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Cover Crop Performance Evaluation in Field and Controlled Studies

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Introduction

Cover crops increase soil organic matter, reduce erosion, suppress weeds, forage for nutrients, and reduce fertilizer costs (Clark, 2007). Cover crop species vary greatly and provide varied benefits. Performance evaluation of cover crop species and mixtures is needed in Virginia. The species of interest that we evaluated were:

Early cover hairy vetch (*Vicia villosa*) is a summer and winter annual legume. It is a N source, weed suppressor, topsoil conditioner, and erosion reducer. Vetch is described as a "semi-viney legume with tendrils; plants hairy; stems 3-5' long; flowers bluish violet and white" with approximately 21,000 seeds per pound with test weights of 60 pounds per bushel (Abaye et al., 2000).

Austrian winter pea (*Pisum arense*) is a summer and winter annual legume (winter crop on the East coast and South region US) resembling garden pea with purple flowers. The abundant hollow-stemmed vining forage can be tilled and decompose easily, providing a quick source of N. It also acts as a weed suppressor and a forage. There are approximately 5,000 seeds per pound with test weights of 60 pounds per bushel (Abaye et al., 2000; Clark, 2007).

Common vetch (*Vicia sativa L.*) is a viney cool season annual legume with leaves composed of 4 to 10 paired leaflets and a taproot that can reach depths of 3 to 50 feet. Common vetch produces purple and white flowers and seeds develop in small brown pods. It accumulates N, suppresses weeds, and is moderately resistant to cold temperatures (Sattell et al., 1998).

Persian clover (*Trifolium resupinatum L.*) is a winter annual legume. It has non-hairy, oval leaflets with toothed margins, and small pink flowers that produce olive green to purple seeds. It is good to use for grazing, however, it is sensitive to weed competition (Hoover and Duiker, 2009; Mississippi State University, 2010).

Indian head lentil (*Lens culinaris* Medik) is a specialty lentil for cover crop use. Lentils are a cool season annual crop with compound leaves (4 to 7 pairs of leaflets) with a tendril at the tips. At

flowering, “each flower produces a short pod containing one or two lens-shaped seeds. Flowers can be white, lilac or pale blue in color and are self-pollinated. At maturity plants tend to lodge because of their weak stems.” “The seeds (2 to 7 mm in diameter) come in colors of tan, brown, or black, and some varieties produce purple or black mottled seeds. Lentil seed number varies from 15,600 to 100,000 seeds/lb” (Oplinger, et al., 1990).

Yellow sweet blossom clover (*Melilotus officinalis, Melilotus alba*) is a biennial summer or winter annual legume. It can help build the soil, act as a fertility source, subsoil aerator, weed suppressor, and erosion preventer. This tall-growing, drought-tolerant plant has a taproot that can extract nutrients that have moved lower in the soil profile. It produces vegetative growth up to 24 inches in the establishment year. Plants can reach 8 feet tall and features bracts of tiny blooms through the second year. Abaye et al. (2000), describes yellow sweet blossom clover as “erect with many branches; deep taproot; stems grow from crown second year; yellow or white flowers; 2-5’ tall, leaflets notched on edges toward tips (unlike alfalfa with smooth edges). Plants and flowers have a sweet vanilla odor.” There are approximately 5000-8000 seeds per pound with test weights of 26-30 pounds per bushel (Abaye et al., 2000).

Arrowhead clover (*Trifolium vesiculosum*) is a drought tolerant annual winter legume with non-hairy, arrowhead-shaped leaves with pronounced veins and a white “V” marking. Blooms are white that can turn pink or purple. The stems are hollow, and fibrous at maturity. Arrowhead clover is often used for grazing (Ball et al., 2005).

Subterranean clovers (*Trifolium subterraneum, T. yanninicum, T. brachycalcycinum*) are reseeding cool season annual legumes. They aid in weed and erosion suppression, act as a N source, and provide a mulch and continuous orchard floor cover. They generally pile up their biomass in a compact layer close to the ground (Clark, 2007).

Crimson clover (*Trifolium incarnatum*) is a winter or summer annual legume. It grows rapidly and provides early season N for full-season crops, builds soil, and prevents erosion. Crimson clover has a “central taproot with many fibrous roots; 3 leaflets per leaf; stem and leaves hairy; pointed, conical flower at top of stem is bright crimson color; plants [stand] 1-3’ tall.” There are approximately 150,000 seeds per pound with test weights of 60 pounds per bushel (Abaye et al., 2000).

Sweet lupin – Lupins are cool-season annual legumes that provide N and have aggressive taproots. “Sweet” varieties, as opposed to “bitter” types, refer to lower concentrations of naturally occurring alkaloids. White lupin (*Lupinus albus L.*) and blue or narrow-leaf lupin (*Lupinus angustifolius L.*) are grown in the southeastern US (Clark, 2007).

Forage radish (*Raphanus sativus*) is a cool season annual. It is known for the taproot which can capture nutrients that have moved to deep depths in the soil profile. The plant can grow to a height of 2-3 ft (Clark, 2007).
Phacelia (*Phacelia tanacetifolia*) is an annual broadleaf that is native to the US and being reintroduced to be used as a cover crop. It is a heavy biomass producer and its flowers attract pollinating insects (Hoover and Duiker, 2009).

Rye (*Secale cereale*) is a cool season annual cereal grain. This hardy quick-growing cereal will scavenge for excess N, prevent erosion, add organic matter, and suppress weeds. “Seedings often have a reddish

coloration; leaves have small auricles with short ligules; seeds are round with the germ-end distinctly pointed; seed color varies from greenish gray and tan to dark brown or black." There are approximately 18,000 seeds per pound with test weights of 56 pounds per bushel (Abaye et al., 2000).

Barley (*Hordeum vulgare*) is a cool season annual cereal grain. It can be grown to prevent erosion, suppress weeds, scavenge excess nutrients, and add organic matter. "Leaves are green with long clasping auricles and a long ligule. Seed usually contains the husk (lemma and palea) that gives the seed a wrinkled appearance. Newer varieties maybe 'hulless' since the lemma and palea are removed at harvest." There are approximately 13,000 seeds per pound with test weights of 48, 57.6, and 60 pounds per bushel for hulled, hulless for feed, and hulless for human consumption varieties, respectively (Abaye et al., 2000).

Spring oat (*Avena sativa*) is a cool season annual cereal. This quick-growing upright annual grass can suppress weeds, prevent erosion, scavenge excess nutrients, add biomass, and act as a nurse crop (Clark, 2007). "Panicle type head; long ligule, auricles absent; leaf margins are heavy; seed usually retains the husk (lemma and palea), which has a very smooth surface; seed color varies with variety from white, yellow, gray to somewhat red. Winter oats require a period of cold temperature to initiate heading. Spring oats have no temperature requirement." There are approximately 14,000 seeds per pound with test weights of 32 pounds per bushel (Abaye et al., 2000).

Wooly pod vetch (Lana) (*Vicia villosa ssp. dasycarpa*) is a cool season annual that is a faster-growing alternative to hairy vetch in Hardiness Zone 7 and warmer. It is a good N source, weed suppressor, erosion preventer, adds organic matter to soil and attracts bees. "Wooly pod vetch has slightly smaller flowers than hairy vetch, and its seeds are more oval than the nearly round seeds of hairy vetch" (Clark, 2007).

Canola (or rape), has two species commonly grown: *Brassica napus* and *Brassica rapa*. *Brassica napus* is a cool season annual in the mustard family with large dark green leaves. Brassicas help prevent erosion, suppress weeds and soil born pests, alleviate soil compaction via taproots, and scavenge nutrients. "At maturity it reaches a height of 3-6' with brilliant yellow flowers and pods that produce 15-40 small black seeds." There are approximately 160,000 seeds per pound with test weights of 50 pounds per bushel (Abaye et al., 2000).

Ryegrass (*Lolium multiflorum*), also known as Italian ryegrass, is a cool season annual grass. It is a quick growing, non-spreading bunch grass used to prevent erosion, improve soil structure and drainage, add organic matter, suppress weeds, and scavenge for nutrients. It has shiny, smooth leaves rolled in the bud, with long and narrow auricles, a short ligule, and spikelets edgewise on the stem with awns on the seed. There are approximately 227,000 seeds per pound with test weights of 24 pounds per bushel (Abaye et al., 2000; Clark, 2007).

Controlled environment chamber trials

In order to compare growth rate of various cover crop species under uniform conditions, seeds of 13 of the cover crop listed above were planted into potting media in four-inch pots, watered to 85% field capacity and placed in a growth chamber in four replications. The chamber was set to deliver a 12 hour day/12 hour night light regime and day/night temperatures were set to mimic those experienced in eastern Virginia in late September with 75° days and 55° nights. Growing degree days (GDD, Celsius) with a base of 4°C were calculated and when accumulated GDD reached 200, 400, 600, and 800, pots were removed and all aboveground plant growth clipped at the soil level, dried, and weighed to determine biomass accumulation. Initial growth rate was greatest for forage radish, canola and phacelia. It should be noted, however that temperatures were maintained at the 75/55° level throughout the study and that growth rate of some of these species would slow dramatically if temperatures in the chambers would have been decreased over time. Among the cereal grains, barley and rye produced the greatest biomass by 400 GDD. Most of the legume cover crops accumulate little (less than 250 lb/ac) biomass prior to accumulating 400 GDD.

Table 1. Cover crop dry matter growth in response to GDD accumulation under controlled conditions.

Cover Crop Species	200 GDD	400 GDD	600 GDD	800 GDD
	--Aboveground dry matter, lb/ac--			
Australian Winter Pea	42	402	2012	5705
Barley	24	617	2318	5580
Canola	41	884	3307	5006
Common Vetch	21	234	1289	3855
Crimson Clover	23	237	946	3106
Early Cover Hairy Vetch	17	226	1666	3673
Phacelia	19	825	2426	4521
Rye	35	425	2394	5654
Ryegrass	5	158	1524	5049
Spring Oats	14	381	1642	5424
Sweet Lupin	36	253	648	1460
Forage Radish	136	1304	4142	7175
Woolypod Vetch	27	417	1775	5322
Mean	34	489	2007	4733
LSD (0.05)	23	241	647	1159

Field trials

Field trials were conducted at five locations in Virginia; three western sites (Blacksburg, Mauzy, and Edinburg) and two eastern sites [New Kent County and the Virginia State University (VSU) Randolph Farm in Petersburg, VA] during Winter/Spring of 2010-2011 and 2011-2012. Plots were planted no-till into corn grain or silage stubble at seeding rates indicated in Table 2.

Cover crop species and mixtures were evaluated under rain-fed conditions and no fertilizer applications. In 2010/2011, 25 treatments were evaluated in the western trials. The treatments containing ryegrass were not included in the eastern trials, resulting in 22 treatments. In 2011/2012, some treatments were eliminated, while a spring oat+barley treatment was added, resulting in 20 and 17 treatments in the western and eastern sites, respectively. The experiment was a randomized complete block design with three replications at each location.

Two harvests were conducted to collect biomass; the first harvest (Winter) occurred in December and the second harvest occurred in March/April (Spring), depending on the site. The objective in every case was to manage the trials in the same manner as the farmer, so the spring harvest timing occurred just prior to terminating the cover crop. The clipped aboveground biomass was dried in a forced-air oven at 60°C for 48 hours, and ground to pass a 2mm screen with a Wiley (Thomas Scientific, Swedesboro, NJ) sample mill. Nitrogen uptake was measured from a ground subsample of the dried biomass using an automatic CN analyzer (Leco Corp, St. Joseph, MI).

Table 2. Treatments and seeding rates for cover crop species.

Cover Crop	Seeding Rate (lb/ac)
Early cover hairy vetch	20
Austrian winter pea	35
Common vetch	35
Persian clover	5
Indian head lentil	25
Yellow sweet blossom clover	5
Arrowhead clover	5
Subterranean clover	15
Crimson clover	15
Sweet lupin	50
Forage radish	8
Phacelia	8
Rye	113
Barley	96
Spring oat	64
Ryegrass	20
Wooly pod vetch (Lana)	20
Barley+crimson clover+forage radish	48+20+5
Rye+wooly pod vetch+Austrian winter pea+forage radish	56+13+13+5
Rye+ryegrass+forage radish	84+20+5
Spring oat+canola	32+4
Spring oat+forage radish	64+5
Barley+crimson clover+wooly pod vetch+Austrian winter pea+ forage radish+canola	20+8+8+8+3+3
Ryegrass+crimson clover+wooly pod vetch+Austrian winter pea +forage radish+canola	20+8+8+8+3+3

Results

Field Trials

The Eastern sites in 2011 (Table 3) resulted in treatment mixtures of barley+crimson clover+wooly pod vetch+Austrian winter pea+tillage radish+canola and rye+wooly pod vetch+Austrian winter pea+tillage radish producing the greatest amounts of dry matter and N uptake in both the winter and spring. These treatments were similar to other treatments in biomass production and N uptake in the winter and spring; however, only these treatments resulted in consistently high numbers. Generally, treatments with smaller biomass production also resulted in lower N uptake. This occurred in the winter and spring for Austrian winter pea, common vetch, Persian clover, Indian head lentil, yellow sweet blossom clover, arrowhead clover, and subterranean clover. Smaller biomass production and N uptake was also observed in crimson clover, sweet lupins, tillage radish, and phacelia in the spring.

The Western sites in 2011 (Table 4) resulted in treatment mixtures of rye+wooly pod vetch+Austrian winter pea+tillage radish and rye+ryegrass+tillage radish producing the greatest amounts of dry matter and N uptake in both the winter and spring. These treatments were similar to other treatments in biomass production and N uptake in the winter and spring; however, only these treatments resulted in consistently high numbers. In the winter, all of the treatments with a mixture of cover crops resulted in the greater amounts of biomass and N uptake than other single-crop treatments in winter. Similar to results in the Eastern sites in 2011, common vetch, Persian clover, Indian head lentil, yellow sweet blossom clover, arrowhead clover, and subterranean clover resulted in the lowest biomass and N uptake over the winter and spring.

Treatments with mixed species resulted in greater biomass in the winter of the Eastern sites in 2012 (Table 5). Several single-species treatments were similar to multi-species treatments in biomass production including crimson clover, sweet lupins, tillage radish, rye, barely, and spring oats. No differences in N uptake were observed in the winter, 2012. In the spring of 2012, there were no differences in biomass production; however, differences in N uptake were observed. Early cover hairy vetch and wooly pod vetch resulted in the greatest N uptake, which were similar in N uptake to common vetch, crimson clover, rye, barley, barley+crimson clover+tillage radish, rye+wooly pod vetch+Austrian winter pea+tillage radish, and wooly pod vetch+Austrian winter pea+tillage radish+canola.

On the Western sites in 2012 (Table 6), early cover hairy vetch, Austrian winter pea, and common vetch resulted in the lowest biomass production and N uptake in both the winter and spring. Multi-species treatments of barley+crimson clover+tillage radish, rye+ryegrass+tillage radish, spring oat+barley, and ryegrass+crimson clover+wooly pod vetch+Austrian winter pea+tillage radish+canola, along with the single-species barley treatment resulted in higher rates of biomass and N uptake than other treatments in both winter and spring.

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Table 3. Dry matter (DM) biomass and N uptake for 2011 Eastern sites (New Kent County and the VSU Randolph Farm in Petersburg).

SPECIES/MIXTURE	WINTER		SPRING	
	DM BIOMASS	N UPTAKE	DM BIOMASS	N UPTAKE
	---------LB/AC---------		---------LB/AC---------	
Early cover hairy vetch	130 g†	4 f	2394 cd	63 bc
Austrian winter pea	942 bcdefg	18 def	707 e	19 d
Common vetch	846 bcdefg	16 def	536 e	16 d
Persian clover	299 efg	5 f	262 e	5 d
Indian head lentil	643 cdefg	16 def	0 e	0 d
Yellow sweet blossom clover	343 defg	8 ef	872 e	17 d
Arrowhead clover	144 fg	2 f	249 e	5 d
Subterranean clover	281 efg	4 f	258 e	5 d
Crimson clover	1126 abcde	19 cdef	995 e	27 d
Sweet lupin	693 cdefg	19 cdef	1133 e	23 d
Forage radish	1689 ab	53 a	206 e	4 d
Phacelia	1219 abc	31 bcd	236 e	5 d
Rye	1125 abcd	32 bcd	2823 c	62 c
Barley	1364 abc	40 ab	4378 ab	87 bc
Spring oat	1059 abcdef	29 bcd	1215 de	21 d
Wooly pod vetch (Lana)	1305 abc	37 abc	2454 c	81 bc
Barley+crimson clover+forage radish	1111 abcde	31 bcd	3274 bc	67 bc
Rye+wooly pod vetch+Austrian winter pea+forage radish	1335 abc	39 ab	4352 ab	92 ab
Spring oat+canola	931 bcdefg	25 bcde	3574 abc	67 bc
Spring oat+forage radish	1318 abc	38 ab	1071 e	22 d
Barley+crimson clover+wooly pod vetch+Austrian winter pea+forage radish+canola	1812 a	53 a	4576 a	121 a

† Means followed by different lower case letters within a column are significantly different (*alpha* = 0.05).

Table 4. Dry matter (DM) biomass and N uptake for 2011 Western sites (Blacksburg, Mauzy, and Edinburg).				
	WINTER		SPRING	
SPECIES/MIXTURE	DM BIOMASS	N UPTAKE	DM BIOMASS	N UPTAKE
	---------LB/AC---------		---------LB/AC---------	
Early cover hairy vetch	830 fgh†	27 defgh	1550 fghi	56 bcdefg
Austrian winter pea	964 efgh	35 cdefgh	1105 ghij	72 bcde
Common vetch	1091 defgh	38 cdefgh	832 ghij	32 defgh
Persian clover	585 h	20 gh	142 j	2 h
Indian head lentil	666 gh	25 efgh	215 j	8 fgh
Yellow sweet blossom clover	145 h	2 h	178 j	4 gh
Arrowhead clover	216 h	5 h	282 j	8 fgh
Subterranean clover	54 h	1 h	124 j	4 gh
Crimson clover	1039 defgh	30 defgh	1934 defg	60 bcdef
Sweet lupin	585 h	20 fgh	420 ij	13 fgh
Forage radish	2671 abc	96 abcde	120 j	5 gh
Phacelia	2662 abc	104 abc	158 j	4 gh
Rye	2831 abc	87 abcdefg	4485 a	134 a
Barley	3650 a	153 a	2622 cdef	86 abc
Spring oat	2241 abcdef	79 bcdefg	667 hij	13 fgh
Ryegrass	1495 bcdefgh	48 bcdefgh	1698 efgh	43 cdefgh
Wooly pod vetch (Lana)	1321 cdefgh	50 bcdefgh	2010 defg	68 bcde
Barley+crimson+forage radish	3027 a	116 ab	3054 bcd	91 abc
Rye+wooly pod vetch+Austrian winter pea+forage radish	2890 ab	92 abcde	3797 abc	97 ab
Rye+ryegrass+forage radish	2650 abc	97 abcd	3938 ab	106 ab
Spring oat+canola	2560 abcd	91 abcdef	2651 cdef	81 abcd
Spring oat+forage radish	2792 abc	102 abc	1085 ghij	21 efgh
Barley+crimson clover+wooly pod vetch+Austrian winter pea+forage radish+canola	2482 abcde	92 abcde	2874 bcde	77 bcd
Ryegrass+crimson clover+wooly pod vetch+Austrian winter pea+forage radish+canola	2335 abcdef	87 abcdefg	2574 cdef	81 abcd

† Means followed by different lower case letters within a column are significantly different (*alpha* = 0.05).

Table 5. Dry matter (DM) biomass and N uptake for 2012 Eastern sites (New Kent County and the VSU Randolph Farm in Petersburg).

	WINTER		SPRING	
SPECIES/MIXTURE	DM BIOMASS	N UPTAKE	DM BIOMASS	N UPTAKE
	---------LB/AC---------		---------LB/AC---------	
Early cover hairy vetch	250 bcde†	10 NS	750 NS	25 a
Austrian winter pea	215 cde	11	140	5 def
Common vetch	159 de	9	411	17 abcde
Crimson clover	376 abc	10	697	20 abcd
Sweet lupin	481 a	9	465	6 cdef
Forage radish	394 ab	12	7	0 f
Phacelia	104 e	4	10	0 ef
Rye	416 ab	9	647	14 abcdef
Barley	435 a	8	870	12 abcdef
Spring oat	411 ab	8	655	9 bcdef
Wooly pod vetch (Lana)	215 cde	8	699	25 a
Barley+crimson clover+forage radish	471 a	11	986	23 ab
Rye+wooly pod vetch+Austrian winter pea+forage radish	495 a	13	664	16 abcde
Spring oat+canola	483 a	8	469	8 bcdef
Spring oat+forage radish	434 a	10	531	8 bcdef
Spring oat+barley	334 abcd	6	718	9 bcdef
Barley+crimson clover+wooly pod vetch+Austrian winter pea+forage radish+canola	352 abc	11	799	21 abc

† Means followed by different lower case letters within a column are significantly different (*alpha* = 0.05).

Table 6. Dry matter (DM) biomass and N uptake for 2012 Western sites (Blacksburg, Mauzy, and Edinburg).

	WINTER		SPRING	
SPECIES/MIXTURE	DM BIOMASS	N UPTAKE	DM BIOMASS	N UPTAKE
	---------LB/AC---------		---------LB/AC---------	
Early cover hairy vetch	63 g†	4 h	800 ghi	24 efghij
Austrian winter pea	144 g	5 gh	307 i	9 ij
Common vetch	209 defg	6 fgh	323 i	8 j
Crimson clover	199 fg	7 efgh	1915 bcdef	57 a
Sweet lupin	207 efg	7 efgh	903 fghi	14 ghij
Tillage radish	386 cdef	12 bcde	510 hi	10 hij
Phacelia	384 cdef	11 cdef	1619 cdefg	39 abcdef
Rye	632 ab	18 ab	1548 defgh	28 defgh
Barley	721 a	19 a	2950 ab	49 abc
Spring oat	498 bc	15 abcd	1910 bcdef	27 defghi
Ryegrass	414 cd	11 cdefg	1414 efgh	19 fghij
Wooly pod vetch (Lana)	71 g	2 h	1277 efghi	37 bcdef
Barley+crimson clover+tillage radish	700 ab	18 ab	2740 ab	55 ab
Rye+wooly pod vetch+Austrian winter pea+tillage radish	651 ab	20 a	2005 bcde	42 abcde
Rye+ryegrass+tillage radish	670 ab	17 abc	2615 abc	45 abcd
Spring oat+canola	242 defg	8 defgh	2000 bcde	31 cdefg
Spring oat+tillage radish	414 cd	11 cdefg	2471 abcd	37 bcdef
Spring oat+barley	666 ab	16 abc	3457 a	53 ab
Barley+crimson clover+wooly pod vetch+Austrian winter pea+tillage radish+canola	410 cde	11 cdefg	2539 abcd	52 ab
Ryegrass+crimson clover+wooly pod vetch+Austrian winter pea+tillage radish+canola	518 abc	15 abc	2875 ab	53 ab

† Means followed by different lower case letters within a column are significantly different (*alpha* = 0.05).