the treatment with the best economic return, assuming that all other management practices were the same among treatments (i.e., herbicide costs were assumed to be the same for all treatments we considered). The disk ripping treatment had very similar trends, so it seemed that neither treatment was consistently better or worse than the other. Fall mowing was either the lowest, or tended to be the lowest scoring treatment for both yield and adjusted return.

Observations

In 2002, the farmer noticed that the plant stand in the direct seeded plots was reduced, he had a problem with the drill tubes being cold and inflexible and cutting off seed going through the draws, but it seemed uniform across treatments. This season he seeded the plots 10 days after the rest of the field, but the yield did not differ.

In 2003, he noticed the soil was not completely dried in the direct seed plots, which caused compaction. That year the spring was extremely wet, but the weather then dried early with little to no rain after early May. This reduced yields for all spring crops, but especially the lentils. The yields in the plots did not necessarily correlate with yields of similar crops on the rest of the farm due to the differential in time of seeding.

While the results of the study were not dramatic, they provided him with enough validity to continue pursuing direct seeding. He is maintaining flexibility in his approach, and in many situations uses a 2-pass seeding system.

Fall Fertility Management for Ailing Kentucky Bluegrass Stands Prior to Direct Seeding to Oats (Valleyford)

Goal

To determine the optimal fall fertilizer regime for Kentucky bluegrass stands in order to get adequate test weight in the following oat crop.

These farmer cooperators have been very successful in taking out old Kentucky bluegrass stands by spraying them with glyphosate and direct seeding oats into them. Part of the reason for this is that oats produce a natural fungicide named *avenacin* that protects the crop from soil pathogens commonly found in perennial grass stands. However, these farmers have not always achieved an adequate test weight (36 lb/bu) grain buyers require on the oats.

It was possible that the fertility regime they used on their bluegrass was having a negative effect on the oats. Typically, the farmers apply 150 lb/A nitrogen to bluegrass fields every fall. These cooperators prefer to apply this regardless of the health of the stand so they can decide the following spring whether or not to spray it out. Research from Canada, however, indicated that the optimal level of nitrogen available to oats was 100 lb/A (Revised Nitrogen Recommendations for Oats in Manitoba; Manitoba Agriculture and Food). Either side of that level yields dropped off. Test weight response to nitrogen was not included in the Canadian study, but could follow a similar trend.

The farmer cooperators decided to test 3 rates of fall nitrogen on bluegrass, 50 lb/A, 100 lb/A, and 150 lb/A, to see which was optimal for the subsequent oat crop.

Methods

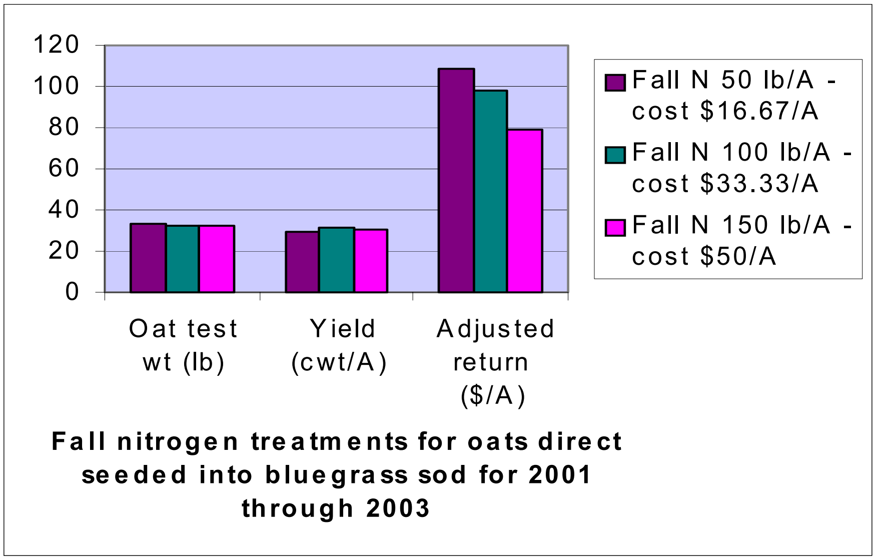
Each fall, the farmers selected a field they knew they would take out of bluegrass production the following spring. We laid out the plots with 4 replications each year. The farmers applied fall nitrogen to the plots as dry 30-0-0-6 (dry 29.5-5-0-3.5 in 2002) at 50 lb/A, 100 lb/A, and 150 lb/A. The first 2 years of the project that was the only fertilizer they used. However, as it was possible that the lack of starter fertilizer was a detriment to the oats, in 2003, they also applied 100 lb/A of 16-20 starter fertilizer at seeding.

The following spring, the farmers sprayed out the bluegrass, using glyphosate at a 48 oz/A rate and immediately seeded oats into the field. Each year they used the variety 'Waldern', which is a dual purpose grain and forage oat. In 2001, the bluegrass was 'Newport'; in 2002, it was the variety 'Goldrush'; and in 2003, it was 'Marquis'. They performed no tillage or residue management operations prior to seeding, although they had baled the bluegrass straw after harvest the previous year. They seeded the oats using a 30-ft wide Flexicoil 6000 drill with a Barton single disk opener with 7.5-in drill row spacing.

Results and Discussion

Figure 4 summarizes the 3-year results of this study for the parameters of primary interest. The full results are shown in Appendix Table 3. In 2001, due to a harvesting error, we only collected data from 1 replication of the treatments.

Figure 4. Effect of 3 levels of fall nitrogen application on Waldern spring oats direct seeded into Kentucky bluegrass stubble at Valleyford, WA, from 2001 to 2003.



Over the 3 years the oat test weight results were inconclusive as the 50 lb/A and 150 lb/A nitrogen treatments both tended to have higher test weight than did the 100 lb/A treatment. In 2001 and 2002, the test weights for all treatments in the test plots were much lower than desired, and were also lower than test weights collected from the rest of the field. In 2002, a very hot, dry spell in July may have contributed to this factor. However, the lack of starter fertilizer the first 2 years may also have contributed to depressed test weights. In 2003, the only season where starter fertilizer was applied, the test weight was 34.4 lb/bu for the 50 lb/A nitrogen treatment, 33.0 lb/bu for the 100 lb/A N, and 32.9 lb/bu for the 150 lb/A N treatment. These results showed the trends we expected, and the highest and lowest test weights were statistically different. However, none of the treatments achieved desired test weight (36 lb/bu), which was probably due partly to the lack of rain from early in May through harvest.

For oat yield, the 3-year data confirmed the Canadian study; the 100 lb/A nitrogen treatment tended to produce the highest yield, and yield tended to drop off with higher or lower nitrogen rates. However, differences were not statistically different so these trends would not necessarily hold every year.

Adjusted return was the gross economic return on a treatment less the cost of the fertility management treatment *only* (no seeding, herbicide, harvest costs). The costs for the treatments included all elements applied (not nitrogen only), but did not include application costs, which were the same across treatments. Treatment costs were: 50 lb/A N - $16.67, 100 lb/A N - $33.33, 150 lb/A N - $50.00, and starter fertilizer - $14/A. We used the target grain prices for oats of $1.40 per 32-lb bushel. However, this price does not accurately reflect market value of the crop, which was not marketable below 36 lb/bu.

The combined data showed that the adjusted return for the oats decreased significantly with each increase in fertilizer rate. From this it was evident that the growers' original decision-making process of applying 150 lb/A nitrogen in the fall was costing them a lot of money, not increasing yield, and possibly negatively impacting the oat test weight and marketability. This cost becomes more marked as fertilizer costs increase. In addition, the growers have to pay interest on their operating loan for those inputs for an extra 6 months. Consequently, they are revising their decision-making process around taking out bluegrass fields and try to make that decision in the fall.

Observations

The farmers have been able to amend the oat test weights to an acceptable level by cleaning the seed, which may remove awns from the grain so it packs tighter. Waldern oats is a combination grain/forage variety, which provides the growers with a dual market. They did find that high nitrogen applications tended to correlate with high nitrate levels in the straw. They had to blend it off in some years as nitrates can be toxic to cattle (ruminant livestock).

Testing the Efficacy of Biocat 1000™ Residue Digester on Cereal Stubble (Four Lakes)

Goal

Test the efficacy of a commercial residue digester, Biocat 1000™, for residue management in fall- and spring-seeded cereals in a direct seeding system.

The grower cooperators at Four Lakes are committed to direct seeding and want to take every opportunity to improve soil health and structure on their farms. Biocat 1000™, a product of Bioburst 'n Grow, is a nutrient solution that is intended to enhance the activity of naturally occurring soil microbes that break down crop residue. In this it is different from many other residue digester products consisting of microbial organisms that act directly on the straw. These microbial products have typically not proven effective in the relatively dry climate of eastern Washington. According to Bioburst 'n Grow, Biocat had performed well in the Midwest and other regions with high rainfall, but they did not have replicated data regarding its performance in dryland eastern Washington.

The farmers at Four Lakes decided to evaluate Biocat in 2 trials: one that compared Biocat with a control treatment that lacked Biocat, and another trial that included the presence and absence of disking in conjunction with Biocat (a total of 4 treatments). In the third year, they included other Bioburst 'n Grow products. They used Colorburst™ as a foliar feed included with the post-emergent herbicide in both trials, and in the 4-treatment trial they also included Seedburst™ as a seed treatment and Greenburst™ with the starter fertilizer.

Methods

The farmers selected sites for the 2-treatment (Biocat vs. No Biocat) and the 4-treatment (Biocat vs. No Biocat) and (Disking vs. No Disking) trials. The 2-treatment trial had 5 replications and the 4-treatment trial had 4 replications. We laid out the plots in the fall of 2000, and maintained the sites and treatments in those exact locations for the next 3 seasons to provide for an accumulative effect of the Biocat.

The farmers applied Biocat following harvest at 35 oz per acre in 10 gal water to the relevant plots. Where applicable they disked the plots in the fall. Immediately following these treatments, we collected residue samples from each plot, clipping off all the standing stubble within a wire ring (measuring 1 square yard) placed randomly within the plot. We took 3 residue samples per plot for the 2-treatment trial and 2 for the 4-treatment trial. We repeated this procedure in the spring (March) at different random sites within each strip.

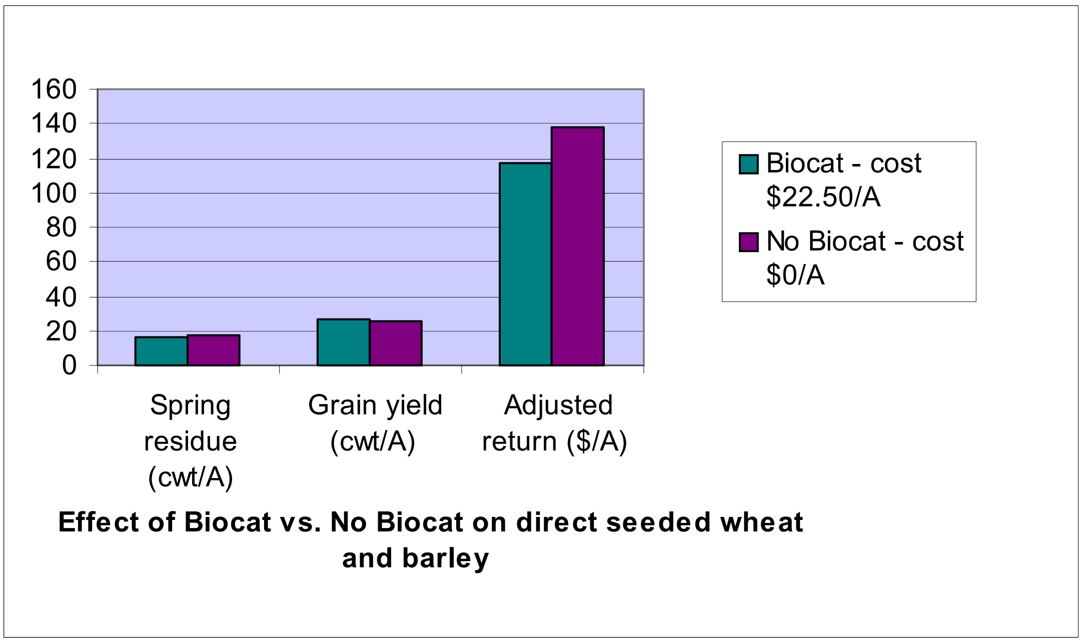
The farmers seeded all the trials with a Concord air drill with Anderson openers on 4-inch paired rows with 10-inch spacing. The crop sequence for the 4-treatment site was: 2001 - Baronesse spring barley seeded into 60 bu Madsen/Eltan residue, 2002 - 377S hard white spring wheat seeded into 1 ton Baronesse spring barley residue, and 2003 - 377S hard white spring wheat seeded into 40 bu 377S residue. The crop sequence for the 2-treatment site was: 2001 - Madsen/Eltan winter wheat seeded into 45 bu Alpowa spring wheat residue, 2002 - Stratus feed barley seeded into 50 bu Madsen/Eltan winter wheat residue, and 2003 - Nu Horizon hard white winter wheat seeded into 1.4 ton Stratus feed barley residue.

In 2003, the farmers used Seedburst (2 oz dry/100lb seed) sold as an additional seed treatment and Greenburst (10 oz/A) with the starter fertilizer on the Biocat strips in the 4-treatment trial. In both trials they also included Colorburst (8 oz/A) with the post-emergent herbicide with the intent of increasing yield and chemical uptake.

Results and Discussion

Figure 5 summarizes the effect of Biocat treatments, and Figure 6 shows the effect of disking on wheat and barley crops at both trial sites for 2001 and 2002. The 2003 data is not included in these charts because the growers included additional products that year. The complete data is shown in Appendix Table 4. Residue and grain yields are in cwt/A in order to use the same scale for the whole graph.

Figure 5. Effect of fall applications of Biocat residue digester on subsequent wheat or barley crops at Four Lakes, WA, from 2001 to 2002.

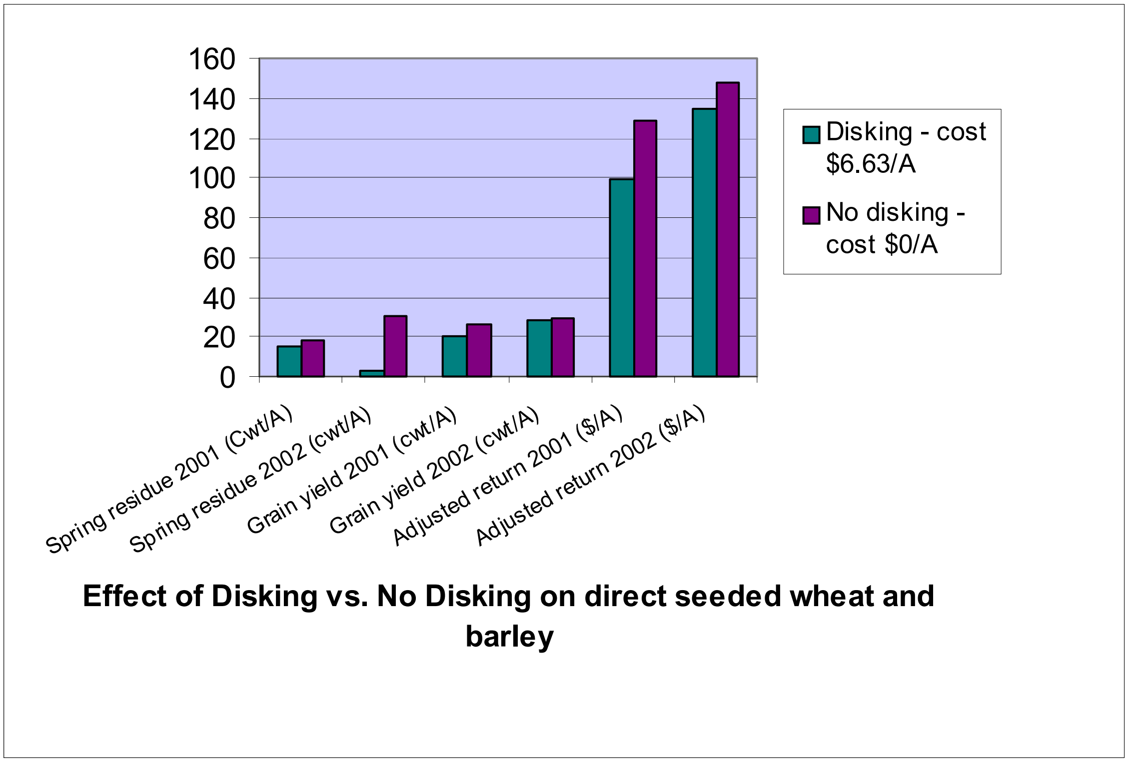


Adjusted return was the gross economic return on a treatment less the cost of the Biocat or disking treatment *only* (no seeding, herbicide, harvest costs). The cost for Biocat treatments was the cost of the product ($18/A) plus application cost ($4.50/A). The cost of disking was $6.63/A, which was a *total cost* that included ownership, depreciation, fuel, maintenance, and wear and tear on the equipment.

Across both trials and for both years (Figure 5), the Biocat and No Biocat treatments had very similar residue levels in the spring (Biocat was applied in the fall with the intention of breaking down residue over the winter). Also, grain yields for both treatments were statistically the same, i.e., Biocat did not provide any yield or residue management advantages. At a cost of $22.50/A (for the product plus application costs), the adjusted return for the Biocat treatments was significantly less than for the No Biocat treatments.

The costs for the additional products used in 2003 were: Seedburst $3.50/A, Greenburst $6.00/A, and Colorburst $6.00/A. We analyzed the data from these 2 trials separately (Appendix Table 5). For the 2-treatment trial that included Biocat and Colorburst vs. the check, there was no significant effect on yield from the bio-additives, but the extra cost of these products ($28.50/A including Biocat application) significantly reduced the adjusted return ($246.15/A vs. $274.40/A for the check). In the 4-treatment trial, the combined additional products did provide a statistical yield benefit in this season, but the additional costs made the adjusted returns significantly less ($21.91/A) for this treatment (Appendix Table 5).

Figure 6. Effect of fall disking on subsequent wheat or barley crops at Four Lakes, WA, from 2001 to 2003.



We have shown the effects of the disking treatment for each year (Figure 6) because the differences were not consistent for both seasons. However, the trends were similar in both 2001 and 2002. The disked strips tended to have lower levels of residue in the spring, but the size of this difference was not consistent across years. Disking in the fall significantly reduced grain yield and adjusted return for the spring crop the following year. This reduction was greater in 2001, which was a dry year, and the disking probably increased moisture loss and reduced crop yield, and also test weight of the grain.

In 2003, the disking data was analyzed separately from the other years because of the additional products applied (Appendix Table 6). Disking in this season provided a significant yield advantage (321 lb/A). But, while the adjusted returns tended to be greater ($13.69/A) for disking in this season, this difference was not statistically significant and might not be repeatable.

Observations and Conclusions

The farmer cooperators noticed the straw that was treated with Biocat disintegrated well when harrowed. In 2003, they dug some plants to show at a field tour and the roots did look bigger and healthier from the plots treated with the Biocat and companion products. In 2002, we sent soil tests for analysis by Soil Foodweb, Inc., who did a qualitative, microscopic examination of the microbes present in the samples. They noted that so far the Biocat had not effectively encouraged the growth of beneficial microorganisms.

Overall, the years of the study were dry and not ideal for testing Biocat. However, the economics of a product needs to benefit the farmer, and the trials clearly did not demonstrate economic benefit from using Biocat and its companion products, though they did increase crop yield in 2003 only.

Using a Rotary Subsoiler to Increase Water Infiltration and Yield with Direct Seeded Winter Wheat (Deep Creek)

Goal

To determine whether fall rotary subsoiling improves water infiltration and yield in direct seeded winter wheat.

The rotary subsoiler has been used intermittently in eastern Washington as a tool to aid water infiltration and to prevent soil erosion that can be intense when rain falls on frozen ground. During these events, sheet erosion may occur as the whole top layer of soil thaws and sloughs off.

The 15-ft rotary subsoiler (Figure 7) punches holes in the ground that are 22 inches deep, 1 inch wide and 30 inches apart, and are offset from row to row. The theory is that if the rotary subsoiler is used at the appropriate time, the holes will remain open, allowing water to run down into the soil profile instead of running off the slope at surface level and taking soil with it. In addition to reducing soil erosion, this should increase the moisture available to the crop the following season.

Figure 7. Paul Gross (center) with his rotary subsoiler used in the trials.

The farmer cooperators wanted to test whether using the rotary subsoiler in the fall after direct seeding winter wheat did increase the yield of that crop.

Methods

We laid out test plots in the fall prior to seeding winter wheat, with 5 replications of the 2 treatments, rotary subsoil and no subsoiling. Each year the farmer seeded Quantum Hybrid 7817 soft white winter wheat using a 55-ft Conservapak drill with hoe openers set on 12-in rows. In the 2001 season, the previous crop was IMC 105 canola (850 lb/A); in 2002, it was chemical fallow; and in 2003, it was 55-bu Quantum Hybrid 7817.

In the fall of 2000 (2001 crop season), early, heavy snowfall precluded the cooperators from doing the rotary subsoiling until March, so we did not include this year's data in the analysis. The next 2 years they performed this operation in the fall after the winter wheat had emerged. We took soil tests down to 4 feet in the spring, and also collected plant stand and weed count data in the plots.

Results and Discussion

The most relevant information from this study of the effects of rotary subsoiling on winter wheat are shown in Figure 8; complete results are in Appendix Table 6.

Figure 8. The effect of fall rotary subsoiling in newly emerged winter wheat on the development of that crop.

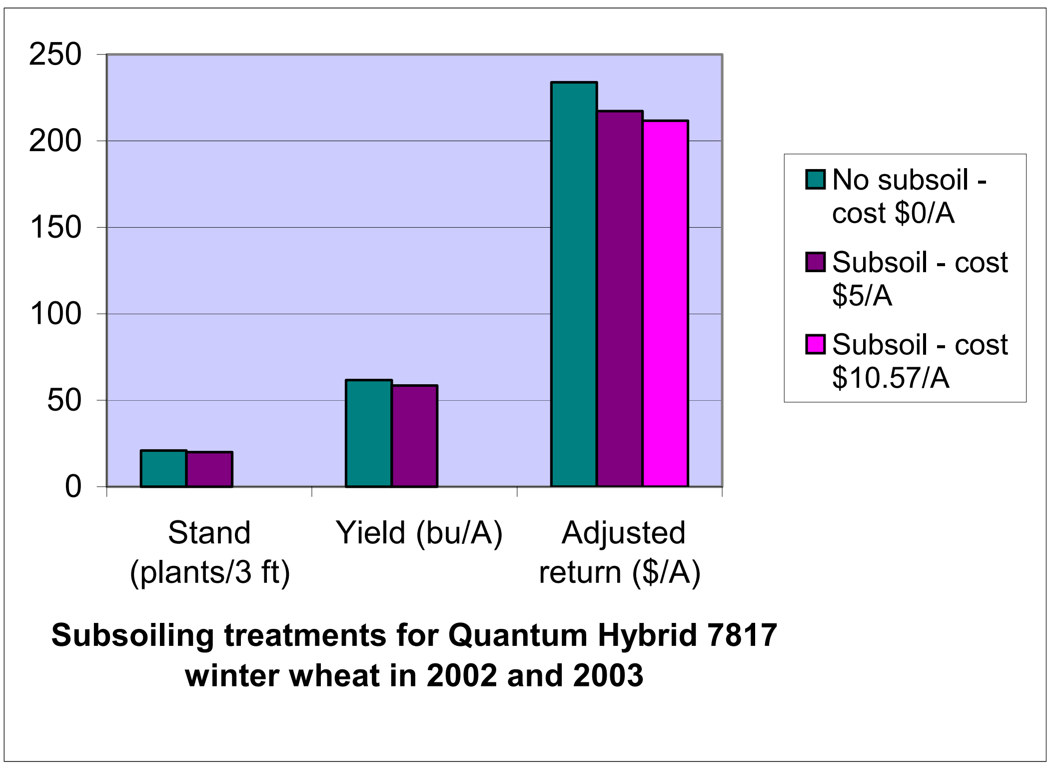


Figure 8 includes data from the 2002 and 2003 crop seasons only because in 2001, the rotary subsoiler treatment was performed in the spring instead of the fall, due to early snow. Stand count was the number of plants per 3 feet of row, and the value for each plot was the mean of 6 randomly located counts.

Adjusted return was the gross economic return on a treatment less the cost of the treatment *only* (no seeding, herbicide, fertilizer, harvest costs). We used *total costs* that included ownership, depreciation, fuel, maintenance, and wear and tear on the equipment. We used 2 costs for the subsoiling treatment;

$5/A was the grower's estimate, and $10.57 was the WSU estimate that we calculated using the MachCost Program. We used the target grain price of $3.80/bu for wheat.

Plant stand counts (taken in the spring) were consistently less in the subsoil plots (20 plants/yd) than in the check plots (21 plants/yd). Yields were similar in both treatments; 61.6 bu/A in the check plots vs. 58.5 bu/A in the subsoil plots. However, in 2002, the subsoil plots yielded significantly less than the check plots. In this season, the subsoiling treatment was performed after the crop had emerged. The subsoil plots had thin, light streaks that were visible from the combine. They also stayed green longer than the check plots. The yield reduction was possibly due to disease that the subsoiler shanks induced by damaging the roots.

The difference between treatments for adjusted return ($16.66/A) was not significant when we used the grower estimate ($5/A) for the equipment cost. However, when we used the WSU estimate ($10.57/A), the adjusted return for the subsoil treatment was significantly less ($22.24/A) than for the check.

Unfortunately, in none of the 3 seasons that we conducted this trial was there a "rain on frozen ground" event, so we were unable to realize the full potential of the rotary subsoiler. However, under the conditions we experienced, the rotary subsoiling was not an economic practice. The cooperator will probably continue to use it on irrigated ground in order to increase water infiltration into the soil.

Observations

When subsoiling at the beginning of the 2002 season, the growers noted that the ground was really soft and they had to weight the wheels or else the shanks tended to roll the soil and young plants. It was likely this did cause some crop damage and yield loss. Prior to harvest, the subsoiled plots appeared streaked (due to variable plant vigor) and stayed greener longer than the untreated plots. They also noted some crop damage from the subsoiler in other years of the project.

Appendix A. Agronomic Data

The farmers who cooperated on this project conducted their trials to answer questions they had about transitioning to direct seeding. WSU Extension helped with design and data collection. We collected plant stand and weed count data from each trial, but these parameters are only presented where relevant. It is unlikely any differences in weed count were due to a species shift from direct seeding as only the Four Lakes trials were on the same site each year. In certain situations, weed differences may reflect the tillage treatments applied. The following tables show these variables and any statistical significance among treatments.

Table A1. The effect of stubble height on subsequent direct seeded winter and spring wheat crops at Latah, WA, from 2001 to 2003.

Treatment	Stand (plants/3 ft in 2 rows) 2001	Stand (plants/3 ft in 2 rows) 2002 δ	Stand (plants/3 ft in 2 rows) 2003	Yield (bu/A) 2001 - 2003	Adjusted return ($/A) Ω 2001 - 2003
Tall stubble (20 inches)	52.7 a Φ	29.0 a	27.9 b	52.1 a	197.91 a
Short stubble (6 inches)	49.1 b	22.9 b	31.3 a	51.2 a	183.93 b

Φ Treatment means in columns followed by different letters are significantly different at the 5% probability level.
δ Where the data is presented separately for each year, the treatment differences were not consistent from year to year.
Ω Adjusted return was the gross economic return on a treatment less the cost of the residue management treatment only (no seeding, herbicide, fertilizer, harvest costs). We used total costs that included ownership, depreciation, fuel, maintenance, and wear and tear on the equipment. We used the costs for a mower, assuming the farmer would not use his combine for mowing a whole field. The costs for the treatments were: mowing - $10.78/A, standing stubble - $0/A. The grain price ($3.80/bu) was the target price for 2001 to 2003.

Table A2. Effect of fall residue management on subsequent direct seeded spring crops at Fairfield, WA, from 2001 to 2003.

Treatment	Stand (plants/3 ft single row)	Weed count/100 ft	Barley yield (lb/A) 2001 δ	Spring wheat yield (lb/A) 2002	Lentil yield (lb/A) 2003	Adjusted return ($/A) 2001 Ω †	Adjusted return ($/A) 2002 †	Adjusted return ($/A) 2003 †	Adjusted return ($/A) 2001 ‡	Adjusted return ($/A) 2002 ‡	Adjusted return ($/A) 2003 ‡
3 - Standing stubble	31.9 a	4.7 b	2086 b	3769 a	792 ab	98.96 ab	238.66 a	94.61 a	98.97 a	238.66 a	94.60 a
1 - Fall mow (6 in high)	31.8 a	4.4 b	2285 b	3673 ab	694 b	97.32 b	221.82 b	72.06 b	97.32 a	221.83 b	72.06 b
2 - Fall disk rip + spring harrow	32.2 a	8.6 a	2729 a	3566 b	866 a	116.33 a	213.55 b	91.14 a	112.29 a	209.51 b	87.10 a

Φ Treatment means in columns followed by different letters are significantly different at the 5% probability level.
δ Where the data is presented separately for each year, the treatment differences were not consistent from year to year.
Ω Adjusted return was the gross economic return on a treatment less the cost of the residue management treatment only (no seeding, herbicide, fertilizer, harvest costs). We used total costs that included ownership, depreciation, fuel, maintenance, and wear and tear on the equipment. The costs for the treatments were: mowing - $10.78/A, harrow - $2.25/A, disk rip - $10/A (grower estimate) and $14.04/A (WSU estimate), standing stubble - $0. Grain prices were: wheat (target price) - $3.80/bu, barley (target price) - $2.21/bu, lentils (loan rate) - $11.94/cwt.
†Disk ripper cost (grower estimate) - $10/A.
‡ Disk ripper cost (WSU estimate) - $14.04/A.

Table A3. Effect of different levels of fall-applied nitrogen on Waldern spring oats direct seeded into Kentucky bluegrass residue at Valleyford, WA, from 2001 to 2003.

Treatment	Stand (plants/3 ft single row)	Test weight (lb)	Yield (lb/A)	Adjusted return ($/A) Ω
50 lb fall N	34.6 a Φ	33.2 a	2929 a	108.24 a
100 lb fall N	33.0 a	32.3 a	3109 a	98.03 a
150 lb fall N	36.2 a	32.2 a	3057 a	79.06 b

Φ Treatment means in columns followed by different letters are significantly different at the 5% probability level.
Ω Adjusted return was the gross economic return on a fertilizer treatment less the cost of the treatment only (no application, seeding, herbicide, harvest costs). The costs for the treatments included all elements applied (dry 29.5-5-0-3.5), but did not include application costs, which were the same across treatments. Treatment costs were: 50 lb/A N - $16.67, 100 lb/A N - $33.33, 150 lb/A N - $50.00, and starter fertilizer - $14/A. We used the target grain prices for oats of $1.40 per 32-lb bushel. However, this price does not accurately reflect market value of the crop which was not marketable below 36 lb/bu.

Table A4. Effect of Biocat and disking (presented separately) as residue management tools on subsequent winter and spring wheat and barley at Four Lakes, WA, from 2001 to 2002.

Treatment	Fall Residue (lb/A) 2001 - 2002	Spring Residue (lb/A) 2001 - 2002	Spring Residue (lb/A) 2001 δ	Spring Residue (lb/A) 2002	Stand (plants/3 ft of 2 rows) 2001 - 2002	Test weight (lb) 2001 - 2002	Test weight (lb) 2001	Test weight (lb) 2002	Yield (lb/A) 2001 - 2002	Yield (lb/A) 2001	Yield (lb/A) 2002	Adjusted return ($/A) 2001 - 2002 Ω	Adjusted return ($/A) 2001	Adjusted return ($/A) 2002
Biocat	3203 a Φ	1602 a			39.1 a	56.3 a			2612 a			116.62 b		
No Biocat	2952 a	1741 a			38.9 a	56.3 a			2599 a			138.45 a		
Disk	2687 b		1547 a	336 b	38.7 a		56.8 a	55.2 b		2058 b	2826 a		99.06 b	134.72 b
No Disk	3468 a		1783 a	3022 a	39.3 a		57.3 a	56.2 a		2606 a	2931 a		128.42 a	147 95 a

Φ Treatment means in columns followed by different letters are significantly different at the 5% probability level. δ Where the data is presented separately for each year, the treatment differences were not consistent from year to year.
Ω Adjusted return was the gross economic return on a treatment less the cost of the treatment only (no seeding, herbicide, fertilizer, harvest costs). Biocat costs do not include application costs. For disking we used total costs that included ownership, depreciation, fuel, maintenance, and wear and tear on the equipment. The costs for the treatments were: Biocat - $18.00/A for 35 oz rate, Biocat application - $4.50/A, disking - $6.63/A, control - $0. Grain prices were: wheat (target price) - $3.80/bu, barley (target price) - $2.21/bu.

Table A5. Effect of Biocat (plus Seedburst, Greenburst, and Colorburst) and disking (presented separately) as residue management and growth enhancement tools on subsequent hard white winter (Nu Horizon) and spring wheat (377S) at Four Lakes, WA, in 2003.

Treatment	Fall Residue (lb/A) 2001 - 2002	Spring Residue (lb/A)	Stand (plants/3 ft of 2 rows) 2001 - 2002	Weeds (count/100 ft)	Test weight (lb)	Yield (lb/A)	Adjusted return ($/A) Ω
Biocat + Seedburst + Greenburst + Colorburst	1677 a Φ	1003 a	41.2 a	20 a	62.2 a	2885 a	141.42 b
No Biocat	1535 a	1003 a	41.1 a	18 a	62.1 a	2631 b	163.33 a
Disk	1584 a	698 b	41.6 a	17 a	62.1 b	2919 a	159.22 a
No Disk	1628 a	1309 a	40.7 a	21 a	62.3 a	2598 b	145.53 a
Biocat + Colorburst	2030 a	946 a	36.1 a	19 a	59.4 a	4337 a	246.15 b
Control	2159 a	980 a	35.6 a	18.4 a	59.6 a	4332 a	274 40 a

Φ Paired treatment means in columns followed by different letters are significantly different at the 5% probability level.
Ω Adjusted return was the gross economic return on a treatment less the cost of the treatment only (no seeding, herbicide, fertilizer, harvest costs). For disking we used total costs that included ownership, depreciation, fuel, maintenance, and wear and tear on the equipment. The costs for the treatments were: Biocat - $18.00/A for 35 oz/A rate, Biocat application - $4.50/A, Seedburst - $3.30 for 2 oz/100 lb seed, Greenburst - $6/A for 10 oz/A, Colorburst - $6/A for 8 oz/A, disking - $6.63/A, control - $0. Grain prices were: wheat (target price) - $3.80/bu. Seedburst, Greenburst, and Colorburst were applied as part of other management practices, so did not have an application cost.

Table A6. Effect of using a rotary subsoiler to increase soil water infiltration and yield in direct seeded winter wheat (Quantum Hybrid 7817) at Deep Creek, WA, from 2001 to 2003.

Treatment	Stand (plants/3 ft single row)	Yield (bu/A)	Adjusted return ($/A) Ω †	Adjusted return ($/A) ‡
No subsoiler	21 a Φ	61.6 a	233.96 a	233.97 a
Subsoiler	20 b	58.5 a	217.3 a	211.73 b

Φ Treatment means in columns followed by different letters are significantly different at the 5% probability level.
Ω Adjusted return was the gross economic return on a treatment less the cost of the management treatment only (no seeding, herbicide, fertilizer, harvest costs). We used total costs that included ownership, depreciation, fuel, maintenance, and wear and tear on the equipment. The costs for the treatments were: No subsoiler - $0/A, Subsoiler (grower estimate) - $5/A, Subsoiler (WSU estimate) - $10.57/A. Grain price was: Wheat (target price) - $3.80/bu.
† Subsoiler cost (grower estimate) - $5/A.
‡ Subsoiler cost (WSU estimate) - $10.57/A.