USDA United States Department of Agriculture

Cover Crop Mixes for Soil Health

Year 1 Progress Report

USDA Natural Resources Conservation Service Brooksville Plant Materials Center
Annual Progress Report Prepared by Janet Grabowski and M.J. Williams

Summary of Preliminary Results

- Regardless of mixture, the 60 seed per square foot treatment reached 90% cover by about 2 months after planting. All cover crop treatments, including the control, achieved 90% canopy coverage within 3 months post planting. This is acceptable by NRCS standards, but only the cover crop plots produced more than 4000 pounds/acre of biomass as required for this conservation practice.
- Lack of rainfall after planting affected nodulation and growth of the legumes in the mixes, and mixtures were dominated by cereal rye and daikon radish (if included in the mixture).
- The roots of the daikon radish pushed out of the soil when they encountered restrictive tillage layers in the soil (right).
- The roller crimper treatment was effective in terminating cereal rye and daikon radish, which were mature at termination date; for the other species, a herbicide treatment was required.
- In part due to poor legume growth, soil nitrogen levels were reduced rather than increased by the cover crop mixes and little nitrogen was available for the subsequent corn crop.

Introduction

The Brooksville Plant Materials Center (PMC), along with six other PMCs in California, Maryland, Missouri, North Dakota, Washington, and Oregon, is participating in a national study looking at the effect of different cover crop mixes on soil health. The mixes being tested in this national study are composed of regionally adapted members of the grass, legume, and forb (specifically brassicas which are members of the mustard family) functional groups planted at 20, 40, and 60 seeds per square foot. There was also a non-planted control plot with native weed cover. After termination of the cover crops, a regionally adapted commodity crop was planted in all plots. This report presents preliminary results from the first year of a planned three-year study at the Brooksville PMC. Results at the conclusion of the study may vary from those presented here as more data is collected.

Methods

The Brooksville PMC is located about 60 miles north of Tampa in the South-Central Florida Ridge. Air temperature and rainfall during the cover crop growing period are shown in Fig. 1 and 2. At this location, the two grasses in the cover crop mixtures were cereal rye (*Secale cereale*) and oats (*Avena* *sativa*). The two legumes in the mix were crimson clover (*Trifolium incarnatum*) and hairy vetch (*Vicia villosa*). The two brassicas used were daikon radish (*Rhaphanus stativus*) and rapeseed (*Brassica napus*). Mixture compositions are shown in Table 1. At this location, field corn (*Zea mays*) was the commodity crop grown.

Table 1. Species components in cover crop mixes planted in the soil health plots at the Brooksville PMC. (Note: % of mix is on seed number, not weight basis).

Mix Composition	Grasses	Legumes	Brassicas
2-species	50% cereal rye	50% crimson clover	None
4-species	45% cereal rye	22.5% crimson clover, 22.5% hairy vetch	10% daikon radish
6-species	22.5% cereal rye, 22.5% oats	22.5% crimson clover, 22.5% hairy vetch	5% daikon radish, 5% rapeseed

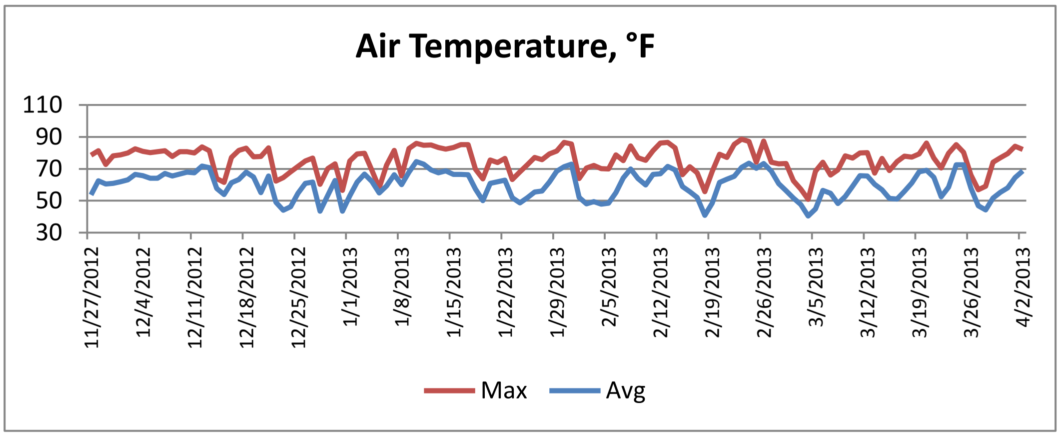

Figure 1. Maximum and average air temperature recorded at the Brooksville PMC from cover crop planting (Nov. 27, 2012) until termination (Apr. 5, 2013)

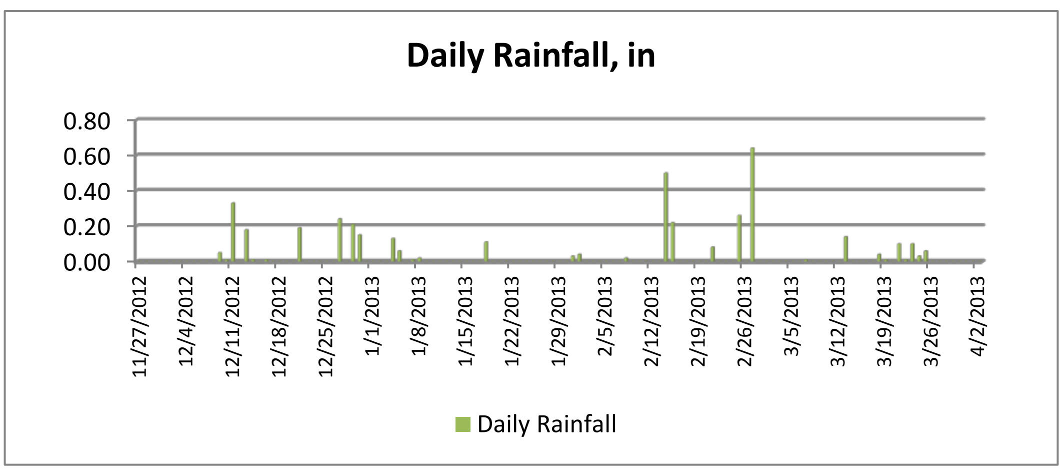

Figure 2. Rainfall recorded at the Brooksville PMC from cover crop planting (Nov. 27, 2012) until termination (Apr. 5, 2013)

The study was planted as a randomized complete block with four replicated plots of each seeding mix treatment. Because of the existing terraces on the site, blocks were not adjacent to each other and plots were somewhat smaller (24- by 45-feet) than at other locations. The soils at the site are classified as either fine sands or fine sandy loams. Soil texture analysis showed that they consisted of 90-95.5% sand, 3-6.1% silt, and 0-4.5% clay. Soil tests analyzed at the University of Florida, Institute of Food and Agricultural Sciences (UF-IFAS) Soil Testing Laboratory showed that the initial pH of the soils before planting ranged from 6.3 to 6.6.

Prior to planting the cover crops for this study, we sprayed glyphosate and thoroughly tilled the entire planting area to start with a common soil condition. We then ran a cultipacker twice over the fields to prepare for planting. Due to the sandy texture of the soils, the cultipacker used did not adequately firm the soil for the no-till drill and the soil kept piling up in front of the coulters cutting the planting furrows. To remedy this problem, we borrowed a roller from a local hay producer that we filled with water to provide increased pressure and thoroughly pack the soil (above).

The fertilizer applied based on the university soil test recommendation for each cropping system are shown in Table 2. Triple superphosphate was the P source and muriate of potash was the K source. For the two blocks that required magnesium for field corn, a mixture of muriate of potash and K-Mag fertilizer was used. Per the study protocol, no nitrogen fertilizer was applied.

Table 2. Fertilizer recommendations received from the Soil Testing Laboratory for the fall 2012 planting of the cover crop mixtures and the spring 2013 planting of field corn at the Brooksville PMC.

	Fall 2012		**Spring 2013**		
Rep	**P Rate (lb/ac)**	**K Rate (lb/ac)**	**P Rate (lb/ac)**	**K Rate (lb/ac)**	**Mg Rate (lb/ac)**
1	0	160	70	70	20
2	60	160	70	175	20
3	0	120	70	70	0
4	100	160	175	140	0

We planted the cereal rye and oats for of the cover crop mixes using a no-till drill (Truax Co. Inc., Minneapolis, MN) on November 27, 2012. We were concerned that, due to the small seed volume, the drill would not uniformly distribute the legume and brassica seed in the plots, so these seed were mixed with chicken crumbles to increase volume and were broadcast on the appropriate plots by hand the following day. After planting, the plots were cultipacked to re-firm the soil and incorporate the broadcast seed. Due to a delay in installing a new irrigation system, cover crop stand establishment was dependent upon natural rainfall during the 2012-2013 growing season (Fig. 1). Soil moisture measured shortly after planting ranged from 2.5% to 8.5% volumetric water content (VWC); below 7% VWC is considered dry for these soils.

Soil compaction was determined using a penetrometer, also called a soil compaction tester (DICKEY-john Corp., Auburn, IL), prior to planting. During the cover crop growing period, canopy cover (diagonal line transect with plant, dead organic matter, and bare soil determined every foot) and plant height was determined every 30 days until termination. Biomass dry matter (DM) production, including radish roots, and species composition was determined at termination by harvesting a 0.5 m^2 subsample in each plot, separating into species or functional groups, drying, and weighing. Nitrogen content (Dairy One, Ithaca, NY) of cover crop biomass was determined for combined aboveground biomass and separately for radish roots. Soil samples for nutrient availability and biological assessment by the Haney Test (Dr. Richard L. Haney, USDA-Agricultural Research Service, Temple, TX) were taken prior to cover crop planting and prior to commodity crop planting.

The cover crops were mechanically terminated using a roller crimper (I&J Manufacturing, Gap, PA) on April 4-5, 2013 (above). The mechanical treatment did not completely kill all of the cover crop species, so we then sprayed with a mixture of glyphosate and 2,4-D prior to planting the field corn.

The corn was planted on April 25, 2013. We did not have a row crop planter to use for this planting, so the same no-till drill as used for the small grain cover crops was modified to plant the corn. A 24-inch row spacing was achieved by blocking all but the first, fourth, and seventh drill. The target population for the corn crop was 20,000 plants per acre and the drill was calibrated to deliver 20,000 seeds per acre plus 10% or 22,000 seeds per acre. The corn crop was irrigated as needed with the new irrigation system. We hand harvested corn from the plots August 20-23, 2013, and the kernels were shelled, dried, and weighed to determine yield for each plot.

Results and Discussion

Canopy Cover

The NRCS Conservation Practice Standard Cover Crop, Code 340, specifies that canopy coverage should reach 90% or greater for most cover crop uses to be considered acceptable (NRCS, 2011). Canopy ratings for the Brooksville PMC planting showed that all plots, including the control reached 90% or greater coverage by about 3 months after planting (Fig. 3). All seed mixes at the 60 seeds per square foot planting rate exceeded 90% cover by about 2 months after planting. There did not appear to be a clear trend between length of time to 90% canopy coverage and seed mix complexity (2, 4, or 6 species) or seeding rate for the two lower seeding rates (20 and 40 seeds per square foot). For example, canopy cover for the 2-species, 40 seed rate plot reached 90% cover more quickly than the 4-species and 6-species mixes at the same planting rate. Similarly, the 4-species, 20 seed rate achieved 90% canopy cover more quickly than the 40 seed per square foot planting rate of the same species mixture. However, these differences were minor. Unless quick cover is essential for a particular conservation use, all cover crop treatments and planting rates were satisfactory by NRCS standards. The contribution of native and non-native cool-season weed species to canopy coverage was also significant, particularly in the control plots. The weeds found most frequently in the plots were cudweed [*Gamochaeta* spp. (syn. *Gnaphalium* spp.)], western tansymustard (*Descurainia pinnata*), and Florida pusley or Mexican clover (*Richardia* spp.). In the fourth replication, a significant percentage of the weed component was black medic (*Medicago lupulina*), a non-native legume that is a common cool-season weed.

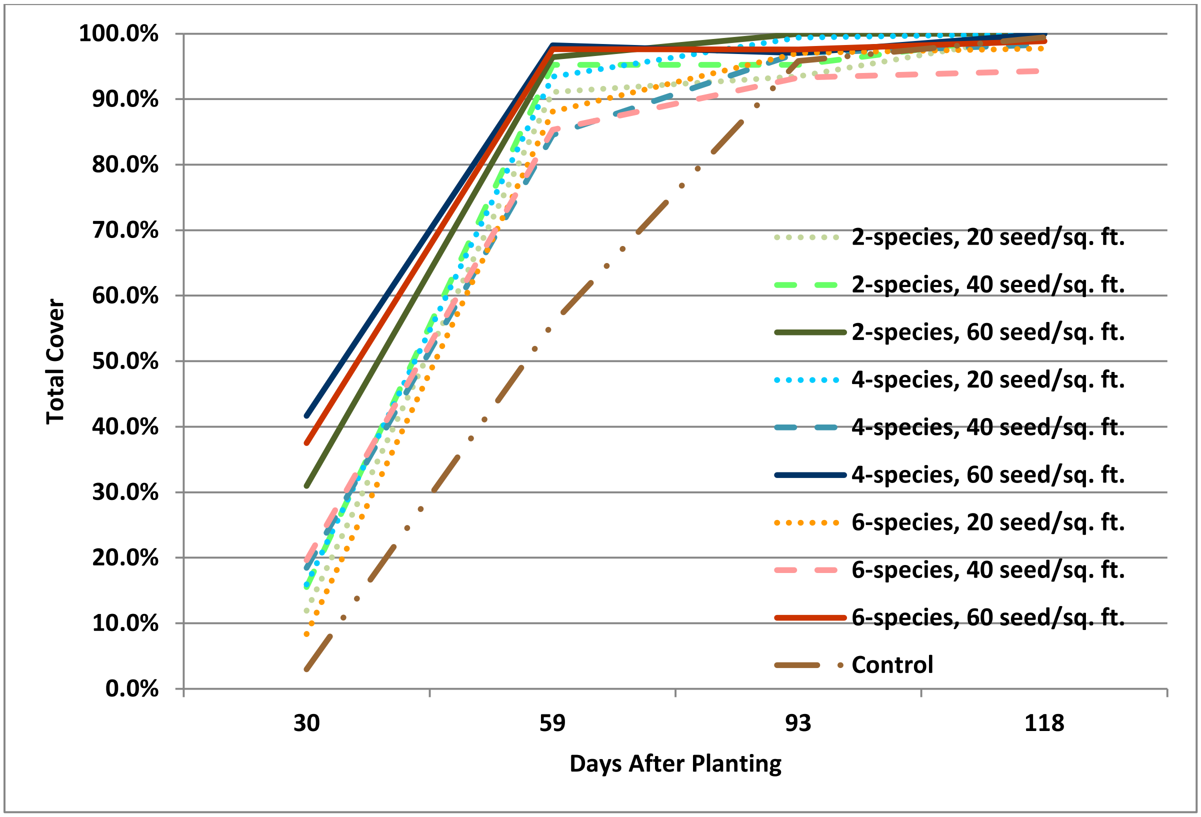

Figure 3. Percent canopy cover in the treatment plots at the Brooksville PMC rated monthly for the period November 27, when the small grain were drilled, through April 5, when mechanical termination of the cover crops was completed.

During our first canopy cover ratings, we were not entirely sure whether the grass seedlings in the rows were those of cereal rye or oats, so we delineated the seedlings as small grains. However, during later ratings, it became apparent that the oat seed germinated much more slowly than the cereal rye. Therefore, the grass seedlings in the photograph at right are cereal rye. This photograph, taken 30 days after planting, shows the 6-species mix planted at the 60 seeds per square foot planting rate. The cereal rye seed germinated quickly and the seedlings grew rapidly. Cereal rye is well adapted to acid, sandy soils, such as those at the PMC (Blount et al., 2002). The picture on the following page shows the 4-species 40 seeds per square foot plot approximately 2 weeks prior to termination. The cereal rye grew from 5- to 7-feet tall and was well past the flowering stage when it was terminated. The roller crimper did a good job of knocking down and killing the plants.

Oat plants were present in the 6-species plots in much lower numbers than cereal rye. Oats are noted as being subject to freeze injury (SARE, 2010); however, 2013 was a very mild winter (Fig. 1), so cold weather injury to the seedlings was not likely the cause. Competition from the other cover crops may have reduced establishment of the oat seedlings. However, the most likely reason that oats did not perform well in the plots is that this species may be poorly adapted for central Florida. Li et al. (2006) do not recommend oats as a cover crop for south Florida vegetable production systems because of poor growth. Oats are less tolerant of acid soils (Ball, et. al, 1991) and require more water than other small grains (SARE, 2010). Because the irrigation system was not functioning, the plants had to rely on natural rainfall, which was infrequent during this cover cropping period (Fig. 2). The oat plants were in the flowering to early seed production stage at termination and many regrew after the roller crimper treatment.

The broadleaf seedlings shown in the photograph on the previous page are diakon radish. Daikon radish is a relatively new cover crop for use in Florida (Johnson, 2013). Germination and growth of daikon radish was excellent at this PMC. The plants flowered heavily (white flowers in photo above) and seed was beginning to form when the crop was terminated. The photograph (right) shows the considerable size to which the roots grew during the growing season. Daikon radish is touted as being a cover crop that is capable of breaking up dense tillage layers in the soil (SARE, 2010). Measurements we took with a soil penetrometer prior to planting the cover crops shows that there is a distinct tillage layer in our plots at the 6-12 inch soil depth (Table 3). Much of the downward growth of the roots was restricted by this tillage layer, which resulted in more of the root extending above the ground than growing down into it (photo, left). Although the larger diameter portion of the root remained above the tillage layer, the smaller diameter root tips appeared to be able to penetrate at least a portion of this layer. It will be interesting to see if the radish plants affect the tillage layer in subsequent years. The roller crimper did an excellent job of snapping off the large roots and terminating the daikon radish plants.

Table 3. Average physical resistance of the soil in the Brooksville PMC cover crop treatment plots prior to cover crop planting as measured using a soil penetrometer measured at three depth ranges.

	0-6 inches depth	6-12 inches depth	12-18 inches depth
	------------------------------ Pound per square inch (PSI) ----------------------		
Rep 1	168	295	224
Rep 2	135	318	279
Rep 3	221	316	259
Rep 4	169	265	245
Average	173	299	252

Rapeseed, the second brassica species (planted only in the 6-species mix plots), was rarely counted in the line transects. It did not appear to tolerate competition from the faster growing cereal rye and daikon radish seedlings. The few larger rapeseeed plants were found only on the margins of the plots. None of the rapeseed plants bolted prior to termination. The roller crimper appeared to release the rapeseed plants from competition and many began to regrow more vigorously after the mechanical termination treatment.

Crimson clover was also infrequently recorded in the canopy counts. The number of crimson clover plants in our plots was low and they did not grow vigorously. Dry soils at planting may have affected both nodulation and survival of this legume. Previous research has shown that crimson clover does not perform well in light, sandy soils in Florida (Blount and Stanley, 2002) and it is not recommended as a cover crop for south Florida due to low biomass production (Li et al., 2006). Because of its shorter-stature, crimson clover was subjected to a great deal of competition from the taller cover crop species and, like oats and rapeseed, it appeared to be released from this competition by the roller crimper. Flowering was not noted prior to termination.

Hairy vetch was the third most commonly counted of the cover crops in the line transects, behind cereal rye and daikon radish. Its vining growth habit allows a single hairy vetch plant to cover a much larger area than the other cover crops in the seed mix, so this result is not unexpected. Although hairy vetch was well represented in the canopy cover counts, the plants mainly grew along the soil surface and did not trail up taller plants as hairy vetch would typically do. So, overall vigor of the plants could only be considered fair. None of the hairy vetch plants flowered during this evaluation period and the mechanical treatment was completely ineffective in terminating growth of this cover crop.

Biomass Production and Nutrient Content

Biomass harvested in all seeded plots consisted predominantly of grasses, mainly cereal rye (Table 4). Legumes were a small percentage of the biomass in the seeded plots. We suspect that nodulation of the crimson clover and hairy vetch seedlings was negatively affected by several weeks of dry weather after planting (Fig. 2) and this led to reduced growth. However, we did not dig up plants to examine the roots for nodules, which would have confirmed this hypothesis. The comparatively high percentage of legumes in the control plots was due to the large number of black medic plants in the fourth replication. Brassicas, which includes both the planted radish and rapeseed, were more abundant in the 4-species mix and the lowest seeding rate of the 6-species mix. Inter-species competition may have affected growth of the brassicas at the higher seeding rates. All cover crop treatments did an excellent job of suppressing weed growth.

Table 4. Percentage by weight of each plant type found in the plant material harvested from 0.5 m^2 samples in each cover crop seed mix and control plot at the Brooksville PMC.

Mix	Rate (seed/ft^2)	Grasses	Legumes	Brassicas	Weeds
2-species	20	97% ab[1]	1% a	0% a	2% b
2-species	40	100% a	0% a	0% a	0% b
2-species	60	100% a	0% a	0% a	0% b
4-species	20	74% bc	9% a	15% a	2% b
4-species	40	70% c	7% a	18% a	6% b
4-species	60	88% abc	1% a	10% a	0% b
6-species	20	81% abc	3% a	14% a	2% b
6-species	40	85% abc	6% a	8% a	1% b
6-species	60	89% abc	3% a	9% a	0% b
Control		1% d	15% a	0% a	84% a

[1]*Means within columns with different letters are significantly different at P<0.05 by Tukey HSD.*

The NRCS cover crop practice standard requires 4000 pounds (2 tons) per acre of dry matter production to be rated acceptable (NRCS, 2011). All of the cover crop mixes in our plots exceeded this amount of biomass production prior to termination, but the control plots did not (Table 5). Although all treatments had almost 2 to 3 times higher biomass production than the control (Table 5), only those treatments that produced 3 times as much biomass as the control were significant. Variation in the plot areas due to prior year management, probably explains the lack of statistical sensitivity. Continued similar treatment of the plot areas over the next two years, will probably reduce this variability. There was no effect of species mixture or seeding rate on biomass production (Table 5). Combined with similar time to reach 90% ground cover, this suggests that the 20 seeds per square foot planting rate is adequate for meeting the NRCS cover crop practice standard at this location regardless of the species composition.

The nitrogen content in the biomass was lower than the control for all of the seeded plots (Table 6). Since cereal rye was the primary constituent of these biomass samples, these results were anticipated. Small grains typically contain 1.5 to 2.5 percent nitrogen at early flowering and less than 1% nitrogen at seed set (Treadwell et al., 2008). The cereal rye plants in our plots were past the early flowering stage when these biomass samples were harvested. The nitrogen content would have likely been even lower if not for the contribution of the small amount of legumes in the samples. Typical nitrogen content

Table 5. Biomass of plant material produced in the soil health plots at the Brooksville PMC harvested March 26-27, 2013 and nitrogen content of the plant tissue.

Mix	Rate (seed/ft^2)	Dry Matter (ton/acre)	N in Dry Matter
2-species	20	2.77 ab[1]	1.0% b
2-species	40	3.23 a	1.0% b
2-species	60	3.64 a	1.3% b
4-species	20	2.82 ab	1.3% b
4-species	40	2.38 ab	1.4% ab
4-species	60	3.16 a	1.2% b
6-species	20	2.82 ab	1.4% ab
6-species	40	2.45 ab	1.4% ab
6-species	60	2.91 ab	1.2% b
Control		1.21 b	2.1% a

[1]Means with different letters are significantly different at P<0.05 by Tukey HSD.

for legumes prior to flowering is 3.5 to 4 percent (Treadwell et al., 2008). Nitrogen content of the control was higher than any of the cover crop plots primarily because of the black medic in replicate 4. Nitrogen content of that replication was 3.2 percent whereas that of the other replications that contained no leguminous weeds were 1.3, 1.6 and 2.1 percent, which indicates that the non-leguminous weeds in these samples also contained moderate amounts of nitrogen.

Table 6. Nitrogen content of diakon radish roots harvested at the Brooksville PMC on March 26-27, 2013. (Note: diakon radish was included in only the 4-species and 6-species seed mixes.)

Mix	Rate (seed/ft^2)	N in Radish Root Dry Matter
4-species	20	1.1% ab[1]
4-species	40	0.9% ab
4-species	60	1.0% ab
6-species	20	1.2% a
6-species	40	0.9% ab
6-species	60	0.8% b

[1]Means with different letters are significantly different at P<0.05 by Tukey HSD.

We also harvested the diakon radish roots and determined yield in the 4-species and 6-species plots where it was planted (Fig. 4). The plots with the 40 and 20 seeds per square foot seeding rate of the 4-species mix had the highest and second highest yield of root material, respectively. However, the yield differences between both seed mixes and all planting rates were not statistically significant.

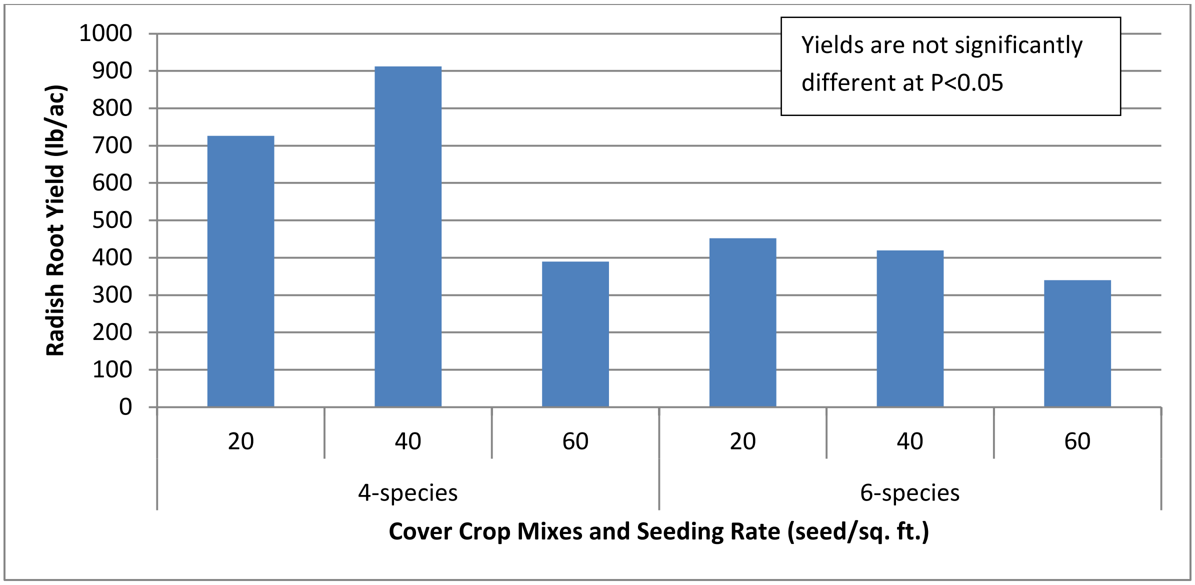

Figure 4. Dry matter yield of daikon radish roots harvested March 26-27, 2013 from the soil health plots at the Brooksville PMC.

The radish root samples were also analyzed for their nitrogen content (Table 6). Nitrogen content ranged from 0.8 to 1.2%. This is at the low end of the range reported for daikon radish roots (1.1-2.5%, Dean and Weil, 2009; Sundermeier, 2008). This may partly be a function of root maturity. Most of the information reported on daikon radish comes from studies where the plants winterkill. Due to the lack of below freezing weather at this location (Table 1), daikon radish would not be expected to winterkill and the roots would continue to grow and mature through the winter and spring until mechanically or chemically terminated. Additionally, it may reflect low soil N levels at planting (see Table 7).

Commodity Crop Production

Overall corn yields were very low and no significant differences were found between yields in any of the plots (Fig. 5). Low corn yields were directly related to low plant population (20,000 plants per acre) and low nitrogen levels available for corn growth since no additional nitrogen was applied.

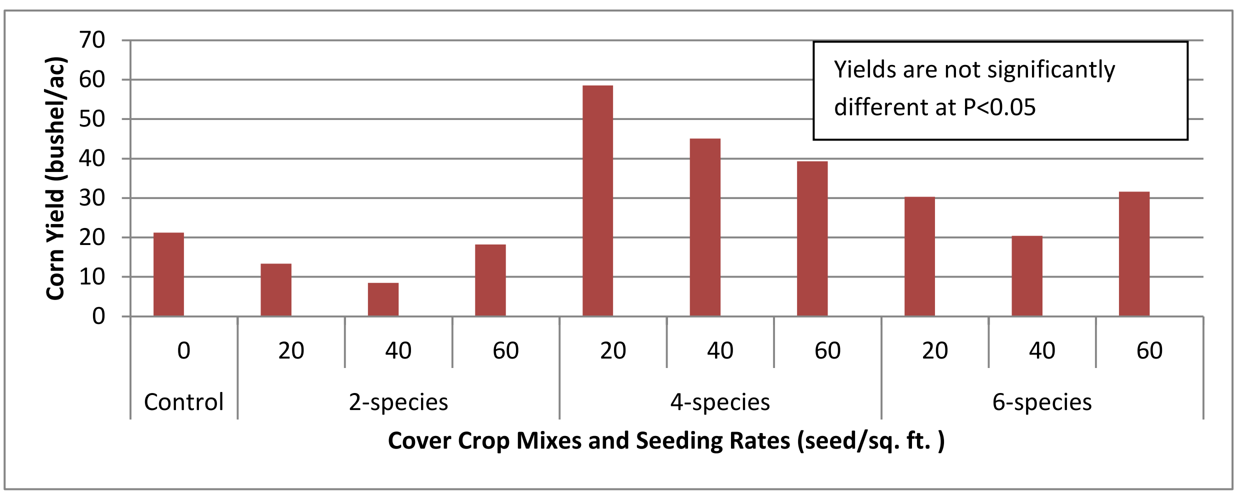

Figure 5. Yield of field corn at 15.5% moisture for plots seeded to cover crops the previous fall at the Brooksville PMC and the control plots. The plots were harvested Aug. 20-23, 2013.

The nitrogen availability in our plots before cover crop planting and before commodity crop planting are shown in Table 7. Initial nitrogen levels were low and no significant differences were found between the treatment plots. However, nitrogen availability was even lower after the cover crops were grown and there were differences between the cover crop treatments. University recommendations called for 150 pound per acre of nitrogen for dryland (low population) corn. The average available nitrogen in our plots at corn planting was about 1/20th of the recommend rate.

There are several possible reasons for the decline in soil nitrogen availability after the first season of cover crop production. One is the low percentage of legumes in all treatment plots due to the dry soil conditions at planting. Legumes constituted less than 10% of the biomass in all cover crop treatments (Table 4) and because of this low legume population little biological nitrogen fixation occurred. Secondly, cereal rye is very efficient at mining nutrients from the soil profile (Newman et al., 2007). Since cereal rye was the principal component of the biomass in the cover crop plots (Table 4), much of the available nitrogen in the soil was utilized for its growth. Also, since there was so little nitrogen in the biomass (Tables 5 and 6), this resulted in a high carbon to nitrogen (C:N) ratio. This was particularly so in the 2-species treatments which were essentially pure cereal rye (Table 4) and would be expected to have a C:N ratio of 40:1. It is no wonder why the 2-species plots were among the lowest corn yielding plots (Fig. 5). Soil microorganisms that degrade plant material require carbon and nitrogen. The optimum balance for normal function of these microorganism is a C:N ratio of 20:1 (Treadwell et al., 2008). Since nitrogen levels were so low in the plant tissues in our plots (Tables 5 and 6), the microorganisms scavenged any remaining nitrogen from the soil, which was immobilized in their bodies and was therefore unavailable for the corn plants.

Table 7. Soil nitrogen availability as determined by a biological assessment test before planting the cover crop and before planting the commodity

Mix	Rate (seeds/ft^2)	N Before Cover Crop Planting (lb/acre)	N Before Commodity Crop Planting (lb/acre)
2-species	20	23.7 a[1]	7.7 b
2-species	40	29.2 a	9.3 ab
2-species	60	31.5 a	10.8 ab
4-species	20	33.2 a	11.9 ab
4-species	40	35.3 a	16.3 a
4-species	60	31.1 a	10.8 ab
6-species	20	30.6 a	8.7 ab
6-species	40	28.1 a	7.8 b
6-species	60	31.0 a	9.4 ab
Control		33.0 a	10.7 ab

[1]Means with different letters are significantly different at P<0.05 by Tukey HSD.

Interestingly, there is an indication that addition of daikon radish to the mix mitigated the effect of the cereal rye. The 4-species mix plots, which had the highest daikon radish population of any of the cover crop mixes (Table 4), had numerically higher soil nitrogen levels (Table 7) and were the highest yielding plots for the corn crop (Fig. 5). Again, C:N ratios could explain this effect. Brassica leaves have a 10-20 C:N ratio and the roots have a 20-30 C:N ration which results in a faster decomposition rate than cereal rye (SARE, 2010). Although equivalent amounts of soil nitrogen would have been expected to be taken up in the daikon radish tissue as in the cereal rye, more was available for the corn to utilize in the 4-species plots due to the higher percentage of diakon radish biomass in these plots.

Weed Suppression

Cover crop residues on the soil surface can limit light penetration, which can help to suppress emergence of weeds in the subsequent commodity crop. Recommended biomass production of 4 to 6 tons per acre dry matter are required to produce a deep enough layer of residues to observe a reduction in weed emergence (Treadwell et al, 2008). Biomass in our plots did not reach the minimum 4-ton level (Table 5); however, weed emergence was still reduced in the cover crop plots. The photograph below on the right shows a large population of weeds, mainly nutsedge (*Cyperus* spp.), in one of our control plots. Compare this to the photograph on the left of the 6-species mixture planted at 60 seeds per square foot. There is an obvious layer of cover crop residues and few weeds are visible in the plot. Cereal rye has been reported to produce alellopathic chemicals that act as natural herbicides to prevent germination of weed seeds (Newman et al., 2007). Perhaps the weed suppression we observed was due to a combination of residues on the soil surface and allelopathy from the large amount of cereal rye tissue in the residues (Table 5). However, corn yields in the control plot were higher than some of the cover crop plots (Fig. 5). Cover crop residues have been shown to be incapable of providing lasting control of nutsedge throughout the commodity crop production cycle (Treadwell et al., 2008) and this may partially explain why yields were not higher in these cover crop plots.


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