Cover Crop Mixes for Soil Health

USDA-NRCS Corvallis Plant Materials Center

Annual Progress Report prepared by Annie Young-Mathews, January 2014

Introduction and Methods

In 2012-2013, the Corvallis Plant Materials Center (PMC) completed the first year of a 3-year national study looking at the effects of different cover crop mixes and seeding rates on soil health. Similar studies are being carried out at PMCs in CA, WA, MO, ND, MD, and FL. The results from this study will help inform local recommendations for effective cover crop mixes and seeding rates to control weeds and add organic matter, N, and biological activity to depleted soils. This report is just a preliminary analysis of data from the first year of the study, and conclusions may change over the next two years as more data are collected.

Three mixes are being tested along with a non-cover cropped control (Table 1). Each mix was seeded at three rates: 20, 40, and 60 seeds per square foot, which, depending on the mix, ends up being a total seeding rate of about 35 to 110 pounds per acre.

We drilled the cover crops on 6-inch spacing in early October after the first rains and terminated them 6 months later in early May by rolling and then spraying them prior to no-till seeding sweet corn in early June.

Table 1. *Cover crop mixes in Corvallis PMC Soil Health Study (% mix is on seed number basis, not weight basis).*

Mix	Grasses	Legumes	Brassicas
2-species	50% cereal rye	50% crimson clover	-
4-species	45% cereal rye	22.5% crimson clover, 22.5% hairy vetch	10% forage radish
6-species	22.5% cereal rye, 22.5% oats	22.5% crimson clover, 22.5% hairy vetch	5% forage radish, 5% turnips

Summary of Preliminary Results

- All cover crop mixes reached 95% total cover by 60 days after planting, except the 2-species mix seeded at 20 or 40 seeds/ft^2, which had only slightly over 80% cover
- Weed cover and biomass was lowest in the mixes that contained brassicas (4- and 6-species) seeded at 40 or 60 seeds/ft^2
- Cover crops increased soil organic carbon levels, decreased compaction, and increased the Soil Health Tool score
- At cover crop termination, soils were cooler and wetter in cover cropped plots than the non-cover cropped control plots
- All treatments produced about 4.5 tons dry matter per acre, but the 2-species mix had a lower N content
- Sweet corn yields were highest in the plots with the 4-species mix at 40 seeds/ft^2; the 2013 seed cost for this mix was about $62/acre
- Slug control appears to be a major challenge in successfully managing a no-till cover cropped rotation in the Willamette Valley
- There are tradeoffs in managing complex cover crop cocktails between gaining more total biomass and plant available nitrogen by terminating later in the spring (early May), and keeping brassicas from going to seed after they flower in March

Results and Discussion

Early Cover and Weed Suppression

Cover crops are often planted in order to hold soil in place and provide cover to help prevent erosion from wind and rain, as well as to suppress weeds (Clark, 2007). The brassicas (radish and turnip) in our plots were quick to germinate and grow in the fall. Their broad leaves provided early cover and helped out-compete many of the usual annual winter weeds. Total cover at 30 days after planting (DAP) averaged 62% for all of the cover crop mixes, which was almost twice that of the weedy control at only 35% cover (Figure 1). By 62 DAP, both seed mix and seeding rate had significant effects on total percent cover. The 4- and 6-species mixes containing the brassicas had the most total cover at 95%, while the 2-species mix seeded at 20 and 40 seeds/ft^2 had an average of only 82% cover, and the control had only 65% cover. This early broadleaf cover presumably made those plots more resistant to erosion and surface crusting from rain drop impaction over the winter.

The different seeding rates and cover crop mixes also significantly affected weed cover (Figure 2). At 30 DAP, weed cover was already higher in the plots seeded at the lowest rate and in those with the 2-species mix. By 62 DAP, those differences were more obvious, and remained so until the legumes took off in spring (around 151 DAP in March). By 97 to 123 DAP, the higher rates of the 4- and 6-species mixes had a cover crop canopy that was almost completely closed in over the weeds that germinated initially. The 20 seeds/ft^2 rate appeared to be too light to suppress or out-compete early weeds. The 2-species mix was also ineffective at controlling weeds, perhaps because the crimson clover and cereal rye didn't provide the early leaf cover that the brassicas (especially the radish) provided in the other mixes.

At cover crop termination in May, weed biomass as a percentage by weight of the total aboveground cover crop biomass was almost three times greater in the 2-species mix and the lowest seeding rate (Table 2). Because there were no significant differences in weeds between the 4- and 6-species mix or the 40 and 60 seeds/ft^2 rates, it appears that a 4-species mix at 40 seeds/ft^2 is sufficient from a weed suppression standpoint, and would provide a cost savings over a more complex mix or higher seeding rate. Better early cover for erosion control may have been achieved by planting earlier (mid-September) when soil temperatures were warmer, but this would have required irrigation since our first rains in 2012 didn't fall until mid-October.

Figure 1. *Effect of 3 cover crop mixes and 3 seeding rates on total percent cover from November 2012 through April 2013 in Corvallis PMC trial.*

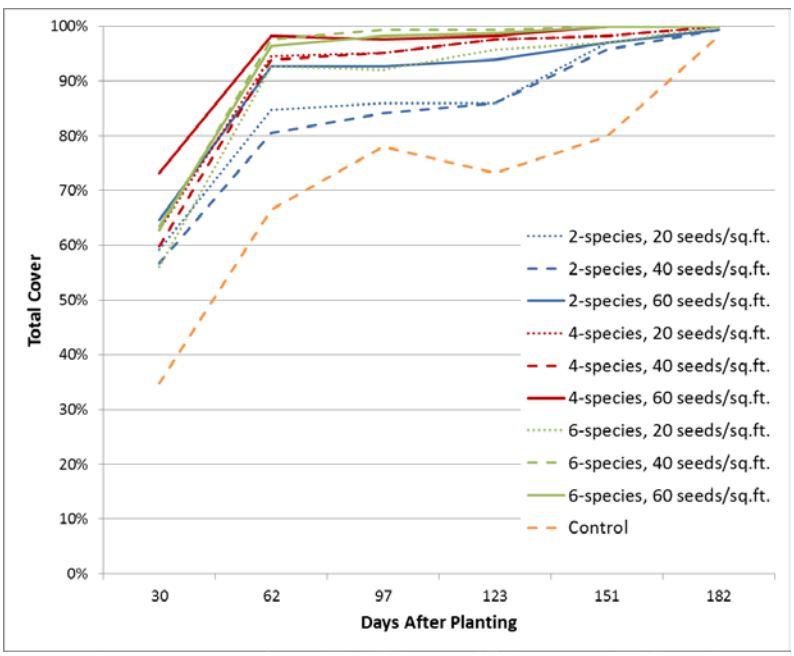
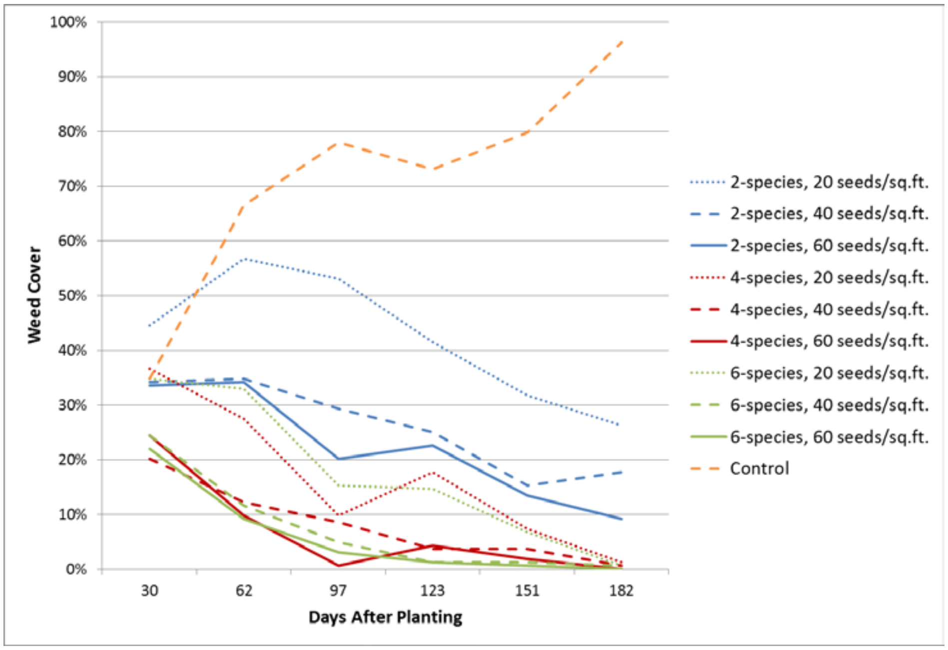


Figure 2. *Effect of 3 cover crop mixes and 3 seeding rates on weed cover from November 2012 through April 2013 in Corvallis PMC trial.*



Nitrogen Benefits and Improved Bottom Line

An important benefit of leguminous cover crops is their ability to provide plant-available nitrogen (PAN) to the subsequent cash crop, thus reducing costs on purchased N inputs such as fertilizer, compost, and manure (Sullivan and Andrews, 2012). At cover crop termination in early May, all three cover crop mixes had produced an average of 4.5 tons dry matter (DM) per acre, which was over twice the weedy biomass production from the non-cover cropped plots (Table 2). The N content of the aboveground DM was higher in the 4- and 6-species mixes than the 2-species mix or the control. According to the OSU cover crop calculator (Andrews et al., 2012), that would result in an estimated PAN of 13 lbs/acre for the 2-species mix, 54 lbs/acre for the 4-species mix, and 59 lbs/acre for the 6-species mix, assuming the cover crop was tilled to incorporate it at the time of termination. However, since our cover crops were killed by rolling and spraying, residue was left on the surface to decompose, and it is likely that the PAN was released to the corn crop more slowly than if it had been incorporated.

Table 2. *Comparisons of average aboveground biomass dry matter, N content, and percent composition according to three cover crop mixes (2-, 4-, and 6-species) and 3 seeding rates (20, 40, and 60 seeds/ft^2) at the Corvallis PMC in 2013. Values within the same column followed by the same letter are not significantly different in Tukey HSD means comparisons at α=0.05.*

Treatment	Dry Matter (tons/ac)	% N in Dry Matter	Cover Crop Biomass Composition			
			Grasses	Legumes	Brassicas	Weeds
2-species	4.41 a	1.4 b	63% a	27% b	0% b	10% a
4-species	4.63 a	2.2 a	28% b	44% a	24% a	4% b
6-species	4.55 a	2.3 a	29% b	44% a	24% a	3% b
20 seeds/ft^2	4.44 a	2.0 a	37% a	38% a	16% a	9% a
40 seeds/ft^2	4.68 a	1.9 a	40% a	38% a	18% a	4% b
60 seeds/ft^2	4.48 a	1.9 a	43% a	38% a	15% a	4% b
Control	2.17 b	1.9	-	-	-	100%

Figure 3. *Corn plants 40 days after planting in plots previously seeded with: (left) 6-species cover crop mix at 40 seeds/ft^2; (middle) 2-species mix at 40 seeds/ft^2; and (right) non-cover cropped control plot. No chemical fertilizer was added to plots prior to planting the corn.*

Almost immediately there were dramatic differences in the growth of the sweet corn planted into the different treatments, presumably largely due to these differences in PAN. Plots planted with 40 or 60 seeds/ft^2 of the 4- and 6-species mixes produced tall healthy corn with dark green leaves, while the control, 20 seeds/ft^2, and 2-species mixes showed varying degrees of stunting and yellowing (Figure 3).

Sweet corn was harvested from all plots in early September, and the highest yielding treatment at 5.7 tons/acre was the 4-species mix seeded at 40 seeds/ft^2 (Figure 4). While this yield is about half the average sweet corn yield for western Oregon of 10 to 12 tons/acre (Hart et al., 2010), it was achieved without the addition of any purchased fertilizers, relying solely on nitrogen fixed by the legumes in the cover crop. This cover crop nitrogen benefit presumably could translate into substantial savings on fertilizer costs in a commercial system. Any savings on inputs would of course have to be balanced against the costs of the cover crop seed (Table 3) and associated costs for planting and terminating the cover crop.

There are also some tradeoffs in deciding when to kill complex cover crop mixes such as these. In order to maximize legume growth and PAN from the legumes, it is best to wait until late April or early May when the legumes are at the budding growth stage, but PAN from the cereal residues peaks at tillering stage (mid- to late March) and then declines quickly and is actually negative by the time cereal heads are visible in late May to June (Sullivan and Andrews, 2012). Brassicas provide PAN when killed at flowering growth stage (March), and can become a weed problem in subsequent crops if allowed to set seed, which they did in our trial by early May.

Figure 4. *Average sweet corn yield following one season of cover cropping according to 3 cover crop mixes (2-, 4-, and 6-species mix) and 3 seeding rates (20, 40, and 60 seeds/ft^2) at Corvallis PMC in 2013. Means with the same letter above the bar are not significantly different in Tukey HSD comparisons at α=0.05.*

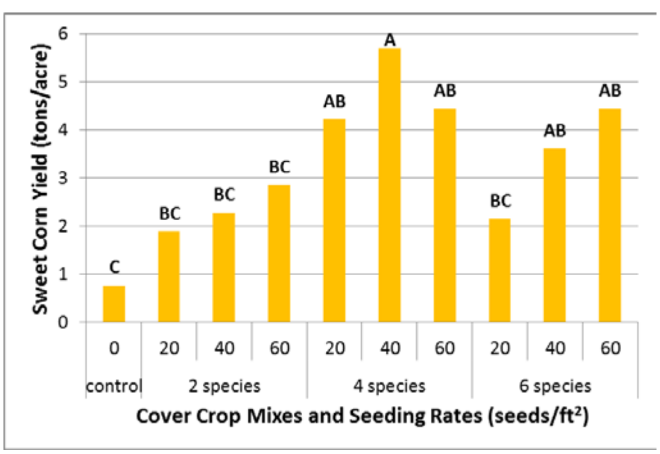


Table 3. *Approximate costs of the different cover crop seed mixes and seeding rates in the Corvallis PMC trial. Costs are based on 2013 quotes from commercial vendors in the Willamette Valley.*

Cover Crop Mix	Seeding Rate (seeds/ft^2)	Seed Cost (per acre)
2-species	20	$12.78
	40	$25.57
	60	$38.35
4-species	20	$31.20
	40	$62.39
	60	$93.59
6-species	20	$34.41
	40	$68.82
	60	$103.24
Control	0	$0.00

Enhancing Soil Health

Cover crops are often planted to improve soil health, including enriching soil organic matter, enhancing nutrient cycling, and improving soil structure. However, building soil health is a slow process and changes aren't expected to happen overnight. Most soil parameters in our trial did not show significant differences according to treatments (seeding rates and mixes) after only one year of cover cropping. However, there were some overall improvements in soil organic carbon, C:N ratios, soil compaction, and Soil Health Calculation values.

Soil organic carbon levels increased in all cover cropped treatments from an average of 96 ppm prior to cover crop planting to 218 ppm at cover crop termination. The soil organic carbon to nitrogen ratio (C:N) also increased from 9.6 to 11.7 after one season of cover cropping. At cover crop termination, the 2-species mix had a higher organic C:N ratio than the 4- and 6-species mixes (12.2 vs. 11.5, $P<0.05$), probably due to the dominant rye cover which has a lower N content and leaves more residual matter than the legumes or brassicas.

We measured the firmness (compaction) of the soil over three depth increments with a soil compaction tester. A resistance of 300 pounds per square inch (psi) generally limits root growth, but roots may still penetrate the soil if natural pores or cracks are present. By May 2013, surface soil compaction in the 0–6" layer decreased from an average of 291 to 78 psi, and sub-surface compaction at the 6–12" depth decreased from 284 to 226 psi, while deep soil compaction (12–18") increased slightly from 333 to 371 psi. Subsoil compaction at the 6–12" depth was significantly less in plots seeded with the 4- and 6-species mixes (average resistance of 213 and 209 psi, respectively) than in those with the 2-species mix (257 psi). This decreased compaction in the 4- and 6-species mixes could be due to a "tillage" effect from the large taproots of the radish and turnip.

While it can be difficult to quantify the overall health of a soil system, Dr. Rick Haney of USDA-ARS developed a Soil Health Tool (SHT) that attempts to do just that (Woods End Laboratories, 2014). The SHT incorporates the balance of organic soil carbon and nitrogen and their relationship to microbial activity. A soil health calculation number can vary from 0 to over 50, and should increase over time if the soil is being managed sustainably. In our trial, the Soil Health Calculation increased significantly from 3.98 at cover crop planting to 6.70 at termination ($P<0.001$), but there were no distinguishable differences among treatments yet. We will continue to monitor this number over the next two years of the study to gauge the effects of our different management practices.

Figure 5. *Photos of Corvallis PMC plot 106 with 4-species cover crop mix seeded at 40 seeds/ft^2. In mid-December (left) 62 days after planting (DAP), there was about 95% cover. By mid-March (middle), at 151 DAP, the radishes were in full bloom. In early May (right), 207 DAP and immediately before cover crop termination, the rye was heading out and the crimson clover and hairy vetch were flowering.*

Delayed Commodity Crop Planting Concerns

One potential drawback of planting cover crops is that they generally delay soil warming and drying in the spring, which may delay tillage and planting of the commodity crop. At cover crop termination in May 2013, our non-cover cropped control plots were indeed warmest and driest at 71°F and 17.3% moisture. Plots seeded with the 2-species mix were warmer and drier than the 4- and 6-species mixes (64° vs. 61 and 60°F, respectively, and 17.3% vs. 18.9 and 18.8% gravimetric water content, respectively). However, the sweet corn commodity crop wasn't planted until a month later in early June, and by that time some of the soil temperature and moisture differences may not have been as pronounced. Unfortunately we don't have temperature and moisture data for commodity crop planting in June, but we plan to collect that data in 2014.

Slug Predation

Slugs are a consistent problem for seedlings in the rainy fall and winter conditions of western Oregon and Washington, but are especially problematic in no-till and conservation till systems where the surface residue provides the ideal humid habitat for slugs to feed and breed. According to the Pacific Northwest Insect Management Handbook, "tillage is the best way to manage slugs" and "control is proportional to tillage frequency, depth, and efficiency" (Dreves and Fisher, 2013). Thus, in systems where tillage is being reduced for soil health benefits, slug pressure that can't be managed economically via biological control (predation by birds and soil predators such as beetles and nematodes) will have to be done through chemical control using slug bait.

We had very high slug pressure on both the no-till sweet corn seedlings in June and the second year no-till cover crop seeding in October of 2013. We applied metaldehyde slug bait shortly after emergence of both crops, but there was already extensive localized damage to the young seedlings and the swollen cereal seeds in the cover crop. Bait may be more effective if applied at the time of seeding to prevent early damage to germinating seedlings. However, slug bait is expensive and is a cost that should be considered in the total cost-benefit analysis of no-till or reduced-tillage systems. For example, Deadline® metaldehyde bait applied at the recommended 10-40 lbs/acre costs $18.50 to $74.00 per acre, while Organic-certified Sluggo® iron phosphate bait applied at the recommended 24-44 lbs/acre costs about $51.50 to $94.40 per acre.

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